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Running Symmetry in Professional Football: Are We Measuring What Matters?

Profesyonel Futbolda Koşu Simetrisi: Gerçekten Ne Düşündüğümüzü Ölçüyor muyuz?

Research Article / Araştırma Makalesi

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Abstract

The aim of this study is to evaluate the relationship between running symmetry measured by GPS devices and the risk of injury and performance metrics among professional soccer players. A total of 18 professional football players from a club competing in the Turkish Super League participated in the research. Throughout the 2022-2023 season, running symmetry data of the players were recorded using a GPS system. Football players' running symmetry and performance metrics can be affected by training history, physical adaptation and cultural training differences. Whether there are differences in such parameters between local and foreign football players who have trained in different leagues and with different methodologies has also been included in the study. The study aims to evaluate not only whether running symmetry is a biomechanical parameter but also its effect on performance variables related to injury risk. Also, metrics such as total distance, high intensity running distance, high metabolic power distance, player load, accelerations and decelerations were also recorded throughout the season. Analysis of the data revealed significant differences in running symmetry among players. Statistical differences were found between defender and attacker and midfielder players in terms of player load values. Moreover, a positive correlation was observed between running symmetry and certain performance metrics, suggesting a potential link between running symmetry and sports performance. Consequently, running symmetry measured via GPS technology may serve as a valuable indicator for performance and injury risk among professional soccer players.

Keywords: Running symmetry, GPS, Performance, Injury, Football

Öz

Bu çalışmanın amacı, GPS cihazlarıyla ölçülen koşu simetrisi ile profesyonel futbolcuların yaralanma riski ve performans metrikleri arasındaki ilişkiyi değerlendirmektir. Türkiye Süper Liginde mücadele eden kulüpten 18 profesyonel futbolcu araştırmaya katılmıştır. 2022-2023 sezonu boyunca GPS sistemi yardımıyla futbolcuların koşu simetrisi verileri kaydedilmiştir. Ayrıca toplam mesafe, yüksek şiddetli koşu mesafesi, yüksek metabolik güç mesafesi, oyuncu yükü, ivmelenme ve yavaşlama gibi performans metrikleri de tüm sezon boyunca kaydedilmiştir. Futbolcuların koşu simetrisi ve performans metrikleri, antrenman geçmişi, fiziksel adaptasyon ve kültürel antrenman farklılıklarından etkilenebilir. Özellikle farklı liglerde yetişmiş, farklı metodolojilerle antrenman yapmış olan yerli ve yabancı futbolcular arasında bu tür parametrelerde farklılıklar olup olmadığı da araştırmaya dahil edilmiştir. Araştırmada koşu simetrisinin yalnızca bir biyomekanik parametre olup olmadığını değil, aynı zamanda sakatlık riski ile ilişkili performans değişkenleri üzerindeki etkisini de değerlendirmeyi amaçlamaktadır. Yapılan analiz sonuçları, oyuncular arasında koşu simetrisinde belirgin farklılıklar olduğunu ortaya koymuştur. Savunma oyuncularıyla oyuncu yükü değerleri açısından hücum ve orta saha oyuncuları arasında istatistiksel olarak anlamlı fark olduğu bulunmuştur. Ayrıca, koşu simetrisi ile belirli performans metrikleri arasında pozitif bir korelasyon gözlemlenmiştir. Bu durum koşu simetrisi ile spor performansı arasında potansiyel bir bağlantı olduğunu göstermektedir. Sonuç olarak, GPS teknolojisiyle ölçülen koşu simetrisinin, profesyonel futbolcularda performans ve sakatlık riski için değerli bir gösterge olarak hizmet edebileceğini öne sürmektedir.

