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ORIGINAL RESEARCH

Transition from U18 to senior basketball in males: A comparison of external and internal game demands

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Abstract

Background: Understanding differences in game demands between senior and U18 basketball players is essential for optimizing training and facilitating the transition to professional basketball. **Objective:** This study aimed to compare physical and physiological game demands between senior and U18 male basketball players from the same club, with an emphasis on positional differences. **Methods:** Twenty-four male players (senior team $n = 12$; U18 $n = 12$) were monitored during home matches across one competitive season. Game demands were assessed using performance metrics such as distance covered, sprints, accelerations, and heart rate responses. Normality of distribution was tested, and independent t-tests or Mann-Whitney tests were applied to identify significant differences between groups. **Results:** Senior players exhibited higher values in training impulse (mean difference 38.98, $p < .001$, moderate effect size) and heart rate (% of maximum; mean difference 3%, $p < .05$), while U18 players performed more sprints per minute (mean difference –0.11 n/min, $p < .05$, small effect size). Positional analysis revealed that U18 backcourt players achieved higher jump loads per mass (mean difference –0.37, $p < .05$), whereas senior frontcourt players covered significantly greater total distances (mean difference 1304.65 m, $p < .001$, large effect size). **Conclusions:** Understanding differences in game demands between senior and U18 basketball players is essential for optimizing training and facilitating the transition to professional basketball, as these differences highlight the specific areas where U18 players need development. These findings provide actionable insights for coaches to optimize training and facilitate the progression of youth players to professional competition.

Keywords: game load, KINEXON, basketball performance, athlete monitoring, talent development

Introduction

Basketball is a dynamic and physically very demanding high-intensity intermittent team sport, characterized by frequent changes of direction, jumps, and body contact (Cui et al., 2019; Zarić et al., 2018), thereby requiring a high level of physical fitness in basketball players (Cabarkapa et al., 2023; Gottlieb et al., 2021). According to Stojanović et al. (2018), basketball players repeatedly perform short high-intensity actions such as sprints, accelerations, decelerations, turns, changes of direction, and jumps. A short sprint occurs every 21 to 39 seconds, and high-intensity actions are repeated every 10 to 20 seconds during the game. These demands may vary between age categories (Sosa et al., 2021), competition level, and sex (Mancha-Triguero et al., 2021). Therefore, coaches of younger selections, typically, along with basketball skill and tactical knowledge (Castillo et al., 2021), tend to level up physical fitness (Coppalle et al., 2021). Understanding the differences between the game loads (i.e., internal and external load) of senior and sub-senior teams is of strategic and individual importance as it provides the information to both team managers and players on what a player should achieve to be able to play competitively at the senior level.

External load is the mechanical stress of an activity, analyzed as kinematic (e.g., distance, speed) or neuromuscular (e.g., impacts, jumps), see Reina et al. (2020). External load measures the physical work performed by a player during training or competition (Vázquez-Guerrero et al., 2020), often assessed in basketball using noninvasive and efficient local positioning systems (LPS; Berkelmans et al., 2018). In contrast, internal load reflects the athlete's psychophysiological response to activity, influenced by factors like motivation, fatigue, and physical condition (Helwig et al., 2023). Internal load is commonly measured with heart rate monitors synchronized with the LPS and other measures like oxygen uptake, blood lactate, and rated perceived exertion (Inoue et al., 2022). Understanding the balance between external and internal load is crucial in managing the transition from junior to senior-level competition. This progression is accompanied by greater physical, technical, and tactical demands, as well as the need for higher effectiveness, which junior players must adapt to in professional competition (Conte et al., 2017).

