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Evaluation and analysis of strength values assessed pre and post pitch training session in an MLS team during the season and after the off season
Evaluación y análisis de valores de fuerza pre y post sesión en un equipo de la MLS durante la temporada y después del periodo transitorio

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Abstract. Background: In recent decades, sports science has advanced significantly, yet injuries in soccer have also increased, possibly due to higher competitive demands. The reasons behind injuries are complex, involving both external and internal factors. It is crucial to focus on modifiable factors such as training load, physical capacities, flexibility, and strength. It is also essential to conduct specific assessments based on the physical needs and the muscle groups most injured in each sport. Therefore, the aim of this study was to (1) determine strength and power values in a professional Major League Soccer (MLS) soccer team during a season, (2) analyze the results of the assessments performed pre and post session, and (3) determine the effect of the transitional period on strength and power. Methods: The study included 22 professional soccer players with an age of 26.3 ± 3.9 years from a Major League Soccer (MLS) team excluding goalkeepers. Six assessments were carried out, of which 3 were pre-pitch session and 3 post-pitch session assessments, assessing eccentric strength in hamstrings using the Nordic hamstring curl with the NordBord system, maximum isometric strength in hip adduction and abduction using the ForceFrame, and lower limb power with the countermovement vertical jump (CMJ) on ForceDecks force platforms. Results: The strength and power values established with the pre-session assessments show a CMJ height of 43.96 ± 3.92cm, in Nordic hamstring curl 382.46±67.79N (L) and 370.66±65.84N (R), in hip adduction 414.79±73.86N (L) and 424.02±71.88N (R), and in hip abduction 411.93±60.19N (L) and 420.77±60.54N (R). The results showed a significant decrease ($P > 0.05$) in the Nordic hamstring curl and both hip adduction and abduction in the post-session assessments compared to the pre-session assessments, the height of the CMJ did not show a meaningful change ($p>0.05$). In the Preseason assessment compared to the data obtained in the pre-session assessments a meaningful decreased of the CMJ height was found ($p<0.05$), while the Nordic hamstring curl and both hip adduction and abduction did not show a meaningful decrease ($p >0.05$). Conclusions: The studied data show lower strength values post-session, except for power expressed in CMJ height. After the transitional period, hamstring and hip strength (ABD-ADD) did not show significant changes, but CMJ height did. It is suggested to carry out strength assessments and strength training before the soccer session in the pitch to obtain accurate baseline profiles and maximize strength and power training adaptations, avoiding biases generated by fatigue. It is also recommended to implement training programs during the transitional period to counteract the effects of detraining.
Keywords: Assessment; Strength; NordBord; ForceFrame; ForceDecks; Prevention; Soccer

