Versione POST-PRINT Conforme alla versione editoriale originale

https://www.tandfonline.com/doi/full/10.1080/24748668.2023.2293608

A video-based time-motion analysis of an elite male basketball team during a season: activity demands according to player position, game quarter and actual time played.

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Abstract

Aim: To investigate differences in the activity levels of top-tier professional basketball players based on their position and the quarter of the game. Methods: Thirteen elite Italian male players volunteered to participate in the study. A computerized semi-automatized time and motion analysis was performed. The players were assessed in terms of their positions (point guard, guard, forward, and center) over different quarters (Q1-Q4) during fifteen home games. A multivariate analysis of variance was performed using role and quarters as predictors. Results: The players covered an average distance per game ranging from 3478.03 ± 589.76 to 4560.97 ± 632.36 m. The guard and point guard covered more ground than the center and forwards $p>0.001$. The average distance covered was higher ($p<0.01$) in Q4 than in the other quarters. Both speed and the percentage of time spent in the jogging to max speed range decreased significantly ($p<0.05$) from Q1 to Q4, while time spent standing and walking tended to increase from Q1 to Q4. The point guard spent the highest percentage of total time performing major accelerations followed by the guard, while the forwards and center spent less time performing accelerations. Overall, 22.8 ± 0.7% of total playing time was spent performing major accelerations, which decreased from Q1 to Q4. Conclusions: These findings suggest that during official league games, the positions of elite basketball players vary in terms of the activities demands they place on players, underscoring the need for individualized role-based conditioning.

Keywords: match analysis, activity demands, elite players, team sports, acceleration, deceleration.

Introduction

Time–motion analysis technologies have been widely used to assess the activity demands of male athletes during team sport competitions, especially in soccer and other outdoor sports in which Global Positioning Systems (GPS) are the most frequently used technology. [1–6] However, since GPS systems cannot be used for indoor team sports such as basketball, most studies focusing on these sports have used video-based motion analysis, focusing on the physiological responses of players during games. [7–12] Only a limited number of studies have quantified the activity levels of elite basketball players during games. [7–10,13,14] Previous investigations examining the activity levels of basketball players have found that basketball requires a higher ratio of high intensity running to sprinting than soccer and field hockey, [15] a high frequency of lateral movements (up to 450 per game) and from 42 to 56 jumps per player per game.[15] Other studies using video-time–motion analysis applied to men's basketball games have found that elite players perform between 997 and 1105 total movements per game, [7–10] and male players spend 50–72%, 17–43%, and 6–20% of total game time performing low-, moderate-, and high-intensity activities, respectively. [7–10,13] Studies involving elite and sub-elite men's and women's basketball players have predominantly investigated activity demands in different speed ranges, often using empirical methods that were dependent on the interpretation of an operator. Such studies categorize player activities broadly and fail to consider the quarters of play over the course of a limited number of games. [8,14,16] Furthermore, these studies, do not take into account important parameters, such as accelerations and decelerations, and they do not analyze the actual time played or distance covered by each player at each position. In fact, they analyze the different positions per game as conceptual categories by combining the activities of the starting players and their substitutes for each game. However, such an approach leads to far-fetched results in terms of the distance covered and time played by each position, overestimating the actual physical demands placed on individual players. In fact, during a game, a player never plays the entire time, and the actual time spent playing should be calculated by performing a long series of game analyses. In addition, in basketball today, players are becoming increasingly more polyvalent and versatile, and are sometimes even required to play two or more positions in the same game. This makes it substantially more difficult to understand the real activity demands of each position. Therefore, investigations are needed that take into account the activity demands that vary according to actual playing time, player position and the stage of the game (quarters). In particular, evaluating players who almost always play the same position would provide important data for developing specific training programs, which in turn, would help those players raise the level of their game. [5] Our aim was therefore to analyze the distance covered by players based on their position and the quarter of play. Moreover, we analyzed their accelerations and decelerations, and different speed demands, as a percentage of time and distance traveled by all

players based on their position and the quarter of the game during official games over the course of an entire elite men's basketball season.

Methods

Participants

Thirteen elite male players of different nationalities playing on a team in the Italian Professional National Basketball League volunteered to take part in the study (age: 26.2 ± 4.3 y; height: 197.5 ± 10.3 cm; weight: 95.0 ± 11.2 kg). The team was consistently in the top half of the league standings, underscoring the elite nature of the players under study. Throughout the data collection period, all the players practiced five days (10 h) per week and played a maximum of two games per week. All research methodologies and procedures received approval from the Human Research Ethics Committee of the University of Urbino (CESU-31-2020).

