Setting Kinematic Parameters That Explain Youth Basketball Behavior: Influence of Relative Age Effect According to Playing Position

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Abstract

Pino-Ortega, J, Gómez-Carmona, CD, Nakamura, FY, Rojas-Valverde, D, and Effect, RA. Setting kinematic parameters that explain youth basketball behavior: Influence of relative age effect according to playing position. *J Strength Cond Res* 36(3): 820–826, 2022—The aims of the present study were to (a) set kinematic behavior parameters during official matches by principal component analysis (PCA), (b) examine the distribution of birth dates in competitive basketball, differentiating by playing position, and (c) analyze the relative age effect (RAE) on kinematic performance according to playing position. A total of 94 young elite athletes participated in an official U18 Euroleague tournament (8 clubs, 4 days, 3 games). Kinematic motion variables were measured using an inertial device worn by all players during matches. A total of 252 variables were measured, a PCA was performed to select them for final analysis and 3 principal components and 6 variables were extracted (maximum acceleration [MAcc], average acceleration [PAcc], landing 8–100 G [Ldg 8–100 g·min^{-1}], relative distance [RD], jump average take off [MJumpsTO], and jump average landing [MJumpsLdg]). These variables explained 66.3% of total variance. Differences were found in RD ($p = 0.04$; $\omega_p^2 = 0.02$), PAcc ($p = 0.04$; $\omega_p^2 = 0.02$), MAcc ($p < 0.01$; $\omega_p^2 = 0.03$), and Ldg 8–100 g·min^{-1} ($p = 0.02$; $\omega_p^2 = 0.02$) because of RAE. There were differences by playing position in Ldg 8–100 g·min^{-1} (guards, $p = 0.04$; $\omega_p^2 = 0.03$), MAcc (forwards, $p < 0.01$; $\omega_p^2 = 0.07$; centers, $p < 0.01$; $\omega_p^2 = 0.44$), PAcc (centers, $p < 0.01$; $\omega_p^2 = 0.34$) and in MJumpsLdg (centers, $p = 0.03$; $\omega_p^2 = 0.13$). Results suggested that RAE does have an impact on kinematic variables, and is affected by playing position in variables such as MAcc, PAcc, MJumpsLdg, and Ldg 8–100 g·min^{-1}. The extracted variables are well-known intensity indicators and fundamental performance variables. This evidence should be taken into account by sport scientists and coaches to develop individualized training programs and match tactics.

Key Words: team sports, indoor tracking systems, inertial devices, principal component analysis

Introduction

Currently, sport science professionals have access to a series of technological tools for the quantification and monitoring of external and internal loads during training and competition (25,35). The use of these technologies has spread to individual and team sports around the world and they are becoming more accessible and cost-effective (12,19).

These technological tools allow daily load monitoring in a noninvasive and accurate manner (22). An example of this type of technology that has been used with great success is the real time location systems, both in outdoor (Global Positioning Systems, GPS) (4,18) and indoor conditions (Ultra-Wide Band, UWB; Local Position Measurements) (10,24,34,52). Outstanding among them, inertial measurement units (IMUs) can be highlighted, because they incorporate and link multiple sensors (accelerometers, gyroscopes, magnetometers, etc.) that allow thorough tracking of the athletes' external loads (6,7,15).

Specifically, in basketball, this technology has been used to analyze the differences between type of session (training vs. competition) (26,43), the specific demands among playing positions (1,40,41,59), the effect of fatigue throughout the match periods (40,49,51), the impact of the players' and team's level (40,47,48,59), and the load demands during a congested-fixture tournament (16,40).

The relative age effect (RAE) is another contextual variable extensively analyzed in basketball (3,30,45). The RAE is the term that explains the existence of age differences among individuals in the same competitive age category. This aspect implies advantages for some players who were born earlier in the competitive year over others at the physical, cognitive, and emotional levels (27,36,50,62). To the best of our knowledge, only 2 studies have investigated the interactive effects of RAE and performance in basketball. Older players scored more points per playing time and obtained a better performance index, effects that gradually decreased as the players' ages increased (30).

