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Profile of Accelerations and Decelerations in Young Basketball Players

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Featured Application: This research deepens the knowledge about the load demands of kinematic variable accelerations and decelerations of young basketball players during competition. After a first description of these demands by periods of play and playing positions, three ranges of acceleration and deceleration are established. In addition, this study has identified the initial and final velocity of acceleration and deceleration for each range. This information will allow coaches to personalize training tasks, adapting them to the demands of the competition for each playing position.

Abstract: Accelerometry is a crucial tool in basketball for quantifying the external load borne by players in response to the demands of intermittent high-intensity sports. To advance scientific knowledge in this field, it is imperative to study accelerometry across various populations, sexes, and competitive levels. The primary objective of this research was to characterize the acceleration (ACC) and deceleration (DEC) profiles of male under-18 basketball players during official games, identifying differences in acceleration and deceleration thresholds during playing periods and specific positions. Additionally, the interaction between specific positions and playing periods in acceleration thresholds was examined. Acceleration and deceleration were characterized using four variables: maximum ACC and DEC, distance covered, initial velocity and final velocity. These parameters were analyzed to understand the response of players participating in the Euroleague Basketball based on playing position and game period. A one-way ANOVA, along with effect size, was employed for statistical analysis. Demands exceeding ACC and DEC > 4 $m{\cdot}s^{-2}$ were found to differentiate player interventions. High-intensity ACC was greater in the first period compared to the third and fourth periods. Distinctions were observed between Guards and Forwards concerning high-intensity ACC being superior to the Centers, and Guards differed from Centers in moderate DEC (2–4 $m{\cdot}s^{-2}$), presenting higher values. For all playing positions, high-intensity accelerations were greater during the first period compared to subsequent periods. The four variables used for characterizing ACC and DEC were found to be interrelated. Distance covered depended on maximum ACC and DEC, initial velocity on covered distance, and final velocity on maximum ACC and DEC, distance, and initial velocity.

Keywords: accelerometry; inertial devices; playing positions; game period; men

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1. Introduction

The Adidas Next Generation Tournament, ANGT, is a top European basketball competition in the under-18 category. This is considered the highest level of European club basketball competition. It is known as the Junior Euroleague. The final phase of this competition is played by eight teams, competing in two groups, and a final game between the two best teams. The high level of play developed in this tournament, serving as a breeding ground for future stars of world basketball, has led to a growing interest in studying player behaviors, both from a physical perspective [1–3], in terms of player talent development [4], and technical–tactical aspects [5]. Additionally, basketball is a sport that involves high-intensity movements, with explosive and powerful actions, such as jumping for rebounding, shooting, or blocking, or accelerations such as driving, lay-ups or fast-breaks [6,7]. Ibáñez et al. [8] have identified a high load in the variables related to accelerometry (Impacts and Player Load), stating that in view of these demands, basketball should be considered an eminently neuromuscular sport. During the course of the game, the players experience peaks of high intensity in these variables, which correspond to the explosive game actions that the players perform to overcome the opponents and achieve the objective of the game [9,10].

Nowadays, micro-technology allows teams and staff to monitor player and competition demands, fostering new frameworks to control training and competition load, increasing players' performance [2] and providing individualized recovery strategies [11]. This technology records information related to External Load (EL) variables, such as distance, speed, impacts, player load or acceleration (ACC) and deceleration (DEC). In fact, accelerations and decelerations have drawn attention in recent years in several studies [12,13], as microtechnology allows, through the change in the accumulated acceleration in three vectors (x, y and z), the monitoring of loads during training and competition [3]. More importantly, the ability to accelerate and decelerate is paramount for basketball success [14]. Due to the short duration of sprints (0.4 to 2.4 s), accelerations and decelerations play a meaningful role in locomotor demands and in basketball performance [12]. Accelerations and decelerations have been defined as the change in magnitude, both positive and negative, in speed, implying a movement of more than 2.5 $m \cdot s^{-2}$ [15]. Accelerometry has become an important focus in basketball as a means to quantify the external load placed on basketball players [16]. Research has demonstrated the usefulness of accelerometers in providing objective data on movements and physical demands during training and competition in basketball [17–19]. Accelerations and decelerations account for up to 12% of live playing time across all playing positions [18]. Analyzing accelerometer data allows coaches to determine the acceleration and deceleration demands for different playing positions during live play [20,21]. A systematic review on this topic organized acceleration and decelerations into total and high-intensity categories, stating that more investigations are necessary on this topic to obtain a clear picture [14].

The importance of individualization in training and match load has been widely stated [22,23]. In basketball, three playing positions have been identified: Guards, Forwards, and Centers [24,25]. Differences have been observed for anthropometric and physical characteristics, such as sprint and jumping ability. For example, among men players, Guards are the ones who, when in ball possession, performed more activities across all intensity ranges than Forwards and Centers, although the proportion of time dedicated to performing high-intensity activities (HIA) when in ball possession was greater for Forwards and Centers than for Guards [24]. Additionally, the importance of game quarter or playing time has been studied, concluding that different playing positions show different demands according to game quarter [23,26] or playing time [25]. The research results highlight the importance of training personalization, considering playing position and the time of the match in order to carry out training processes adapted to the specific demands of each player [20,27]. For this purpose, the use of data from inertial devices equipped with micro-sensors helps the coaches in their decision making for the design of tasks [28,29].

There is limited research that takes an individualized approach to work-intensity zones in basketball players. Accelerometry profiles are beginning to be studied in basketball, establishing different intensity ranges depending on the population under study. For instance, with semi-professional basketball players, Sánchez-Ballesta et al. [30] employed four levels (0.5–0.99 m·s^{-2}; 1–1.99 m·s^{-2}; 2–2.99 m·s^{-2}; >3 m·s^{-2}). On the other hand, Ibáñez et al. [13] identified five levels of intensity in professional basketball players (<0.95 m·s^{-2}; 0.96–2.53 m·s^{-2}; 2.54–5.31 m·s^{-2}; 5.32–12.25 m·s^{-2}, >12.26 m·s^{-2}). Other researchers have employed two intensity levels (<2 m·s^{-2}; >2 m·s^{-2}) [31,32] with both semi-professional players and players under 18. The researchers' effort to characterize accelerometry in real game and training contexts has focused on describing the ranges of velocity change, but they have not considered the initial and final velocity at which these changes are made.