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Data on elite junior basketball players are essential, given the high participation rates of youth in basketball worldwide and the growing need to provide age-specific data for developing training and player management strategies (Hulteen et al., 2017). Evaluating adolescent players, particularly those in the U18 category, is crucial as it supports a smoother and more structured transition to senior-level competition (Antoranz et al., 2024; Pérez-Chao et al., 2023; Sosa et al., 2021). For instance, a study on external match demands of U18 junior players showed a decline in external physical demands as the match progressed (Sosa-Marin et al., 2024). Furthermore, Pérez-Chao et al. (2023) compared U18 player loads in quarters won and quarters lost. The authors reported that external load remained consistent regardless of game result, quarter result, and quarter point difference. Sosa et al. (2021) analyzed velocity thresholds in basketball across different age groups and found that the proportion of time spent at elevated intensities is higher during junior than in senior competition. These studies underscore the importance of tailored training approaches to optimize player development, selection to senior teams, and ensure long-term success. However, while some research exists, there is a noticeable lack of research comparing the external and internal game load of U18 players and senior players. Such studies would assist senior team coaches in evaluating the readiness of U18 players to compete at the professional level.

Considering this, the first aim of this study was to determine whether there are differences in the external and internal game load of professional male basketball players (seniors) and U18 players from the same club. The second aim was to identify differences between backcourt (seniors vs. U18) and frontcourt players (seniors vs. U18) in external and internal game load. We hypothesized that there would be no significant difference in most of the selected variables of external and internal game load between senior and U18 teams from the same club. Additionally, we hypothesized that backcourt and frontcourt players of senior and U18 teams would not differ in their external and internal game load.

Methods

Participants

Twelve professional male basketball players (age 24.5 ± 4.8 years, body height 199.2 ± 7.6 cm, body mass 95.4 ± 10.8 kg) and twelve U18 male basketball players (8.2 ± 0.7 years, body height 196.1 ± 8.1 cm, body mass 88.7 ± 8.6 kg) volunteered to participate in the study. The senior players played for the team in the Hungarian Basketball League in the 2023/2024 Championship. The U18 team was competing in the highest U18 Hungarian Basketball League. No player participated in the observed matches while sick or injured. Players who played less than 8 min/match were excluded from the analysis. This was recommended by the head coach as players who played less than 8 min/match typically involved young players with specific roles or those in recovery, neither of whom significantly contributed to the team (2.44% of total playing time). Both categories of players contributed minimally to the team's performance (3.16% of the total game time of all players). Players were categorized by position as frontcourt players (senior team n = 4, U18 team n = 4) and backcourt players (senior team n = 8, U18 team n = 8). This categorization is in line with the trend in modern basketball where players, while being specialized for certain positions, often rotate and execute tasks specific to different playing positions (Scanlan et al., 2014). Typically, positions 1 and 2 are backcourt players, while positions 3, 4, and 5 are frontcourt players (Russell et al., 2021). Both groups trained 10.5 hours/week and played one match weekly, following a very similar training plan and program.

Procedures

A cross-sectional research design was used to examine the performance of male basketball players during eight senior and seven U18 matches. Data were collected using the KINEXON PERFORM LPS (KINEXON Sports, Munich, Germany) during home games in the first half of the 2023/2024 basketball season, from October to January. The KINEXON system is an advanced local positioning technology with ultra-wideband capability, providing sub-10 cm accuracy and 20 ms latency. It utilizes ultra-wideband signals to track player movements at a 20 Hz frequency, capturing 2D and 3D motion, directional changes, and performance metrics. Validity (standardized typical error of the estimate 0.06–0.48, standardized bias ranged between 0.01 and 2.85, and Pearson correlation coefficient values all > .90) and reliability (coefficient of variation < 10% and intra-class correlation coefficient > .90) were shown elsewhere (Fleureau et al., 2020; Gamble et al., 2023; Gottlieb et al., 2021).

Players were equipped with inertial sensors integrated into specially designed vests and a smart heart rate belt (Suunto, Vantaa, Finland) for heart rate monitoring. While the system tracked movements exclusively on the court, heart rate data were continuously collected both during play and while players were on the bench.

Ethical approval for the study was granted by the Human Research Ethics Committee of the Faculty of Physical Education and Sports, University of Banja Luka (No. 11/505-143 2/23), and all procedures adhered to the Helsinki Declaration (Williams, 2008).

