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An Integrated Approach to Explore Interlimb Asymmetries, Neuromuscular Parameters, and Injuries in Semiprofessional Soccer Players

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Abstract: Interlimb asymmetries have been widely studied with controversial results, suggesting that the magnitude of asymmetries is highly task-dependent and could be related to injury risk. This study aimed to establish an optimal method for assessing asymmetries and evaluate interlimb power performance and range of motion asymmetries in injured and non-injured male semiprofessional soccer players. A prospective and descriptive design was applied, and 20 male semiprofessional soccer players participated. The players underwent a battery of screening tests (i.e., countermovement jump [CMJ], half-squat, hip abduction and hip adduction isometric force, knee flexion and extension isokinetic torque, and lower limb range of movement). The healthy players had a greater range of motion in the hip extension and ankle flexion of the dominant leg and hip abduction and knee flexion of the non-dominant leg. However, the injured players exhibited greater asymmetry in hip abduction maximum isometric strength. These findings suggest the importance of establishing a comprehensive method to assess the range of motion interlimb asymmetries related to injury risk in semiprofessional soccer players.

Keywords: football; injury risk; imbalance; lower limb

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1. Introduction

Soccer is a highly demanding sport characterized by an unpredictable combination of high-intensity actions (i.e., change of direction, sprinting, jumping, kicking) with periods of low-intensity activity [1]. Due to the great demands and load that soccer players must support during their practice, soccer is considered a risky team sport [2,3], so adequate physical fitness levels are required to reduce the injury risk [4,5]. Due to the negative effects that injuries have on athletes' performance, club finances, and long-term player health in professional soccer, an investigation of internal factors affecting injury risk is warranted.

Previous control motor theories suggest that the presence of interlimb asymmetries could represent a potential constraint limiting athletes' movement strategies and leading to motor behaviors that increase injury risk [6]. To assess interlimb asymmetries in soccer populations, previous studies have used different fitness tests in isolation or in combination with only one or two other tests, such as the effects of the countermovement jump (CMJ), isometric and isokinetic strength, and/or range of movement on the risk of injury [7,8]. However, considering that the magnitude of asymmetry is highly task-dependent with a large variation between tasks [9–11], a wider screening test battery is needed. Furthermore, the findings in the scientific literature regarding the relationship between interlimb asymmetries and injury risk are highly inconsistent, and it is not possible to draw a clear conclusion regarding this association, possibly due to the lack of standardized assessment protocols for various tests [7,8,12]. On one hand, several studies did not associate interlimb strength and/or range of movement asymmetries with injury risk [13–18]. On the other hand, studies have found that players with functional asymmetries possess a higher risk of sustaining hamstring strains, and the rate of muscle injury increases in subjects with untreated strength imbalances [10,19–21]. This gap highlights the need to continue searching for optimal assessment methods and investigating how these asymmetries may contribute to injury risk, as understanding these relationships could provide valuable insights for injury prevention strategies in this population.

Considering this controversy, a comprehensive muscle interlimb asymmetry profile in soccer players is needed. Thus, the main aim of this study was to establish an optimal method for assessing asymmetries and secondarily to evaluate asymmetries in terms of CMJ height, half-squat mean propulsive power and velocity, isometric strength, knee flexion and extension maximum isokinetic strength, and range of movement in a small sample of male semiprofessional soccer players. Considering the literature [6,10,21] and the existing controversy, we hypothesized that the soccer players who suffered an injury would present higher rates of interlimb asymmetry in all the variables analyzed.

2. Materials and Methods

2.1. Study Design

In this exploratory study, a prospective and descriptive design was applied to evaluate and compare interlimb asymmetries between injured and healthy male semiprofessional soccer players, as well as to explore the association between interlimb asymmetries and the occurrence of musculoskeletal injuries in the four months after the assessment. This information could be valuable to establish an optimum assessment method. Participants underwent a battery of screening tests (i.e., CMJ, half-squat, hip abduction and hip adduction isometric force, knee flexion and extension isokinetic torque, and lower limb range of movement). All the procedures were executed under standard environmental conditions (i.e., humidity, temperature, and training gear). Four trained researchers supervised all the procedures. Participants were asked to refrain from strenuous exercise 48 h before each testing session to control fatigue stress, to sleep at least 8 h the night before, and to adhere to their usual diet.