Despite the demonstrated importance of accelerations and decelerations in basketball, few studies have focused specifically on these actions in youth players. As youth athletes mature and progress to higher levels of competition, the game demands change considerably [33,34]. Therefore, it is critical to understand the acceleration/deceleration profiles across playing positions in youth players. As far as is known, in studies establishing the ranges of kinematic variables in general and accelerometry in particular, researchers have defined the magnitude changes and intervals in acceleration and deceleration but have not described from what initial and final velocity that change occurs, as well as the distance traveled in those acceleration ranges. Therefore, the main objective of this research was to characterize the acceleration and deceleration profiles of under-18 male basketball players during official games more precisely. This objective was operationalized into the following objectives: (i) To identify differences in acceleration and deceleration thresholds during game periods; (ii) To discover differences in acceleration and deceleration thresholds by playing position; (iii) To analyze the interaction between specific positions and game periods on acceleration thresholds; and (iv) To study the relationship between the variables that define an acceleration. It was hypothesized that differences in the acceleration profiles of players would be identified between different periods of play, as well as between specific positions.

2. Materials and Methods

2.1. Design

A quasi-experimental empirical design of a descriptive and cross-sectional nature [35,36] was employed in this research to characterize the accelerometry of players in a basketball tournament and to identify the differences between game periods and playing positions.

2.2. Participants

Ninety-four elite players (age = 17.6 ± 0.8; height = 1.91 ± 0.08 m; body mass = 82.5 ± 8.8 kg; and body mass index = 22.7 ± 1.8 kg/m^2) took part in the study. The eligibility criteria were defined based on the following: (i) No injuries or being in a rehabilitation period; (ii) Players who participated more than 6 min within a quarter. All players were informed of the aims of the study and procedures following the Ethical Standards in Sport and Exercise Science [37]. With the approval of the University Bioethics Committee (Reg-Cod 67/2017) and following the procedures of the Declaration of Helsinki (World Med, 2013), the database was created from the recording of load variables obtained from the Local Positioning System (LPS) and microelectromechanical inertial sensors (MEMS) of the participating teams of the Euroleague Basketball ANGT finals.

2.3. Sample

The data sample for the analysis consisted of 1205 cases. Each case corresponds to data obtained from each player during their participation in each quarter of the 13 recorded games. The system used for data acquisition of player positioning employed Ultra-Wide Band (UWB) technology and inertial measurement units (IMUs) placed on the players during the monitored games.

2.4. Variables

For this study, acceleration and deceleration were defined as dependent variables. Specifically, four variables were used to characterize each of these variables: (i) Maximum acceleration or deceleration, measured in $m \cdot s^{-2}$; (ii) Distance traveled during that period, measured in meters; (iii) Start speed, measured in $km \cdot h^{-1}$; (iv) Final speed, measured in $Km \cdot h^{-1}$. In addition, three acceleration and deceleration thresholds were established: Low ACC or DEC (0–1 $m \cdot s^{-2}$), Moderate ACC or DEC (2–4 $m \cdot s^{-2}$), High ACC or DEC (>4 $m \cdot s^{-2}$).

There were two independent variables in this research: the periods of play (first period, second period, third period and fourth period), and the playing positions (Guards, Forwards, and Centers). The players were classified into these three groups of playing positions from the official roster of the competition.

2.5. Materials and Instruments

Positional data were gathered by a time motion-tracking system which includes a Local Positioning System (LPS) device, based on UWB technology, and an Inertial Measurement Unit (IMU; WIMU PROTM, Real Track Systems, Almeria, Spain).

The six antennae were installed five hours before the match, forming a hexagon for better signal emission (4.5 m from the perimeter line for antennae located in the corners and 5.5 m from the perimeter line for the antennae located in the middle of the court) and reception at a height like that of the device attached to the athletes' bodies for better accuracy and held by a tripod. Once installed, they were switched on one by one, with the master antenna turned on last. From that moment, it was necessary to respect a 5 min protocol to avoid technology lock [38]. To allow data time synchronization, the master antennae managed the time using a common clock which allows data recording at the same time. When all devices were switched on in the center of the reference system, a process of automatic recognition between antennae and devices was carried out for 1 min. In this study, the raw data were recorded at an 18 Hz sampling frequency because low frequencies have been shown to have a lower quality of measurement, and 18 Hz with UWB has not shown less accuracy because of noise problems. The conditions were maintained with low temperatures, humidity gradients, and slow air circulation to allow easier positioning. This UWB system has demonstrated valid and reliable measures during continuous situations [39].

The validity of the inertial measurement unit WIMU PROTM (Real Track Systems, Almeria, Spain) was assessed by Bastida Castillo et al. [40]. The devices were attached to the players' upper back in a pocket attached to a tight-fitting garment, placed between the scapulae at the T2–T4 level to avoid unwanted movements. The tight-fitting garments were the same for each player in each game. A sampling frequency of 100 Hz was used.

2.6. Procedure

According to the Rico-González et al. [41] guidelines, the use of the ultra-wide band (UWB) was explained, considering 21 points out of 23. For the description of the methodology for the use of MEMS, 17 points were considered out of 20. The rest of the items cannot be explained, as the authors did have not this information.

For data collection, a UWB system served as the reference system, complemented by tracking devices carried by players, namely IMUs. The UWB system comprised six antennae that functioned as both transmitters and receivers of radiofrequency signals. These antennae served distinct purposes, with five designated as tags and one serving as the master antenna responsible for managing the others (synchronization) and overseeing time management. The antennae, particularly the master antenna, automated the localization of devices within the play area using Time Difference of Arrival (TDOA).

Upon antenna activation, the system, through an algorithm, determined the position of each antenna. Each device recorded 18 position data points per second (X, Y coordinates), along with corresponding timestamps. Based on positional data and time, the device calculated velocity (V = e/t). Velocity calculations employed differential Doppler, and acceleration was subsequently derived from velocity.

After each game session, the data were downloaded to a computer (PC). The analysis software used was Spro 1.9.1 (RealTrack Systems, Almeria, Spain), compatible with the Windows operating system. This software facilitated the analysis of raw data, and various algorithms were developed for acceleration and deceleration analysis. Using the speed data, the software calculated acceleration and deceleration by applying mathematical derivatives to the velocity variable.

2.7. Statistical Analysis

Data were presented as mean, standard deviation, and relative frequency. The Kolmogórov–Smirnov test was used to check the normality of data distribution [42]. One-way ANOVA was used to compare ACC and DEC demand variables according to match quarters and playing position. If ANOVA reached the level of significance, Bonferroni's post-hoc was computed to identify pairwise differences. The between-subject effect size (ES) was calculated for practical significance. Thresholds for Cohen's d statistics were 0.2 (small), 0.5 (moderate), and 0.8 (large) [37]. The relationship between dependent variables was analyzed by Pearson's correlation test. The magnitude of the correlation was determined by the scale proposed by Hopkins [43] as follows: $r < 0.1$, trivial; $r = 0.1$–0.3, small; $r = 0.3$–0.5, moderate; $r = 0.5$–0.7, strong; $r = 0.7$–0.9, very strong; $r = 0.9$–0.99, almost perfect; and $r = 1.0$, perfect. All the analyses were performed in the Statistical Package for the Social Sciences (SPSS, IBM® Corporation, Chicago, IL, USA, version 25.0), with a significance level of 5%.