Variables

Distance covered

The total distance covered by each player during the game (Distance, m) was calculated by summing up the smallest positional changes recorded within a minimum interval of 0.5 m and 1 s. To gauge the intensity of locomotion, the total distance covered was expressed relative to time (DistanceRel, m/min).

On-Court speed

Player speed was tracked in real-time using the differentiation of filtered positional data. The analysis included both average running speed (SpeedAvg, km/h) and maximum running speed (SpeedMax, km/h) achieved during the game.

Number of sprints

A sprint was identified when a player maintained a speed above 15.12 km/h for at least 0.5 s. Only the relative frequency of sprints per minute (SprintsRel, *n*/min) was considered for analysis.

Acceleration and deceleration events

Accelerations and decelerations were recorded when a player's acceleration exceeded 1.5 m/s² for a minimum of 0.5 s. For this study, only the rate of accelerations and decelerations per minute (AccelerationsRel, *n*/min; DecelerationsRel, *n*/min) was analyzed.

Accumulated acceleration load

This metric represents the cumulative physical load experienced by a player during gameplay. It combines various movement data (e.g., 2D motion, jumps, and impacts) into a single value. For this study, the accumulated load per minute was evaluated.

Number of jumps

The total jumps during play were identified using accelerometer data, focusing on jumps with a minimum flight time of 0.3 s. Only the jump frequency per minute (JumpsRel, *n*/min) was analyzed. Jump height was calculated based on airtime using the formula:

$$\text{jump height} = (0.5g{*}\text{flight time})^2/2g,$$

where g is the gravitational acceleration.

Jump load per player's body mass

The energy expenditure from jumping was estimated using each jump's height and the player's body mass. The total jump load for each player was calculated as the sum of all individual jump loads, using the formula:

$$\text{jump load} = \text{body mass}{*}\text{gravitational acceleration}{*}\text{jump height}.$$

Heart rate

Heart rate data were captured using Suunto Smart Heart Rate belt (Suunto, Helsinki, Finland) integrated into the KINEXON Sport Vest (KINEXON Sports, Munich, Germany). Only the maximum heart rate relative to the player's personal maximum (HR % of max) was analyzed. Personal maximum was determined through treadmill testing at the start of the season and updated if higher values were recorded more than three times during gameplay.

Training impulse

Training impulse (TRIMP) was used to quantify the overall game load and assess metabolic demand. It was calculated using the following formula:

$$\text{TRIMP} = \text{SUM}(0.1225{*}e^{3.9434{*}\text{fractionalElevation}}){*}\text{sessionTime},$$

where fractionalElevation = (HRi – HRmin)/(HRmax – HRmin), and HRi, HRmin, and HRmax represent the instantaneous, minimum, and maximum heart rates, respectively (Stagno et al., 2007).

Statistics

The data were analyzed using JASP (Version 0.19.1; University of Amsterdam, Amsterdam, The Netherlands). Descriptive statistics (mean and *SD*) are shown for backcourt and frontcourt seniors and U18 players. Normality of distribution was tested using the Shapiro-Wilk test. Between-competition level differences were investigated using an independent sample *t*-test for data with normal distribution and a Mann-Whitney test for data with a violated normality of data distribution. Significance was set at $p < .05$. The effect sizes for parametric tests were calculated using Cohen's *d* (Sullivan & Feinn, 2012) and interpreted as follows: ≥ 0.2 (small), > 0.5 (moderate), > 0.8 (large), and > 1.2 (very large). The non-parametric effect sizes were calculated using rank-biserial correlation and interpreted as follows: .10–.29 (small), .30–.49 (medium), and ≥ .50 (large).

Results

The descriptive statistics are shown in Table 1. Considering the whole sample, normality of distribution was violated in AccumAccelLoad, HR (% of max), and TRIMP. Considering the backcourt players, normality of distribution was violated in DistanceRel, AccumAccelLoad, and TRIMP. Considering frontcourt players, the normality of distribution was violated in AccumAccelLoad and HR (% of max). For these variables, a non-parametric Mann-Whitney test was conducted.