Anahtar Kelimeler: Koşu simetrisi, GPS, Performans, Yaralanma, Futbol

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Introduction

In the sports industry, especially in football, technological advancements and analytical programs have led to a situation where more quantitative data can be collected and analyzed daily, as noted by sports science researchers (Millington & Millington, 2014). At the same time, we are currently in a period where professional athletes rank among the top earners in society, with contracts signed with players based on the expectation of their contributions to team success and shared objectives with their clubs. For example, Cristiano Ronaldo was reported to have earned approximately fifty-three million dollars in the 2015-2016 season, over which he played forty-eight matches for Real Madrid FC, earning over $1 million per match and underscoring the substantial value athletes can bring to an organization (Saba, 2016).

Injuries suffered by footballers, or similar circumstances, can result in significantly less contribution to their teams, contrary to the club's expectations at the start of the season. To illustrate the financial impact of athletes' injuries on clubs, a detailed analysis can be performed using the example of the English player Wayne Rooney. This analysis is conducted by calculating the cost of the matches missed during the player's injury by multiplying these by his weekly wage. According to Transfermarkt (2024), if it is assumed that Rooney experienced injuries intermittently for 3 months over a period of 9 months, missing 36% of the matches during this time, and if it is considered that Rooney was earning two hundred fifty thousand pounds per week, then the player has the cost £7.5 million approximately to the club for this period. Therefore, it can be understood that Manchester United has paid either two point seven million pounds or 36% of seven point five million pounds to an athlete who could not perform physically during the injury period. Luke Shaw, earning seventy thousand pounds a week, missed 7 months in other words 86% of the same 9-month period due to injuries, costing the club approximately £1.8 million (Saba, 2016). The examples provided illustrate how injuries can impact more than just the matches lost, particularly in the case of players with higher salaries. The financial implications of injuries extend beyond mere lost matches for clubs, encompassing other significant expenditures such as medical care, rehabilitation costs, decreased ticket sales, and funding for potential end-of-season activities.

After injuries in football, if surgery is required during the recovery process, athletes must then undergo a comprehensive rehabilitation program (Mangine, Minning, Eifert-Mangine, Colosimo & Donlin, 2008). Experts adding alternative treatments like cryotherapy often incur additional costs for clubs, especially when using external resources, for athletes who are unable to contribute their physical performance skills to their club. The key to maximizing the 'profit' that can be obtained from players is to closely monitor their performance in training or matches, regularly adjust training programs to maximize benefits from the player or focus on minimizing the time spent away from the field/team by emphasizing a quick rehabilitation period post-injury. If the rehabilitation process is rushed, proper recovery and return to the field may not occur, potentially leading to the development of new injuries. The extra time spent in returning players to the field can result in the inability to implement physical performance (Schmitt, Tim & McHugh, 2012). When considering wearable technologies in football, Global Positioning Systems (GPS) and related equipment can accurately and reliably collect quantitative variables such as total distance, high intensity running, sprint distances, or the impact on the ground during training and matches, thus analyzing players' physical performance (Kelly, Coughlan, Green & Caulfield, 2012; Montgomery, Pyne & Minahan, 2010). Wearable GPS devices are becoming increasingly popular among top sports teams such as the English Premier League, NFL, and NBA (Aoki et al., 2017). These technological advancements allow coaches to gather a comprehensive dataset exceeding 100 variables, encompassing both internal and external load parameters, daily.

