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Physical and physiological demands according to gender, playing positions, and match outcomes in youth basketball players

Demandas físicas y fisiológicas según género, posiciones de juego y resultados del partido en jugadores de baloncesto juveniles

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Abstract

This study aimed to compare physical and physiological demands in youth basketball players according to gender, playing positions, and match outcomes. 64 players (32 female and 32 male) from eight youth sub-elite basketball teams were monitored using an Ultra-Wide Band system and inertial measurement unit in three consecutive matches. The results showed some significant differences, although with magnitudes qualified as small. When the teams won, the guards covered a greater distance at 0-6 km/h than when they lost. When teams lost, the centers covered more distance at 12-18 km/h and 18-21 km/h. The winning female teams presented a lower maximal heart rate (HRmax) compared to the losing teams. The forwards of the winning teams performed greater efforts at 70-80% HRmax, while the forwards of losing teams performed more efforts at 90-95% HRmax. The greatest number of accelerations and decelerations were performed by the female guards and the male forwards. The number of jumps was higher in the male guards and forwards than in the female ones. HRmax was higher in the forwards of the female teams. Efforts at 80%-90% HRmax were higher in male centers. When the female teams won, they had a lower HRmax than when they lost. When efforts exceed 90% of HRmax the teams lost. In conclusion, despite the differences found, the effect of these contextual variables on physical and physiological demands is unclear. Nevertheless, knowing the game's requirements can help the design of training that enhances the performance of youth basketball players.

Keywords: performance analysis; collective sport; external load; internal load.

Resumen

El objetivo de este estudio fue comparar las demandas físicas y fisiológicas en jóvenes jugadores de baloncesto según sexo, posiciones de juego y el resultado de partido. 64 jugadores (32 mujeres y 32 hombres), de ocho equipos juveniles de baloncesto sub-élite, fueron monitoreados utilizando un sistema de Ultra Banda-Ancha y unidades de medición inercial en tres juegos consecutivos. Los resultados evidenciaron algunas diferencias significativas, aunque con magnitudes calificadas como pequeñas. Cuando los equipos ganaban, los bases recorrieron mayor distancia a 0-6 km/h en comparación a cuando perdían. Cuando se perdía, los pivots recorrieron más distancia a 12-18 y 18-21 km/h. Las jugadoras de los equipos ganadores alcanzaron una frecuencia cardiaca máxima (FCmáx) más baja respecto a los equipos perdedores. Los aleros de los equipos ganadores realizaron más esfuerzos a 70-80% FCmáx, mientras que, en los equipos perdedores, los bases realizaron más esfuerzos a 90-95% FCmáx. La mayor cantidad de aceleraciones y desaceleraciones fueron realizada por las bases femeninas y los aleros masculinos. El número de saltos fue mayor en los distribuidores y aleros masculinos que en los femeninos. La FCmáx fue más alta en los aleros de los equipos femeninos. Los esfuerzos a 80%-90% FCmáx fueron mayores en los pivots masculinos. Cuando los equipos femeninos ganaban, presentaban una FCmáx menor que cuando perdían. Los esfuerzos ≥90% FCmáx fueron superiores en mujeres que hombres cuando sus equipos perdían. En conclusión, a pesar de las diferencias encontradas, no queda claro el efecto de estas variables contextuales sobre las demandas físicas y fisiológicas. No obstante, conocer estas exigencias del juego pueden ayudar al diseño de entrenamientos que potencialicen el rendimiento de jugadores jóvenes de baloncesto.

Palabras claves: análisis de rendimiento; deporte colectivo; carga externa; carga interna.

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Introduction

With emerging technologies geared towards the analysis of sports performance, wearable sensors offer the opportunity to obtain relevant information on the workload of athletes during competitions and training. In basketball, the use of remote technologies allows the quantification of physical and physiological demands during training and matches (Montgomery et al., 2010).

Basketball is a collective sport that combines offensive and defensive simultaneous actions (Trninić et al., 2010), characterized by aerobic and anaerobic efforts (Narazaki et al., 2009) with multiple neuromuscular and biomechanical actions that demand a tremendous physical and physiological effort from the players in short periods (Scanlan et al., 2018; Vásquez-Guerrero et al., 2019). Research conducted in competitions showed that male and female players performed actions above 85% of the maximal heart rate in more than 70% of the total time played (Hůlka et al., 2013; Vencúrik et al., 2015). In male players with an average of 16.88 ± 0.72 years, the heart rate reported has been 167.47 ± 13.01 bpm (Hůlka et al., 2013). Consequently, the lactate concentration in the blood has been reported at 5.49 ± 1.24 mmol/l and has shown variations in blood lactate concentrations during the match, with higher peaks in the first period in compassion with the second period (Abdelkrim et al., 2007).