3. Results

The relative percentages of acceleration and deceleration demands according to different intensity thresholds across basketball match quarters (Q1–4) are displayed in Figure 1. The following relative percentage values were found for acceleration (ACC) and deceleration (DEC) actions according to the intensity thresholds: low-intensity (ACC: Q1 = 86.0%; Q2 = 87.3%; Q3 = 87.7%; Q4 = 88.8%; DEC: Q1 = 87.2%; Q2 = 88.8%; Q3 = 88.9%; Q4 = 90.2%), moderate-intensity (ACC: Q1 = 13.4%; Q2 = 12.3%; Q3 = 11.8%; Q4 = 10.8%; DEC: Q1 = 12.1%; Q2 = 10.6%; Q3 = 10.5%; Q4 = 9.3%), and high-intensity (ACC: Q1 = 0.6%; Q2 = 0.4%; Q3 = 0.4%; Q4 = 0.4%; DEC: Q1 = 0.7%; Q2 = 0.6%; Q3 = 0.6%; Q4 = 0.5%).

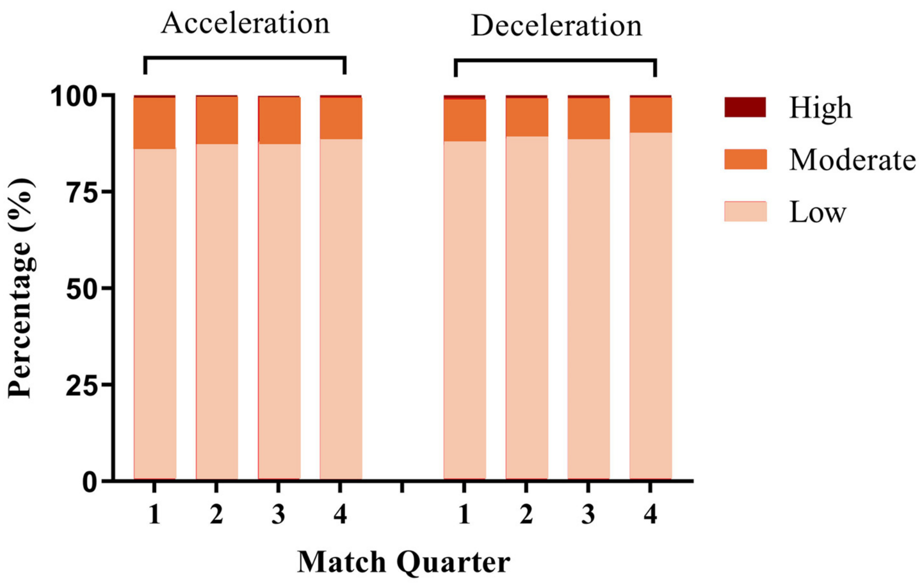

Figure 1. Acceleration and deceleration profile during competitive basketball matches by quarter. Note: Low = 0–1 $m \cdot s^{-2}$; moderate = 2–4 $m \cdot s^{-2}$; and high = >4 $m \cdot s^{-2}$.

The ACC and DEC demands of basketball players during competitive matches by quarter are displayed in Table 1. Statistical and practical differences were found for distance covered ($F_{(3, 903)}$ = 3.52; p = 0.015; ES > 0.2) and for the final speed achieved ($F_{(3, 903)}$ = 4.72; p = 0.003; ES > 0.2) in high ACC actions between match quarters. Specifically, a greater distance was covered in high ACC actions in the first match quarter in comparison to the third (p = 0.050; ES = 0.22) and fourth quarters (p = 0.047; ES = 0.23). No practical significance (ES > 0.2) was found for other ACC and DEC variables across match quarters.

Table 1. Comparison of acceleration and deceleration profiles during competitive basketball matches by quarter (mean and ±sd).

Variables	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Low ACC (0–1 m·s^{-2})				
Max ACC (m·s^{-2})	0.72 (0.52)	0.68 (0.51)	0.69 (0.52)	0.67 (0.51)
Distance (m)	1.53 (2.04)	1.42 (1.97)	1.47 (2.02)	1.35 (1.90)
Start speed (km·h^{-1})	2.10 (2.56)	1.93 (2.46)	1.96 (2.43)	1.86 (2.35)
Final speed (km·h^{-1})	4.68 (3.38)	4.38 (3.27)	4.47 (3.26)	4.24 (3.15)
Moderate ACC (2–4 m·s^{-2})				
Max ACC (m·s^{-2})	2.62 (0.48)	2.63 (0.48)	2.61 (0.47)	2.61 (0.47)
Distance (m)	4.80 (3.46)	4.82 (3.43)	4.65 (3.43)	4.51 (3.28)
Start speed (km·h^{-1})	2.27 (1.92)	2.21 (1.88)	2.24 (1.93)	2.18 (1.85)
Final speed (km·h^{-1})	12.30 (4.34)	12.32 (4.32)	12.11 (4.30)	11.93 (4.20)
High ACC (>4 m·s^{-2})				
Max ACC (m·s^{-2})	4.57 (0.69)	4.55 (0.61)	4.63 (0.69)	4.56 (0.69)
Distance (m)	5.53 (3.49) ^{c,d}	5.35 (3.18)	4.76 (2.99)	4.80 (2.82)
Start speed (km·h^{-1})	3.30 (2.74)	3.36 (2.39)	3.22 (2.77)	3.14 (2.73)
Final speed (km·h^{-1})	17.01 (4.92) ^{c,d}	16.84 (5.21)	15.85 (4.79)	15.55 (5.23)
Low DEC (0–1 m·s^{-2})				
Max DEC (m·s^{-2})	0.72 (0.51)	0.69 (0.51)	0.70 (0.51)	0.68 (0.50)
Distance (m)	1.69 (2.43)	1.58 (2.38)	1.60 (2.37)	1.51 (2.30)
Start speed (km·h^{-1})	4.81 (3.56)	4.53 (3.47)	4.58 (3.42)	4.37 (3.33)
Final speed (km·h^{-1})	2.08 (2.54)	1.92 (2.43)	1.95 (2.41)	1.84 (2.32)
Moderate DEC (2–4 m·s^{-2})				
Max DEC (m·s^{-2})	2.63 (0.49)	2.63 (0.48)	2.63 (0.49)	2.62 (0.48)
Distance (m)	4.22 (3.30)	4.28 (3.30)	4.13 (3.27)	4.00 (3.20)
Start speed (km·h^{-1})	11.92 (4.43)	12.02 (4.42)	11.79 (4.30)	11.55 (4.25)
Final speed (km·h^{-1})	2.27 (1.79)	2.24 (1.82)	2.18 (1.75)	2.17 (1.71)
High DEC (>4 m·s^{-2})				
Max DEC (m·s^{-2})	4.63 (0.71)	4.60 (0.71)	4.60 (0.64)	4.61 (0.66)
Distance (m)	4.97 (2.70)	4.94 (3.02)	4.74 (2.65)	4.70 (2.58)
Start speed (km·h^{-1})	17.38 (4.88)	16.84 (5.33)	16.74 (4.75)	16.79 (4.96)
Final speed (km·h^{-1})	2.57 (1.50)	2.75 (1.46)	2.75 (1.80)	2.55 (1.57)

ACC = acceleration; DEC = deceleration; c = significant and practical different from 3rd quarter ($p \leq 0.05$; $ES > 0.20$); d = significant and practical different from 4th quarter ($p \leq 0.05$; $ES \geq 0.20$).