Table 2 shows the analysis of differences in general and according to a playing position. On a general level, significant difference occurred between senior and U18 players in SprintsRel, HR (% of max), and TRIMP. Significant differences between senior and U18 backcourt players occurred in SprintsRel, JumpLoadPerMass, and TRIMP. In frontcourt players, a significant difference between senior and U18 players occurred in DistanceRel, SprintsRel, HR (% of max), and TRIMP.

A large difference in the distribution of senior and U18 frontcourt players in Distance covered is shown in Figure 1. Moderate difference in SprintsRel occurred between senior and U18 backcourt players, while the difference was in frontcourt players (Figure 2). Difference of occurred in JumpLoadPerMass in backcourt players (Figure 3). The difference in HR (% of max) was moderate on a general level and very large between frontcourt players (Figure 4). The differences in TRIMP were moderate on a general level, small between backcourt players, and very large between frontcourt players (Figure 5).

Discussion

This study examined variations in external and internal loads between professional male basketball players (senior players) and U18 players from the same club during basketball games. It also explored differences in these loads between backcourt players (senior players vs. U18) and frontcourt players (senior players vs. U18). The main findings were as follows: 1) Among the 10 external load variables analyzed, significant differences were observed in

Table 1 Descriptive statistics for senior and U18 players according to playing position

Variable / Competition level	Backcourt players		Frontcourt players	
	Mean	*SD*	Mean	*SD*
Distance (m)				
Senior players	3636.15	1264.23	4877.65	1134.33
U18 players	3937.11	1060.70	3573.00	1088.27
DistanceRel (m/min)				
Senior players	71.43	7.34	67.95	3.69
U18 players	72.26	6.81	66.61	7.79
SpeedAverage (m/s)				
Senior players	4.29	0.44	4.07	0.22
U18 players	4.33	0.42	4.00	0.48
SpeedMax (m/s)				
Senior players	24.07	1.92	23.94	0.99
U18 players	23.61	1.49	24.08	0.88
SprintsRel (*n*/min)				
Senior players	0.76	0.25	0.53	0.12
U18 players	0.88	0.21	0.66	0.14
AccelerationsRel (*n*/min)				
Senior players	6.38	0.62	6.17	0.37
U18 players	6.35	0.63	6.07	0.86
DecelerationsRel (*n*/min)				
Senior players	6.09	0.67	5.80	0.39
U18 players	6.14	0.60	5.90	0.86
AccumAccelLoad (AU/min)				
Senior players	7.14	0.68	6.68	0.32
U18 players	7.33	0.94	6.44	0.91
JumpsRel (*n*/min)				
Senior players	0.71	0.21	1.01	0.16
U18 players	0.81	0.23	0.92	0.30
JumpLoadPerMass (AU/kg)				
Senior players	2.36	0.73	3.24	0.47
U18 players	2.73	0.86	3.10	0.99
HR (% of max)				
Senior players	68.24	7.34	72.60	8.23
U18 players	68.46	5.95	59.83	12.43
TRIMP (AU)				
Senior players	111.94	55.50	172.65	54.44
U18 players	86.75	46.07	86.89	57.72

Note. AU = arbitrary unit.

Table 2 Differences between seniors and U18 players in general and according to playing position

