International Journal of
Disabilities Sports and Health Sciences

e-ISSN: 2645-9094

RESEARCH ARTICLE

Position-Specific Movement Characteristics and Heart Rate Profile of Hearing-Impaired Futsal Players: A Simulated Game Analysis

Sümer ALVURDU[*1], Kadir KESKİN[1] and Yasin ARSLAN[2]

[1]Gazi University, Faculty of Sports Sciences, Department of Physical Education and Sports Teaching, Ankara / Türkiye
[2]Gazi University, Faculty of Sports Sciences, Department of Coaching Education, Ankara / Türkiye
*Corresponding author: sumeralvurdu@gazi.edu.tr

Abstract
The aim of this study is to compare the movement characteristics and heart rate (HR) response of hearing-impaired futsal players based on their playing positions during a simulated game. The study involved twelve players from the Turkish Deaf Men's Futsal National Team, and *PlayerLoad (PL)* metrics such as total PL (PL_{TOTAL}), PL per minute ($PL \cdot min^{-1}$), peak PL (PL_{PEAK}), low to very high PL bands (PL_{LOW}-PLV_{HIGH}), and *external load* variables such as acceleration (ACC), deceleration (DEC), explosive efforts (EXP_{EFF}), and right/left change of direction (COD-R, COD-L), were analyzed using inertial movement analysis (IMA). Additionally, the internal load metrics, including minimum, average, and maximum HR (HR_{MIN}, HR_{AVE}, HR_{MAX}), percentage of HR_{MAX} (%HR_{MAX}) and percentage of time spent in different HR zones (HR_{ZONE1} to HR_{ZONE4}) were continuously monitored. IMA variables and HR metrics, based on playing position, were analysed with the Kruskal-Wallis H test. Group comparisons were conducted using the Mann-Whitney U test, and Bonferroni correction was applied. As a result, PL variables change with notable distinctions between defenders and wingers. Additionally, the PL_{VHIGH} stands out as the only significant difference when comparing wingers and pivots. Wingers generally exhibit different external load, including ACC and COD-L, compared to defenders. Additionally, differences were observed in COD-L between pivots and defenders, as well as in COD-R between pivots and wingers. In conclusion, external and internal load metrics during the simulated game vary depending on the players' positions in hearing-impaired futsal players, highlighting the importance for coaches to consider this diversity in their athlete monitoring approaches.

Keywords
External Load, Internal Load, Inertial Movement Unit, Indoor Soccer, Deaf Athletes

INTRODUCTION

The number of people with hearing impairments worldwide is predicted to reach 900 million by 2025; over 90 million of these individuals will reside in Europe (Peracino, 2015). There are over 2,070 sports and social clubs with their own websites that connect deaf individuals throughout the world (Szulc et al., 2017). The training of athletes in disabled sports is becoming increasingly urgent in connection with the development of this branch of sport. However, the training process in deaf sports, especially in team sports, cannot be equated with the training of healthy athletes (Sobko, 2013). Therefore, various physical and physiological factors can affect the performance of hearing impaired players during training and matches. Previous research show that individuals with hearing impairment have lower physical capacity and motor skill performance when compare with hearing athletes (Cobanoglu et al., 2021; Dummer et al., 1996; Favretto et al., 2019). However these studies has primarily focused on hearing-impaired athletes in team sports like soccer (Yapici et al., 2023), handball (Serdar & Nebahat, 2020; Vujkov et al., 2010), basketball (Sobko, 2013), and volleyball (Kazakov et al., 2023), rather than the specific demands of Futsal.

Received: 23 February 2024 ; **Revised** ; 25 March 2024 ; **Accepted:** 03 May 2024; **Published:** 25 May 2024

How to cite this article: Alvurdu, S., Keskin, K., and Arslan, Y. (2024). Position-Specific Movement Characteristics and Heart Rate Profile of Hearing-Impaired Futsal Players: A Simulated Game Analysis. *Int J Disabil Sports Health Sci*;7(3):621-629.https://doi.org/10.33438/ijdshs.1441768

The activity profile of players in futsal serves as a pivotal aspect influencing game strategies, training regimens, and player performance. Through the integration of various technological approaches, researchers have been able to gain profound insights into the intricate dynamics of futsal matches. Time and motion analysis techniques have elucidated the diverse physical demands placed on players, highlighting the frequency and intensity of movements such as sprinting, changes of direction, and acceleration (Barbero-Alvarez et al., 2008; De Oliveira Bueno et al., 2014). Moreover, physiological parameter monitoring, encompassing metrics like heart rate (HR) and oxygen consumption, provides valuable data on the metabolic demands and physiological responses of players throughout the game (Castagna et al., 2009; Makaje et al., 2012; Milioni et al., 2016). Furthermore, the utilization of cutting-edge tracking technologies such as GPS and accelerometers (inertial movement units) enables detailed assessments of players' spatial distribution, movement patterns, and velocity profiles during match play (Ribeiro et al., 2020; Yiannaki et al., 2020). By utilizing these technological advances, researchers are better able to decipher the nuanced activity profile of futsal players. According to our knowledge, there is not any study on hearing-impaired players have focused on acute mechanical and physiological responses during the training or game in any team sports. In line with this, the hypothesis of this study was to determine the movement characteristics of hearing-impaired players during the futsal game who are subject to typical futsal rules (Beato et al., 2014), except for the usage of flags only to signify violations and all other events during the match. Therefore, the present study aims to investigate the movement characteristics and HR responses of hearing-impaired futsal players and to compare the external and internal load metrics based on their playing positions during a simulated game.