The relative percentage of acceleration and deceleration demands according to different intensity thresholds by playing position are displayed in Figure 2. The following relative percentage values were found for acceleration and deceleration (DEC) actions of Guards (G), Forwards (F), and Centers (C) according to the intensity thresholds: low-intensity (ACC: G = 86.8%; F = 87.6%; and C = 88.8%; DEC: G = 87.6%; F = 89.3%; and C = 88.9%) moderate-intensity (ACC: G = 12.6%; F = 11.9%; and C = 10.7%; DEC: G = 11.5%; F = 10.2%; and C = 8.6%), and high-intensity (ACC: G = 0.5%; F = 0.4%; and C = 0.4%; DEC: G = 0.8%; F = 0.4%; and C = 0.4%).

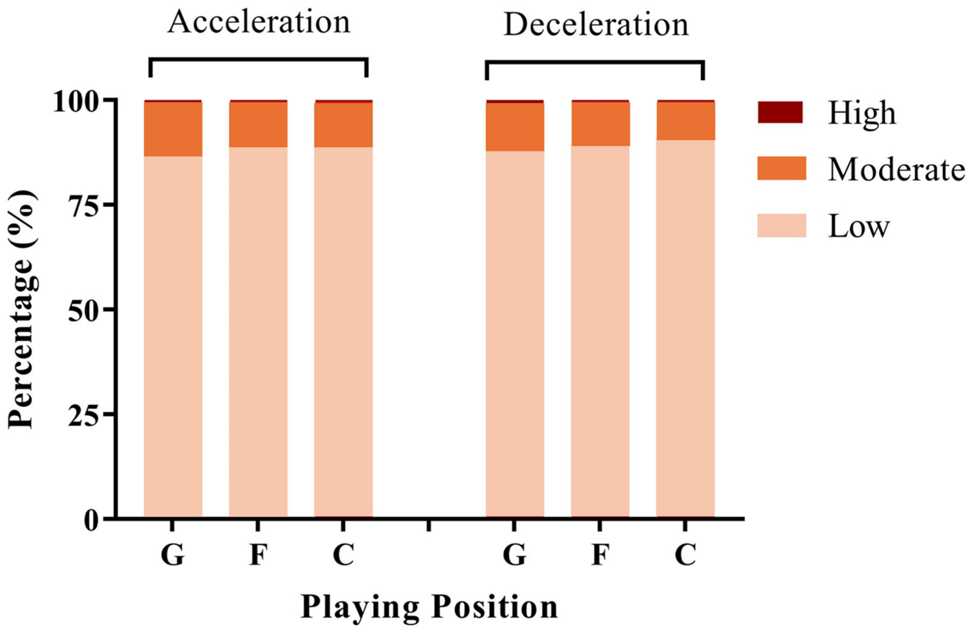

Figure 2. Acceleration and deceleration profile during competitive basketball matches by playing position. Note: G = Guards; F = Forwards; C = Centers; low = 0–1 m·s^{-2}; moderate = 2–4 m·s^{-2}; and high = >4 m·s^{-2}.

The ACC and DEC demands of basketball players during competitive matches by playing position are displayed in Table 2. Statistical and practical differences were found for distance covered ($F_{(2, 854)}$ = 3.20; p = 0.041; ES > 0.2), start speed ($F_{(2, 854)}$ = 4.11; p = 0.017; ES > 0.2), and final speed ($F_{(2, 854)}$ = 3.42; p = 0.033; ES > 0.2) in high ACC actions between playing positions. Specifically, Centers covered lesser distances than Guards (p = 0.043; ES = 0.25) and Forwards (p = 0.044; ES = 0.25), achieved lower start speeds than Guards (p = 0.040; ES = 0.27) and Forwards (p = 0.015; ES = 0.33), and achieved lower final speeds than Guards (p = 0.030; ES = 0.28) and Forwards (p = 0.049; ES = 0.20). No practical significance (ES > 0.2) was found for other ACC and DEC variables between playing positions.

The ACC and DEC demands of basketball players by playing position and match quarter are displayed in Table 3. Statistical differences were found for high ACC demands in all playing positions across basketball match quarters (p < 0.05; ES > 0.20). Specifically, final speeds achieved by Guards were higher in the first quarter than fourth quarter (p = 0.036 and ES = 0.25). Forwards covered greater distances in high ACC in the first and second quarters than third (first versus third [p = 0.045; ES = 0.29]; second versus third [p = 0.030; ES = 0.039]) and fourth quarters (first versus fourth [p = 0.045; ES = 0.23]; second versus fourth [p = 0.38; ES = 0.33]), the start speeds were higher in the first quarter in comparison to the fourth quarter, and final speeds were greater in the first quarter than third (p = 0.048; ES = 0.31) and fourth (p = 0.045; ES = 0.39) quarters. Centers covered greater distances in high ACC in the first in comparison to second quarters (p = 0.022; ES = 0.60), third quarter (p = 0.04; ES = 0.55), and fourth quarters (p = 0.04; ES = 0.56) and achieved greater final speeds in the first quarter than second quarter (p = 0.049; ES = 0.51), third quarter (p = 0.025; ES = 0.40), and fourth quarter (p = 0.048; ES = 0.56). Regarding DEC demands, statistical differences were found for Forwards and Centers in high DEC demands (p < 0.05; ES > 0.20). Forwards achieved greater start speeds in the first in comparison to the second quarter (p = 0.045; ES = 0.33) and fourth quarter (p = 0.021; ES = 0.36). Centers achieved lower start speed in high DEC in the fourth compared with the first quarter (p = 0.047; ES = 0.41), second quarter (p = 0.045; ES = 0.54), and third quarter (p = 0.047; ES = 0.47).

Table 2. Comparison of acceleration and deceleration profile during competitive basketball matches by playing position (mean and ±sd).