GPS technologies have great importance and potential within sports sciences and coaching practices. Devices such as accelerometers, gyroscopes, heart rate monitors, and GPS systems enable the collection of critical variables for assessing training load. These variables include objective measurements necessary for evaluating athletes' performance, such as speed, heart rate, total distance covered, high intensity running distance, sprint distance, ground reaction force, running or walking symmetry, and body load. Particularly, data of walking and running symmetry obtained through GPS technology help coaches and sports scientists to make training plans and injury prevention strategies more consciously by determining symmetric and asymmetric differences in left and right walking/running patterns. The symmetry of walking/running derived from these systems is defined by equal measurements of variables such as acceleration/deceleration and ground reaction forces on both sides (Kim & Lee 2013; Staab et al., 2014; Vogt, Banzer, Bayer, Schmidtbleicher & Kerschbaumer, 2006). When the maximum forces exerted on the ground are the same during right and left foot impacts, they are labelled as "symmetric", whereas variations in these forces are termed "asymmetric". The measurement and tracking of running symmetry in team sports are an area that is still developing but are considered important (Kenneally-Dabrowski, Serpell & Spratford, 2017). The symmetry index offers a way to quantitatively measure this balance between the right and left sides, allowing for the percentage difference between left and right walking/running data to be measured; where a zero (0) value indicates perfect symmetry, and values below or above zero indicate asymmetry. Consequently, higher scores emphasize the presence of greater asymmetry in an athlete (Carpes, Mota & Faria 2010; Robinson, Herzog & Nigg, 1987). Brughelli, Cronin, Mendiguchia, Kinsella & Nosaka, (2010) have reported that athletes who have previously suffered hamstring injuries show greater asymmetry in the horizontal component of ground reaction force during sub-maximal running compared to those who have not. Therefore, the detection of asymmetric differences during walking and running is crucial for the continuous maintenance of athlete health and performance (Kenneally-Dabrowski et al., 2017).

This research focuses on the relationship between walking/running symmetry data obtained from GPS devices used in assessing the training load of professional football players and the risk of injury. The second aim of the study is to investigate the impact of running symmetry data collected during official competitions and training sessions throughout the season on the risk of injury occurrence in professional football players. Considering this data, the study aims to contribute to the more effective and safe organization of training programs, return-to-play practices after injuries, and preventive performance monitoring.

Method

Research Model

The study utilized the descriptive survey model, a method commonly used in research to provide a detailed and thorough analysis of a situation. The study utilizes both retrospective and relational survey models.

Research Group

In this context, the sample of the research includes professional football players competing in the top category of a football club in the Turkish Super League during the 2022-2023 season. The professional football players included in this study (n=18) were selected from the same football club. All participants (age= 27.2±6.3 years, height= 184.0±7.3 cm, body weight= 81.0±8.5 kg and body fat percentage= 5.3±1.6%) were thoroughly informed both orally and in writing before the commencement of the study and signed voluntary consent forms.

Data Collection Tools

Performance and running symmetry data from the participants were collected using a GPS system (Vector S7; Catapult Sports, Melbourne, Australia) throughout the 2022-2023 Turkish Super League season. The injury data was collected for a period of 1 month (4 weeks) prior to the player's injury, using a GPS system (Catapult Vector S7, Catapult Sports, Melbourne, Australia). Only non-contact injuries were included in the analysis. The injuries were not grouped by specific muscle or joint types, as this was not the focus of the study. The importance of research is to evaluate the relationship between running symmetry and injury occurrence. Running symmetry efforts are only calculated if they meet the set minimum velocity and minimum consecutive footstrike thresholds that have been set in the OpenField cloud. For a Running Symmetry Effort to be calculated, the velocity must exceed the minimum velocity for all footstrikes, and the amount of consecutive Footstrikes in the effort must be above the minimum consecutive footstrike threshold. For example, a running symmetry effort will be calculated if a device detects 8 or more consecutive Footstrikes, where the Velocity is over 3.3m/s during each footstrike. (Default thresholds of 3.3m/s and 8 consecutive footstrikes) (Tacca et al., 2022). Data from the load tracking of all field and fitness (gym) training sessions of the participants during the specified season are included. Research has shown that 10-Hz GPS devices are both valid and reliable for measuring distance and speed (Crang et al., 2022; Scott, Black, Quinn & Coutts, 2013). These devices were placed in specially designed pockets. These pockets are located at the midpoint of the participants' scapula bones on the back of specially made athletic vests. The vests' dimensions are 81mm in length, 43.5mm in width, and they weigh 53 grams. Throughout the season, athletes consistently used these devices. This consistent use was to minimize potential measurement errors (Asian-Clemente, Rabano-Muñoz, Requena, Santalla & Suárez-Arrones, 2022). The GPS trackers were turned on 15 minutes prior to every game and practice to guarantee good satellite connection and accurate data (Duffield, Reid, Baker & Spratford, 2010). The data obtained during the study were regularly transferred to Microsoft Excel for analysis after training sessions and matches, with necessary checks performed to remove any incomplete or erroneous data from the research scope.