MATERIALS AND METHODS

Participants

A priori analysis was conducted on G*Power (version 3.1.9., University of Kiel, Germany) which provided an estimated sample of 12 with a power (1-β) of 80% and an α error of 5,0% with an effect size 0.8 for pair comparisons. The inclusion criteria for the participants during the preparation period for the international futsal tournament were as follows: (1) training duration 5 times a week with an average duration of 80 minutes, (2) not having suffered a lower limb injury in the last 6 months, (3) no intensive training 48 hours prior to the simulated game. A total of 12 male futsal players (age: 21.5 ± 2.8 years; height: 177.9 ± 4.9 cm; and body weight: 72.2 ± 4.8 kg) from Turkish Deaf Men's Futsal National Team voluntarily participated in the study. The positions of the players were categorized into defenders (n=3), wingers (n=6) and pivots (n=3) (Caetano et al., 2015). Goalkeepers were not included in the study. The participants avoided smoking, strenuous exercise, and consuming alcohol, energy and/or caffeinated beverages for the 24 hours before the simulated game. All participants completed a written informed consent form after receiving a full description of research, risks, benefits, confidentiality, and participant rights. This study was approved by Gazi University Ethical Commission with the reference number of 2024-109 and conducted in accordance with the ethical principles of Declaration of Helsinki.

Data Collection

The activity profile of players during the game were monitored using Catapult Optimeye S5 (CatapultSports, Melbourne, Australia) with IMU technology, comprising a tri-axial accelerometer, gyroscope, and magnetometer, which provide data for inertial movement analysis (IMA) at a sampling rate of 100 Hz. The validity of the IMU systems has been demonstrated by the previous studies for running-based team sport (Alanen et al., 2021; Armitage et al., 2021; Luteberget et al., 2018; Nicolella et al., 2018; Roell et al., 2018), and the IMA to measure external load metrics of the players during the training and games has been used widely by various indoor sports, such as handball (Luteberget & Spencer, 2017; Wik et al., 2017), basketball (Espasa-Labrador et al., 2023; Ransdell et al., 2020) and futsal (Spyrou et al., 2021; Yiannaki et al., 2020).

Variables of movement characteristics obtained with IMA were included *PlayerLoad (PL)* metrics such as total PL (PL_{TOTAL}), PL per minute ($PL \cdot min^{-1}$), peak PL (PL_{PEAK}), low to very high PL bands (PL_{LOW} to PL_{VHIGH}), and *external load* variables such as acceleration (ACC), deceleration (DEC), explosive efforts (EXP_{EFF}), and right/left change of direction (COD-R, COD-L).

PL is an abbreviation for the cumulative sum of accelerations along all three axes recorded by a triple-axis accelerometer throughout motion (at a frequency of 100 Hz), presented as an arbitrary unit (a.u). To obtain an intensity index, PL is divided by time, resulting in PL per minute ($PL \cdot min^{-1}$), and PL bands are classified into four categories: PL_{LOW} (1-2 g); PL_{MED} (2-3 g); PL_{HIGH} (3-4 g); PL_{VHIGH} (> 4g) (Ward et al., 2018).

ACC_{LOW}, ACC_{MED}, and ACC_{HIGH} represent the overall inertial movements captured under a positive forward acceleration vector within the elevated range (from 1-2 $m \cdot s^2$, 2-3 $m \cdot s^2$, greater than 3 $m \cdot s^2$), while DEC indicates those detected under a negative deceleration vector within the same threshold (Akenhead et al., 2013). COD defines the total inertial movements observed in a sideways left-right vector above the specified limit. EXP_{EFF} includes all inertial movements regardless of direction (including ACC, DEC, and COD, excluding jumps) within intermediate and higher thresholds (greater than 2.5 $m \cdot s^2$) (Casamichana & Castellano, 2015; Spyrou et al., 2021).