Variables	Guards	Forwards	Centers
Low ACC (0–1 m·s^{-2})			
Max ACC (m·s^{-2})	0.70 (0.52)	0.68 (0.52)	0.70 (0.51)
Distance (m)	1.48 (2.02)	1.50 (2.01)	1.25 (1.80)
Start speed (km·h^{-1})	2.03 (2.55)	2.02 (2.42)	1.69 (2.17)
Final speed (km·h^{-1})	4.53 (3.39)	4.53 (3.25)	4.09 (2.95)
Moderate ACC (2–4 m·s^{-2})			
Max ACC (m·s^{-2})	2.62 (0.48)	2.61 (0.46)	2.62 (0.48)
Distance (m)	4.67 (3.30)	4.87 (3.49)	4.64 (3.51)
Start speed (km·h^{-1})	2.37 (2.02)	2.17 (1.84)	2.02 (1.55)
Final speed (km·h^{-1})	12.30 (4.28)	12.28 (4.26)	11.81 (4.36)
High ACC (>4 m·s^{-2})			
Max ACC (m·s^{-2})	4.61 (0.73)	4.51 (0.53)	4.57 (0.72)
Distance (m)	5.39 (3.27) ^{c}	5.37 (3.08) ^{c}	4.59 (3.06)
Start speed (km·h^{-1})	3.39 (2.76) ^{c}	3.53 (2.72) ^{c}	2.71 (2.14)
Final speed (km·h^{-1})	16.84 (5.18) ^{c}	16.40 (5.26) ^{c}	15.48 (4.31)
Low DEC (0–1 m·s^{-2})			
Max DEC (m·s^{-2})	0.70 (0.51)	0.70 (0.51)	0.72 (0.50)
Distance (m)	1.56 (2.26)	1.69 (2.49)	1.51 (2.46)
Start speed (km·h^{-1})	4.59 (3.48)	4.70 (3.48)	4.32 (3.32)
Final speed (km·h^{-1})	2.01 (2.54)	2.00 (2.41)	1.96 (2.15)
Moderate DEC (2–4 m·s^{-2})			
Max DEC (m·s^{-2})	2.66 (0.50)	2.60 (0.47)	2.59 (0.48)
Distance (m)	4.17 (3.08)	4.34 (3.46)	3.90 (3.42)
Start speed (km·h^{-1})	12.08 (4.27) ^{c}	11.89 (4.41)	11.12 (4.42)
Final speed (km·h^{-1})	2.34 (1.87)	2.19 (1.71)	1.96 (1.47)
High DEC (>4 m·s^{-2})			
Max DEC (m·s^{-2})	4.65 (0.72)	4.53 (0.58)	4.57 (0.64)
Distance (m)	4.92 (2.66)	5.04 (2.87)	4.64 (2.05)
Start speed (km·h^{-1})	17.35 (4.82)	16.69 (5.31)	16.48 (4.88)
Final speed (km·h^{-1})	2.73 (1.62)	2.69 (1.41)	2.38 (1.54)

ACC = acceleration; DEC = deceleration; c = statistical and practical different from Centers ($p \leq 0.05$; $ES \geq 0.2$).

As can be seen in Tables 1–3, the distance traveled at each speed threshold increases with increasing intensity. At low intensities, the distances traveled for ACC and DEC are small, both by quarters and by playing position (less than 2 m). In high-intensity ACC and DEC, these distances are greater than 5 m. These results show the interaction between speed and distance traveled, which must be considered for the design of specific training tasks.

Table 4 shows the correlation matrix between polled acceleration and deceleration demands. Regarding the acceleration demands, it was found that the final speed displayed a strong coefficient of correlation with maximum acceleration and distance covered ($r > 0.70$) and correlation with start speed ($r = 0.483$). Moreover, we found a moderate coefficient of correlation between maximum acceleration and distance covered. Concerning deceleration demands, we found that start speed displayed a strong and positive coefficient of correlation with distance covered ($r = 0.840$) and a moderate and negative coefficient with maximum deceleration ($r = -0.688$). Additionally, we found a moderate and negative coefficient between distance covered and maximum deceleration ($r = -0.451$) and a moderate and positive coefficient between the final speed and the start speed ($r = 0.475$).

Table 3. Comparison of acceleration and deceleration demands of basketball players according to the playing position and match quarters.