In the study, the performance and running asymmetry data collected from participants were analyzed based on the following parameters provided by the GPS system: total distance covered, distance covered per minute, high-intensity running distance between speeds of 20-25 km/h, sprint distance at speeds greater than 25 km/h, maximum speed, player load, high metabolic power distance, acceleration and deceleration distance at >2 $m \cdot s^{-2}$ ($ACC\text{-}DEC_{distance}$), total number of accelerations and decelerations ($ACC\text{-}DEC_{number}$), and running asymmetry.

Data Analysis

In the phase of data evaluation, data was arranged using Microsoft Excel 2003, and statistical analyses were carried out using SPSS version 23 software. The Shapiro-Wilk test was utilized to ascertain if the data displayed a normal distribution. After the normality assessment, when the data was normally distributed, comparisons were made using the independent samples t-test at a significance level of $\alpha = 0.05$. The one-way ANOVA test was utilized to analysis three or more groups comparison. In correlation analysis, a correlation coefficient (r) below 0.50 suggests a weak correlation, while a coefficient between 0.50 and 0.70 indicates a moderate correlation, and a coefficient above 0.70 indicates a strong relationship (Durmuş, Yurtkoru & Çinko, 2013).

Ethical Statement

The research was conducted following the approval from the Ethics Committee of Istanbul Esenyurt University, dated 11/07/2023, with approval number E-12483425-299-32889.

Findings

This section presents the findings of the analyses conducted to examine performance-related variables in the context of injury duration, player positions, and running asymmetry among professional football players competing in the Turkish Super League during the 2022–2023 season. Comparative analyses were performed using one-way ANOVA to identify differences in physical performance metrics across player positions and varying durations of injury. Additionally, Pearson product-moment correlation analysis was utilized to investigate the relationships between running asymmetry and other performance parameters.

Table 1. Descriptive and comparative data by player position in Turkish Super League (2022-2023)

Variables	Positions	N	Mean	*Sd*	f	*p*	Group differences
Duration (minute)	Defense	108	61.944	19.9817	1.980	.140	
	Midfielder	186	57.694	20.8381			
	Attacker	22	63.727	18.1244			
Total Distance per minute (m)	Defense	108	59.7776	31.25357	.385	.681	
	Midfielder	186	57.0060	36.00345			
	Attacker	22	62.1409	22.35480			
High intensity running distance (m)	Defense	108	181.898	264.0748	.609	.544	
	Midfielder	186	186.306	251.0865			
	Attacker	22	124.409	122.9079			
Sprint distance (m)	Defense	108	25.296	42.9499	.809	.446	
	Midfielder	186	32.134	49.8573			
	Attacker	22	34.364	48.9115			
Total distance (m)	Defense	108	4917.056	2696.7925	2.182	.114	
	Midfielder	186	4447.333	2391.9270			
	Attacker	22	3877.091	1608.4614			
Maximum velocity (km/h)	Defense	108	26.5734	22.55457	.058	.944	
	Midfielder	186	26.6025	17.29713			
	Attacker	22	25.1818	3.94771			
Player load (a.u.)	Defense	108	555.491	295.6559	4.126	**.017***	1>2>3 p=0.017
	Midfielder	186	477.468	233.2858			
	Attacker	22	431.727	176.1039			
High metabolic power distance (m)	Defense	108	572.324	456.5746	.347	.707	
	Midfielder	186	567.134	494.7507			
	Attacker	22	656.318	415.8615			
ACC-DEC distance (m)	Defense	108	318.426	252.7247	1.877	.155	
	Midfielder	186	271.699	193.3069			
	Attacker	22	256.818	145.7658			
ACC-DEC (number)	Defense	108	265.278	129.0021	1.802	.167	
	Midfielder	186	234.500	139.0493			
	Attacker	22	240.909	120.6695			
Running Asymmetry (%)	Defense	108	2.5278	2.29774	1.772	.172	
	Midfielder	186	2.8383	2.93099			
	Attacker	22	3.6818	2.03274			