HR was monitored continuously at 1-sec. intervals using a chest strap sensor (Polar T31 coded transmitter, Polar Electro Oy, Finland) and minimum, average and maximum HR (HR_{MIN}, HR_{AVE}, HR_{MAX}), percentage of HR_{MAX} (%HR_{MAX}) and percentage of time spent in different HR zones (HR_{ZONE1} to HR_{ZONE4}) were calculated where Zone 1 = 50-60% HR_{MAX}, Zone 2 = 60-70% HR_{MAX}, Zone 3 = 70-80% HR_{MAX}, Zone 4 = 80-90% HR_{MAX}, and Zone 5 = 90-100% HR_{MAX} (Fox et al., 2018). HR_{MAX} was determined using age-predicted equation (Berkelmans et al., 2018).

A simulated futsal game was played on a taraflex indoor court (20 x 40 m) and lasted 40 min and consisted of two 20-min halves separated by a 10-min interval. The official FIFA laws of the game were adopted, and a referee and a coach were appointed on the side-lines to provide technical and tactical guidance during the matches to create similar conditions to official matches. The players performed 25 min of their official game warm-up routines that consisted of 5-minute general sub-maximal aerobic warm-up exercises including jogging, running, skipping forward and backward, 5 min stretching and mobility, 5 min dynamic activities (short sprints, change of direction) and 10 min futsal-specific drills without and with opposition in a progressive pattern till shooting action.

The simulated game was organized as a friendly match against a futsal team from the 1st Division Futsal League. In line with the real game scenarios, where players were substituted by the national team coach during the game without considering the time they spent on the field or bench. Time-outs were also standardized by interrupting the game once per half when there were 10 minutes remaining in both halves.

Statistical Analysis

The data are presented as mean and standard deviation. The normal distribution of the data was assessed using the Shapiro-Wilk test. Inertial movement analysis variables, based on playing position, were analysed with the Kruskal-Wallis H test. Group comparisons were conducted using the Mann-Whitney U test, and a Bonferroni correction was applied. A significance level of $p<0.05$ was considered. The statistical analysis was performed using the SPSS 25 software package.

RESULTS

The movement characteristics of hearing-impaired futsal players total PL_{TOTAL}, $PL \cdot min^{-1}$, PL_{PEAK}, and PL_{HIGH} showed significant differences between groups. The distinctions were observed mainly between defender and winger positions, except for the PL_{PEAK} and PL_{VHIGH} (Table 1). Significant differences were observed only in the PL_{VHIGH} variable between winger and pivot positions ($p<0.05$). There were no significant differences in PL_{PEAK} across playing positions ($p>0.05$). Specific PL variables show varying responses among playing positions, with notable distinctions between defenders and wingers. Additionally, the PL_{VHIGH} variable stands out as the only significant difference when comparing wingers and pivots. The consistency in PL_{PEAK} across positions implies uniformity in this aspect of PL.

Differences in external load across playing positions were observed. ACC_{LOW}, ACC_{MED}, ACC_{HIGH}, DEC_{LOW}, COD-L_{LOW}, and COD-L_{MED} showed significant variances between wingers and defenders, favoring wingers. Additionally, COD-L_{HIGH} differed significantly between pivots and defenders, and COD-R_{LOW} differed between pivots and wingers ($p<0.05$). DEC_{MED}, DEC_{HIGH}, COD-R_{MED}, COD-R_{HIGH} did not differ between playing positions ($p< 0.05$).

Table 1. PL variables measures during the match and comparison for the playing positions.

Variables	Mean ± SD	Position	Mean Rank	Significant Comparisons	Adjusted p	U
PL_{TOTAL} (a.u)	479.73 ± .00	Pivot	5	Defender-Winger	0.009	7.5
	672.58 ± 48.09	Winger	9.5			
	355.14 ± 50.21	Defender	2			
	545.00 ± 146.22	Total				
PL_{PEAK} (a.u)	4.27 ± .00	Pivot	3	-	0142	9.5
	5.50 ± .78	Winger	7.8			
	5.44 ± 1.30	Defender	7.3			
	5.18 ± .94	Total				
$PL{\cdot}min^{-1}$ (a.u)	4.53 ± .00	Pivot	5	Defender-Winger	0.009	7.5
	6.34 ± .45	Winger	9.5			
	3.35 ± .47	Defender	2			
	5.14 ± 1.37	Total				
EXP_{EFF} (no)	30,00 ± .00	Pivot	7	Defender-Winger	0.030	6.5
	32.83 ± 6.52	Winger	8.5			
	23.00 ± 1.73	Defender	2			
	29.66 ± 6.12	Total				
PL_{LOW} (a.u)	278.00 ± .00	Pivot	7	Defender-Winger	0.030	6.5
	317.16 ± 46.04	Winger	8.5			
	176.66 ± 40.99	Defender	2			
	272.25 ± 69.78	Total				
PL_{MED} (a.u)	173.00 ± .00	Pivots	5	Defender-Winger	0.009	7.5
	271.50 ± 24.60	Winger	9.5			
	151.00 ± 10.39	Defender	2			
	216.75 ± 60.25	Total				
PL_{HIGH} (a.u)	24.00 ± .00	Pivots	5	Defender-Winger	0.009	7.5
	68.33 ± 16.63	Winger	9.0			
	20.66 ± 1.15	Defender	2			
	45.33 ± 26.55	Total				
PL_{VHIGH} (a.u)	3.00 ± .00	Pivots	2.5	Winger-Pivots	0.015	7
	11.50 ± 3.44	Winger	9.5			
	3,66 ± .57	Defender	4.5			
	7.41 ± 4.87	Total				