Other studies have focused on analyzing the motor activities of players during matches. Basketball players can perform an average of 652 ± 128 motor movements per match (Matthew and Delextrat, 2009) or 33 ± 7 actions per minute (Torres-Ronda et al., 2016). The total distances covered by the male and female players oscillate between 5000 to 6000 m during a complete match (Stojanović et al., 2018). The relative distance (m/min) per game for male (26.1 ± 5.3 years old) and female (22.0 ± 3.7 years old) have been reported in 127.5 ± 5.2 and 128.5 ± 5.3, respectively (Scanlan et al., 2015).

The studies that have made comparisons between gender are very few and do not report statistically significant differences in intermittent demands, high-intensity, and shuffling activity (Scanlan et al., 2015). In under-18 male players, the total distance covered per minute was 67 to 79 m/min (Pino-Ortega et al., 2019), while in under-18 divisions, female players performed 112 to 122 m/min (Reina et al., 2020). On the other hand, male players, cover around 3% of the total distance at speeds that exceed 18 km/h and performing an average of 0.17 ± 0.13 sprints per minute (Puente et al., 2017). Female players performed sprints every 33 seconds of the live time, and 48.3 ± 2.9% of the sprints performed are linear that oscillate between 1–5 m the distance (Conte et al., 2015). During a match, female players' number of jumps per minute has been reported as 1.1 ± 0.3 (Delextrat et al., 2015), while male players perform 0.6 to 0.7 (Fox et al., 2019).

It has also been documented those contextual factors can influence basketball players' physical and physiological demands (Fox et al., 2019; Pino-Ortega et al., 2019). Evidence indicates differences by playing positions in motor activities and physiological demands (García et al., 2020; Torres-Ronda et al., 2016). For example, guards have reported higher workloads than forwards and centers (Stojanović et al., 2018). These players performed more accelerations, reached a higher maximal speed, and covered more distance than other positions (Pino-Ortega et al., 2019). In female players, it has been found that center players perform fewer sprints, although they do more jumps compared to the other positions (Delextrat et al., 2015).

Regarding the accelerations, it has been reported that the guards performed more intense accelerations in the last quarter, although of short duration (Reina, et al., 2019). Likewise, through principal component analysis (PCA), it has been shown that the internal load varies during training sessions depending on the playing positions (Svilar et al., 2018). In this sense, relative HR and absolute HR vary by the playing positions (Scanlan et al., 2012). In female players, more than 77% of the efforts performed by the forwards were above 85% of the maximal heart rate (Vencúrik et al., 2015), while in the case of the male, the centers performed efforts above 92% of the maximal heart rate (Puente et al., 2017). Likewise, it has been concluded that these differences should be analyzed according to gender (Scanlan et al., 2015).

Some studies have explored differences between winning and losing teams; though, these comparisons have been mainly focused on technical and tactical actions like throws, rebounds, turnovers, assists, and point score (Conte and Lukonaitiene, 2018; Ibáñez et al., 2009; Lorenzo et al., 2010; Simovic et al., 2019). Few studies have analyzed the influence of the match outcome on motor activities. Recently, an investigation with male professional basketball players has not observed differences between winning and losing teams in the external load indicators (distances covered, accelerations and decelerations, number of steps, and jumps) (Castillo et al., 2021). Likewise, with male teams, Fox et al. (2019) reported a lower number of jumps, high-intensity accelerations, and decelerations when teams won. In NCAA Collegiate Division 1, female basketball players only reported that when the teams lost, high inertial movement analysis (a metric that combines acceleration, deceleration, change of direction, and free running) was higher than when teams won (Ransdell et al., 2020). Studies that have investigated the physiological responses according to match outcomes were not identified.

Given the influence of contextual factors (playing positions and match outcome) on the physical performance, and the difference reported between genders in the motor and physiological demands, it is necessary to carry out analyzes that integrate these variables to obtain useful information to develop more basketball-specific training processes (Pino-Ortega et al., 2019; Stojanović et al., 2018). Therefore, the objective of this study was to compare the physical and physiological demands in youth basketball players according to gender, playing positions, and match outcomes.

Methodology

Participants

Eight youth basketball teams participated in this study. A total of 64 players (32 female and 32 male). These players trained 3-4 times per week and competition least once per week. The specific physical characteristics of the sample can be seen in detail in Table 1. As a criterion of players' inclusions, no presented kind of neuro-musculoskeletal limitations was considered.

Table 1. Characteristics of the sample.