**p<0.05*

Upon examining Table 1, a statistically significant difference was found in the player load values of football players competing in the 2022-2023 season in relation to the positions they played (p<0.05).

The Bonferroni post-hoc test was conducted to identify between which positions the difference occurred. The analysis indicated that the average load on defenders was significantly higher compared to that on midfielders and forwards.

Table 2. Comparative analysis based on the duration of injury in Turkish Super League (2022-2023 season)

Variables	Duration of Injury (Days)	N	Mean	*Sd*	f	*p*	Group differences
Duration (minute)	1 or less	123	60.000	25.0177	.065	.937	
	1.01 – 4	115	59.565	16.8675			
	More than 4	77	58.922	17.2960			
Total Distance per minute (m)	1 or less	123	42.0121	38.10412	28.348	**.000***	3>2>1 p=0.000
	1.01 – 4	115	66.7960	26.34628			
	More than 4	77	71.6697	24.25934			
High intensity running distance (m)	1 or less	123	268.171	342.7880	13.343	**.000***	1>2>3 p=0.000
	1.01 – 4	115	128.513	140.5466			
	More than 4	77	120.247	134.0851			
Sprint distance (m)	1 or less	123	40.650	54.8971	5.273	**.006***	1>3>2 p=0.006
	1.01 – 4	115	21.887	41.1181			
	More than 4	77	25.299	40.8154			
Total distance (m)	1 or less	123	5210.024	3396.0547	6.998	**.001***	1>2>3 p=0.001
	1.01 – 4	115	4186.122	1530.3679			
	More than 4	77	4129.818	1448.4117			
Maximum velocity (km/h)	1 or less	123	25.4074	4.93166	.528	.590	
	1.01 – 4	115	26.5478	21.73535			
	More than 4	77	28.2064	26.39152			
Player load (a.u.)	1 or less	123	568.179	353.7686	7.192	**.001***	1>2>3 p=0.001
	1.01 – 4	115	459.843	149.7850			
	More than 4	77	455.714	156.6194			
High metabolic power distance (m)	1 or less	123	358.415	451.9375	24.045	**.000***	2>3>1 p=0.000
	1.01 – 4	115	715.209	455.0163			
	More than 4	77	714.455	418.2634			
ACC-DEC distance (m)	1 or less	123	336.447	287.1197	5.732	**.004***	1>2>3 p=0.004
	1.01 – 4	115	261.504	132.6737			
	More than 4	77	245.364	153.3344			
ACC-DEC (number)	1 or less	123	221.797	130.9658	3.309	**.038***	2>3>1 p=0.038
	1.01 – 4	115	265.339	131.2095			
	More than 4	77	253.234	142.9788			

**p<0.05*

Upon examining Table 2, a statistically significant difference was observed in the scores of distance covered per minute (m), high-intensity running distance, sprint distance, total distance, player load, high metabolic power distance, $ACC\text{-}DEC_{distance}$, and $ACC\text{-}DEC_{number}$ in relation to the duration until injury among football players competing in the 2022-2023 season ($p<0.05$).

The Bonferroni post-hoc test analysis was applied to determine between which durations these differences occurred. It was found that as the duration until injury decreased, the distance covered per minute also decreased, and as it increased, the values for high-intensity running distance, total distance, Player Load, and $ACC\text{-}DEC_{distance}$ also decreased. For other parameters such as sprint distance, high metabolic power distance, and $ACC\text{-}DEC_{number}$ ($>2\ m{\cdot}s^{-2}$), the running asymmetry value for durations “1.01 – 4” was observed to increase more compared to durations “More than 4” and “1 or less”.