Variables	Guards				Forwards				Centers			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Low ACC (0–1 m·s^{-2})												
Max ACC (m·s^{-2})	0.74 (0.53)	0.68 (0.51)	0.70 (0.52)	0.67 (0.51)	0.71 (0.52)	0.67 (0.52)	0.68 (0.52)	0.66 (0.51)	0.72 (0.51)	0.69 (0.51)	0.71 (0.52)	0.68 (0.51)
Distance (m)	1.59 (2.08)	1.47 (2.02)	1.54 (2.09)	1.39 (1.93)	1.61 (2.09)	1.46 (1.98)	1.51 (2.01)	1.43 (1.97)	1.31 (1.84)	1.28 (1.86)	1.28 (1.87)	1.13 (1.62)
(km·h^{-1})	2.16 (2.65)	2.01 (2.58)	2.05 (2.54)	1.94 (2.46)	2.21 (2.58)	1.98 (2.42)	2.04 (4.56)	1.89 (2.32)	1.75 (2.23)	1.71 (2.20)	1.68 (2.17)	1.61 (2.09)
Final speed (km·h^{-1})	4.79 (3.50)	4.48 (3.41)	4.58 (3.40)	4.34 (3.27)	4.81 (3.38)	4.45 (3.23)	4.57 (3.24)	4.33 (3.13)	4.25 (3.04)	4.12 (2.99)	4.12 (2.98)	3.87 (2.78)
Moderate ACC (2–4 m·s^{-2})												
Max ACC (m·s^{-2})	2.62 (0.47)	2.63 (0.48)	2.63 (0.48)	2.61 (0.47)	2.61 (0.47)	2.63 (0.47)	2.60 (0.46)	2.60 (0.46)	2.65 (0.49)	2.63 (0.48)	2.59 (0.48)	2.60 (0.47)
Distance (m)	4.74 (3.37)	4.78 (3.33)	4.61 (3.31)	4.50 (3.17)	4.94 (3.54)	4.92 (3.47)	4.94 (3.46)	4.68 (3.39)	4.78 (3.52)	4.92 (3.66)	4.29 (3.40)	4.48 (3.38)
Start speed (km·h^{-1})	2.38 (2.02)	2.37 (1.99)	2.45 (2.12)	2.31 (1.95)	2.24 (1.92)	2.15 (1.81)	2.18 (1.83)	2.09 (1.78)	2.09 (1.52)	2.02 (1.67)	1.88 (1.38)	2.08 (1.60)
Final speed (km·h^{-1})	12.37 (4.33)	12.47 (4.27)	12.31 (4.30)	12.07 (4.21)	12.38 (4.34)	12.36 (4.28)	12.33 (4.28)	12.01 (4.13)	12.08 (4.37)	12.13 (4.54)	11.28 (4.17)	11.65 (4.28)
High ACC (>4 m·s^{-2})												
Max ACC (m·s^{-2})	4.65 (0.83)	4.62 (0.70)	4.62 (0.73)	4.55 (0.66)	4.57 (0.55)	4.44 (0.40)	4.53 (0.56)	4.46 (0.58)	4.45 (0.62)	4.44 (0.59)	4.62 (0.72)	4.69 (0.86)
Distance (m)	5.67 (3.48)	5.44 (3.20)	5.26 (3.44)	5.19 (3.00)	5.63 (3.37) [c,d]	5.95 (3.37) [c,d]	4.79 (2.35)	4.93 (2.80)	5.78 (3.92) [b,c,d]	4.05 (1.96)	3.91 (2.72)	4.01 (2.22)
Start speed (km·h^{-1})	3.23 (2.44)	3.54 (2.54)	3.48 (3.11)	3.33 (2.97)	3.85 (3.20) [d]	3.53 (2.34)	3.36 (2.42)	3.18 (2.54)	2.79 (2.19)	2.70 (1.38)	2.73 (2.56)	2.78 (2.16)
Final speed (km·h^{-1})	17.25 (4.71) [d]	17.57 (5.26)	16.50 (5.24)	15.97 (5.38)	17.38 (5.21) [c,d]	16.55 (5.52)	15.81 (4.62)	15.26 (5.48)	16.73 (3.92) [b,c,d]	14.95 (3.06)	15.05 (4.52)	14.53 (3.88)
Low DEC (0–1 m·s^{-2})												
Max DEC (m·s^{-2})	0.72 (0.51)	0.69 (0.51)	0.69 (0.51)	0.68 (0.50)	0.71 (0.52)	0.69 (0.51)	0.69 (0.51)	0.68 (0.50)	0.74 (0.50)	0.71 (0.50)	0.73 (0.51)	0.70 (0.49)
Distance (m)	1.64 (2.28)	1.64 (2.28)	1.58 (2.25)	1.49 (2.21)	1.82 (2.56)	1.65 (2.44)	1.70 (2.50)	1.61 (2.44)	1.61 (2.56)	1.53 (2.50)	1.50 (2.46)	1.39 (2.31)
Start speed (km·h^{-1})	4.83 (3.57)	4.57 (3.53)	4.62 (3.45)	4.42 (3.38)	4.99 (3.61)	4.63 (3.48)	4.72 (3.47)	4.49 (3.35)	4.52 (3.45)	4.34 (3.35)	4.32 (3.29)	4.11 (3.17)
Final speed (km·h^{-1})	2.15 (2.65)	1.99 (2.56)	2.04 (2.52)	1.92 (2.43)	2.19 (2.56)	1.96 (2.39)	2.02 (2.39)	1.87 (2.29)	1.76 (2.21)	1.70 (2.18)	1.68 (2.14)	1.61 (2.06)
Moderate DEC (2–4 m·s^{-2})												
Max DEC (m·s^{-2})	2.66 (0.51)	2.66 (0.50)	2.67 (0.50)	2.64 (0.48)	2.59 (0.47)	2.60 (0.46)	2.60 (0.48)	2.59 (0.47)	2.61 (0.47)	2.60 (0.48)	2.55 (0.46)	2.57 (0.50)
Distance (m)	4.20 (3.12)	4.28 (3.04)	4.17 (3.12)	4.04 (3.05)	4.37 (3.45)	4.43 (3.50)	4.39 (3.49)	4.16 (3.40)	4.07 (3.54)	4.18 (3.61)	3.59 (3.11)	3.67 (3.30)
Start speed (km·h^{-1})	12.11 (4.32)	12.31 (4.28)	12.12 (4.27)	11.79 (4.18)	11.94 (4.49)	12.01 (4.49)	11.95 (4.31)	11.63 (4.29)	11.40 (4.60)	11.49 (4.55)	10.62 (4.09)	10.81 (4.28)
Final speed (km·h^{-1})	2.35 (1.84)	2.37 (1.92)	2.35 (1.93)	2.29 (1.80)	2.27 (1.83)	2.21 (1.74)	2.16 (1.60)	4.16 (3.40)	2.02 (1.36)	2.01 (1.62)	1.79 (1.31)	2.00 (1.55)
High DEC (>4 m·s^{-2})												
Max DEC (m·s^{-2})	4.64 (0.76)	4.67 (0.80)	4.65 (0.69)	4.63 (0.60)	4.66 (0.72)	4.48 (0.51)	4.52 (0.54)	4.43 (0.41)	4.48 (0.39)	4.49 (0.59)	4.78 (0.92)	4.52 (0.51)
Distance (m)	4.91 (2.62)	4.95 (3.03)	4.96 (2.61)	4.88 (2.29)	5.29 (2.76)	4.96 (2.95)	4.89 (2.69)	4.89 (3.16)	4.64 (3.01) [d]	5.46 (3.20) [d]	4.59 (2.69) [d]	3.93 (2.87)
Start speed (km·h^{-1})	17.37 (4.36)	17.35 (5.28)	17.26 (4.82)	17.44 (4.84)	17.75 (5.61) [b,d]	15.91 (5.62)	16.77 (4.62)	15.84 (4.97)	16.78 (5.12) [d]	17.19 (4.32) [d]	17.06 (5.08) [d]	14.76 (4.67)
Final speed (km·h^{-1})	2.67 (1.59)	2.85 (1.58)	2.83 (1.78)	2.57 (1.54)	2.57 (1.37)	2.69 (1.10)	2.88 (1.85)	2.65 (1.20)	2.32 (1.33)	2.40 (1.58)	2.28 (1.66)	2.55 (1.67)

b = significant and practical difference from 2rd quarter ($p \leq 0.05$); c = significant and practical difference from 3rd quarter ($p \leq 0.05$; d = significant and practical difference from 4th quarter ($p \leq 0.05$).

Table 4. Correlation matrix.

Acceleration	**Distance**	**Start Speed**	**Final Speed**
Max ACC (m·s^{-2})	0.554 *	−0.017	0.719 *
Distance (m)		0.254 *	0.869 *
Start speed (km·h^{-1})			0.483 *
Deceleration	**Distance**	**Start Speed**	**Final Speed**
Max DEC (m·s^{-2})	−0.451 *	−0.688 *	0.025
Distance (m)		0.840 *	0.245 *
Start speed (km·h^{-1})			0.475 *

Max ACC = maximum acceleration; Max DEC = maximum deceleration * = statistical correlation ($p < 0.05$).

4. Discussion

The main objective of this research was to characterize the acceleration and deceleration profiles of U18 male basketball players during official games, identifying the differences in acceleration and deceleration thresholds during game periods and by playing positions, as well as the interaction between playing positions and game periods in acceleration thresholds. The results of this research have made it possible to know more precisely the acceleration and deceleration profiles of the sample under study, as well as to verify that there are differences in these profiles between periods and between playing positions. In addition, the relationship between the variables that characterize these accelerations and decelerations has been verified. The main novelty provided by this study is the identification of the initial and final speed at which the speed changes occur (ACC and DEC), as it allows coaches a more specific design of the tasks, attending to the real demands of the competition.