2.2. Participants

At the beginning of the study, all the participants were healthy and without injury. Twenty semiprofessional male soccer players (injured, *n*: 5, age: 25.000 ± 2.545 years, body mass: 77.876 ± 7.243 kg, height: 180.00 ± 5.95 cm, body fat: 14.941 ± 3.048%, bone mineral density: 1.422 ± 0.192 g·cm^2; healthy, *n*: 15, age: 24,671 ± 5562 years, body mass: 70.37 ± 5.49 kg, height: 176.83 ± 6.49 cm, body fat: 15.487 ± 2.834%, bone mineral density: 1.494 ± 0.192 g·cm^2) participated in this investigation. No indicators of osteopenia or osteoporosis were observed in any player. All players competed for the same team in a national league in Spain. The inclusion criteria for this study were that participants should not have experienced musculoskeletal injuries in the two months prior to the tests, in addition to completing all required tests. On average, the players trained four times per week, with one official competition per week. Regarding group allocation, five players suffered an injury in the four months after the study and, therefore, were allocated into the injury group. All the rest of the participants were allocated to the healthy group (n = 15). All the participants were notified of the research procedures and signed informed consent forms. The study was approved by the local Ethics Committee (code: Ui1-PI019). The procedures were consistent with the institutional ethical requirements for human experimentation following the Declaration of Helsinki as revised in 2013.

2.2.1. Injury Definitions and Data Collection

This study was conducted according to the guidelines provided by the Union of European Football Associations (UEFA) for epidemiological research [22]. Injury was defined as "an injury that occurred during a scheduled training session or match that caused absence from the next training session or match" [22]. Interlimb asymmetries were considered following the concept of the performance of two limbs not being equal (dominant and non-dominant limbs) [23]. Musculoskeletal injury was defined as damage affecting the muscles, bones, ligaments, tendons, or other soft tissues supporting the body's structure and movement [24]. The club's medical staff diagnosed all injuries and followed the progression during the rehabilitation process [25]. Injuries were registered on a computerized standard report based on the UEFA instruction manuals [26].

2.2.2. Injury Surveillance

The occurrence of injuries in the four months following the study was recorded as a categorical variable (yes/no), and consequently, athletes were allocated ex post in two groups (healthy and injured). The researcher in charge recorded the occurrence of any injury through an individual interview with each participant. Sports injury is a broad term with various definitions in the scientific literature [2,27–30]. For the present study, injuries were considered as musculoskeletal damage in the lower limb that prevented athletes from competing or training for at least three days [31].

2.3. Procedures

The measurements of the dependent variables were conducted in a double session, and the occurrence of injuries was recorded four months after the assessment. Two familiarization sessions were conducted during the two weeks preceding the experimental session. After the anthropometric measurements, a standardized warmup consisting of dynamic movements and low-intensity running was conducted. At this point, all the tests were conducted in random order (https://www.random.org/lists/, accessed on 28 September 2024). All the tests were performed both bilaterally and unilaterally. The dominant leg was defined by each participant's preferred leg for shooting [32]. Fourteen players were right-dominant.

2.3.1. Anthropometric Measurements

Anthropometric measurements of body mass and height were obtained with an electronic scale (OHAUS Corp., Florham Park, NJ, USA) and a stadiometer (Seca 213, Hamburg, Germany), respectively. Body composition (body fat percentage and bone mineral density of the legs) was measured from a whole-body scan by means of DXA using a total body scanner (Hologic QDR Series, Delphi A model, Bedford, MA, USA), with analysis performed according to the manufacturer's procedures and previous research [33].

2.3.2. Countermovement Jump

Bilateral and unilateral CMJ were conducted according to the literature [34]. Participants performed two tries separated by a rest of 45 s. A platform with infrared rays (Optojump Next, Microgate 1, Bolzano, Italy) was used to obtain jump height. The highest height was kept for further statistical analyses.

2.3.3. Half-Squat Power Test

A partial high-bar back squat [35] was performed with 30 kg and 40 kg according to previous research [33]. The range of movement was standardized with a goniometer from the standing position of the participants to 90° of knee flexion. A horizontal band was placed at this height to establish the squat depth. Participants performed the eccentric phase at a controlled pace until they touched the horizontal band (midthigh). At this point, participants were instructed to perform a maximum-speed concentric phase returning to full extension. Two minutes of rest were allowed between the loads and a 30 s rest between the bilateral and unilateral squats. Measurements of mean propulsive power and velocity were obtained with an encoder (SmartCoach Power Encoder SPE-35, SmartCoach Europe AB, Stockholm, Sweden).