	Female	Male	Playing Positions		
			Guards	Forwards	Centers
n	32	32	14	28	22
Age (years)	16.19 ± 1.00	16.80 ± 1.03	16.57 ± 1.09	16.63 ± 1.11	16.24 ± 0.94
Height (cm)	167.56 ± 7.34	177.70 ± 7.09	168.93 ± 9.11	171.81 ± 8.69	175.67 ± 7.98
Weight (kg)	65.67 ± 13.94	74.73 ± 11.76	65.58 ± 11.01	65.44 ± 10.95	78.97 ± 14.29
BMI (kg/m^2)	23.22 ± 3.82	23.62 ± 3.06	22.77 ± 2.17	22.11 ± 2.91	25.52 ± 3.88
Body Fat (%)	22.62 ± 8.50	14.27 ± 4.98	16.76 ± 6.90	15.29 ± 5.65	24.04 ± 9.01
SMM (kg)	26.81 ± 3.96	36.44 ± 5.10	32.49 ± 4.35	31.96 ± 6.53	30.17 ± 7.95
VO2max (ml/kg/min)	40.63 ± 1.69	44.21 ± 2.53	44.08 ± 2.61	42.89 ± 2.82	40.53 ± 1.70

Note: n= number of participants, cm= centimeters, kg= kilograms, BMI= body mass index, SMM= skeletal muscle mass, VO2max= maximal oxygen uptake, ml= milliliter, min= minute.

Each participant was informed of the design of the competition and the measurement equipment and procedures. Participants ≥18-year-old gave their consent to participate in the study. In the case of players <18-year-old gave their ascent, and the legal guardian gave their consent. The protocol of this study was reviewed and approved by the Institutional Review Board of the Universidad Nacional, Costa Rica (Protocol Reg. Code 2019-P004).

Only the data of the players who participated up to 60% of the total playing time per quarter were included in the analysis. This criterion has already been used in previous research (Gómez Carmona et al., 2019; Pino-Ortega et al., 2019).

Design

Teams participated in an official tournament of three consecutive matches during a weekend (Friday, Saturday, and Sunday). Male's competition was performed on the first weekend and female's competition was performed on the second weekend. Each team played a match per day. Every day there were two matches in the same time slot (between 16:00 - 20:00 hours). The competition´s schedule was defined randomly.

The tournament was organized according to FIBA rules. Each match consisted of two periods and four quarters of 10 minutes. A pause of 2 min between quarters was allowed. The dimensions of the court were 28 m by 15 m. Likewise, four professional referees (two referees and two table referees) led each match during the tournament.

Instruments

Ultra-wide band (UWB) indoor system: This system (WIMUPro™, RealTrack Systems, Almería) was used to quantify physical demands. Eight antennas were placed around the court held by a tripod at the height of 3 m, as is shown in Figure 1. Antenna's settings allow referencing the boundary lines of the court virtually. This virtual delimitation allows controlling played time by each player considering substitutions role in the basketball. The software only registered the data when the players were within the court.

Inertial measurement unit (IMU): IMU has a sensor as accelerometers, magnetometers, and gyroscopes that allow register motor variables as the distance traveled, speed, change of direction, accelerometry, jumps, and player load. Likewise, using a cardiac monitor GARMIN linked with IMU devices, heart rate may be obtained. Software SPro™, RealTrack Systems, Almería, Spain, allow obtaining absolute and relative data. Each player wore a special neoprene vest that fit the body to wear the IMU device at the T2-T4 level and between the scapulae.

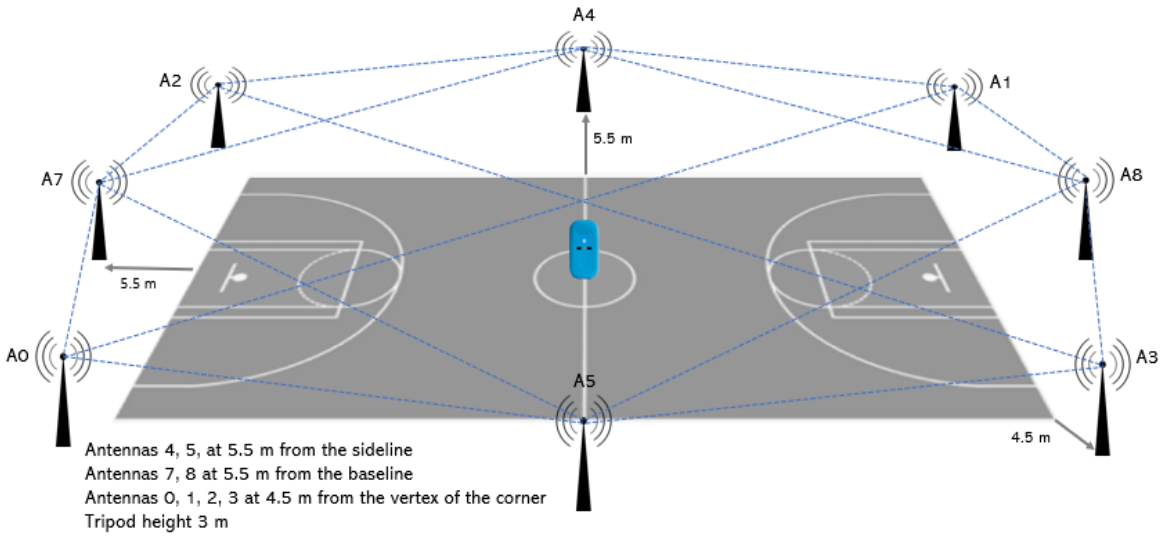

Figure 1. UWB indoor system placed on the court.