To objectively analyze the effect of RAE in basketball workload performance, it is necessary to assess kinematic variables

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with a valid instrument (12). These kind of instruments as inertial measurement devices have been used widely in sports during training and competition (25). To manage the vast amount of data that these portable instruments record (around 250 variables derived from position-tracking and mechanical systems) and their interaction with contextual variables, it is necessary to implement a series of data reduction techniques to allow adequate data mining (38). Among the techniques used to reduce the amount of data, it is possible to highlight correlation clustering, *k*-means clustering, and canonical correlation analysis. More recently, principal component analysis (PCA) has been proposed as a way of synthesizing the variables into a smaller series that explains a large proportion (+70%) of the total series (29,61). In other words, a small series of variables (5–15 variables) that are not correlated to each other can explain a high percentage of the variance of the complete data. This procedure has been used in only one previous research in basketball that analyzed locomotion performance (55).

Because of the aforementioned reasons, it is important to analyze the effects of contextual variables (such as the RAE in youth basketball players) on performance, through the use of objective and portable technology. In addition, it is necessary to apply statistical techniques that allow sports scientists and practitioners to analyze the general behavior of the players and understand what variables of training or competition are the most significant for their final performance. Therefore, the aims of the present study were to: (a) set kinematic behavior parameters during official matches by PCA, (b) examine the distribution of birth dates in competitive basketball, differentiating by playing position, and (c) analyze the effect of the RAE on kinematic performance according to playing position in youth elite-level male basketball players during the Euroleague tournament.

Methods

Experimental Approach to the Problem

Locomotion variables of 8 teams were assessed using inertial measurement devices during 13 matches of a congested fixture tournament corresponding to U18 Euroleague finals. A PCA was performed to extract most significative variables of the match and then look after the effect of RAE and player position in the kinematic performance.

Subjects

A total of 94 young (U18) elite basketball players (mean ± *SD*: age: 17.6 ± 0.8 years; height: 1.91 ± 0.08 m; body mass: 82.5 ± 8.8 kg; body mass index: 22.7 ± 1.8 $kg \cdot m^{-2}$) participated voluntarily in the present research. Subjects were recruited and from 8 clubs classified to the final round of the Euroleague tournament (U18 Adidas New Generation 16–17 final round, Istanbul, Turkey). These subjects performed a total of 13 official matches during a 4-day tournament. All players met the following inclusion criteria that consisted of playing >60% of total playing time per quarter.

As all players were over 16 years old, they signed a written assent before the tournament started. The protocol follows the Helsinki Declaration and it was approved by the Institutional Review Board (University of Murcia, Reg. Code 2061/2018). In addition, the teams' staffs and tournament managers gave their written consent for participation in this research.

Instruments. Inertial measurement units (WIMU PRO; RealTrack Systems, Almeria, Spain) were used to track time-motion variables. These IMUs assessed all players' kinematics throughout the tournament games using 3D accelerometers, 3D gyroscopes, a 3D magnetometer, a 10 Hz GPS, and 20 Hz UWB indoor tracking technology. The IMU measures movement using a micro-electromechanical system with a sampling frequency of 100 Hz. The devices measure 81 × 45 × 16 mm and weigh 70 g. During the games, an IMU was worn by each player and was attached using a neoprene vest at T2-T4 height and in the middle of the scapulae. The accuracy and between-unit reliability of UWB and accelerometers for time-motion analysis have been previously analyzed (9,10).

Variables: Time-Motion Analysis. To compare results among playing positions according to the RAE, variables were selected using PCA and the following match performance variables: (a) relative distance (RD, $m \cdot min^{-1}$); mean acceleration (MAcc, $m \cdot s^{-2}$), peak acceleration (PAcc, $m \cdot s^{-2}$), total landings 8–100 G (Ldg 8–100/min, $count \cdot min^{-1}$), mean duration jumps take off (MJumpsTO, seconds), and mean duration jumps landing (MJumpsLdg, seconds).

Playing Position. To identify differences by playing positions, the total sample was grouped into the 3 regular basketball roles: 13 centers (n = 154), 47 forwards (n = 466), and 34 guards (n = 374). The players' roster was obtained from the official championship webpage and cross checked with the team staff before the start of each match.

Relative Age Effect. The cut-off date for youth categories of clubs participating in the Adidas Next Generation 16–17 basketball finals tournament is January 1st (quarters are composed as a function of this cut-off). The variables analyzed include the birth quarter of the players (quarter of the year that the players were born): Q1 (January, February, March) (34 players; n = 320), Q2 (April, May, June) (30 players; n = 300), Q3 (July, August, September) (21 players; n = 196), and Q4 (October, November, December) (9 players; n = 99).