Upon examining Table 3 and analyzing the Pearson Product-Moment Correlation to determine the relationship between running asymmetry values and various parameters, no significant relationship was observed between the duration until injury and maximum speed (km/h). However, a significant negative correlation was found with duration and distance covered per minute, whereas a significant positive correlation was observed with high-intensity running distance, sprint distance, total distance, player load, high metabolic power distance, $ACC\text{-}DEC_{distance}$, and $ACC\text{-}DEC_{number}$ ($p<0.05$).

Table 3. Pearson Product-Moment Correlation analysis between running asymmetry and all parameters

	Variables	1	2	3	4	5	6	7	8	9	10	11	12
1	Duration of injury	1											
2	Duration	0.094	1										
3	Total distance per minute	0.028	**-.203***	1									
4	High intensity running distance	0.011	**.349***	**-.436***	1								
5	Sprint distance	0.054	**.183***	**-.296***	**.709***	1							
6	Total distance	0.036	**.722***	**-.260***	**.754***	**.492***	1						
7	Maximum velocity	-0.013	-0.016	0.039	**.169***	0.096	0.069	1					
8	Player load	0.061	**.734***	**-.267***	**.734***	**.493***	**.958***	0.054	1				
9	High metabolic power distance	0.071	**.163***	**.752***	**-.179***	-0.082	0.063	0.108	0.06	1			
10	ACC-DEC (distance)	0.076	**.621***	**-.301***	**.704***	**.513***	**.838***	0.11	**.868***	**.124***	1		
11	ACC-DEC (number)	0.071	**.566***	**.301***	0.098	0.09	**.511***	0.049	**.548***	**.693***	**.601***	1	
12	Running Asymmetry	0.039	-0.056	**.319***	**-.259***	**-.149***	**-.206***	0.055	**-.204***	**.253***	**-.199***	0.07	1

**p<0.05*

Discussion

The purpose of this study is to examine the effects of running symmetry data, collected during official matches and training sessions throughout the season, on the risk of injury occurrence in professional football players. Running asymmetry is considered to have significant effects on athletic performance and injury risk. Research indicates that addressing inter-limb asymmetries through targeted interventions can enhance physical performance and reduce the risk of injuries in athletes (Pardos-Mainer, Bishop & Gonzalo-Skok, 2020). In a similar study, researchers linked observed walking asymmetry during high-intensity track runs to a history of injuries, arguing that monitoring and addressing asymmetry is crucial for injury prevention and performance optimization (Gilgen-Ammann, Taube & Wyss, 2017).

The data presented in Table 2 show the relationships between injury duration and certain performance variables. However, although the running asymmetry was not directly included in the table, the relationship between running asymmetry and injury duration was evaluated in the distribution analyses performed with the relevant variables. The findings suggest that the increase in running asymmetry continues, especially with high metabolic power distribution and acceleration/deceleration progression. This situation suggests that running asymmetry may be indirectly related to injury duration. Although there were significant differences in the loading parameters of the players in different positions in the study, no significant change was observed in running asymmetry values. This situation may be related to the individual movement mechanics and adaptation processes of the players. Especially in high-level football players, a certain running symmetry can be maintained thanks to repeated training and motor learning processes, and this may cause position-based load differences not to be directly reflected in running asymmetry. In addition, it is thought that the relationship between loading parameters and running asymmetry may vary depending on individual biomechanical and neuromuscular factors rather than being linear. "Future studies could be expanded to include factors such as individual movement strategies and musculoskeletal adaptations to better understand the relationship between player load and running asymmetry.