Physical demands

For this analysis, the variables were analyzed concerning the played minutes (/min), which allows reducing the margin of error that can generate differences in the minutes played by each player. The variables were: total distance covered per minute (TD), distance covered per minute at five different intensities per minute according to previous studies (Abdelkrim et al., 2010; Puente et al., 2017, Vásquez-Guerrero et al., 2019): a) 0-6 km/h, b) 6-12 km/h, c) 12-18 km/h, d) 18-24 km/h and 5) ≥24 km/h. Accelerations (Acc), decelerations (Dec), and jumps concerning the number performed per minute (n/min). Maximal speed expressed in meters per second (m/s).

Physiological demands

The variables considered were the maximal heart rate (HRmax) expressed in beats per minute (bpm) and the percentage of time spent a different heart rate zones concerning the maximal heart rate: 50–60% HRmax, 60–70% HRmax, 70–80% HRmax, 80%–90% HRmax and ≥90% HRmax.

Playing Positions

Each player was categorized according to their usual playing position (Pino-Ortega et al., 2019; Puente et al., 2017; Reina et al., 2020). In this sense, players were categorized in guards (n=14), forwards (n=28), and centers (n=22).

Match outcomes

As a reference to the match outcomes, these were categorized into a) winners and b) losers.

Statistical analysis

The distribution of the data was confirmed with the Kolmogorov-Smirnov test ($p > 0.05$). All data were reported as mean ±standard deviations. Factorial ANOVAs were performed to compare variables between gender, playing positions, and match outcomes. The magnitude of the differences was estimated using partial omega squared (ω_p^2). According to Cohen (1988), ω_p^2 values were qualified as small (> 0.01), moderate (> 0.06), and large (> 0.14). When was necessary, Bonferroni Post Hoc tests were used to identify specific differences. For the data analysis, the Statistical Package for the Social Sciences (SPSS, IBM, SPSS Statistics, v.22.0 Chicago, IL, USA) was used, and at $p < 0.05$ was the alpha value prior set for all analyses.

Results

Table 2. Physical and physiological demands performed by players according to match outcomes and playing positions.

	Wining			Losing		
	Guards	**Forwards**	**Centers**	**Guards**	**Forwards**	**Centers**
Physical demands						
TD (m/min)	69.70 ± 16.29	71.16 ± 16.62	66.26 ± 17.96	62.41 ± 22.84	73.49 ± 18.45	69.14 ± 22.55
D 0–6 km/h (m/min)	31.21 ± 5.85*[a]	29.30 ± 7.16	27.45 ± 6.48 [b]	27.58 ± 7.25*	30.24 ± 5.62 [a]	26.97 ± 6.93 [c]
D 6–12 km/h (m/min)	24.90 ± 7.75	25.57 ± 9.70	23.78 ± 7.91	21.89 ± 10.66	26.45 ± 9.06	23.35 ± 9.72
D 12–18 km/h (m/min)	11.56 ± 4.41 [a]	14.24 ± 6.73 [b]	13.95 ± 5.85 *[b]	11.23 ± 5.64 [ac]	14.95 ± 5.98 [ab]	17.11 ± 7.94 *[bc]
D 18–24 km/h (m/min)	1.66 ± 1.19 [a]	1.60 ± 1.19 [a]	0.95 ± 0.93 *[bc]	1.38 ± 1.08	1.45 ± 1.21	1.48 ± 1.79*
D ≥24 km/h (m/min)	0.03 ± 0.11	0.06 ± 0.17	0.01 ± 0.06	0.03 ± 0.11	0.08 ± 0.20	0.02 ± 0.13
Acc (number/min)	29.15 ± 7.80	26.88 ± 3.26	25.24 ± 3.43	29.00 ± 10.42	27.02 ± 3.17	24.96 ± 2.79
Dec (number/min)	29.09 ± 7.79	26.74 ± 3.24	25.05 ± 3.37	28.92 +10.50	26.84 +3.23	24.75 ± 2.78
Maximal Speed (m/s)	5.24 ± 0.46	5.12 ± 0.82	4.95 ± 0.47	5.08 ± 0.79	5.15 ± 0.64	4.88 ± 0.70
Jumps (number/min)	0.88 ± 0.41	0.88 ± 0.47	1.13 ± 0.55	0.70 ± 0.36	0.84 ± 0.43	1.07 ± 0.56
Physiological demands						
HRmax (bpm)	188.00 ± 23.62*	188.00 ± 17.68	189.00 ± 10.56	189.45 ± 20.73*	188.70 ± 13.97	189.56 ± 16.07
50–60% HRmax	6.98 ± 12.59	6.00 ± 15.96	7.01 ± 13.80	12.20 ± 22.64	7.49 ± 18.95	5.58 ± 16.14
60–70% HRmax	12.83 ± 13.22	6.41 ± 7.49	8.10 ± 13.07	8.20 ± 10.61	7.41 ± 9.24	9.13 ± 17.20
70–80% HRmax	21.06 ± 17.86 *[a]	16.47 ± 14.15 [a]	9.96 ± 8.72 [bc]	12.06 ± 10.66 *	13.92 ± 11.87	9.80 ± 9.03
80–90% HRmax	31.95 ± 21.19	31.51 ± 15.89	29.11 ± 16.44	29.34 ± 17.31	32.12 ± 17.69	28.09 ± 18.53
≥90% HRmax	16.44 ± 17.37 *[a]	24.20 ± 15.53 [a]	28.92 +14.87 [bc]	22.41 ± 15.48 *	23.73 ± 16.15	27.00 ± 16.34

