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Positional Differences in Internal and External Training Load Metrics in Elite Football Academy League Players

Elit Futbol Akademi Ligi Oyuncularında İç ve Diş Antrenman Yükü Metriklerinde Pozisyonel Farklılıklar

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Abstract: This study aims to provide guidance for evidence-based training optimization by examining differences in position-specific internal and external training loads of elite youth soccer players. A total of 27 players from a U17 team competing in the Elite Academy League participated in the study, comprising four fullbacks, four forwards, eight wingers, seven midfielders, and four center-backs. The mean age of the players was 17 years, the mean height was 179.19 ± 6.05 cm, and the mean body weight was 71.62 ± 6.38 kg. Data were collected during the competition period. Internal training load was assessed using heart rate (minimum, average, and maximum) and Rating of Perceived Exertion (RPE). External load parameters included measures such as total distance, number of sprints, accelerations and decelerations, and time spent in Speed Zone 4 (21.0-23.99 km/h) and Speed Zone 5 (24.0 > km/h). The statistical analysis using the Kruskal-Wallis test determined the significance level as $p \leq 0.05$. As a result of the study, significant differences were found among the values of Sprint ($p < 0.001$), Speed Zone 5 ($p < 0.001$), Acceleration ($p < 0.001$), Deceleration ($p = 0.029$), Training Load ($p < 0.001$) and Maximum Heart Rate ($p < 0.001$) according to positions. These findings emphasize the specific physical and physiological requirements of each position. Therefore, coaches and sports scientists must develop position-specific training programs considering these requirements. Such an approach can help athletes improve their performance, reduce the risk of injury, and ensure an effective recovery process. Tailoring training protocols to positional demands can enhance player performance, reduce injury risk, and optimize recovery strategies in elite youth football.

Anahtar Kelimeler: *Soccer, heart rate, perceived exertion*

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INTRODUCTION

Football is an intermittent high-intensity sport that demands diverse physical and physiological requirements based on player positions. Monitoring internal and external loads during training is crucial for enhancing performance, reducing injury risks, and accelerating recoveries (Djaoui et al., 2017). According to Borresen & Lambert (2009), Halson (2014), and Martin & Andersen (2000),

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the internal load is defined as the athlete's perceived physiological stress, including factors such as heart rate, rating of perceived exertion, and blood lactate levels. This study quantifies the external load in terms of mechanical parameters related to, for example, the total distance covered in a session, the number of sprints, or accelerations. It captures both aspects of load measurements to gain a detailed insight into what football players at different playing positions go through (Bourdon et al., 2017).

Such technological developments include the GPS system, accelerometer, and heart rate monitor, enhancing real-time monitoring and evaluation of these loads (Akenhead & Nassis, 2016). Such monitoring allows a coach to individualize training for different playing positions based on differing physiological and mechanical requirements. For example, playing forwards will generally require more high-intensity sprint repetitions. In contrast, midfield play covers more considerable total distances at different speeds over one game, while defenders accelerate and decelerate frequently during games (Arjol-Serrano et al., 2021; Bloomfield et al., 2007).

Position-specific load monitoring is a crucial factor in optimizing performance and reducing injury risks. In high-intensity sports such as football, players' internal and external loads vary significantly depending on their playing positions. Research indicates that midfielders cover greater distances compared to other positions, while forwards run shorter distances but at higher speeds (Castellano et al., 2011). These differences not only influence physical demands but also have a direct impact on injury risks.

The variability in tactical roles leads to distinct internal and external load dynamics for each position. Overloading players without adequate recovery increases the likelihood of injury, whereas undertraining can lead to a decline in match performance (Malone et al., 2017). Therefore, managing load based on position-specific requirements is vital for enhancing both physical endurance and injury prevention. Coaches and performance specialists should develop individualized training programs that consider each player’s unique load profile, thereby maximizing performance while minimizing injury risks.

While there is a growing interest in internal and external loads, little is known about their interaction and variation among playing positions. More specifically, previous studies used external load parameters (e.g., sprint counts or total distance) and internal load indicators, including heart rate variability (Casamichana et al., 2013; de Dios-Álvarez et al., 2021; Maughan et al., 2021; Nobari et al., 2020). However, few have systematically embedded these measures into all footballing positions. This gap in the literature also shows the need for further studies that consider both types of loads simultaneously (Nobari et al., 2021).

Given the positional demands in football, this study aims to quantify differences in internal and external training loads, providing a foundation for position-specific training prescriptions. We hypothesize that forwards will experience higher sprint frequencies and greater internal loads due to the intermittent nature of their role. At the same time, midfielders will demonstrate higher total distances covered at moderate intensities. Defenders are expected to show lower overall distance but higher acceleration and deceleration rates, reflecting the demands of their position. By exploring these differences, this study seeks to contribute to developing position-specific training and recovery protocols, ultimately improving both performance and player well-being.