The analysis indicated that wingers generally exhibit different external load respones, including accelerations and left-sided changes of direction, compared to defenders. Additionally, differences were observed in left-sided changes of direction between pivotss and defenders, as well as in right-sided changes of direction between pivots and wingers. The absence of significant differences in certain variables suggests similarities in deceleration and right-sided changes of direction between specific playing positions (Table 2).

Among the internal load parameters associated with HR variables, distinctions were identified solely in HR_{MAX}, $\%HR_{MAX}$, and duration of HR_{ZONE3} when comparing pivot and winger positions ($p<0.05$). Conversely, HR_{MIN}, HR_{AVE}, duration of HR_{ZONE3}, HR_{ZONE4} exhibited uniformity across the playing positions ($p>0.05$). The internal load parameters related to HR demonstrated distinctions only in specific aspects (HR_{MAX}, $\%HR_{MAX}$, and duration of HR_{ZONE3}) when comparing pivots and wingers. The uniformity in other HR variables across playing positions suggests similarities in HR_{MIN}, HR_{AVE} and the duration spent in various HR zones (Table 3).

Table 2. External load variables during the match and comparison for the playing positions

Variables	Mean ± SD	Position	Mean Rank	Significant Comparisons	Adjusted p	U
ACC_{LOW}	40.0 ± .00	Pivot	5	Defender-Winger	0.009	7.5
	50.66 ± 11.89	Winger	9.5			
	19.66 ± 8.08	Defender	2			
	40.25 ± 15.84	Total				
ACC_{MED}	13.00 ± .00	Pivot	7	Defender-Winger	0.030	6.5
	14.66 ± 4.41	Winger	8.5			
	2.66 ± 1,15	Defender	2			
	11.25 ± 6.03	Total				
ACC_{HIGH}	4.00 ± .00	Pivot	5	Defender-Winger	0.008	7.5
	8.16 ± 1.194	Winger	9.5			
	3.00 ± .00	Defender	2			
	5.83 ± 2.79	Total				
DEC_{LOW}	68.00 ± .00	Pivot	5	Defender-Winger	0.009	7.5
	81.00 ± 8.65	Winger	9.5			
	33.33 ± 1.73	Defender	2			
	65.83 ± 21.12	Total				
DEC_{MED}	23.00 ± .00	Pivot	8	-	0.063	5.5
	21.83 ± 8.65	Winger	7.8			
	11.00 ± 1.73	Defender	2.3			
	19.41 ± 7.78	Total				
DEC_{HIGH}	5.00 ± .00	Pivot	4	-	0.099	4.6
	8.00 ± 2.00	Winger	8.6			
	3.66 ± 4.61	Defender	4.6			
	6.16 ± 3.09	Total				
COD-L_{LOW}	136.00 ± .00	Pivot	4	Defender-Winger	0.050	6.0
	205.33 ± 34.71	Winger	9.3			
	98.66 ± 68.70	Defender	3.3			
	161.33 ± 60.89	Total				
COD-L_{MED}	34.00 ± .00	Pivot	8	Defender-Winger	0.043	6.0
	35.83 ± 5.77	Winger	8			
	14.66 ± 6.35	Defender	2			
	30.08 ± 10.46	Total				
COD-L_{HIGH}	13.00 ± .00	Pivot	10	Defender-Pivot	0.041	7.1
	9.50 ± 4.13	Winger	6.5			
	5.33 ± 2.30	Defender	2.8			
	9.33 ± 4.09	Total				
COD-R_{HIGH}	73,0000 ± .00	Pivot	3	Winger-Pivot	0.035	6.1
	184.83 ± 48.67	Winger	9.1			
	103.00 ± 51.96	Defender	4.6			
	136.41 ± 65.17	Total				
COD-R_{MED}	17.00 ± .00	Pivot	3	-	0.61	5.5
	27.83 ± 5.56	Winger	8.6			
	22.00 ± 8.66	Defender	5.6			
	23.66 ± 7.07	Total				
COD-R_{HIGH}	8.00 ± .00	Pivot	9	-	0.050	5.9
	7.16 ± 2.04	Winger	7.3			
	4.33 ± .57	Defender	2.3			
	6.66 ± 2.01	Total				