Notes: * significant difference ($p<0.05$) between gender.
[a] different ($p< 0.05$) from centers
[b] different ($p< 0.05$) from guards
[c] different ($p< 0.05$) from forwards

Statistically significant interactions were found between match outcome and playing positions in distances covered per minute played at 0-6 km/h ($F_{(2, 443)}= 3.466$; $p= 0.032$; $\omega_p^2= 0.012$, *small*), 12-18 km/h ($F_{(2, 443)}= 5.730$; $p= 0.003$; $\omega_p^2= 0.020$, *small*) and at 18-24 km/h ($F_{(2, 443)}= 6.697$; $p= 0.001$; $\omega_p^2 = 0.024$, *small*). After post hoc analyses (see Table 2) was found that the guards of the winning teams covered more distance at 0-6 km/h than the guards of the losing teams. The centers of the losing teams traveled more meters at 12-18 km/h and 18-24 km/h than the centers of the winning teams. In the winning teams, the forwards and centers covered more meters per minute at 12-18 km/h, while the guards and forwards covered more distance at 18-24 km/h. When teams lost, centers covered more distance at 12-18 km/h (see Table 2).

It were also found statistically significant interactions in physiological demands such as HRmax ($F_{(2, 443)}$= 6.720; p= 0.001; ω_p^2= 0.025, *small*), 70%-80% HRmax ($F_{(2, 443)}$= 4.338; p= 0.014; ω_p^2= 0.015, *small*), ≥90% HRmax ($F_{(2, 443)}$= 5.172; p= 0.006; ω_p^2= 0.018, *small*). In Table 2, is observed that the guards of the losing teams had a higher HRmax (bpm) and performed more efforts at >90% HRmax compared to the guards of the winning teams. In the winning teams, the guards registered the greatest percentage of effort at 80-90% HRmax higher >90% HRmax but the lowest percentage effort at 70-80% HRmax compared with other positions.

Table 3. Physical and physiological demands performed by players according to match outcomes and gender.

	Wining		**Losing**	
	Male	**Female**	**Male**	**Female**
Physical demands				
TD (m/min)	69.09 ± 20.34	69.08 ± 17.90	68.13 ± 24.47	69.00 ± 18.74
D 0–6 km/h (m/min)	28.72 ± 6.58	29.61 ± 6.88	27.65 ± 7.10	28.80 ± 6.38
D 6–12 km/h (m/min)	23.81 ± 9.16	25.73 ± 7.95	23.15 ± 10.94	24.71 ± 8.82
D 12–18 km/h (m/min)	14.49 ± 6.46	12.37 ± 5.24	14.97 ± 7.90	14.32 ± 6.19
D 18–24 km/h (m/min)	1.62 ± 1.19	1.16 ± 1.06	1.83 ± 1.59	1.05 ± 1.10
D ≥24 km/h (m/min)	0.04 ± 0.15	0.02 ± 0.09	0.08 ± 0.20	0.01 ± 0.08
Acc (number/min)	26.88 ± 2.52	26.96 ± 6.82	27.20 ± 5.69	26.49 ± 7.04
Dec (number/min)	26.73 ± 2.57	26.83 ± 6.80	27.00 ± 5.80	26.37 ± 7.06
Maximal Speed (m/s)	5.17 ± 0.69	5.02 ± 0.57	5.17 ± 0.70	4.88 ± 0.70
Jumps (number/min)	1.03 ± 0.47	0.90 ± 0.52	0.95 ± 0.48	0.83 ± 0.50
Physiological demands				
HRmax (bpm)	187.92 +18.46	188.79 ± 16.31 *	186.90 ± 18.80 ¥	191.53 ± 14.67 *¥
50–60% HRmax	6.47 ± 14.14	6.75 ± 14.63	10.71 ± 20.43 ¥	5.75 ± 17.90 ¥
60–70% HRmax	11.13 ± 13.81	6.12 ± 7.80	11.28 ± 14.51	5.40 ± 10.92
70–80% HRmax	17.25 ± 14.72	13.45 ± 13.66	14.18 ± 11.05	9.51 ± 9.65
80–90% HRmax	31.88 ± 18.71	29.66 ± 16.28	30.29 ± 18.36	29.24 ± 17.52
≥90% HRmax	21.79 ± 16.91	25.97 ± 15.77 *	18.65 ± 14.33 ¥	30.30 ± 15.65 *¥