Resumen. Antecedentes: En las últimas décadas las ciencias del deporte han avanzado mucho, pero las lesiones en el fútbol también han aumentado, posiblemente debido a mayores demandas competitivas. Las causas de las lesiones son multifactoriales: factores extrínsecos e intrínsecos. Es crucial enfocarse en factores modificables como la carga de entrenamiento, capacidades físicas, flexibilidad y fuerza. También es fundamental realizar evaluaciones especificas según las necesidades físicas y los grupos musculares más afectados en cada deporte. Es por ello el objetivo de este trabajo fue (1) Determinar los valores fuerza y potencia en un equipo de fútbol profesional de la Major League Soccer (MLS) durante una temporada, (2) Analizar los resultados de las evaluaciones realizadas en Pre y post sesión; (3) Determinar el efecto del periodo transitorio sobre la fuerza y potencia. Metodología: El estudio estuvo constituido por 22 futbolistas profesionales con una edad de 26.3 ± 3.9 años de un club de la Major League Soccer (MLS) excluyendo porteros. Se llevaron a cabo evaluaciones 6 evaluaciones de las cuales 3 fueron pre sesión y 3 post sesión de campo; valorando la fuerza excéntrica en isquiosurales en el curl nórdico usando el NordBord, fuerza isométrica máxima en aducción y abducción de cadera utilizando el ForceFrame, y potencia del tren inferior con el salto vertical con contramovimiento (CMJ) en las plataformas de fuerza ForceDecks. Resultados: Los valores de fuerza y potencia establecidos con las evaluaciones pre sesión muestran una altura de CMJ de 43.96 ± 3.92cm, en curl nórdico 382.46±67.79N (I) y 370.66±65.84N (D), en aducción de cadera 414.79±73.86N (I) y 424.02±71.88N (R), y en abducción de cadera 411.93±60.19N (I) y 420.77±60.54N (R). La comparación entre evaluaciones Pre y Post mostraron valores estadísticamente más bajos ($p< 0.05$) en el curl nórdico, la aducción y abducción de cadera, mientras que en el CMJ no presento cambios significativos ($p=0.056$). Por el contrario, después del periodo transitorio solamente el CMJ mostró valores más bajos ($p< 0.05$) a comparación del curl nórdico, y aducción y abducción de cadera ($p>0.05$). Conclusiones: Los datos estudiados muestran valores de fuerza más bajos post sesión, excepto en la potencia expresada en la altura del CMJ. Tras el periodo transitorio, la fuerza en isquiosurales y cadera (ABD-ADD) no muestran cambios significativos, pero la altura del CMJ sí. Se sugiere realizar evaluaciones y entrenamiento de fuerza pre sesión para obtener perfiles basales precisos y maximizar las adaptaciones del entrenamiento de fuerza y potencia evitando los sesgos generados por la fatiga. También se recomienda implementar programas de entrenamiento durante el periodo transitorio para contrarrestar los efectos del desentrenamiento.
Palabras clave: Evaluación; Fuerza; NordBord; ForceFrame; ForceDecks; Prevención; Fútbol

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Introduction

Soccer is one of the most popular sports in the world (Luthje et al., 1996; Inklaar, 1994), characterized as a team sport by intermittent actions of high intensity interspersed with recovery breaks (low-intensity actions), allowing partial recovery from the previous effort (Stone and Kilding, 2009). Despite the short duration of high-intensity actions such as jumps, changes of direction, strikes, and sprints, they have a high influence on the final outcome in competitions (Costela et al., 2017).

Over the past couple of decades, sports sciences have been developing; however, contrary to what one might think, injuries within soccer have also been on the rise (Ekstrand et al., 2022). It is important to understand that injuries are multifactorial and that there are both extrinsic and intrinsic factors (Bahr and Krosshaug, 2005). Therefore, it becomes important to pay more attention to those factors that are more controllable and modifiable, such as the strength and various physical capacities of the players, programming, and planning of microcycles, pitch and gym sessions, nutrition, rest, and even the player's stress level. A clear example is that players with lower strength values (Timmins et al., 2016) and a smaller range of motion (van Dyk et al., 2018) are exposed to a greater risk of injury, or seen another way, there is a relationship between a lower risk of injury and better performance in sports actions (Suchomel et al., 2016; Kirkendall et al., 2010).

A strong correlation has also been demonstrated where teams that present a lower injury rate achieve a better ranking in the tournament, more victories, and more points (Eirale et al., 2013), probably due to a greater availability of players eligible for training and competitions, favoring and providing continuity and stability to both individual physical and collective technical-tactical work.

To take into account these modifiable factors, it is necessary to have control in the monitoring and quantification of internal and external load; some examples of these tools would be global positioning systems (GPS) to determine the external load during competitions and training (Hoppe et al., 2018), the subjective rate of perceived exertion or RPE (Miguel et al., 2021); the countermovement jump (Alba-Jiménez et al., 2022) to monitor the response to external load, and sport-specific strength assessments considering muscle groups based on injury incidence. This monitoring strategy facilitates the organization, prescription, and optimization of session stimuli, thereby maximizing each athlete's performance (Balsalobre-Fernandez, 2015). Additionally, it aids in identifying the adaptations and fatigue experienced by athletes, which is crucial for preventing overtraining and reducing the risk of injury (Halson, 2014; Campbell, 2017).

Within the incidence of injury in soccer, we can find the hamstrings as the foremost, where an injury rate 10 times higher in competitions than in training is shown (Ekstrand et al., 2022); along the same line of research, Jones et al. (2019) established an injury rate of 39% for the hamstrings being the most affected muscle group, followed by the hip adductors with 25.6%; the adductors being the most injured muscles of the groin and hip followed by the iliopsoas (Werner et al., 2019).