Procedures

The tournament lasted from May 18th to 21st, 2017 in Istanbul, Turkey. The 8 teams were randomly divided and competed in 2 groups. The winning team in each group qualified for the final. Thirteen matches were recorded (12 from the tournament round, 6 per group; and 1 from the final round). A total of 915 records were obtained from the players. All matches were played between 8:00 and 14:00 in the "Ahmet Comert Arena" (tournament round) and the "Sinan Erdem Dome" stadium (final round).

The IMU devices were calibrated and the UWB system was installed around the court following a previous study protocol (10). Before the match started, the IMUs were placed in a specific customized neoprene vest located on the middle line between the scapulae at the T2-T4 level, fitted tightly to the body as typically worn in games (54,60).

At the end of each match, raw time-motion data was downloaded and exported in excel format using a specialized manufacturer's software (S PRO, RealTrack Systems). Age double confirmation was obtained from the official competition webpage: http://www.adidasngt.com/u18/competition/players, and checked with the team staff. For the subsequent analysis, all within quarter breaks were considered as playing time (e.g., free-throws, fouls, ball out, changes and others) to analyze natural match behavior, but time-outs and interquarter breaks were excluded. This criterion was used to homogenize the sample considering the player's match participation, especially when the analyzed variables represented the intensity of playing actions (46).

Statistical Analyses

A total of 925 cases were analyzed to select variables. First, relative (per time unit) and maximum variables were selected from a total of 250 to compare action among players and groups. Principal component analysis procedure was performed following previous guidelines (21,44). An exploration of the correlation matrix between variables was made before running the PCA. A threshold of $r < 0.7$ correlation between variables was considered for extraction (56). Variables with *variance* = 0 were excluded from the analysis. Variables were scaled and centered (*Z-score*). Principal component analysis was suitable considering Kaiser-Meyer-Olkin values and Bartlett Sphericity test significance (8,31). Eigenvalues <1 were excluded from the extraction of principal components (31). An orthogonal rotation (VariMax method) was performed to identify high correlations of components and ensure that each principal component provided different information. Principal component loadings >0.6 were retained for interpretation and the highest factor loading was extracted when a cross loading was found between components (5,44).

The distribution of the data was then analyzed with the Kolmogorov-Smirnov test (23), leading to the selection of the subsequent statistical analyses. To identify whether there was an RAE, an analysis of the frequencies was performed to describe the RAE for the whole sample and as a function of the specific playing position and the overall players. The distribution of players' birth dates by quarter as a function of playing position was compared with the chi-square test. Finally, a one-way analysis of variance was performed to compare means of RD, PAcc, MAcc, Ldg 8–100 $g \cdot min^{-1}$; MJumpTO, and MJumpLdg by birth quarters, according to the playing positions. The magnitude of the differences was qualitatively interpreted using partial omega squared (ω_p^2) as follows: >0.01 small; >0.06 moderate and >0.14 large (14). Alpha was prior set at $p \le 0.05$. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS, IBM, SPSS Statistics, v.22.0 Chicago, IL) and graphs were prepared using Prism software (GraphPad Software, San Diego, CA).

Results

Principal Component Analysis

The PCA selected 6 variables: MAcc, PAcc, Ldg 8–100 $g \cdot min^{-1}$, RD, MJumpsTO, and MJumpsLdg. These variables explained 66.3% of total variance by 3 principal components. The PC1 (RD and Ldg 8–100 $g \cdot min^{-1}$) explained 29% of total variance (Table 1 and Figure 1).

Relative Age Effect

First, the results are shown regarding the analysis of the RAE using the frequencies and the distribution of the players' birth dates according to playing position throughout the tournament. Related to playing appearances, most of them were born between January and March (Q1, $n = 320$, 34.9%) and between April and June (Q2, $n = 300$, 32.8%) among guards (Q1, $n = 95$, 32.2%; Q2, $n = 83$, 28.1%), and forwards (Q1, $n = 205$, 44.1%; Q2, $n = 144$, 30.9%). In contrast, centers were mostly born in Q2 and between July and September (Q3, $n = 52$, 33.8%). A low percentage of players in all positions was found to be born between October and December (Q4, $n = 99$, 10.9%) (Table 2).