METHODS

Research Model

A longitudinal, prospective, and observational design was conducted on a male academy football player for one season.

Participants

This study included 27 athletes from an Under-17 football team competing in the elite football academy league (positions: 4 fullbacks, four forwards, eight wingers, seven midfielders, and four center-backs). The participants had a mean age of 17 years (Mean ± standard deviation (SD); height: 179,19 ± 6,05 cm, body mass: 71,62 ± 6,38 kg). Throughout the 2022-2023 season, the athletes' internal and external training loads were monitored for 5 months, spanning 19 weeks.

Ethical Approval

This study was approved by Kütahya Dumlupınar University Social and Human Sciences Scientific Research and Publication Ethics Committee on 04/07/2024 with decision number 308. All participants were fully informed about the research procedures and voluntarily participated in the study. The study was conducted in accordance with the Declaration of Helsinki.

Data Collection Tools

During Elite Academy League training sessions, internal and external loads were monitored using a 10Hz GPS sensor integrated with a microelectromechanical system (MEMS). Each player had a

GPS unit and a 200Hz MEMS motion sensor, including a tri-axial accelerometer, gyroscope, and magnetometer. The device, weighing 39g and measuring 36 × 68 × 13 mm, was secured to the player's chest with a specialized strap, positioning the sensor over the xiphoid process. Monitoring was carried out using the Polar Team Pro system (Figure 1).

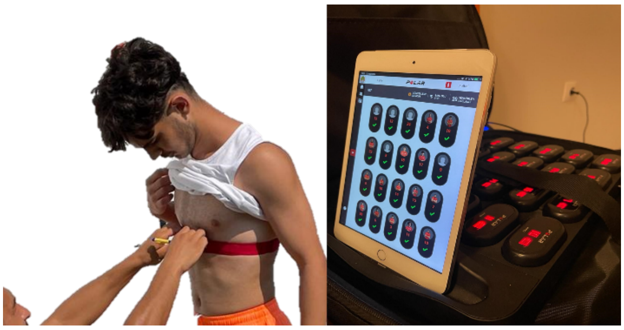

Figure 1. Polar Team Pro system

Previous studies have demonstrated that GPS devices operating at a sampling frequency of up to 10Hz offer enhanced accuracy, with no substantial data acquisition benefits from higher frequencies. To ensure optimal satellite signal acquisition and synchronize the device's clock with the satellite's atomic clock (Maddison & Ni Mhurchu, 2009), all devices were activated 15 to 30 minutes before data collection. This procedure enabled connection to more than four satellites and maintained a horizontal dilution of precision (HDOP) below 5, as recommended by the manufacturer. Each player consistently used the same GPS unit to minimize measurement error across all training sessions. The reliability of such devices has been extensively documented in the literature (Evangelio et al., 2019; Silva et al., 2015). Polar Team Pro hardware and software were used to objectively record the mechanical data for each player, which was subsequently processed via the system's web platform and exported as comma-separated values (CSV) in compliance with RFC 4180 standards.

Data Collection

This research was conducted with academy athletes who are prospective professionals. The athletes competed in the Elite A-League under the Turkish Football Federation. Monitoring of the athletes' internal and external training loads began at the start of the competitive period. The internal training loads were calculated by multiplying the perceived exertion (RPE) by the duration of the training (in minutes). Internal load parameters included Hr Min (BPM), Hr Avg (BPM), and Hr Max (BPM). External training load data were based on the following parameters: training duration (minutes), total distance (meters), number of sprints, Speed Zone 4 (21.0-23,99 km/h), Speed Zone 5 (24.0 > km/h), acceleration (3 to 50.00 m/s²), and deceleration (-3 to -50.00 m/s²).

Analysis of Data

The Shapiro-Wilk test was employed to assess the normality of the data. Since the results indicated that the data were not normally distributed, the Kruskal-Wallis test was utilized to evaluate statistical differences. This non-parametric test revealed variations in internal and external load parameters across positions. To quantify the magnitude of these differences, eta-squared (η^2) values were calculated as effect size indicators. The thresholds for interpreting η^2 values were as follows: 0-0.009 signified negligible effects, 0.01-0.0588 indicated small effects, 0.0589-0.1379 represented medium effects, and values exceeding 0.1379 denoted significant effects. A significance level of $p \leq 0.05$ was adopted for all statistical analyses. Data processing and all subsequent analyses were done using the R programming language.