Just as strength trainings and assessments on muscle groups should be prioritized based on the specific injury incidence in the sport, different applications and manifestations of strength that are most related to those high-intensity actions that are most determinant for competition (Costela et al., 2017), such as the countermovement jump due to its high correlation with sports actions like triple flexion-extension (ankles, knees, and hips), changes of direction, and speed in sprints (Loturco et al., 2020; Harper et al., 2020), must also be taken into account and evaluated. Based on this premise, it was determined to assess 1) the Nordic curl exercise to determine the maximum eccentric strength of the hamstrings, 2) the maximum isometric strength of hip adduction and abduction, and 3) the countermovement jump. These assessments were chosen due to their correlation with the muscle groups that have a higher incidence of injuries in soccer, as well as their relevance for the muscular demands associated with high-intensity actions. This choice is based on the work of Paul and Nassis (2015), who highlighted the importance of conducting functional and specific assessments for the environment in question in order to obtain more valuable and reliable information. However, to date, no study has been conducted analyzing neuromuscular performance assessed at different times (pre-session and post-session) throughout a season with professional Major League Soccer (MLS) players. Therefore, the objectives of the present study were (1) to determine the strength values in a professional Major League Soccer (MLS) team during a season, (2) compare the results of the strength and power values in the pre-session and post-session assessments; (3) determine the effect of the transitional period on strength and power.

Methods

Study design

The design of the present study was a descriptive longitudinal study of repeated measures, where data from 18 group assessments were collected during the 2022 season. The process began with the first group assessment on February 26 and ended with the last on November 5, 2022. On the other hand, in the 2023 preseason, a single group assessment session for each device (NordBord, ForceFrame, ForceDecks) was conducted on January 8.

It is important to emphasize that all assessments were adapted and adjusted based on the demands imposed by the competitive calendar, in addition to being synchronized with the rest periods set by the scheduling of international friendly matches, in accordance with the planning of the Fédération Internationale de Football Association (FIFA). Thus, the assessments were conducted in a real professional environment, with training loads carefully adjusted and effective recovery strategies applied. This approach is essential to avoid a negative impact on neuromuscular fatigue and the subjective perception of the player (McLean et al., 2010). The study was explained to the players at the start of the season, indicating the steps that were to be followed. Once explained, all team players signed informed consent. Likewise, the protocol developed in the present study was approved by the research ethics committee of the Universidad Europea del Atlántico (CEI-114).

Participants

The sample consisted of 22 professional field soccer players, excluding goalkeepers, with an average age of 26.3 ± 3.9 years and professional experience of 7.5 ± 2.5 years. The average height was 1.81 ± 0.05 m, with an average weight of 79.2 ± 7.7 kg. Body composition showed a fat percentage of 10.2 ± 1.8% and a lean body mass of 71.1 ± 5.40 kg. These players were part of a Major League Soccer (MLS) team, the professional soccer league of the United States.

For the selection of participants, inclusion criteria were established that considered only the data of players who were without injury, discomfort, or pain at the time of conducting the group assessments. Therefore, individual assessments or those in Return to Play stages (post-injury) were not included in the analysis. "Injury" was defined as any condition of pain or disability experienced by a player during a match or training session that required medical attention according to Gabbet (2004). This inclusion criterion was considered because it has been shown that there is a decrease in strength due to the interruption of the excitation-contraction coupling process by damage to the musculotendinous structures (Warrent et al., 2017).

Instruments

The devices used for data collection in this study are detailed below:

1. NordBord (Vald Performance, Queensland, Australia): The use of this system enables the assessment of eccentric strength in Newtons of the hamstrings during the Nordic curl exercise, allowing us to obtain accurate data related to maximum strength, average strength, torque, and potential asymmetries. It's important to highlight that these same variables can be assessed in isometric exercises of the posterior chain using the same device. Opar et al. (2013) used it to identify strength deficits and in turn detect players with a higher probability of injury during the preseason.