¥ differences between gender (p< 0.05), * differences between match outcomes (p< 0.05).

Interactions in physiological demands between the match outcomes and gender were also identified in HRmax ($F_{(1, 443)}$= 14.107; p< 0.001; ω_p^2= 0.028, *small*), 50-60% HRmax ($F_{(1, 443)}$= 5.116; p= 0.024; ω_p^2= 0.009, *small*), and ≥90% HRmax ($F_{(1, 443)}$= 13.189; p< 0.001; ω_p^2= 0.026, *small*), they are shown in Table 3.

In Table 3, Post hoc analyses found that the female losing teams had a higher HRmax and percentage of efforts at >90% HRmax than the female winning teams. In the losing teams, HRmax and the percentage of efforts at ≥90% HRmax were higher in females than in males.

Table 4. Physical and physiological demands performed by players according to playing positions and gender.

	Male			Female		
	Guards	**Forwards**	**Centers**	**Guards**	**Forwards**	**Centers**
Physical demands						
TD (m/min)	63.88 ± 23.21	73.91 ± 20.67	68.45 ± 22.80	69.17 ± 12.93	70.83 ± 19.61	67.44 ± 19.13
D 0–6 km/h (m/min)	28.15 ± 7.51	29.20 ± 6.09	26.92 ± 6.73	31.26 ± 4.86	30.26 ± 6.77	27.35 ± 6.73
D 6–12 km/h (m/min)	21.83 ± 10.54	25.64 ± 9.61	23.01 ± 9.82	25.99 ± 6.50	26.32 ± 9.21	23.89 ± 8.32
D 12–18 km/h (m/min)	11.80 ± 5.66	16.66 ± 6.77	16.38 ± 8.40	10.54 ± 3.74	12.71 ± 5.37	15.23 ± 6.35
D 18–24 km/h (m/min)	1.65 ± 1.18	1.79 ± 1.30	1.77 ± 1.81	1.21 ± 0.99	1.29 ± 1.05	0.90 ± 1.11
D ≥24 km/h (m/min)	0.06 ± 0.15	0.03 ± 0.11	0.06 ± 0.22	0.04 ± 0.14	0.01 ± 0.07	0.01 ± 0.01
Acc (number/min)	27.57 ± 6.12 *	27.74 ± 2.72 *[a]	25.52 ± 3.03 [c]	32.03 ± 13.17 *[a]	26.24 ± 3.46 *[a]	24.81 ± 3.12 [bc]
Dec (number/min)	27.53 ± 6.21 *	27.53 ± 2.79 *[a]	25.21 ± 3.07 [c]	31.90 ± 13.21 *[ac]	26.13 ± 3.45 *[b]	24.68 ± 3.05 [b]
Maximal Speed (m/s)	5.19 ± 0.72	5.24 ± 0.73	5.06 ± 0.60	5.07 ± 0.55	5.04 ± 0.72	4.81 ± 0.59
Jumps (number/min)	0.86 ± 0.41 *[c]	1.10 ± 0.51 *[b]	1.04 ± 0.48	0.64 ± 0.31 *[a]	0.66 ± 0.28 *[a]	1.14 ± 0.60 [bc]
Physiological demands						
HRmax (bpm)	188.98 ± 21.62 [c]	184.73 +17.02 *[b]	188.34 ± 15.69	188.49 ± 22.89 [c]	191.46 ± 14.38 *[b]	189.93 ± 12.49
50–60% HRmax	13.96 + 21.67 *[ac]	6.57 ± 15.22 [b]	4.06 ± 12.42 *[b]	1.43 ± 6.03 *[a]	6.84 ± 19.20	7.63 ± 16.50 *[b]
60–70% HRmax	11.96 ± 11.95	9.18 ± 9.36	12.57 ± 20.17	6.50 ± 11.31	4.89 ± 6.84	6.16 ± 10.79
70–80% HRmax	16.88 ± 14.54	16.78 ± 13.82	12.69 ± 8.89	14.00 ± 15.50	13.93 ± 12.44	8.06 ± 8.41
80–90% HRmax	28.88 ± 20.28	31.39 ± 16.53	33.56 ± 18.11 *	33.84 ± 15.85 [a]	32.15 ± 16.98 [a]	25.33 +16.51 *[bc]
≥90% HRmax	16.39 ± 15.36	21.63 ± 16.24	23.46 ± 14.54	27.10 ± 16.74	26.01 ± 15.18	30.70 ± 15.79