Relative Age Effect in Kinematical Parameters According to Playing Positions

Figure 2 shows the comparison of selected variables related to load demands in relation to RAE. When pooling all playing positions, there were differences in RD ($F = 2.52$; $p = 0.04$; $\omega_p^2 = 0.02$), PAcc ($F = 2.72$; $p = 0.04$; $\omega_p^2 = 0.02$), MAcc ($F = 4.84$; $p < 0.01$; $\omega_p^2 = 0.03$), and Ldg 8–1·00 $g \cdot min^{-1}$ ($F = 3.23$; $p = 0.02$; $\omega_p^2 = 0.02$). No differences were found in MJumpsTO ($F = 1.54$; $p = 0.21$; $\omega_p^2 = 0.00$) and MJumpsLdg ($F = 2.01$; $p = 0.11$; $\omega_p^2 = 0.00$). Within each playing position, differences across Q1-Q4 were found in guards (Ldg 8–100 $g \cdot min^{-1}$ ($F = 2.54$; $p = 0.04$; $\omega_p^2 = 0.03$), forwards (MAcc [$F = 7.06$; $p < 0.01$; $\omega_p^2 = 0.07$]), and centers (PAcc [$F = 11.31$; $p < 0.01$; $\omega_p^2 = 0.34$], MAcc [$F = 16.97$; $p < 0.01$; $\omega_p^2 = 0.44$], and MJumpsLdg [$F = 3.24$; $p = 0.03$; $\omega_p^2 = 0.13$]).

Discussion

The aim of present study was to: (a) set kinematic behavior parameters during official matches by PCA, (b) examine the distribution of birth dates in competitive basketball, differentiating by playing position, and (c) analyze the RAE on kinematic performance according to playing position. First, we extracted 6 variables from a total of 252 measured variables (MAcc, PAcc, RD, MJumpsTO, MJumpsLdg, Ldg 8–100 $g \cdot min^{-1}$), and these variables are similar to those extracted in previous studies (40,59). An impact of relative age of young players was found in external load during official matches in MAcc, PAcc, RD, and Ldg 8–100 $g \cdot min^{-1}$. There were some effects of relative age per playing position in Ldg 8–100 $g \cdot min^{-1}$ PAcc, MAcc, and MJumpsLdg.

Previous PCA have suggested that variables such as accelerations, decelerations, changes in direction and jumps, are essential performance indicators in basketball (53,55), and these results partly confirm our findings. Other variables such as

Table 1

Principal component analysis results with each loading.*†

	PC 1 Volume load	PC 2 Speed changes	PC 3 Jumping performance
Eigenvalue	2.323	1.784	1.197
% Variance	29	22.3	15
% Cumulative variance	29	51.3	66.3
Peak acceleration ($m \cdot s^{-2}$)		0.889	
Average acceleration ($m \cdot s^{-2}$)		0.787	
Landing 8–100 $g \cdot min^{-1}$ (count)	0.756		
Relative Distance (m)	0.884		
Jump average take off (s)			0.846
Jump average landing (s)			0.76

*PC = principal component.
†Eigenvalues and variance explained.

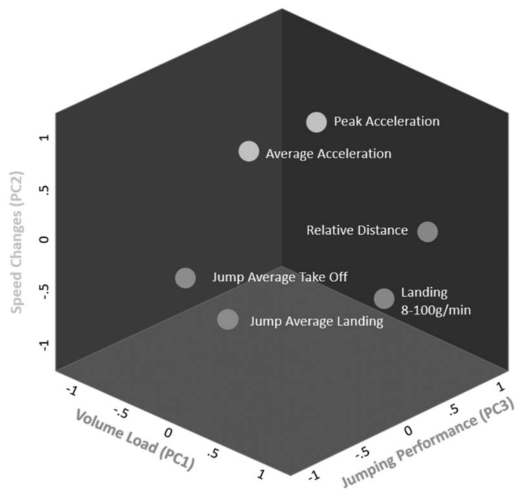

Figure 1. Rotated Principal component distribution in junior basketball play.

anaerobic power, speed dribble, high-intensity shuttle run, and dribble test, all of which involving consecutive acceleration, deceleration, and changes of direction during the game, are also fundamental for optimal performance in youth basketball (2). It is reported that these variables could differ by playing position.

Some elite basketball kinematical approaches suggest that there are differences not only between the physical demands, but also between those variables that explain behavior during the game across playing positions. Accelerations, decelerations, and changes in direction are common actions performed during the game by forwards, guards, and centers, but guards tend to perform greater jump actions (55). In youth basketball, variables such as RD (48,59) are not fundamental for the game, but high-intensity actions represent better performance (40). Consequently, guards seem to perform more actions with these characteristics such as accelerations >2 m·s^{-2}, decelerations <-2 m·s^{-2}, and peak acceleration than other basketball positions (forwards and centers) because of the tactical and positional factors of the game (1,48,60).