Variable	All players		Backcourt players		Frontcourt players	
	Mean difference	Effect size	Mean difference	Effect size	Mean difference	Effect size
Distance (m)	158.24	Trivial	−358.00*	Small	1304.65***	Large
DistanceRel (m/min)	0.15	Trivial	−0.83	Trivial	1.34	Small
SpeedAv (m/s)	0.01	Trivial	−0.04	Trivial	0.08	Small
SpeedMax (m/s)	0.27	Trivial	0.46	Small	−0.14	Trivial
SprintsRel (*n*/min)	−0.11*	Moderate	−0.12*	Moderate	−0.13**	Large
AccelerationsRel (*n*/min)	0.07	Trivial	0.03	Trivial	0.10	Trivial
DecelerationsRel (*n*/min)	−0.05	Trivial	−0.05	Trivial	−0.10	Trivial
AccumAccelLoad (AU/min)	−0.06[a]	Trivial	−0.15[a]	Small	0.03[a]	Small
JumpsRel (*n*/min)	−0.05	Trivial	−0.09	Small	0.09	Small
JumpLoadPerMass (AU/kg)	−0.26	Trivial	−0.37*	Small	0.14	Trivial
HR (% of max)	3.00[a]*	Moderate	−0.22	Trivial	10.00[a]***	Very large
TRIMP (AU)	38.98[a]***	Moderate	21.89[a]*	Moderate	85.76***	Very large

Note. AU = arbitrary unit. [a]Mann-Whitney test was used. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 1 Distribution of differences between Senior and U18 frontcourt players in distance covered

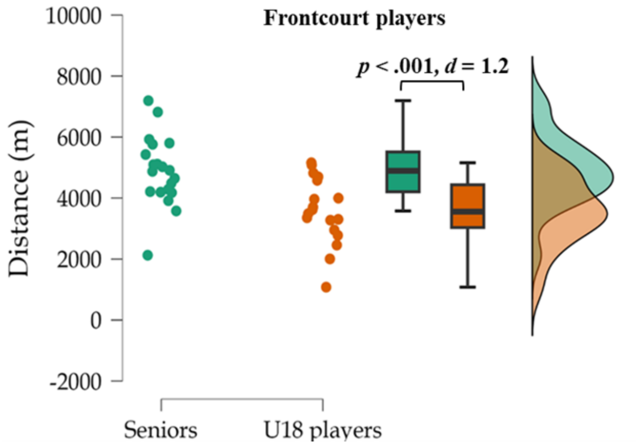
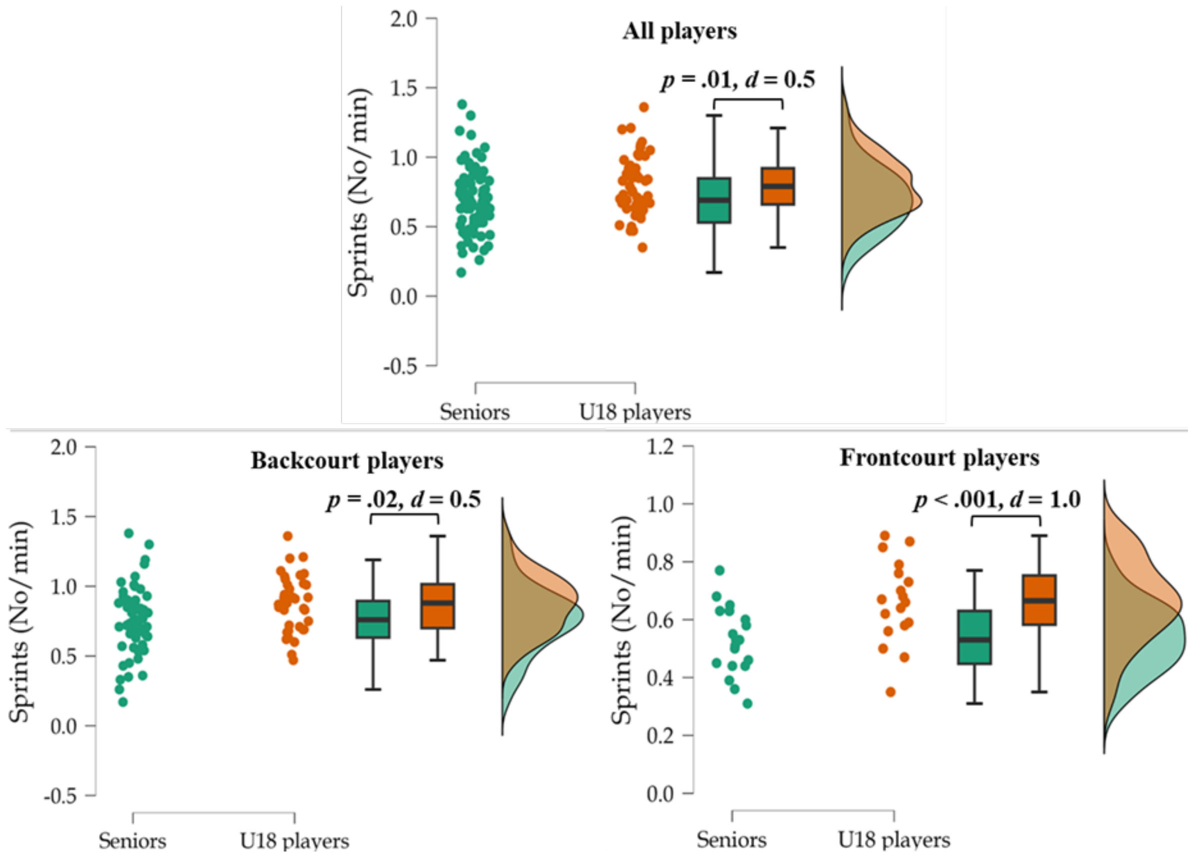