In this study conducted on professional football players in the Turkish Super League, significant positional differences have been observed (Table 2). Analyzing the values associated with different positions, the player loads were as follows: defenders (n=108, average=555.491, Sd=295.6559), midfielders (n=186, average=477.468, Sd=233.2858), and forwards (n=22, average=431.727, Sd=176.1039). Statistical analysis has revealed significant differences in Player Load between these positions (p=0.017), with defenders bearing a significantly higher average load compared to midfielders and forwards. The research findings suggest that the higher statistical load on defenders, compared to other positions in terms of Player Load, is likely due to the distinct roles and responsibilities on the field. Especially considering the dimensions of the football field, it has been observed through studies that the duties and responsibilities of each position demand different physical requirements (Castillo-Rodríguez, Durán-Salas, Giménez, Onetti-Onetti & Suárez-Arrones, 2023; Gimenez, Castellano, Lipińska, Zasada & Gómez, 2020). The significantly higher player loads on defenders reflect the intensity and continuity of the defensive roles they undertake during games. Defenders are typically engaged in direct confrontation with the opposing team's attackers, placing them in positions that require high-intensity physical activity continuously. This scenario leads to frequent and high-speed changes in direction, contributing to the increase in player load due to actions required by their defensive tasks.

The relationship between football players' injury durations and their physical performances is complex and multifaceted. Research has observed that professional football players experience greater declines in performance levels after injuries compared to controls, suggesting a potential link between the duration of injury and physical performance (Ross, Savage-Elliott, Brown & Mulcahey, 2020). Similar findings have been observed in our study (Table 2), where it was found that as the duration of injury decreased, the values for distance covered per minute (m) also decreased, and as the duration increased, high-intensity running distance (m), total distance (m), Player Load, and ACC-DEC$_{distance}$ (>2 $m \cdot s^{-2}$) values also decreased. Similar results have been reported by Carey, Huffman, Parekh & Sennett, (2006) where researchers noted a one-third reduction in performance of injured players upon their return to matches. This indicates that injuries can have a significant impact on athletes' performance when they return to the field (Carey et al., 2006).

When examining the statistical analysis results (Table 3), although no significant relationship was observed between the duration until injury and Maximum Speed (km/h), a positive correlation was found between the duration until injury and both high intensities running distance and sprint distance parameters. Previous studies, such as those by Vial, Cochrane Wilkie, Turner & Blazevich, (2023) suggest that fatigue levels can influence extremity asymmetries during sprints; sprints performed without fatigue prioritize speed, while those performed with fatigue may prioritize reducing injury risk (Vial et al., 2023). However, other studies, differing from these results, have also examined the relationship between kinematic step cycle asymmetry and sprint performance, and Haugen, Danielsen, McGhie, Sandbakk & Ettema, (2017) found that asymmetry in athletic sprinters does not have an impact on sprint performance or injury rates. Conversely, when looking at the speeds rather than sprint distances of professional footballers, research by Mikel et al., (2021) highlights that the gender of athletes and running speed do not significantly affect asymmetry. These results are consistent with the outcomes of our investigation (V_{max} (km/h) $p=0.069$). Furthermore, thresholds of asymmetry that could negatively impact directional change performance in athletes have been identified, emphasizing that assessing and addressing asymmetry is crucial to prevent declines in performance (Philipp, Garver, Crawford, Davis & Hair, 2020). Running asymmetry can potentially affect a footballer's speed, agility, and overall biomechanical efficiency, or their ability to perform optimally on the field. Additionally, running asymmetry can predispose football players to various lower extremity injuries, such as hamstring or quadriceps strains, ACL tears, and ankle sprains, which can have significant consequences for their careers.