2.3.4. Hip Abduction and Adduction Maximum Isometric Force

Maximum isometric force in hip abduction and adduction was assessed using a handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments, Lafayette, IN, USA). Following previous research [36,37], participants lay in a supine position with their legs extended. Two warmup sets at 50% and 80% of the self-perceived maximal isometric voluntary contraction were performed. Afterward, five tries of five seconds of a maximum isometric voluntary contraction for each hip movement were conducted. The best result was recorded for the statistical analyses.

2.3.5. Isokinetic Maximum Torque During Knee Extension and Flexion

Isokinetic concentric torques during knee extension and flexion were assessed following the methods employed by previous research [36,38]. Three attempts were performed. The highest peak torque was recorded (Biodex System-4, Biodex Corp., Shirley, NY, USA) for further analysis. If a variation >5% was found, the mean of the two closest values was kept for the analysis.

2.3.6. Lower Limb Range of Movement

A battery of passive range of movement measures employed in the literature was performed in both the dominant and non-dominant leg [34,36]. Passive range of movement tests included (1) hip flexion with flexed and (2) extended knee, (3) hip extension with flexed knee, (4) hip abduction with flexed knee, (5) knee flexion, and (6) ankle dorsiflexion with flexed and (7) extended knee. A valid laser-guided digital goniometer (HALO Medical Devices, Subiaco, Australia) was used to obtain the measurements [39]. Two measurements were taken separated by 30 s, and the average value of both was calculated for further analysis.

2.4. Statistical Analysis

Descriptive data are presented as mean ± standard deviation (SD). After basic data curation, the normality of data distribution was assessed through the Shapiro–Wilk test. All the variables showed a normal Gaussian distribution ($p > 0.05$). Only certain asymmetry, power, and range of movement variables showed a non-normal distribution ($p < 0.05$). Interlimb asymmetries were calculated as [(dominant–non-dominant)/(dominant)] × 100.

3. Results

Both groups were similar ($p > 0.05$) in terms of their age, height, body fat, and bone mineral density. However, the healthy group showed more range of movement in the hip extension and ankle flexion with extended knee of the dominant leg and the hip abduction with flexed knee and knee flexion of the non-dominant leg (Table 1).

Table 2 shows the differences in asymmetry scores in the study group (injured or healthy group). It is worth highlighting that the injured group presented greater asymmetry in the hip abduction maximum isometric force. Additionally, moderate effects were observed in the hip flexion extended knee asymmetry and knee flexion asymmetry.

Table 1. Mean and standard deviation of the test performance variables.

	Group			
	Injured		Healthy	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Neuromuscular Performance				
Bilateral CMJ Height (cm)	34.32	1.77	32.74	4.35
Dominant Leg CMJ Height (cm)	18.03	2.72	18.81	2.23
Non-Dominant Leg CMJ Height (cm)	19.43	1.67	17.40	2.85
Bilateral Half-Squat 30 kg Power (W)	283.58	19.62	272.61	26.01
Dominant Leg Half-Squat 30 kg Power (W)	223.30	27.47	227.66	19.39
Non-Dominant Leg Half-Squat 30 kg Power (W)	215.40	27.42	220.45	22.73
Bilateral Half-Squat 40 kg Power (W)	357.32	22.63	353.96	34.39
Dominant Leg Half-Squat 40 kg Power (W)	290.30	33.50	290.71	30.61
Non-Dominant Leg Half-Squat 40 kg Power (W)	280.62	27.28	287.45	34.12
Bilateral Half-Squat 30 kg Velocity (m/s)	0.94	0.08	0.89	0.08
Dominant Leg Half-Squat 30 kg Velocity (m/s)	0.74	0.09	0.76	0.06
Non-Dominant Leg Half-Squat 30 kg Velocity (m/s)	0.72	0.09	0.74	0.08
Bilateral Half-Squat 40 kg Velocity (m/s)	0.88	0.06	0.86	0.07
Dominant Leg Half-Squat 40 kg Velocity (m/s)	0.71	0.08	0.72	0.07
Non-Dominant Leg Half-Squat 40 kg Velocity (m/s)	0.69	0.06	0.70	0.09
Dominant Hip Abduction Maximum Isometric Force (n)	247.22	43.17	236.95	32.56
Non-Dominant Hip Abduction Maximum Isometric Force (n)	216.50	30.87	224.11	32.44
Dominant Hip Adduction Maximum Isometric Force (n)	239.37	58.75	235.50	31.12
Non-Dominant Hip Adduction Maximum Isometric Force (n)	234.23	63.79	232.02	28.66
Dominant Knee Extension Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ ($n\cdot$m)	486.67	132.91	450.63	90.78
Non-Dominant Knee Extension Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ ($n\cdot$m)	487.40	89.21	446.04	99.19
Dominant Knee Flexion Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ ($n\cdot$m)	244.30	56.17	244.68	58.10
Non-Dominant Knee Flexion Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ ($n\cdot$m)	241.74	53.22	243.85	73.93
Range of Movement (°)				
Dominant Hip Flexion Flexed Knee	145.80	6.46	149.20	8.72
Non-Dominant Hip Flexion Flexed Knee	144.20	7.56	148.00	8.26
Dominant Hip Flexion Extended Knee	89.00	9.17	89.27	14.71
Non-Dominant Hip Flexion Extended Knee	86.00	7.38	89.80	17.24
Dominant Hip Extension	9.20	1.79	12.73	4.28
Non-Dominant Hip Extension	10.20	1.64	12.80	4.51
Dominant Hip Abduction Flexed Knee	68.60	9.94	77.27	10.54
Non-Dominant Hip Abduction Flexed Knee	65.00	6.44	74.47	9.49
Dominant Knee Flexion	119.00	7.91	121.47	12.62
Non-Dominant Knee Flexion	110.00	14.27	120.93	11.16
Dominant Ankle Flexion Extended Knee	53.80	3.96	58.47	3.78
Non-Dominant Ankle Flexion Extended Knee	55.60	4.28	56.73	3.90
Dominant Ankle Flexion Flexed Knee	55.00	3.32	58.47	4.02
Non-Dominant Ankle Flexion Flexed Knee	54.80	7.26	57.73	4.59