Notes: * significant difference ($p< 0.05$) between genders.
[a] different ($p< 0.05$) from centers
[b] different ($p< 0.05$) from guards
[c] different ($p< 0.05$) from forwards

Statistically significant interactions were found between playing positions and gender in the number of accelerations/minute ($F_{(2,\ 443)}$= 16.714; $p< 0.001$; ω_p^2= 0.065, *small*), decelerations/minute ($F_{(2,\ 443)}$= 15.717; $p< 0.001$; ω_p^2= 0.061, *small*), and jumps/minute ($F_{(2,\ 443)}$=13.587; $p< 0.001$; ω_p^2= 0.052, *small*), HRmax ($F_{(2,\ 443)}$= 8.783; $p< 0.001$; ω_p^2= 0.033, *small*), 50-60% HRmax ($F_{(2,\ 443)}$= 9.850; $p< 0.001$; ω_p^2= 0.037, *small*), and 80-90% HRmax ($F_{(2,\ 443)}$= 5.898; p= 0.003; ω_p^2= 0.021, *small*).

Table 4 showed greater accelerations and decelerations per minute by the guards of the female teams than the guards of the male teams. The forwards of the male teams performed more accelerations and decelerations per minute than the forwards of the female teams. The guards performed the highest number of accelerations and decelerations per minute in both sexes, followed by the forwards. In contrast, the lowest number of actions were registered by centers.

The number of jumps per minute was higher in the male guards and forwards than the female ones. In the male teams, the highest number of jumps per minute was performed by the forwards and guards, while in the female, who most jumped were the centers.

HRmax was higher in female than male forwards. The percentage of effort at 50-60% HRmax was higher in male than female guards but lower in male than female centers. The percentage of effort at 80-90% HRmax was higher in male than female centers. In female teams, forwards presented a higher HRmax than the other positions, but in male teams, forwards registered the lowest HRmax. Centers of the female teams had the lowest percentage of effort at 80-90% HRmax compared to forwards and guards.

Discussion

The objective of this study was to compare the physical and physiological demands in youth basketball players based on gender, the playing positions, and the match outcomes. When comparing the obtained results with previous investigations, the data indicate that the meters covered per minute were slightly lower than those reported in Spanish players aged 19 to 35 years (Puente et al., 2017), under-18 (Pino-Ortega et al., 2019), and in Turkish U-19 players (Abdelkrim et al., 2010). Likewise, when comparing the distances covered by female players, the participant players covered a relative distance lower than Under-18 (Reina et al., 2020). A study found distances covered higher at intensities 10.81–25.2 km/h in male than female players, but without differences in distances standing/walking and jogging (Scanlan et al., 2015).

The results showed significant differences in some analyzed variables, although with magnitudes of the differences qualified as small (Cohen, 1988). In this sense, the guards of the winning teams covered a greater distance at 0-6 km/h than the guards of the losing teams, while the centers of the losing teams covered more meters at 12-18 km/h and 18-24 km/h than the centers of the winning teams. According to previous studies, the difference between winning and losing teams is usually related to high-intensity actions, with a magnitude of the differences classified as moderate or large (Fox et al., 2019; Ransdell et al., 2020). Losing teams performed more high-intensity actions like accelerations, decelerations, jumps, and change of direction (Fox et al., 2019; Ransdell et al., 2020).

Some reasons that could explain these differences can be related to the score. Having a negative difference in points could provoke that the players perform more high-intensity actions to balance the score. In this line, a study tried to approach this line by analyzing how the final score differences can affect physical performance (Gómez Carmona et al., 2019). The authors reported that the total distance covered, distance >16 km/h, accelerations, decelerations, and impacts were greater when the score was unbalanced (difference in points > 10) at the end of each quarter (Gómez Carmona et al., 2019).

Likewise, tactics used by teams can affect physical activities, mainly the distances traveled at high speeds (Sampaio et al., 2014). Teams often apply different defensive or offensive tactics (Choi et al., 2015; Conte et al., 2015; Leite et al., 2014). The defensive style (man-to-man or zone) will vary the player's physical activities on the field (Castillo et al., 2021). When a team lost and selected a zone-based defense, it registered fewer high decelerations and jumps (Castillo et al., 2021).