Accelerations and decelerations are critical actions in team sports like basketball [44], enabling players to change direction and speed rapidly during a game [1]. The results have shown that the number of low-intensity accelerations and decelerations (0–1 m·s^{-2}) recorded during the game are very high (ACC 87.45% and DEC 88.77%), with a slight increase across periods, while high-intensity accelerations and decelerations are scarce (ACC 0.45% and DEC 0.6%), decreasing as the game progresses. Moderate-intensity accelerations and decelerations range between 12.1% (ACC) and 10.63% (DEC). Reina, García-Rubio, Pino-Ortega and Ibáñez [15] identified that in women's basketball, this accelerometry profile is maintained, with a predominance of a greater number of low-intensity ACC and DEC, increasing as the game progresses. The dynamics of the game during the final quarter, in which the total duration increases due to an increase in stoppages (increase in the number of fouls and timeouts) [25], causes a decrease in maximum speed and explosive distance covered [45]. This game dynamic must be considered by coaches to prepare their players for a more explosive start to the game, knowing that as the game progresses, they will have more recovery time during play, although the demands of high-intensity ACC and DEC are maintained.

Regarding the quality of accelerations, differences have only been identified between the variables that characterize accelerations and decelerations during game periods in the High ACC (>km·h^{-1}). Both accelerations and decelerations above 2 m·s^{-2} showed this downward trend in intensity over successive quarters. The distance covered and final speed in the first period was higher than in the third and fourth periods. As the game progressed, fewer high-intensity meters were covered and the final speed was lower [26]. This fact has been evidenced in different studies, both with male players [13,46,47], female players [25,48,49], U18 players [26], and basketball referees [45].

The dynamics of the game produced a slowing down of play over the course of the quarters, especially between the first and last periods. Koyama et al. [50] identified the movements that required greater acceleration during basketball games, with defensive actions demanding the highest acceleration when trying to react to prevent the reception of the ball, transitioning from passive defensive movements to explosive movements. At the start of the game, play was more continuous, with a greater number of ACC and DEC recorded. Play during the last quarter slowed down, increasing in time due to the increased number of timeouts that could be requested and fouls produced by fatigue [48,49]. In addition, these results must be taken with caution, since the physical demands of the game are influenced by contextual game variables, such as the scoreboard, strategy, and pace of play [23].

The number of accelerations and decelerations by specific playing positions maintains the same trend as with all players overall, with many low-intensity accelerations (between 87.6 and 89.3), few moderate-intensity accelerations (between 0.4 and 0.8), and few high-intensity accelerations (between 8.6 and 12.6). The thresholds for acceleration and deceleration decreased over the four quarters of the game, indicating that the intensity of these actions decreased as the game progressed [13,45]. Centers are the players who perform the most low-intensity actions, while Guards have the highest high-intensity demands. These results are confirmed by the qualitative analysis of ACC and DEC, as it has been identified that Guards and Forwards cover more distance, start implementing this acceleration at a higher initial speed, and end at a higher final speed than Centers. These differences are only identified in Moderate DEC between Guards and Centers, with Guards initiating braking at a higher speed. The general decrease in distance covered, and number of high-intensity accelerations and decelerations between the first and last quarter of games in all playing positions in the Euroleague Basketball Next Generation Tournament, have also been identified by [26]. These results are consistent with the known movement patterns and physiological demands of different positional roles in basketball [51,52]. Guards tend to cover more distance running and making high-intensity efforts, while Centers operate closer to the rim and rely more on jumping ability [7,53]. Petway, Freitas, Calleja-González, Leal and Alcaraz [14] also identified that Guards performed more high-speed runs than Forwards and Centers during collegiate basketball games. The higher volume of high-intensity accelerations and decelerations performed by point Guards and Forwards exerts substantial stress on their musculoskeletal and neuromuscular systems. This fact should be considered by coaches to personalize their preparation. To do this, at the beginning of the training session they must perform the most intense tasks, adapting them to the playing positions. Furthermore, since point Guards and Forwards have similar demands, they will be able to perform similar tasks, differentiated from Centers.

In the characterization of the accelerometry profile by playing positions, it has been identified that Guards and Forwards also showed significant differences compared to Centers in key variables of the acceleration profile, including greater distance covered and higher initial and final speeds during accelerations above 4 $m \cdot s^{-2}$. Statistically significant differences have only been identified in moderate-intensity decelerations (>2–4 $m \cdot s^{-2}$) in the starting speed between Guards and Centers. These results further highlight the superior acceleration and speed capabilities of perimeter players (Guards and Forwards). These results are consistent with those found by Vázquez-Guerrero, Jones, Fernández-Valdes, Moras, Reche and Sampaio [3], confirming that Guards and Forwards show better acceleration performance and reach higher maximum running speeds than Centers. Physical and anthropometric differences are inherent between specific positions, especially between interior and exterior players [54,55]. Smaller players have lower body mass, making it easier for them to accelerate than for larger players [19]. Additionally, Guards and Forwards have to cover more longitudinal and horizontal distance due to game demands, while the activity of Centers is more restricted to spaces near the rim [15].

When analyzing the differences by playing positions by match period, differences have been identified between all players and periods only in the thresholds of High ACC and High DEC (>4 $m \cdot s^{-2}$). For Guards, differences were only identified in final speeds between the first and fourth periods. The high-intensity demands of Forwards were differentiated between the first and second periods compared to the third and fourth periods in the distance covered and the exit speed between the first and fourth periods. Similarly, these players decelerated differently between the first period and the second and fourth periods.

Finally, Centers showed differences between the first and the rest of the periods in the distance covered with ACC > 4 m·s^{-2} and the final speed. Additionally, these players performed decelerations differently between the first three periods compared to the fourth in the distance covered and the initial braking speed. During the first quarter, actions are carried out at higher intensity than during the second half of the game [10,23,56]. Garcia et al. [57] highlighted the differences by playing positions in the physical demands during game quarters in professional players, suggesting the need to take these differences into account to optimize individual and team performance. The demands of repetitive high-intensity accelerations and decelerations seem to take a cumulative toll on the physiological and neuromuscular function of players. The decrease in acceleration capacity over the course of a game may be the result of energy depletion, metabolite accumulation, muscle damage, and central nervous system fatigue, factors that may contribute to the deterioration of acceleration capacity [58,59]. Developing greater resistance to fatigue through training may help delay performance decline.