In football injuries, especially those involving the quadriceps muscles, impairments in joint range of motion (ROM) and strength are associated with disruptions in running symmetry (Chmielewski, Rudolph, Fitzgerald, Axe & Snyder-Mackler, 2001; Shelbourne & Klotz, 2006). Research shows that performance or strength coaches can effectively use unilateral strength training programs tailored to athletes to reduce asymmetry and enhance their performance (Chen, Yi & Tian, 2023). However, depending on the context of the asymmetry, it can have both positive and negative effects. While asymmetry in upper extremity movements can enhance physical performance, it may also increase the risk of injuries in sports involving walking/running (Gao et al., 2022). Additionally, research indicates that inter-leg strength asymmetry is associated with both performance and injury risk in adolescent long-distance runners, emphasizing the need to address and understand asymmetry in this population (Blagrove, Bishop, Howatson & Hayes, 2020). Consequently, running asymmetry can have multifaceted effects on athletic performance and injury risk. While a certain degree of asymmetry can be beneficial in specific contexts, excessive or unaddressed asymmetry can lead to increased injury risk and decreased performance. Therefore, understanding individual asymmetry profiles and implementing targeted interventions to manage asymmetry are crucial for optimizing athletic performance and reducing injury risk. As running symmetry varies greatly among individuals, comparing an individual's symmetry to their own baseline data provides a more robust prediction than comparing it to the team average or assuming perfect symmetry for everyone.

Conclusion

In conclusion, although the value of running asymmetry may not contain statistically significant differences, it is observed that players' running asymmetry values increase when transitioning from defense to attack based on the average data. In football injuries, the duration players are side-lined can lead to substantial financial burdens for clubs due to salaries paid and the lack of corresponding physical performance and skills utilization. Therefore, in the sports world, especially in football, various methods are employed to accurately predict injuries that arise from non-contact or the effects of training load on the player. Our study aimed to demonstrate the applicability of the "Running Asymmetry" parameter within the GPS system, i.e., running symmetry, and the results are expected to provide a different perspective to coaches, performance trainers, physiotherapists, and other stakeholders in football.

Considering the negative financial impact of injuries in football and their detrimental effect on players' careers, monitoring training load and predicting injury onset using the running asymmetry parameter could be an important method. Understanding the relationship between injury timing and physical parameters, including in professional footballers, and optimizing running symmetry could be crucial for enhancing performance and minimizing the probability of injury. Although the results may not be statistically definitive, the positive correlations identified in practical applications suggest that this study could pioneer greater emphasis on the value of running asymmetry. Further detailed outcomes could emerge from analyzing larger research groups, including different age groups, in studies conducted before and after injuries.

Based on the findings of the present study, several recommendations are proposed to guide future research and practical applications: Firstly, although running asymmetry appears to be a promising parameter for monitoring player injuries, current evidence remains inconclusive. More comprehensive datasets and a standardized approach that integrates multiple parameters are necessary to draw definitive conclusions regarding its diagnostic value.

Secondly, the observed positive associations between running asymmetry and high-intensity running, sprint distance, and acceleration-deceleration metrics highlight the relevance of this variable in injury monitoring. Future studies should consider combining running asymmetry with additional biomechanical and physiological parameters not examined in the present study to enhance predictive accuracy.

Thirdly, further efforts should be directed towards improving the precision and validity of data derived from running asymmetry. Comparing this parameter with more detailed and extensive injury datasets could yield a clearer understanding of its sensitivity and specificity.

Additionally, considering the limited number of studies focusing on running asymmetry, especially within football, it is recommended that future research explore its relationship with injuries across various age groups and both male and female athletes. Such demographic analyses may offer valuable insights into population-specific injury patterns and risk factors. Moreover, a comparative analysis involving different GPS-based tracking systems could be beneficial in assessing the reliability and consistency of running asymmetry and training load measurements. This approach would contribute to the development of more robust monitoring strategies.

Finally, to provide more actionable insights for coaches, performance staff, and rehabilitation professionals, longitudinal studies incorporating multi-seasonal and multi-team data are encouraged. This broader scope could support the formulation of more effective training, recovery, and injury prevention strategies.

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Conflict of Interest

There is no conflict of interest between the authors regarding the publication of this article.

Author Contribution

Research Idea: ST; Research Design: ST and KK; Data Analysis: OA and TK; Writing: ST and OA; Critical Examination: ST

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