2. ForceFrame (Vald Performance, Queensland, Australia): This device is distinguished by its configuration with four load cells (two internal and two external), enabling the simultaneous evaluation of hip adduction and abduction movements without requiring changes in the sensor position. This feature promotes high replicability of the assessments and the reliability of the results. Additionally, it provides real-time metrics including maximum strength in Newtons, average strength, and detection of potential asymmetries. The ForceFrame has been used to assess isometric strength of hip adduction to determine the contribution of such muscle strength in sports actions like sprinting and changes of direction (Jones et al., 2021).

3. ForceDecks (Vald Performance, Queensland, Australia): Jump assessments have been evaluated with different devices such as contact mats, optical devices, and mobile applications; these devices provide metrics such as contact time, flight time, and jump height. However, force platforms are the “gold standard” device due to their high precision and reliability (Hatze, 1998). These uniaxial force platforms are devices that allow us to determine vertical ground reaction forces (vGRF) in different assessments such as the CMJ (Gillet et al., 2021), from which derived metrics of time and force at different moments of the movement such as power, speed, displacement, asymmetries, and the most popular metric (used in this work): jump height in centimeters.

Procedure

The assessment sessions were distributed as follows: 6 assessments focused on the Nordic curl exercise using the NordBord, another 6 assessments focused on measuring the maximum isometric strength of adductor and abductor movements using the ForceFrame, and finally, 6 assessments addressed the countermovement jump (CMJ) using the ForceDecks force platforms. It should be noted that these assessments were divided into 3 pre-session and 3 post-session.

In the first step of the procedure, individual profiles for each of the players were generated in the VALDHUB cloud. This approach allowed for the automation of the registration and storage of each assessment performed using the three measurement devices (NordBord, ForceFrame, and ForceDecks). These assessments were scheduled to be carried out in three distinct instances:

1. Pre-session: Before each pitch training session, a group activation circuit lasting 15 minutes was performed. This circuit was focused on specifically activating the muscle groups that would be evaluated later.

2. Post-session: At the end of the pitch training sessions, players underwent the corresponding assessments of the day. Since these assessments were conducted immediately after the field session, it was not considered necessary to perform specific muscle activation.

3. Preseason: After the transitional period, assessments were conducted during the first week of the 2023 preseason (early January 2023). Since the central objective of this day was the completion of the assessments, a field training session was not scheduled. However, a standardized warm-up circuit was carried out, lasting 15 minutes and focused on the muscle groups subjected to evaluation.

The assessments were standardized using the following guidelines for sets, repetitions, and execution protocols. For the NordBord, 1 set of 3 repetitions of the Nordic curl exercise was performed. During this process, the importance of maintaining a neutral hip position and resisting

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the fall as much as possible was emphasized to favor the maximum development of eccentric strength in the hamstrings. Regarding the ForceFrame, 2 sets of maximum isometric contractions in abduction and adduction for 3 seconds each, with a 2-second pause between each contraction, were performed. These contractions were done in a supine position with a 45° hip flexion. For the ForceDecks, 1 set of 3 maximal countermovement jumps was conducted. At all times, the correct execution of the jumps was emphasized, with the instruction to reach the maximum height possible. Between each jump, a 20-second pause period was determined.

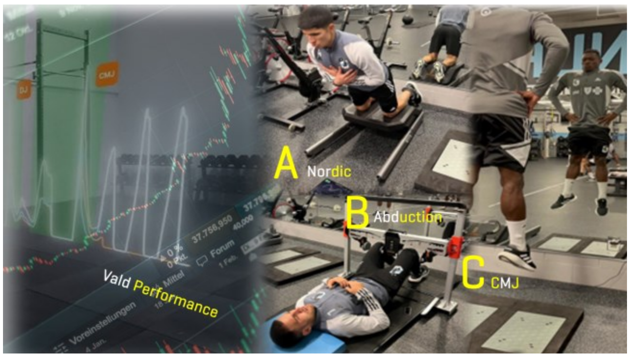

Figure 1. Assessment protocol with Vald Performance systems (A- Nordic Curl; B-Aducction/abduction; C- CMJ)

At the end of the 2022 season, players were provided with standardized training plans specifically designed for the transitional period (off season), which lasted for 9 weeks: the first 2 weeks were for rest; weeks 3 and 4 featured a training frequency of 3 times per week, including two structural strength sessions for upper and lower body and one aerobic session; in weeks 5, 6, and 7, one more session per week focused on intermittent aerobic work was added; and in weeks 8 and 9, a power session was added.