With respect to RAE, the present results show an overrepresentation of players who were born during the initial months (Q1 and Q2) in comparison to those born during the final months of the year (Q3 and Q4), with some differences in the proportions between playing positions. Our results are consistent with other studies involving male basketball players (3,30,45,58), which have detected the presence of RAE in young male teams, although its effect among female basketball players is not clear (3,20).

The evidence suggests that this effect tends to disappear when the playing level increases (3,20,42) and does not predict a high-performance career or selection for national teams (63). In this respect, a strong influence of relative age on sport performance was observed in U14, U16, and U17 basketball players, whereas a smaller influence was detected in U18 and U19 and no significant effect in U20 and U21 players (3,20,58).

The advantage of the RAE is evident in physical (20) and cognitive (11) development. With respect to physical characteristics, young players who were born in the first quarter of the year perform better according to anthropometric (height) and physiological characteristics (body mass and strength) with respect to players who were born in the last quarter of the year, so older players have a competitive advantage (28,32,37,58). Especially, male adolescents show improved speed, endurance, agility, strength (13), and jumping performance (57) with respect to RAE. However, regarding cognitive development, players born early in the year accumulate more motor experiences in the sport context, leading to a better sport performance than players born later in the year (39,62), making them able to better comprehend contextual information, because they have more developed prediction and selective attention processes (33). Also, older players may benefit from more experienced coaches, better facilities and sport programs, and higher competition levels (17).

Therefore, the RAE effect has been shown with reference to the kinematical demands in basketball competition. The present study suggested that a player's birth trimester had an effect on kinematic variables such as accelerations, jumps, distance, and landing according to playing position. No previous investigation has analyzed this fact, so these results show its effect also in the physical demands experienced by the players, which had previously been contrasted with respect to the technical-tactical performance in official games by playing positions. A relation between guards and points scored, successful 2-point field-goals and Performance Index Rating (PIR), forwards and blocks committed, and centers and points scored, successful and unsuccessful 2-point field goals, blocks received, fouls committed, and PIR (30). Older male players scored better in total points and in performance index rating when results were normalized to played time (3). However, this effect has not been found in female players.

Although the results of this study have provided valuable information about the influence of relative age on external load in young players during a congested-fixture tournament, some limitations must be acknowledged. Because of the nature of the tournament (3–4 matches in 4 days), results should be carefully analyzed, and must be applied with some caution to other scenarios (e.g., regular tournament). Because of the tournament conditions, some contextual factors such as fatigue, temperature, recovery protocols applied, and nutrition (e.g., food and water intake) were not controlled or assessed. Considering this study

Table 2
Descriptive statistics (frequencies and %) and distribution of the dates of birth according to the specific playing positions for playing appearances throughout the tournament.*

	Guards		Forwards		Centers		All positions	
Quarter	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
Q1	95 (32.2%)	73.8	205 (44.1%)	87.3	20 (12.9%)	21.8	320 (34.9%)	182.8
Q2	83 (28.1%)	73.8	144 (30.9%)	87.3	73 (47.4%)	21.8	300 (32.8%)	182.8
Q3	67 (22.7%)	73.8	77 (16.6%)	87.3	52 (33.8%)	21.8	196 (21.4%)	182.8
Q4	50 (16.9%)	73.8	40 (8.4%)	87.3	9 (5.9%)	21.8	99 (10.9%)	182.8
χ^2	15.55		104.70		37.46		53.29	
Sig.	<0.01		<0.01		<0.01		<0.01	

*Q1-Q4 = birth quarter; χ^2 = Chi-square value; Sig. = significance.