Figure 2 Distribution differences between Senior and U18 players in number of SprintsRel in general and per position



only one – U18 players performed more sprints per minute than senior players. For the two internal load variables (HR % of max and TRIMP), seniors recorded higher values; 2) Backcourt U18 players performed more sprints per minute and experienced greater jump loads relative to body mass compared to senior players, while seniors had higher TRIMP values; 3) Frontcourt senior players covered greater distances and recorded higher HR (% of max) and TRIMP values than U18 players. However, frontcourt U18 players performed more sprints per minute.

In most external load variables, no significant differences were observed between backcourt senior players and U18 players. Thus, the basketball-specific movement volume and intensity of backcourt senior players are similar to those of backcourt U18 players. This suggests that backcourt U18 players have developed desirable (mature, senior-level) movement patterns. Although the senior players and U18 teams did not play against each other, but competed in their respective leagues (Hungarian National Basketball League 1 for seniors and Hungarian National U18 League), it is evident that the seniors represent a higher-quality team compared to the U18 players.

While some research confirmed the notion that lower-quality teams exert more physical effort to compensate

Figure 3 Difference in JumpLoadPer mass between Senior and U18 backcourt players

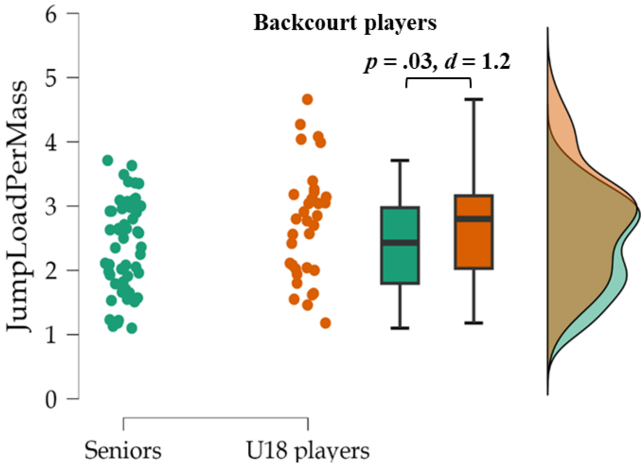
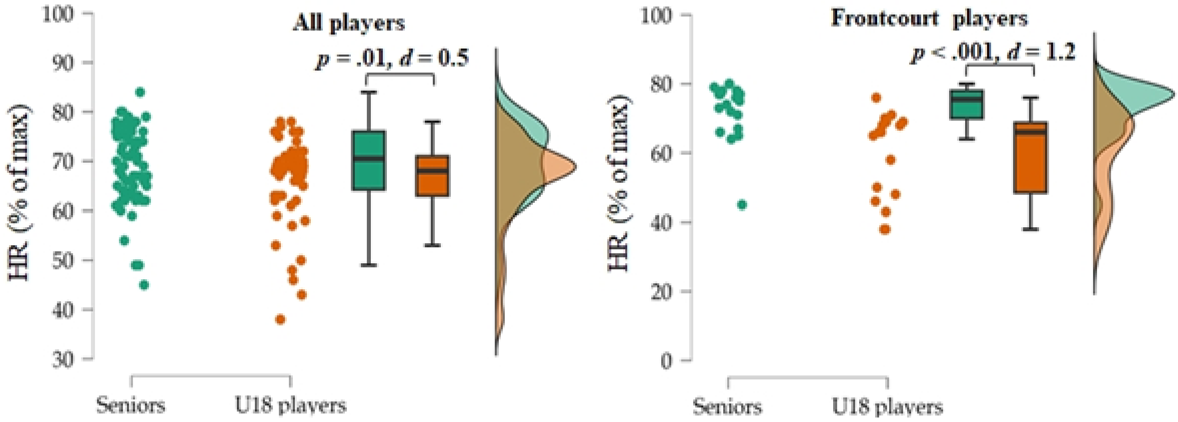