Differences between playing positions have been reported in previous research. Guards and forwards spend more percentage of their playing time in sprint activities, high-specific movement, and medium-specific movement than centers (Abdelkrim et al., 2007). Guards and forwards performed higher accelerations and decelerations per minute than the centers (Reina, et al., 2019). Likewise, previous results indicate that gender can affect the physical activities of the playing positions (Scanlan et al., 2015). However, the differences in the numbers of accelerations, decelerations, and jumps between gender and playing positions observed in Table 4, should be analyzed with caution because to the magnitude of the differences were small.

Reviewing literature, a study that compared males and females showed that the backcourt female players performed more jumps per minute than the backcourt male players (effect size qualified as moderate and large), and in the frontcourt players, there were no differences between genders (Scanlan et al., 2015). In this same study, regarding high-intensity shuffle, no differences were found between gender according to these playing positions (Scanlan et al., 2015).

Recent data from male players showed that center (0.4 ± 0.2) performed a significantly higher number of jumps than forwards (0.2 ± 0.1) and guards (0.2 ± 0.1) with an effect size moderate-large (García et al., 2020). These differences between playing positions may be due to the specific actions that demand each playing position (Sampaio et al., 2008). For example, guards in defense-offense transitions tend to perform covered at a high-intensity (García et al., 2020; Reina, et al., 2019). In females, a higher percentage of jumps has been evidenced when the team has possession of the ball (Conte et al., 2015; Stojanović et al., 2018). The specific anthropometric characteristics of the men and women can be the fact determinant on the physical performance of the players during the matches (Ziv and Lidor, 2009). Likewise, the status of physical capacities like strength, power, aerobic and anaerobic affect directly the specific movement, running activities and high-intensity action requires to play a basketball game (Abdelkrim et al., 2010; Narazaki et al., 2009; Torres-Ronda et al., 2016; Ziv and Lidor, 2009).

Based on the results, the average maximal heart rate in the players in this study was higher than reported in male players with an average age of 19 years, which was 173 ± 6 bpm (Montgomery et al., 2010). In female basketball players >18 years old, during competition, the maximal heart rate was registered at an average of 192 bpm (Reina et al., 2019), which is slightly higher than what was found in this study. Both in male and female players, around 50% of the time of a match, players perform efforts between 85% and 95% of the maximal HR, both in the first and second half (Abdelkrim et al., 2010; Hůlka et al., 2013; Vencúrik et al., 2015), a trend observed in the results of this study. Physiological responses have correlated with running activities (Matthew and Delextrat, 2009).

The results of this study reflected a small effect of match outcome on physiological responses. Specifically, in the winning teams, the guards had a higher percentage of efforts at 70-80% HRmax, while at ≥90% HRmax was higher in the guards of the losing teams. A previous study with male players has not found differences in the heart rate responses between winning and losing teams (Fox et al., 2019), which may justify the small effect found. However, it is known that when teams are losing, they tend to increase their physical efforts to equalize or reverse the score, and this increases the physiological demands. On the other hand, analyzing the results reported in investigations that showed results depending on the playing position, it has been found that the physical efforts made by male forwards and centers represent 89% and 92% of the maximal heart rate, respectively (Puente et al., 2017). For their part, in females, it is shown that guards, forwards, and centers perform 70.9%, 77.2%, and 74.1% of the efforts, respectively above 85% of the maximal heart rate (Vencúrik et al., 2015). The above may be related to the differences in physical activities between playing positions reported both in the literature (Puente et al., 2017; Sampaio et al., 2008), as well as those found in this study.

Limitations

While this study aimed to analyze youth basketball players' physical and physiological demands according to gender, playing positions, and match outcomes, the study had limitations. The main limitation was concerning the sample size and the number of matches analyzed. A longitudinal monitorization of an entire season could control the changes in the physical demands of female and male players. Also, the type of physical tests applied before the tournament did not provide individual data to customize heart rate and speed thresholds. That would have allowed knowing if the players performed maximal efforts during the match. Also, it would have facilitated determining the percentage of activities and the travels made according to the customized ranges for each player. It would even have been appropriate to relative the maximal speed of the players due not all players have the same peak speed.

Conclusion

There were statistical differences in some physical and physiological demands during competitive matches according to the match outcomes, playing positions, and gender. However, given the magnitudes of the differences were small, the influence of these contextual variables seems to be neither clear nor conclusive. These magnitudes do not show a relevant effect of match outcomes, playing positions, and gender, whereby, these results should be analyzed with caution, due they may lack practical significance. Therefore, more research is required to confirm or refute them.

Nevertheless, the data obtained showed the physical and physiological demands experienced by youth players during the games, which can be useful for coaches and physical trainers to consider when designing trainer sessions. For example, propose training exercises in which players perform travels between 1 to 3 meters at intensity 18-21 km/h, including acceleration and deceleration exercises. Besides, knowing the demands of the players can help in the search for strategies that enhance cardiovascular and physical performance. Likewise, understanding the physical requirements of the players can guide the different post-match recovery strategies that can be implemented.

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