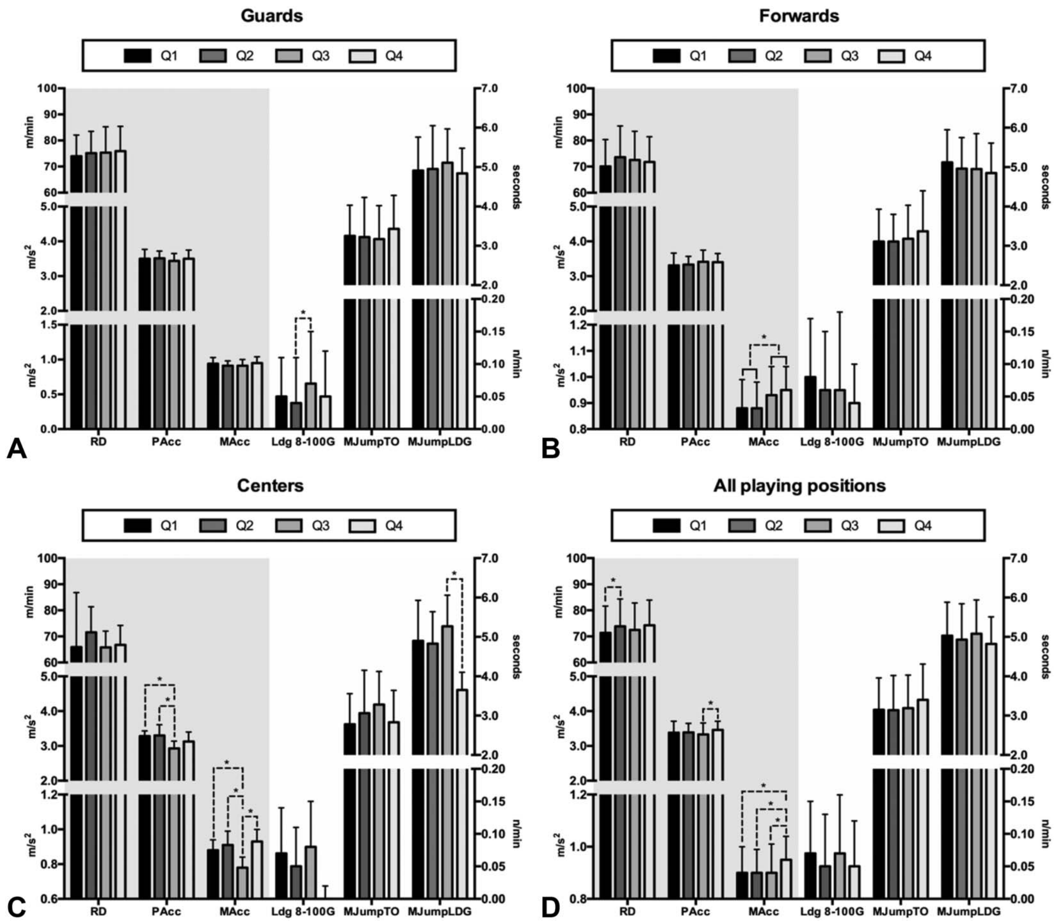

Figure 2. Playing positions (A: Guard; B: Forward; C: Centers) and (D) overall player demands variation according to relative age effect. *Statistical differences ($p < 0.05$).

was developed using nonprobabilistic accidental sample members of the 8 best clubs of youth European basketball, as expected, these results must be addressed considering the specific age range of the sample analyzed, and should not be extrapolated to other populations that show different kinematical behavior because of their age or professional status.

After PCA, 3 principal components and 6 variables were extracted (maximum acceleration [MAcc], average acceleration [PAcc], landing 8–100 G [Ldg 8–100 g·min^{-1}], RD, jump average take off [MJumpsTO], and jump average landing [MJumpsLdg]) from a total of 252 measured with IMU technology.

Results suggested that RAE does have an impact on kinematic variables in young players during a congested-fixture tournament and this external load is affected by playing position in variables such as MAcc, PAcc, MJumpsLdg, and Ldg 8–100 g·min^{-1}. Based on previous evidence, the variables extracted in this study are recognized intensity indicators and fundamental performance variables in basketball.

As one of the main findings of this study, it was found that the distribution of the dates of birth differed from specific playing positions. This may affect the kinematic demands of the games according to players positions. This evidence should be taken into account by sport scientists and coaches to develop individualized training programs and match tactics.

Future studies may analyze the effect of other contextual variables that could influence RAE and match kinematics as weight, height, fat percentage, strength, cognition, and player's sports history.

Practical Applications

The understanding of the influence of relative age of young players on external load should be taken into account by technical staff to design specific conditioning training programs, tactical scenarios, match strategies, and recovery protocols during this kind of congested-fixture tournament. Some practical applications of the results could be applied: (a) Because of the RAE on RD, PAcc, MAcc, and Ldg 8–100 gmin^{-1}, technical staff should design specific physical load demands in training sessions according to player's age. (b) Considering RAE, technical staff should design specific and individualized between-period recovery protocols and improve team rotation tactics (e.g., playing time distribution among players) to avoid fatigue.

Microsensor technology has shown its effectiveness to monitor physical external load. Technical staff should consider it as a reliable, accurate, and portable tool to manage and prescribe individualized training loads, considering the impact of some internal and external variables that could affect the player's performance during a match, tournament, and even throughout an entire season.

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