FINDINGS

Table 1 presents the descriptive statistics for the dataset. The results of the Shapiro-Wilk normality test indicated that the data did not follow a normal distribution (Shapiro-Wilk p <0.001).

Table 1. Descriptive Statistics

	Mean	Std. Error of Mean	Std. Deviation	Coefficient of variation	Shapiro -Wilk	P-value of Shapiro-Wilk
Total Distance	5180.639	68.266	1759.083	0.340	0.942	< .001
Sprint	20.791	1.385	35.697	1.717	0.185	< .001
Speed Zone 4	382.175	10.642	274.215	0.718	0.848	< .001
Speed Zone 5	306.324	13.526	348.265	1.137	0.651	< .001
Acceleration	61.685	1.691	43.580	0.706	0.667	< .001
Deceleration	50.382	0.818	21.045	0.418	0.936	< .001
Training Load	143.173	8.939	228.764	1.598	0.159	< .001
Hr Min Bpm	96.485	1.018	26.180	0.271	0.733	< .001
Hr Avg Bpm	149.083	0.618	15.913	0.107	0.975	< .001
Hr Max Bpm	200.982	8.421	216.659	1.078	0.037	< .001
Rpe	7.227	0.765	19.691	2.725	0.065	< .001
Training Time	79.325	0.649	16.703	0.211	0.951	< .001

Differences among positions in various internal and external load parameters are visually depicted in Figure 1. Significant differences were identified across positions for several key metrics, including Sprint (p <0.001), Speed Zone 5 (p <0.001), Acceleration (p < 0.001), Deceleration (p = 0.029), Training Load (p < 0.001), and Maximum Heart Rate (HR Max BPM) (p < 0.001).

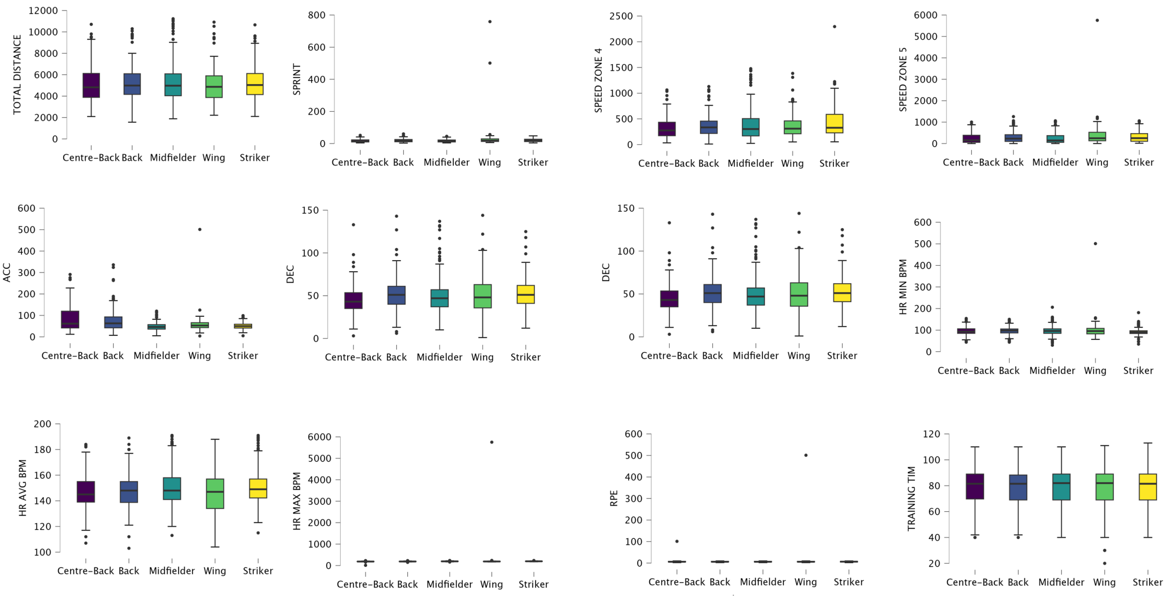

Figure 2. Differences in Internal and External Loads by Position

The results of the Kruskal-Wallis test, which was applied to analyze these differences, are comprehensively outlined in Table 2 presents the results of the Kruskal-Wallis test, highlighting statistically significant differences across positional groups.