Statistical analysis

Data are presented as mean and SD. The normal distribution of the data was confirmed by the Shapiro-Wilk test for all variables ($P > 0.05$). Pre-post measurements for each session were compared by T-paired Test, pairwise comparisons were identified using Bonferroni post hoc corrections. Furthermore, a one-way repeated-measured analysis of variance (ANOVA) was conducted to compare the four different moments alongside the season for each variable (CMJ, Nordbord and Abd-Add measurement), with Games-Howell post-hoc corrections. Last, effect size (d Cohen) was determined with the following ranges: <0.2 trivial, 0.2 to 0.6 small, 0.6 to 1.2 moderate and >1.2 large (Hopkins, Marshall, Batterham, & Hanin, 2009). Statistical analyses were performed using the software package Jamovi (Jamovi version 1.2.25, Sidney, Australia). Alpha was set at a $P \leq 0.05$.

Results

The descriptive results for the countermovement vertical jump (CMJ) indicate that the evaluated soccer players achieved an average height of 42.9 ± 4.13 cm. In terms of the hamstrings eccentric strength manifested in the Nordic curl, similar values were observed for the hamstrings of both legs, with the right leg's average Newtons being slightly lower at 358.6 ± 66.89 compared to the left leg at 368.4 ± 64.30. A similar effect was observed, albeit with a slightly higher trend for the right leg's musculature in the results for maximum isometric strength in adduction (404.6±82.10 N on the right side and 398.4±82.90 N on the left side) and maximum isometric strength in hip abduction (400.9±66.92 N on the right side and 395.7±66.84 N on the left side).

Table 1.
General descriptives

	N	Missing	Mean	SE	SD	Minimum	Maximum
CMJ	154	0	42.9	0.333	4.13	33.20	53.6
NC_L	114	40	368.6	6.022	64.30	216.00	577.0
NC_R	114	40	358.6	6.265	66.89	230.00	525.3
ADD_L	120	34	398.4	7.600	82.90	170.00	608.0
ADD_R	120	34	404.6	7.523	82.10	164.00	595.0
ABD_L	120	34	395.7	6.101	66.84	170.00	541.0
ABD_R	120	34	400.9	6.109	66.92	164.00	597.0

Note. CMJ: Counter Movement Jump; NC_L: Nordic Curl_Left; NC_R: Nordic Curl_Right; ADD_L: Adduction_Left; ADD_R: Adduction_Right; ABD_L: _ Abduction Left; ABD_R: Abduction_Right. All values are measured in N.

Table 2.
Pre session values

	Moment of the season	N	Mean	SD	Minimum	Maximum
CMJ	PRE SESSION	66	43.96	3.92	37.1	52.9
NC_L	PRE SESSION	54	382.46	67.79	216	577
NC_R	PRE SESSION	54	370.66	65.84	247	523
ADD_L	PRE SESSION	57	414.79	73.86	219	608
ADD_R	PRE SESSION	57	424.02	71.88	228	595
ABD_L	PRE SESSION	57	411.93	60.19	299	540
ABD_R	PRE SESSION	57	420.77	60.54	286	597

Note. CMJ: Counter Movement Jump; NC_L: Nordic Curl_Left; NC_R: Nordic Curl_Right; ADD_L: Adduction_Left; ADD_R: Adduction_Right; ABD_L: _ Abduction Left; ABD_R: Abduction_Right. All values are measured in N.

The pre-session values used to establish the strength and power profiles of the players show an average CMJ height of 43.96 ± 3.92cm. In the Nordic Curl, slightly higher values were found on the left side (382.46 ± 67.79N) compared to the right side (370.66 ± 65.84N). In hip adduction, the right side is slightly stronger than the left side (414.79 ± 73.86N left side and 424.02 ± 71.88N on the right side), the same trend was found in hip abduction (411.93 ± 60.19N left side and 420.77 ± 60.54N right side).