The results show greater variability in the response of Forwards and Centers in their demands above 4 m·s^{-2} for both ACC and DEC. During the first game periods, intensities are higher compared to the last period. Guards are the players who behave the same throughout the game. The specific external load demands by playing position have been evidenced in numerous studies [21,22,32]. Personalization of training in basketball should be carried out because players have unique physical and physiological characteristics, as well as different levels of skill and athletic ability. The game demands that players perform specific technical–tactical actions of their role [4,60], which is reflected in the physical response during games [2,8,47]. Together, these findings provide new insights into how acceleration capacity decreases in different playing positions as fatigue accumulates during competition. Although all players experienced decreases in accelerometry performance, the earlier and more pronounced decreases in acceleration distance and speed in Centers and Forwards compared to Guards suggest that they may be more susceptible to fatigue during games. Specific training for these positions could focus on improving repeated sprint ability and metabolic conditioning.

Finally, the characterization of ACC and DEC through maximum ACC/DEC, distance covered, initial speed, and final speed has allowed for precise identification of how speed changes occur in young basketball players. The data show the relationship between the different variables related to acceleration and deceleration [15,61]. The greater the acceleration, the greater the distance covered while accelerating and the final speed. The greater the distance covered while accelerating, the higher the initial and final speed, so the initial and final speeds are related. In decelerations, this relationship is inverse. The greater the deceleration, the shorter the distance covered while accelerating and the initial speed. The more distance needed to decelerate, the higher the initial and final speed, so the initial speed of deceleration is related to the final speed.

With the increasing availability of accelerometer and tracking technologies, the acceleration profile provides an objective and insightful approach to assessing physical performance in field sports such as basketball [62]. By better understanding the accelerometry demands of competition and the factors affecting acceleration capacity, coaches and strength and conditioning professionals can adopt a more evidence-based approach to preparing basketball players. The use of real-time accelerometer monitoring during games and training provides instant feedback to inform training priorities and load management during the season [16,63]. Ongoing research on accelerations and decelerations will continue to shape strength and conditioning practices in basketball.

4.1. Study Limitations

Several limitations were encountered in the execution of this study, as the information obtained originates solely from a championship involving elite under-18 male players. Therefore, the results may not be generalizable to the broader population of players, although they provide an initial approximation for characterizing accelerometry.

In this research, the minimum playing time of each player per quarter was established as a limiting factor to be included in the data analysis. It is true that the results may be affected by the total playing time of each player, so this value should be considered in future research.

Furthermore, for a more personalized training approach, it would be beneficial to employ broader classifications of specific positions.

Another possible limitation of the study is that the results may be conditioned by the level of physical condition of the participating teams. The level of the participants was very high, as it was the final phase of the Adidas Next Generation Tournament, but a physical condition test for all players could not be carried out.

4.2. Practical Applications

Characterizing ACC and DEC based on four external load variables enables a precise identification of the demands that competition imposes on players within the three acceleration thresholds. Coaches must design tasks that replicate competition demands to prepare players and minimize the risk of injuries.

Coaches must design three types of tasks to meet the speed demands of the players: Type I, low-intensity speed-change tasks (starts, braking, changes of direction, receiving movements, unmarking) with short movements (less than 2 m); Type II, medium-speed-change tasks (large receiving movements, reception movements in a quarter court) with medium displacements (between 2 and 5 m); and Type III, high-speed-change tasks (sprints from one side of the court to the other, changes from one side of the court to the other) with large movements (more than 5 m). In each of them, the three speed-change thresholds are worked specifically.

Training sessions should align with the evolution of acceleration intensity. The beginning of training should induce higher-intensity ACC and DEC, while towards the end, these intensities should decrease. It is crucial to acknowledge that the game always requires high-intensity actions. Specific tasks for particular positions can be implemented at the start of training to provoke high-intensity demands. Towards the end of collective training sessions, such as five-on-five drills, these high-intensity demands will reflect what the collective game demands.

Beneficial training interventions may include plyometric exercises and resisted sprints to enhance power, sessions involving repeated sprints, paced runs, or interval training targeting the glycolytic energy system. Incorporating deceleration exercises, such as parachute sprints, can also be valuable.

Personalization training is fundamental for proper player development, especially during the developmental stages. Regardless of specific positions, players engage in more high-intensity ACC and DEC at the beginning of the game than towards the end. Therefore, initiating games at maximum intensity with thorough pre-game preparation is crucial.

The variation in high-intensity ACC and DEC during the game is more pronounced in Forwards and Centers. For all players, the start of the game represents the period of maximum demands, requiring peak physical activation. Game dynamics result in lower-intensity demands for Forwards and Centers, remaining relatively constant for Guards. Coaches should consider the evolving demands of the game when rotating players.

Ultimately, to elicit high-intensity demands in ACC and DEC, coaches should design specific tasks for each position. Low- and moderate-intensity tasks can be performed collectively by all players, since the game does not impose position-specific differences. When designing personalized tasks, coaches should consider variables characterizing ACC and DEC, namely Max ACC, the distance to be covered, and the velocity at which the task should be initiated and concluded. Personalizing training by playing positions will be able to differentiate tasks between perimeter players (Guards and Forwards) and interior players (Centers). For perimeter players, type-III tasks must be designed with greater distances than those of Centers.

5. Conclusions

This study provides valuable insights into the ACC and DEC performed by under-18 basketball players during competition, highlighting the effects of fatigue across game periods and differences between playing positions. It was identified that demands exceeding ACC and DEC > 4 m·s^{-2} differentiate player interventions.

The greatest amount of high-intensity ACC occurs during the first quarter, decreasing during the second half of the game. In addition, Guards and Forwards present higher high-intensity ACC demands than Centers. Similarly, in moderate DEC, Guards differ from Centers in the speed at which deceleration begins.

For all playing positions, high-intensity accelerations (>4 m·s^{-2}) are greater during the first period compared to subsequent periods. While Guards only show differences in final velocity between the first and fourth periods, Forwards exhibit variances in distance covered between the first and second periods versus the third and fourth periods, as well as in the initial and final acceleration velocity between the first and fourth periods. Additionally, high-intensity deceleration is superior in the first period compared to the second and fourth. Finally, Centers demonstrate differences between the first period and the rest in the distance covered with high-intensity accelerations and the final velocity attained.

The four variables characterizing ACC and DEC are interconnected. Distance depends on maximum ACC and DEC, initial velocity on distance covered, and final velocity on maximum ACC and DEC, distance, and initial velocity.

This research must continue to be developed in the future to identify these profiles in other populations, professional players, women, or players in training. The data provided by each group of players by sex and competitive level will allow the training processes to be personalized, adapting them to each population and playing position. For all these reasons, it is recommended that the protocols for speed training be reviewed, adapting them to the objective data provided by microtechnology, including, for each speed-change threshold, the distance that players must travel, as well as the initial and final speed before each speed change, with specific game tasks.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by Ethics Committee of University of Extremadura (protocol code 79/2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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