Table 2. Kruskal-Wallis Test by Players Position

					95% CI for Rank η²	
Factor	**Statistic**	**df**	**p**	**Rank η²**	**Lower**	**Upper**
Total Distance	1.709	4	0.789	0.000	0.000	0.016
Sprint	26.793	4	< .001	0.035	0.011	0.080
Speed Zone 4	7.583	4	0.108	0.005	0.000	0.036
Speed Zone 5	19.836	4	< .001	0.024	0.007	0.065
Acc	48.815	4	< .001	0.068	0.037	0.128
Dec	10.823	4	0.029	0.010	0.000	0.041
Training Load	58.291	4	< .001	0.084	0.045	0.137
Hr Min Bpm	6.694	4	0.153	0.004	0.000	0.033

Factor	Statistic	df	p	Rank η^2	95% CI for Rank η^2 Lower	95% CI for Rank η^2 Upper
Hr Avg Bpm	7.185	4	0.126	0.005	0.000	0.031
Hr Max Bpm	91.562	4	< .001	0.133	0.093	0.186
Rpe	1.534	4	0.821	0.000	0.000	0.018
Training Tim	0.162	4	0.997	0.000	0.000	0.012

DISCUSSION

This study aims to determine the difference in training loads between the internal and external aspects of football players' positions. Based on the analysis of the study, it was feasible to establish statistically significant differences between positions in Sprint, Speed Zone 5, Acc, Dec, Training Load, and Hr Max Bpm values. The results thus obtained supported our hypotheses. For each group of players, the duties and responsibilities of each position during the football matches are different. Differences in positional responsibilities directly influence the physical and physiological demands experienced by players (Akenhead et al., 2016). Various research works have been done to analyze the activity patterns of football players in the recent past (Baptista et al., 2018). Some comparisons include total distance covered, distance covered at various speed intervals, high speed, and sprint distance based on positions (Oliveira et al., 2019; Sarmento et al., 2024). At the same time, the differences in mean heart rate and the highest heart rate percentage values were also evaluated (Sarmento et al., 2024).

Advancements in wearable technology, such as GPS tracking, allow precise monitoring of players' competition demands (Martín-García et al., 2018). Hence, the training load that the athletes sustain during training can also be recorded with the help of technological tools (Buchheit & Simpson, 2017). The data is then collected, and training programs can be more specific after the game (Buchheit et al., 2018). It will also allow for the identification of variability in the training load of athletes and the development of individualized training programs for them (Sarmento et al., 2024). In team sports with positional-based games, such as football, the training load may vary depending on the players' task (Silva et al., 2023). Positional roles influence the frequency of sprints and high-intensity efforts, contributing to distinct heart rate responses across positions. The four studies reviewed in the literature that compared the internal and external loads of football players in different positions revealed statistically significant differences when comparing the players by position (Sarmento et al., 2024). A comprehensive systematic review by Sarmento et al. (2024)

reviewed 178 studies. All these studies measured football players' internal and external loads in different positions. This compilation of reviews presents the variance in the internal and external load demand on players by position, thus supporting the findings of this study. The research concludes that the training should be according to the specific game.

The data highlights positional differences, particularly among defenders. On average, central midfielders covered 10,457 meters, whereas fullbacks and wingers showed greater distances due to their offensive and defensive responsibilities. To now, slightly meeting the lower requirements of their full strategic backs is responsible for the defensive and attacking aspects, which may make them travel a lot in a match (Bortnik et al., 2024). The variations might be attributed to the team's formation or the coach's strategic approach, mainly in the defensive and offensive lines (Low et al., 2022). Forward and central defenders were also reported to have covered less distance. Forwards traveled an average of 10,068m (8,621–11,254m), and central defenders 9,598m (range: 7,525–10,627m). The positions might explain this difference, as forwards are attack-minded players expected to contribute to creating goalscoring chances, which entails shorter but quicker bursts of acceleration (Vigh-Larsen et al., 2018). On the other hand, central defenders are required to form a defensive shape that covers less territory and is more based on tactical movement. The game's dynamics may also influence the values produced within the positions.

CONCLUSION

Through this research, statistically significant differences were observed between player positions in key performance parameters, including Sprint performance, Speed Zone 5, Acceleration (Acc), Deceleration (Dec), Training Load, and Maximum Heart Rate (HR Max BPM). These findings highlight the distinct physical and physiological demands of each playing position in football. For example, forwards and wide players tend to record higher Sprint and Speed Zone 5 values, reflecting their need for high-speed movement during offensive plays and counterattacks. In contrast, defensive players exhibit greater acceleration and deceleration rates, emphasizing their ability to change direction and regulate speed when engaging opponents. Additionally, differences in Training Load suggest positional variations in physical activity intensity and volume throughout the game. Likewise, fluctuations in HR Max BPM may indicate the varying aerobic and anaerobic energy system demands across different playing roles. By implementing position-specific training strategies, coaches and sports scientists can optimize conditioning programs, improving performance and reducing injury risks. Future research should further investigate the impact of tactical formations, match intensity, and periodization strategies on positional load demands. This would allow for more refined training adaptations, particularly in youth football development.

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