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Table 3.
Comparison of values pre and post session

	Group	N	Mean	SD	SE	P	ES
CMJ	POST SESSION	66	42.6	3.91	0.481	0.056	0.337
	PRE SESSION	66	44.0	3.95	0.490		
NC_L	POST SESSION	40	350.5	56.30	8.901	0.017	0.506
	PRE SESSION	54	382.5	67.79	9.225		
NC_R	POST SESSION	40	341.2	64.29	10.165	0.033	0.453
	PRE SESSION	54	370.7	65.84	8.960		
ADD_L	POST SESSION	47	373.2	85.71	12.502	0.009	0.523
	PRE SESSION	57	414.8	73.86	9.782		
ADD_R	POST SESSION	47	376.4	84.01	12.254	0.002	0.613
	PRE SESSION	57	424.0	71.88	9.521		
ABD_L	POST SESSION	47	374.8	72.01	10.504	0.005	0.565
	PRE SESSION	57	411.9	60.19	7.972		
ABD_R	POST SESSION	47	376.4	69.05	10.072	0.001	0.687
	PRE SESSION	57	420.8	60.54	8.019		

Note. CMJ: Counter Movement Jump; NC_L: Nordic Curl_Left; NC_R: Nordic Curl_Right; ADD_L: Adduction_Left; ADD_R: Adduction_Right; ABD_L: _ Abduction Left; ABD_R: Abduction_Right. All values are measured in N.

Table 4.
ANOVA Repeated measures for the 4 moments of the season

	MOMENTS OF THE SEASON	N	Mean	SD	SE	P
CMJ	PRE SESSION 1	22	43.7	3.94	0.841	0.044
	PRE SESSION 2	22	44.2	4.30	0.918	
	PRE SESSION 3	22	44.0	3.67	0.782	
	PRESEASON	22	40.7*	4.58	0.976	
CN_L	PRE SESSION 1	16	379.9	64.52	16.131	0.849
	PRE SESSION 2	17	381.6	73.04	17.714	
	PRE SESSION 3	21	385.1	69.10	15.078	
	PRESEASON	20	367.5	63.45	14.188	
CN_R	PRE SESSION 1	16	365.9	62.86	15.714	0.912
	PRE SESSION 2	17	368.8	75.79	18.382	
	PRE SESSION 3	21	375.8	62.30	13.596	
	PRESEASON	20	360.9	70.52	15.768	
ADD_L	PRE SESSION 1	17	416.4	84.12	20.403	0.952
	PRE SESSION 2	18	421.3	79.82	18.813	
	PRE SESSION 3	22	408.2	62.56	13.337	
	PRESEASON	16	413.9	93.97	23.493	
ADD_R	PRE SESSION 1	17	427.7	81.11	19.673	0.853
	PRE SESSION 2	18	432.7	76.41	18.009	
	PRE SESSION 3	22	414.1	62.13	13.247	
	PRESEASON	16	418.5	93.95	23.487	
ABD_L	PRE SESSION 1	17	396.1	54.51	13.197	0.492
	PRE SESSION 2	18	412.8	60.70	14.307	
	PRE SESSION 3	22	423.5	63.86	13.614	
	PRESEASON	16	399.5	60.20	15.050	
ABD_R	PRE SESSION 1	17	411.4	52.42	12.713	0.659
	PRE SESSION 2	18	425.2	65.97	15.550	
	PRE SESSION 3	22	424.4	63.68	13.577	
	PRESEASON	16	402.1	61.97	15.493	

Note. CMJ: Counter Movement Jump; NC_L: Nordic Curl_Left; NC_R: Nordic Curl_Right; ADD_L: Adduction_Left; ADD_R: Adduction_Right; ABD_L: _ Abduction Left; ABD_R: Abduction_Right. All values are measured in N.
**P<0.05, differences among pretest3 and pretemp*

The results obtained through the assessments of the Nordic curl and maximum isometric strength in hip adduction and abduction, as shown in Table 3, display significantly lower values $p< 0.05$ post-session than pre-session. These results are particularly relevant as they can be primarily associated with the state of acute neuromuscular fatigue. In contrast, the CMJ assessment does not show a statistically significant change, P=0.056, with results showing a value of 44.0±3.95 cm pre-session and 42.6±3.91 cm post-session.