Table 3. HR variables during the match and comparison for the playing positions

Variables	Mean ± SD	Position	Mean Rank	Significant Comparisons	Adjuste p	U
HR_{MIN} (beat/min)	70.0 ± .00	Pivot	11	-	0.052	6.3
	62.83 ± 3.92	Winger	5			
	64.00 ± 1.73	Defender	5			
	64.91 ± 4.14	Total				
HR_{AVE} (beat/min)	138.48 ± .00	Pivot	7	-	0.089	4.8
	144.17 ± 9.79	Winger	8.1			
	124.63 ± 7.47	Defender	2.6			
	137.86 ± 11.10	Total				
HR_{MAX} (beat/min)	213.00 ± .00	Pivot	11	Winger-Pivot	0.022	4.6
	188.66 ± 4.45	Winger	4.3			
	196.00 ± 8.66	Defender	6.3			
	196.58 ± 11.42	Total				
$\%HR_{MAX}$	73.27 ± .00	Pivot	2	Winger-Pivot	0.030	6.5
	82.21 ± 2.02	Winger	7.5			
	79.64 ± 3.02	Defender	7			
	79.33 ± 4.25	Total				
HR_{ZONE1} (min)	22.36 ± 4.10	Pivot	5.3	-	0.651	0.8
	24.76 ± 7.45	Winger	6.3			
	25.70 ± 4.19	Defender	8			
	24.39 ± 5.76	Total				
HR_{ZONE2} (min)	21.09 ± 7.04	Pivot	10.3	Winger-Pivot	0.031	6.5
	13.72 ± 1.71	Winger	3.8			
	17.00 ± 2.42	Defender	8			
	16.38 ± 4.63	Total				
HR_{ZONE3} (min)	13.68 ± 2.51	Pivot	5.3	-	0.802	0.4
	14.62 ± 3.80	Winger	7			
	14.57 ± 3.44	Defender	6.6			
	14.37 ± 3.17	Total				
HR_{ZONE4} (min)	10.05 ± 1.83	Pivot	2.6	-	0.058	5.6
	15.02 ± 2.83	Winger	8.6			
	11.65 ± .19	Defender	6			
	12.93 ± 3.06	Total				
HR_{ZONE5} (min)	6.08 ± 1.88	Pivot	7.6	-	0.807	0.4
	5.43 ± 2.44	Winger	6.1			
	4.81 ± 1.71	Defender	6			
	5.44 ± 2.02	Total				

DISCUSSION

The objective of this study was to investigate the activity profile and physiological demands incurred by elite deaf futsal players during a competitive match. This study represents the inaugural examination of the activity profile within the domain of elite deaf futsal players. The findings of the positional analysis in this study align with the activity profiles observed in nondeaf futsal players, where wingers typically exhibit greater player load compared to pivots and defenders (Serrano et al., 2020). The PL_{TOTAL} was higher among wingers (672.58±48.09) compared to pivots (479.73±0.00) and defenders (355.14±50.21). Similarly, the PL_{PEAK} was greater for wingers (5.50±0.78) compared to pivots (4.270±0.00) and defenders (5.44±1.30). Additionally, $PL \cdot min^{-1}$ was higher in wingers (6.34 ± 0.45) compared to pivots (4.53 ± 0.00) and defenders (3.35±0.47). Moreover, EXP_{EFF} were also observed to be elevated in the winger position (32.83±6.52) compared to pivots (30.00±0.00) and defenders (23.00±1.73). This occurrence is attributed to the inherent characteristics of the winger role, which typically involves sustained high-speed play, frequent bursts of explosive actions like dribbling, and extensive movement across the playing field.

In contrast to existing literature, our findings reveal that defenders exhibit the lowest PL variables, a phenomenon less commonly observed in prior studies. This contrasts with research involving nondeaf players, where defenders and wingers typically demonstrate similar activity levels, as documented by Serrano et al. (2020), while pivots tend to exhibit lower values. This observation is partially attributed to the characteristic playing style of pivots, who often engage in short bursts of effort and maintain a stationary position near the goal throughout the match. Furthermore, defenders and wingers frequently engage in positional rotation during matches, where they assume diverse roles and responsibilities, thereby blurring the distinction between the positions (Caetano et al., 2015). However, positional rotation between defenders and wingers among deaf futsal players may be less prevalent due to communication challenges. In deaf futsal, the reliance on visual communication may slow down or complicate the coordination required for positional rotation. As a result, deaf futsal players may be less inclined to switch positions frequently, leading to less prevalent positional rotation compared to hearing counterparts. This notion may be supported by a study comparing performance-related parameters between deaf Czech Republic national team soccer players and hearing counterparts from the Czech Republic First League. Neuls et al. (2019), found no significant differences between deaf and non-deaf soccer players, likely because the testing procedures do not involve communication challenges, whereas effective communication is crucial during team gameplay.