Table 2. Interlimb asymmetry, presented as a percentage (%). Results for all the neuromuscular and range of movement tests conducted.

	Group			
	Injured		Healthy	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Neuromuscular Performance Asymmetries (%)				
CMJ Height Asymmetry	8.48	7.30	13.65	11.60
Half-Squat 30 kg Power Asymmetry	6.12	2.74	6.21	3.84
Half-Squat 40 kg Power Asymmetry	6.40	2.62	5.28	3.40
Half-Squat 30 kg Velocity Asymmetry	4.46	2.10	5.03	2.78
Half-Squat 40 kg Velocity Asymmetry	4.28	2.94	5.70	3.01
Hip Abduction Maximum Isometric Force Asymmetry	12.06	3.88	7.12	4.77
Hip Adduction Maximum Isometric Force Asymmetry	6.32	1.94	5.63	3.94
Knee Extension Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ Asymmetry	10.18	6.77	7.30	6.30
Knee Flexion Maximum Isokinetic Force at $30^{\circ}\cdot s^{-1}$ Asymmetry	11.32	4.00	14.11	13.85

Table 2. *Cont.*

	Group			
	Injured		Healthy	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Range of Movement Asymmetries (%)				
Hip Flexion Flexed Knee Asymmetry	2.74	1.88	3.73	2.82
Hip Flexion Extended Knee Asymmetry	4.68	2.12	9.11	9.44
Hip Extension Flexed Knee Asymmetry	10.00	6.09	14.71	10.51
Hip Abduction Flexed Knee Asymmetry	6.64	5.89	8.97	7.33
Knee Flexion Asymmetry	8.10	6.97	4.84	3.38
Ankle Flexion Extended Knee Asymmetry	4.68	2.76	6.80	5.29
Ankle Flexion Flexed Knee Asymmetry	7.96	3.56	5.81	4.72

4. Discussion

This study aimed to explore interlimb asymmetries using a comprehensive battery of neuromuscular and range of motion tests in injured and healthy semiprofessional soccer players and to establish an optimal method for assessing asymmetries. To the best of our knowledge, this is the first study to analyze the interlimb asymmetries (in such a complete battery of tests) in the CMJ, squat velocity and power, isometric and isokinetic maximal strength, and range of movement and establish their relationship with the presence of injury in semiprofessional soccer players. The main results of the present study show that the healthy group had a greater range of motion in the hip extension and ankle flexion of the dominant leg and hip abduction and knee flexion of the non-dominant leg. However, the injured group exhibited greater asymmetry in maximum isometric hip abduction strength. Nonetheless, no differences were found in the other measures of asymmetry compared between the players who suffered an injury and those who did not. Although we observed some differences, it is important to highlight that the small sample size, particularly the five injured players, limits the generalizability of these findings, and this study should be viewed as an exploratory analysis.