Table 4 presents the results of each measurement taken throughout the season (pre-session) and preseason. The analyzed data only showed significant differences in the CMJ parameters between the assessment conducted in pre-session 3 and that of the preseason. The values showed a decrease in jump height, with a result of 44.1 cm in the third pre-session evaluation and 40.7 cm in the preseason assessment, being $p< 0.05$. Although the results do not show statistically significant differences in the rest of the evaluations, a trend towards a decrease in values after the transitional period compared to those obtained in pre-session evaluations was observed.

Moreover, the highest strength values predominantly occurred in pre-session 2 in ADD (right segment 432.7±76.41N, left segment 421.3±79.82N) and ABD right segment 425.2±65.97N, while left segment's highest occurred in pre-session 3 (425.3±63.86N), and in pre-session 3 in NC (right segment 375.8±62.30N, left segment 385.1±69.10N), being these the reference values to take into account the decrease produced regarding the values of the transitional period.

Discussion

The objectives of this work were to (1) determine the strength values in a professional Major League Soccer (MLS) team during a season, (2) analyze the results of the assessments performed in pre and post-session; (3) determine the effect of the transitional period on strength and power. In relation to these, the main findings were a) the different muscle groups evaluated obtained similar strength values in both legs, b) a significant reduction in strength and power values was observed after the training session, except for the CMJ height, and c) strength levels remained stable after the transitional period, except for the CMJ height, which significantly decreased.

Regarding the eccentric strength values of the hamstrings, Brogden et al. (2020) found an average of 300N in Nordic hamstring with U16 academy players. Furthermore, it has been established that a risk threshold for injury may be placed at 350N (Timmins et al., 2016), while in the Premier League, values of up to 500N have been observed (Taberner and Cohen, 2018). The current results (382.46N in the left leg and 370.66N in the right leg) are within a recommended range.

Although it is suggested that Nordic exercises are effective in reducing the probability of injuries in soccer players according to a meta-analysis work (Avila-Quintero et al., 2024), and that is also recommended to strengthen the hamstrings through unilateral exercises to reduce the risk of high asymmetries and therefore promote injury prevention (Wiriawan et al., 2024) ,it is essential to consider that injuries are multifactorial and that these values only provide a starting point as a valuable tool for identifying strength deficiencies and asymmetries in the hamstrings allowing us to adapt and plan specific training programs according to the needs.

For maximum isometric strength in hip adduction and in comparative analysis with previous studies, similarities and discrepancies are observed in relation to the results obtained in this research. Jones et al. (2021) found that U18 players exhibited an average of 429 ± 52N, figures that align with the findings of this study, where values of 414.79 ± 73.86N in the left leg and 424.02 ± 71.88N in the right leg were recorded. Conversely, in a study with semi-professional soccer players, Moreno-Pérez et al. (2022) reported an average of 325N.

For the maximum isometric strength values in hip abductors, and in the same research work by Moreno-Pérez et al. (2022), it was observed that the results were higher compared to this study. In their work, participants presented average values of 518N. In contrast, the results obtained from the present work were 411.93± 60.19N in the left leg and 420.77 ± 60.54N in the right leg.

Lastly, regarding the assessments of the CMJ, Loturco et al. (2020) found an average height of 40 cm in professional soccer players, results that align with those obtained in this research (43.96 ± 3.92cm). It's worth mentioning that it is a widely recognized evaluation and easily implemented across various sports disciplines involving triple flexion-extension actions, providing multiple benefits as a reliable tool for detecting neuromuscular fatigue (Nedelec et al., 2014), as well as for creating strength profiles (Nuzzo et al., 2008) and for Return to Play stages (Cohen et al., 2014; Taberner et al., 2020). It should be noted that the evaluation of the jump´s height is important for sports performance and for the identification of new talents (Fernández-Galván et al., 2024), where other benefits have been found regarding jumping specifically from plyometric training, like the improvement of the change of direction and jumping performance in youth male soccer players (Muñoz et al., 2024) and to promote long-term strength and power in young, healty males (Raharjo et al., 2024).