In the assessment of external load variables, wingers demonstrated elevated levels of acceleration and deceleration activities, exhibiting significant disparities compared to defenders but not pivots. Concerning change of direction activities, wingers exhibited differences in COD-L_{LOW} and COD-L_{MED} compared to defenders, whereas COD-L_{HIGH} varied between defenders and pivots, and COD-R_{LOW} differed between wingers and pivots. Similar to our results, Ohmuro et al. (2020) observed a difference in the proportion of high intensity running without ball possession between the defender and winger positions, with wingers exhibiting higher values. Illa et al. (2020) demonstrated that wingers exhibit greater high deceleration distance (m/min) compared to defenders and pivots (wingers = 69±13; defenders = 66±12; and pivots = 63±13). According to Serrano et al. (2020), wingers demonstrated a greater distance covered in high-speed running (17.03 ± 4.86) compared to pivots (12.99 ± 4.37) and defenders (15.44 ± 5.10). Caetano et al. (2015) utilized a video automatic tracking system to investigate sprint frequency during futsal competitions, revealing that players typically engage in an average of 26±13.3 sprints per match. Regarding playing position, they found no variations in sprint distance covered, peak velocity, initial velocity, recovery time between consecutive sprints, or the number of sprints per minute in normally hearing players. This may be attributed to the sport's tactical and technical features, which promote player flexibility in changing positions, as well as the unlimited substitutions or the option of utilizing a "flying goalkeeper" during matches (Spyrou et al., 2020). However, this scenario differs in deaf players, which may account for the variance observed between playing positions.

Regarding the HR variables, significant differences were only observed between pivots and wingers for the following parameters: HR_{MAX}, $\%HR_{MAX}$, and duration of HR_{ZONE3}. This discovery is notably intriguing, as we observed significant differences in mechanical load type variables (e.g., ACC, DEC, COD, and PL) between playing positions. However, for internal load parameters, specifically HR variables, there were no meaningful differences. For instance, wingers exhibited the highest values for several variables, including PL_{TOTAL}, EXP_{EFF}, $PL \cdot min^{-1}$, ACC, DEC, and COD. Therefore, it would be reasonable to anticipate higher HR values among wingers in comparison to pivots and defenders. Conversely, one might expect lower HR values for defenders and pivots, given their comparatively lower mechanical loads. However, this scenario did not align with the findings of our study. Therefore, it can be inferred that deaf futsal players experienced difficulty in regulating their HR values, suggesting that factors other than the mechanical load of the games contributed to the increased HR observed in hearing-impaired players.

In team sports involving deaf individuals, communication challenges can significantly impact gameplay and team dynamics. Unlike hearing athletes who rely on verbal cues and auditory signals to communicate with teammates and coaches during matches, deaf athletes often rely on alternative methods of communication, such as sign language, gestures, or visual cues. The heightened physiological demands in deaf team sports may arise from the need for increased vigilance, coordination, and spatial awareness. Deaf athletes must rely more heavily on visual cues to interpret the movements of teammates, opponents, and the ball, requiring heightened focus and attention throughout the game. This heightened vigilance can lead to increased physiological stress and energy expenditure compared to hearing athletes who may rely more on auditory cues.

Conclusion

In conclusion, mechanical demands of the simulated game differ based on the players' positions, underscoring the necessity for coaches to factor this variation into their preparation strategies. Moreover, players must manage their external and internal load effectively. Consequently, practitioners should prioritize implementing strategies for athletes' self-reconciliation and recovery to optimize performance and minimize the risk of fatigue-related issues. This emphasizes the crucial role of both coaching and athlete monitoring in maximizing athletic performance in hearing-impaired futsal players.

Practical Implication

The results of this study will contribute to a better understanding of the physical demands and physiological responses of hearing-impaired athletes in Futsal, which can inform the development of training programs, and strategies to optimize their performance and minimize the risk of injury. The findings will also provide valuable insights into the unique challenges faced by hearing-impaired athletes in team sports, highlighting the importance of inclusive sports and adaptive strategies to promote the participation and success of athletes with disabilities.

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The authors received no financial support for the research, authorship, and/or publication of this article.

Ethics of the Research

This study was approved by Gazi University Ethical Commission with the reference number of 2023-134 and conducted in accordance with the ethical principles of Declaration of Helsinki.