Figure 4 Difference in HR (% of max) between Senior and U18 players in general and between frontcourt players

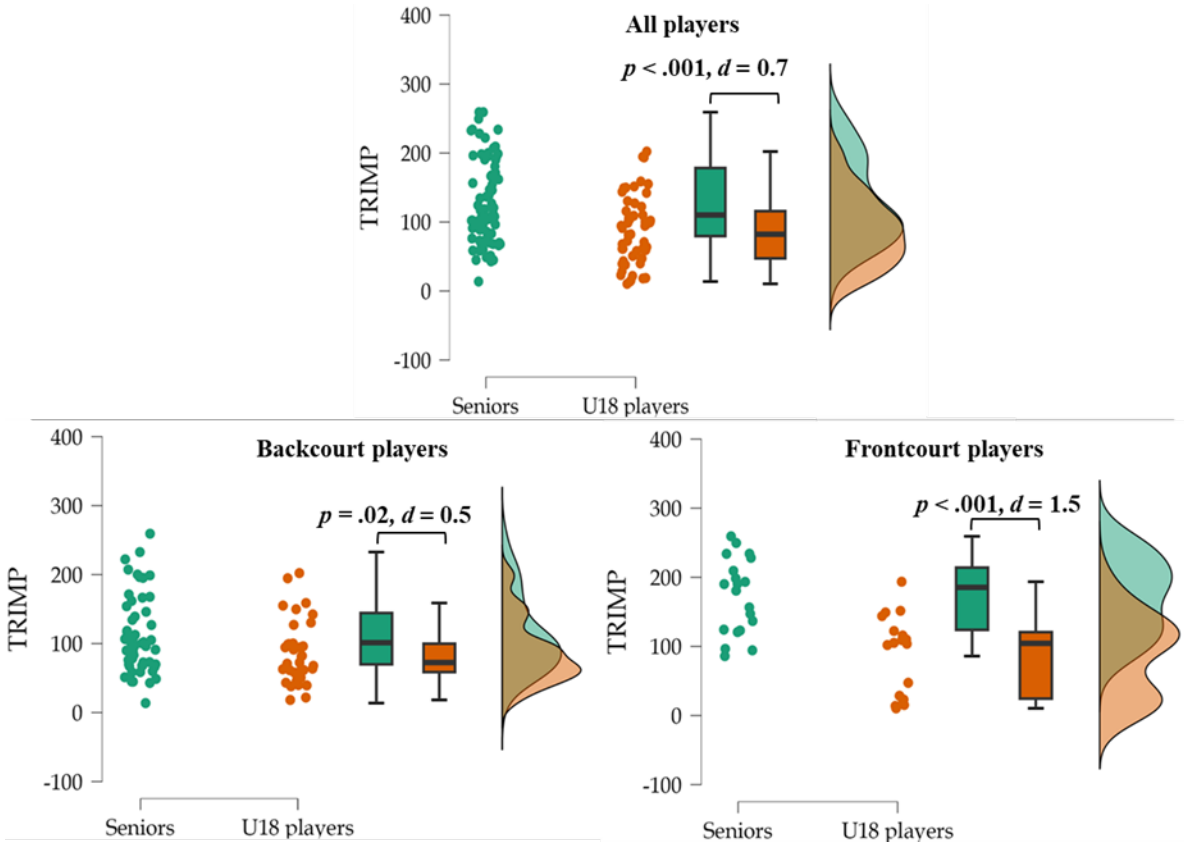


for their technical and tactical deficits (Pino-Ortega et al., 2019) as well as for worse decision-making and game interpretation (Petway et al., 2020), our findings differ. It is evident that frontcourt senior players from this study covered a greater total distance in games and had higher values of HR (% of max) and TRIMP compared to U18 players. This suggests that senior frontcourt players exert themselves more during games than U18 frontcourt players. The cumulative effect of fatigue among key players on the senior team (frontcourt players) may also contribute to this finding, as they perform a higher number of intense actions, reflected in greater internal load (Iturricastillo et al., 2018). According to Ferioli et al. (2020), activity demands during playing time (regardless of ball possession) are similar across positions, except for frontcourt players, who spend more time performing high-intensity actions than backcourt players.

In contrast, the U18 team performed more sprints per minute than the senior team, while no significant differences were found in the remaining nine external load variables. This is not unexpected given the results from the study by Sosa et al. (2021), who showed that junior players spent higher percentages of game time in the fastest speed zone (i.e., running speed > 18.0 km/h). This could be in part due to their smaller height and weight compared to senior frontcourt players (Ibáñez et al., 2024). This finding may serve as evidence for U18 team coaches that their training in previous years was effective, as the movement volumes and intensities of the U18 players have reached senior team levels.

Higher values for senior players could be further explained by the specific nature of the sample. Specifically, the frontcourt players of the senior team showed higher internal load values than the backcourt players of the same team. These frontcourt players are considered the most skilled (i.e., foreign players with the highest earnings with the highest seasonal Performance Index Rating; Vuckovic et al., 2025). Similarly, Ferioli et al. (2020) found differences between Italian Division I, II, III, and IV teams, showing that elite professional players (Division I) spent more time at high and moderate intensities than lower-division players during competition. Likewise, Australian elite players and international-level junior Tunisian players performed more total match movements than their sub-elite and national-level counterparts, respectively (Ben Abdelkrim et al., 2010; Scanlan et al., 2011).