A focus on neuromuscular values in specific tests is required to determine whether an athlete is ready to train and compete [40], as prematurely returning to play without being adequately prepared may contribute to the explanation of the high risk of recurrent injuries in soccer [41]. Therefore, restoring pre-injury values is crucial to performing at the highest level and reducing the injury risk during match-play [42], emphasizing a controlled rehabilitation process in which players regain full range of motion, coordination, and at least 90% of their muscle strength before returning to play [43]. The results of our study showed that healthy players had a greater range of motion in hip extension and ankle flexion in the dominant leg and in hip abduction and knee flexion in the non-dominant leg compared to injured players. These differences could be explained by the demands of soccer as a team sport, which require players to perform a series of high-intensity repeated movements such as sudden accelerations and decelerations, quick changes of direction, jumps, and landing tasks [1]. These movements impose strong concentric and eccentric loads on the hip, knee, and ankle joints in shortened and contracted positions [44]. Since these actions are performed several times during training sessions and matches, the reduced range of motion in both the dominant and non-dominant leg joints may have influenced the occurrence of injuries in these players. Therefore, it might be interesting for strength and conditioning specialists to conduct a specific assessment to determine when the player is ready to return to compete once injured.

Previous research has analyzed interlimb strength asymmetries in soccer players [9,45], proposing a threshold of 10–15% asymmetry as an injury risk factor [46]. The mean overall values in our study are below this threshold, and this could be mediating the results obtained. However, the presence of population thresholds for asymmetries and injury risk is under debate, and a more individual approach should be adopted. As proposed by a previous study [12], asymmetries can be considered common in asymmetric sports and be viewed as a window for development. Therefore, training should be focused on improving the performance and function of the non-dominant limb without neglecting the dominant limb [12].

The obtained results are in line with previous research that did not associate interlimb strength and/or range of movement asymmetries with injury risk [10,13–18], because no differences were found in any neuromuscular and range of motion asymmetry scores between the injured and healthy groups, except greater asymmetry in maximum isometric hip abduction strength in the injured players. A probable explanation for the non-significant association between interlimb asymmetries and injury occurrence is the relationship between fatigue, asymmetries, and injury risk [9]. Previous research has proposed that the combination of fatigue and interlimb asymmetry could be a risk factor mediating the occurrence of injury more than baseline (without fatigue) asymmetry [9]. In this regard, repeated sprints increase interlimb asymmetries through acute fatigue [47]. Considering that our results, in general, did not associate baseline interlimb asymmetry with injury occurrence, future research could evaluate the effect of match-related fatigue before and after the game. The association between asymmetries and injury risk cannot be confirmed or ruled out [7,8,12]. Focusing on the potential effects of interlimb asymmetries on performance, previous studies have analyzed the effects of interlimb jump asymmetries on the sprint [48,49], jump [11,48,49], and change of direction [50] performance in athletes, with controversial results.

Although this is an exploratory study, there are certain limitations that should be considered in future research. Even though our results showed, in general, no effect of interlimb asymmetries on the occurrence of injuries, given the limited sample size, particularly in the injured group, the power of our analysis is reduced, and the results should be interpreted with caution. This study should be seen as an exploratory analysis, opening the door to future research with larger and more diverse samples to confirm or refute these findings. Additionally, factors such as training load, intensity, or match participation could influence both performance in the screening tests and injury risk and should be considered in future investigations. Although not the focus of the current study, it could be interesting to analyze the severity, type of injury, or the time of absence following the injury in future research.

In summary, our results could not confirm the association between interlimb asymmetries and the occurrence of injuries. Bearing in mind the evidence presented and the scientific literature consulted, individualization of interlimb asymmetry tests and thresholds should be considered in practical applications. The observed differences can serve as trends for coaches and future researchers in the assessment of asymmetries to detect limitations that may be associated with a higher risk of injury. However, further research on this topic is needed.

5. Conclusions

The present study evaluates interlimb asymmetries using a comprehensive test battery. The results reveal differences in interlimb asymmetries (e.g., range of motion), but no important differences in neuromuscular parameters between healthy soccer players and those who sustained injuries in the four months following the study. This finding suggests that the risk of injury may be more closely related to interlimb range of motion asymmetries in soccer players than to neuromuscular parameters. Overall, our results do not confirm a definitive association between interlimb asymmetries and injury occurrence. These findings should be regarded as the result of an exploratory study that contributes to the evaluation of asymmetries related to injuries in soccer players and outlines future lines of research to pursue.

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