Author Contributions

Study Design, SA, YA; Data Collection, SA, KK; Statistical Analysis, SA, KK; Data Interpretation, KK; Manuscript Preperation, SA, KK, YA; Literature Search, SA, KK, YA. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport*, *16*(6), 556-561. [CrossRef]

Alanen, A., Räisänen, A., Benson, L., & Pasanen, K. (2021). The use of inertial measurement units for analyzing change of direction movement in sports: A scoping review. *International Journal of Sports Science & Coaching*, *16*(6), 1332-1353. [CrossRef]

Armitage, M., Beato, M., & McErlain-Naylor, S. A. (2021). Inter-unit reliability of IMU Step metrics using IMeasureU Blue Trident inertial measurement units for running-based team sport tasks. *Journal of sports sciences*, *39*(13), 1512-1518. [CrossRef]

Barbero-Alvarez, J. C., Soto, V. M., Barbero-Alvarez, V., & Granda-Vera, J. (2008). Match analysis and heart rate of futsal players during competition. *Journal of sports sciences*, *26*(1), 63-73. [CrossRef]

Beato, M., Coratella, G., & Schena, F. (2014). Brief review of the state of art in futsal. *The Journal of sports medicine and physical fitness*, *56*(4), 428-432. [PubMed]

Berkelmans, D. M., Dalbo, V. J., Fox, J. L., Stanton, R., Kean, C. O., Giamarelos, K. E., Teramoto, M., & Scanlan, A. T. (2018). Influence of different methods to determine maximum heart rate on training load outcomes in basketball players. *The Journal of Strength & Conditioning Research*, *32*(11), 3177-3185. [CrossRef]

Caetano, F. G., de Oliveira, M. J., Marche, A. L., Nakamura, F. Y., Cunha, S. A., & Moura, F. A. (2015). Characterization of the sprint and repeated-sprint sequences performed by professional futsal players, according to playing position, during official matches. *J. Appl. Biomech*, *31*, 423-429. [CrossRef]

Casamichana, D., & Castellano, J. (2015). The relationship between intensity indicators in small-sided soccer games. *Journal of human kinetics*, *46*(1), 119-128. [CrossRef]

Castagna, C., D'Ottavio, S., Vera, J. G., & Álvarez, J. C. B. (2009). Match demands of professional Futsal: a case study. *Journal of Science and Medicine in Sport*, *12*(4), 490-494. [CrossRef]

Cobanoglu, G., Suner-Keklik, S., Gokdogan, C., Kafa, N., Savas, S., & Guzel, N. A. (2021). Static balance and proprioception evaluation in deaf national basketball players. *Baltic Journal of Health and Physical Activity*, *13*(1), 2. [CrossRef]

De Oliveira Bueno, M. J., Caetano, F. G., Pereira, T. J. C., De Souza, N. M., Moreira, G. D., Nakamura, F. Y., Cunha, S. A., & Moura, F. A. (2014). Analysis of the distance covered by Brazilian professional futsal players during official matches. *Sports biomechanics*, *13*(3), 230-240. [CrossRef]

Dummer, G. M., Haubenstricker, J. L., & Stewart, D. A. (1996). Motor skill performances of children who are deaf. *Adapted physical activity quarterly*, *13*(4), 400-414. [CrossRef]

Espasa-Labrador, J., Calleja-González, J., Montalvo, A. M., & Fort-Vanmeerhaeghe, A. (2023). External Load Monitoring in Female Basketball: A Systematic Review. *Journal of human kinetics*, *87*, 173. [CrossRef]

Favretto, E., Fin, W., dos Santos Albarello, J. C., Halmenschlager, G. H., Bona, C. C., Pimentel, G. L., & Calegari, L. (2019). Cardiorespiratory fitness and muscular strength of deaf futsal players. *Journal of exercise rehabilitation*, *15*(3), 424. [CrossRef]

Fox, J. L., Stanton, R., & Scanlan, A. T. (2018). A comparison of training and competition demands in semiprofessional male basketball players. *Research quarterly for exercise and sport*, *89*(1), 103-111. [CrossRef]

Illa, J., Fernández, D., Tarragó, J. R., & Reche, X. (2020). Most demanding passages in elite futsal: an isolated or a repeat situation? *Apunts. Educación física y deportes*, *4*(142), 80-84. [CrossRef]

Kazakov, B., Tabinbaev, A., Ubbiev, B., & Masharipov, R. (2023). Psychophysiological Characteristics of Athletes-Volleyball Players with Hearing Impairment. *Journal of Coastal Life Medicine*, *11*, 332-336. [CrossRef]

Luteberget, L. S., Holme, B. R., & Spencer, M. (2018). Reliability of wearable inertial measurement units to measure physical activity in team handball. *International Journal of Sports Physiology and Performance*, *13*(4), 467-473. [CrossRef]

Luteberget, L. S., & Spencer, M. (2017). High-intensity events in international women's team handball matches. *International Journal of Sports Physiology and Performance*, *12*(1), 56-61. [CrossRef]

Makaje, N., Ruangthai, R., Arkarapanthu, A., & Yoopat, P. (2012). Physiological demands and activity profiles during futsal match play according to competitive level. *Journal of Sports Medicine and Physical Fitness*, *52*(4), 366. [CrossRef]