Figure 5 Difference in TRIMP between Seniors and U18 players in general and relative to playing position



Limitations

The sample size could have been larger and could have included other teams to provide conditioning strategies, load management, and player transition protocols. Tracking game load during away matches would certainly provide a more comprehensive understanding of the research problem. Tracking home only home games may introduce a bias due to home advantage effects. However, the inability to secure permission from opposing teams to set up tracking equipment proved to be an insurmountable obstacle. An additional limitation of this study lies in the lack of global scientific consensus regarding player position categorization. Some authors divide players into two positions, others into three, and some into five. This discrepancy creates challenges in comparing studies.

Conclusions

This study on professional (senior) and U18 male basketball players revealed nuanced differences in external and internal game loads, primarily driven by player position and maturity level. Overall, U18 players demonstrated similar external load profiles to seniors, highlighted by a higher frequency of sprints per minute across the junior group, suggesting the development of mature, senior-level movement patterns in the U18 cohort. However, internal load (HR % of max and TRIMP) was generally higher for senior players, particularly among frontcourt senior players, who also covered greater distances. This suggests that the highest-quality professional players exert themselves more intensely during games, possibly reflecting the demands on key players. Conversely, backcourt U18 players' external loads closely mirrored their senior counterparts, further supporting the effectiveness of their previous training and their readiness for the senior level. Future research should expand the sample to validate these position-specific load variations and inform more precise conditioning and transition strategies.

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Conflict of interest

The authors report no conflict of interest.

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