Reviewing the literature reveals that, after a simulated soccer game, Fransson et al. (2018) detected decrements in hamstring strength of -14 ± 3%, -9 ± 2% in adductors, and -6 ± 1% in abductors. In this context, our results similarly demonstrate decreases in strength when assessments are conducted after the main soccer training session. These decreases may relate to the acute neuromuscular fatigue generated during the pitch session and the negative effect on adaptations due to concurrent training, defined as the simultaneous training of strength and endurance in the same periodized training regimen (Fyfe et al., 2014), where it has been seen that the physiological response of aerobic training can affect and/or attenuate the desired adaptations in strength training (Hickson, 1980). To avoid this, different recommendations exist, such as planning high-intensity aerobic training in the morning followed by a minimum rest period of 3 hours before strength training (Baar 2014), or what we suggest based on the results obtained; conducting the strength session prior to the pitch session, with the advantage of obtaining a post-activation potentiation (PAP) effect, a phenomenon by which muscle performance is increased due to an enhancement in muscular contractile ability following a high-intensity voluntary contraction (Wyland 2015; Seitz & Haff, 2016; Tillin & Bishop, 2009). Several studies have demonstrated the positive effects of PAP on performance in soccer (Gamberi 2019), specifically in improvements in jump outcomes observed also in different team sports (Gouvêa et al., 2013), in improving changes of direction (Zois et al., 2011), and in the ability to repeat sprints (Low et al., 2015; Sanchez-Sanchez et al., 2018); possibly due to short-term neuromechanical adaptations like an increase in muscle-tendon stiffness (Tillin and Cooke, 2009).

Regarding the long-term transitional period combined with a significant decrease in training loads and a return to training with high increases in intensity, presents a high risk of injury (Jeong et al., 2011). It can be classified as short-term: <4 weeks; and long-term: >4 weeks (Mujika and Padilla, 2000). Therefore, it is suggested to prescribe individualized training plans for the transitional period as much as possible, of low frequency, with accessible tools, with clear instructions and objectives (Silva et al., 2016), planning two weekly sessions separated by 48-72 hours (Rønnestad et al., 2011), including one weekly session of HIIT (Slettaløkken and Rønnestad, 2014), which could serve as a reference starting point.

Conclusions

The results demonstrate that the values of maximum eccentric strength and maximum isometric strength are more sensitive to acute neuromuscular fatigue; and it seems that the strength adaptations can be maintained for a longer time since there was no significant change in the values after the transitional period. Unlike power strength, specifically addressing the CMJ height, which conversely showed lower sensitivity to acute fatigue represented by a significantly low change between pre-session and post-session evaluation, but with a significantly high change after the transitional period, showing more sensitivity over a period of detraining. However, the low sensitivity to acute post-session fatigue of the CMJ height could be due to changes in movement strategies such as an increase in contact time or contraction time of the movement resulting in greater force application and showing a height similar to the CMJ height in pre-session.

Practical Applications

In line with the objectives and established results, it is determined that there are multiple benefits to performing

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assessments and strength and/or power sessions pre-session over post-session (before pitch session), such as maximizing the development of applied strength allowing optimal execution without the negative effects of fatigue thus optimizing the positive adaptations of training and even favoring the quality of specific sports actions in the technical-tactical session by the effect of post-activation potentiation. This also leads to obtaining more significant strength values when establishing the benchmarks and profiling of our athletes, allowing for better monitoring of player adaptation, and optimizing Return to Play stages in case of injury.

Other benefits of designing strength sessions in pre-session based on the objectives of the main pitch session would allow synchronizing, unifying, and better preparing the main muscle structures according to the specific demands and desired objectives of the day, enriching the session; thus, reducing the volume of generic warm-ups and increasing the effective specific work time.

Therefore, this approach is highly recommended, as values in post-session assessments experienced reductions, mainly attributed to acute neuromuscular fatigue and possibly psychological fatigue. Similarly, the prescription and execution of training plans during the transitional period (off season) are suggested as a key maintenance strategy to minimize the loss of previously acquired physical adaptations as much as possible, facilitating the return to training and promoting the reduction of injury risk during the next preseason.

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