Milioni, F., Vieira, L. H., Barbieri, R. A., Zagatto, A. M., Nordsborg, N. B., Barbieri, F. A., Dos-Santos, J. W., Santiago, P. R., & Papoti, M. (2016). Futsal match-related fatigue affects running performance and neuromuscular parameters but not finishing kick speed or accuracy. *Frontiers in physiology*, *7*, 518. [CrossRef]

Neuls, F., Botek, M., Krejci, J., Panska, S., Vyhnanek, J., & McKune, A. (2019). Performance-associated parameters of players from the deaf Czech Republic national soccer team: A comparison with hearing first league players. *Sport Sciences for Health*, *15*, 527-533. [CrossRef]

Nicolella, D. P., Torres-Ronda, L., Saylor, K. J., & Schelling, X. (2018). Validity and reliability of an accelerometer-based player tracking device. *PloS one*, *13*(2), e0191823. [CrossRef]

Ohmuro, T., Iso, Y., Tobita, A., Hirose, S., Ishizaki, S., Sakaue, K., & Yasumatsu, M. (2020). Physical match performance of Japanese top-level futsal players in different categories and playing positions. *Biology of sport*, *37*(4), 359-365. [CrossRef]

Peracino, A. (2015). Hearing loss and dementia in the aging population. *Audiology and Neurotology*, *19*(Suppl. 1), 6-9. [CrossRef]

Ransdell, L. B., Murray, T., Gao, Y., Jones, P., & Bycura, D. (2020). A 4-year profile of game demands in elite women's division I college basketball. *The Journal of Strength & Conditioning Research*, *34*(3), 632-638. [CrossRef]

Ribeiro, J. N., Gonçalves, B., Coutinho, D., Brito, J., Sampaio, J., & Travassos, B. (2020). Activity profile and physical performance of match play in elite futsal players. *Frontiers in psychology*, *11*, 1709. [CrossRef]

Roell, M., Roecker, K., Gehring, D., Mahler, H., & Gollhofer, A. (2018). Player monitoring in indoor team sports: concurrent validity of inertial measurement units to quantify average and peak acceleration values. *Frontiers in physiology*, *9*, 141. [CrossRef]

Serdar, E., & Nebahat, E. (2020). The Relationship Between Hearing Level and Speed and Speed of Linear Direction Change of Handball Players with Hearing Impairments. *The Journal of Eurasia Sport Sciences and Medicine*, *2*(2), 26-32. [CrossRef]

Serrano, C., Felipe, J. L., Garcia-Unanue, J., Ibañez, E., Hernando, E., Gallardo, L., & Sanchez-Sanchez, J. (2020). Local positioning system analysis of physical demands during official matches in the spanish futsal league. *Sensors*, *20*(17), 4860. [CrossRef]

Sobko, I. (2013). Characteristics of competitive activity of qualified basketball with hearing impairment compare to qualified healthy basketball player. *Physical education of students*, *17*(4), 82-86. [CrossRef],

Spyrou, K., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Physical and physiological match-play demands and player characteristics in futsal: a systematic review. *Frontiers in psychology*, *11*, 569897. [CrossRef]

Spyrou, K., Freitas, T. T., Marín-Cascales, E., Herrero-Carrasco, R., & Alcaraz, P. E. (2021). External match load and the influence of contextual factors in elite futsal. *Biology of sport*, *39*(2), 349-354. [CrossRef]

Szulc, A. M., Buśko, K., Sandurska, E., & Kołodziejczyk, M. (2017). The biomechanical characteristics of elite deaf and hearing female soccer players: comparative analysis. *Acta of bioengineering and biomechanics*, *19*(4), 127-133. [PubMed]

Vujkov, S., Đukic, M., & Drid, P. (2010). Aerobic capacity of handball players with hearing impairment. *Biomedical Human Kinetics*, *2*(2010), 58-61. [CrossRef]

Ward, P., Tankovich, M., Ramsden, J. S., Drust, B., & Bornn, L. (2018). Volume and intensity are important training related factors in injury incidence in American Football Athletes. Sloan Sports Analytics Conference 2018. [CrossRef]

Wik, E. H., Luteberget, L. S., & Spencer, M. (2017). Activity profiles in international women's team handball using PlayerLoad. *International Journal of Sports Physiology and Performance*, *12*(7), 934-942. [CrossRef]

Yapici, H., Soylu, Y., Gulu, M., Kutlu, M., Ayan, S., Muluk, N. B., Aldhahi, M. I., & Al-Mhanna, S. B. (2023). Agility Skills, Speed, Balance and CMJ Performance in Soccer: A Comparison of Players with and without a Hearing Impairment. Healthcare, [CrossRef]

Yiannaki, C., Barron, D., Collins, D., & Carling, C. (2020). Match performance in a reference futsal team during an international tournament–implications for talent development in soccer. *Biology of sport*, *37*(2), 147-156. [CrossRef]