Video recording and time–motion analysis

Players were filmed throughout the 15 home games of the regular season in the Italian A1 Professional Basketball League. The games consisted of four 10-min quarters (Q1, Q2, Q3, Q4), with 3- min breaks between Q1-Q2 and Q3-Q4, and a 15 min half-time break between Q2-Q3. However, during the course of the game, the game clock is paused on several occasions, such as when there is a foul, a free throw, a 24-second shot clock violation etc., and this implies that the actual game time is longer than the official game clock. Games were filmed using a digital video camera (Toshiba Camileo X200, Japan). The camera was set up in a fixed position at midcourt 15-18 m from one sideline and 25-28 m above the court, so that the entire court could be captured at all times (Fig. 1). All video was taken using a full-HD color setting at 25 frames per second. A semi-automated computerized video tracking software (SportVU®, STATS LLC., Chicago, USA) was used to analyze the physical performance of elite players at 25 frames per second. Player tracking was started manually by clicking on each player's estimated ground center of gravity projection and then the software automatically tracked that player. Manual corrections were made when needed, for example, when two players' positions almost overlapped. To avoid inter-operator errors, the same researcher performed all the tracking after having undergone a thorough training process using 10 hours of basketball films. The camera view was also calibrated using a four-point transformation with pre-measured distance dimensions of the playing area. The image of the basketball court was transformed into a two-dimensional (2D) model to allow calculation of the length and width of player positions (x and y, respectively). The x and y coordinates and distances were first recorded in pixels and subsequently converted to meters. Finally, the software calculated the distance, speed, and accelerations. Players were tracked for the whole game, including all stoppages in play. The time and activities considered for analysis referred to all time played, excluding only time-outs and breaks

between quarters (Figure 2). All games were played on a high-quality indoor parquet court (Vitrifrigo Arena, Pesaro, Italy). In our study, player activity was calculated for four different positions (one point guard, one guard, two forwards, and one center) and different quarters of the game (Q1-Q4). Data referred to each player was not cumulated with their substitutes or with those of other players in the same position, thus allowing individual player assessment. In order to obtain the distance covered by the point guard, guard and center positions we only analyzed the player who covered the greatest distance in that position, while for the forwards we considered the average of the two players who covered the greatest distances in that role. In addition, the polyvalence of players who change positions in certain phases of the game was considered during this analysis by always assigning the correct role to each player on the court. This was done for each of the 15 games analyzed. On the other hand, for the analysis of activity demands in terms of speed, acceleration, and deceleration, all thirteen players were considered. Each player's time and distance were transformed into a percentage of his own playing time (*%time*) and distance (*%distance*), which were then used for statistical analyses. For the analysis of game activities, the speed ranges were established based on the following model proposed by several authors [17–20] for soccer and futsal : i) standing 0 to ≤0.7 km/h, ii) walking 0.7 to ≤6 km/h, iii) jogging 6 to ≤12 km/h, iv) low speed 12 to ≤15 km/h, v) moderate speed 15 to ≤18 km/h, vi) high speed 18 to ≤21 km/h, vii) maximum speed (sprint) >21 km/h. For the deceleration (negative) and acceleration (positive) ranges, we used those proposed by Osgnach et al, (2010) for soccer [21]: i) max deceleration (MD; <-3 ms^{-2}), ii) high deceleration (HD; from -3 to -2 ms^{-2}), iii) intermediate deceleration (ID; from -2 to -1 ms^{-2}), iv) low deceleration (LD; from -1 to 0 ms^{-2}), v) low acceleration (LA; from 0 to 1 ms^{-2}), vi) intermediate acceleration (IA; from 1 to 2 ms^{-2}), vii) high acceleration (HA; from 2 to 3 ms^{-2}), and viii) max acceleration (MA; >3 ms^{-2}).

Statistical analyses

Means and standard deviations were determined for all descriptive and activity measures. To determine the likelihood of a type I error, a Greenhouse Geisser correction was performed to ensure the sphericity of all measures. The dependent variables were the *%time* and *%distance* values. Multivariate Analysis of Variance (MANOVA) was performed using as predictors the nominal variables: position (point guard, guard, forward and center) and quarters (categorized into four quarters from Q1 to Q4) and as dependent variables: the matrix of relative values of the variables obtained by the time-motion analysis. In the MANOVA model, the interaction between the two predictors was also considered; this was used to test whether there was significant variation over the four Qs as a function of each specific position. The estimators used to test the predictors' significance in the multivariate model were Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest

Root. Conservatively, predictors were considered significant when all estimators showed a probability of the null hypothesis of less than 5%. The ANOVA model was used to estimate how the dependent variable of distance covered changed according to player position and game quarter. Post-hoc comparisons were performed using the HSD Tukey test. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS software (SPSS Inc., Chicago, IL, USA).

Figure 1: Camera placement in the Vitrifrigo Arena, Pesaro, Italy.

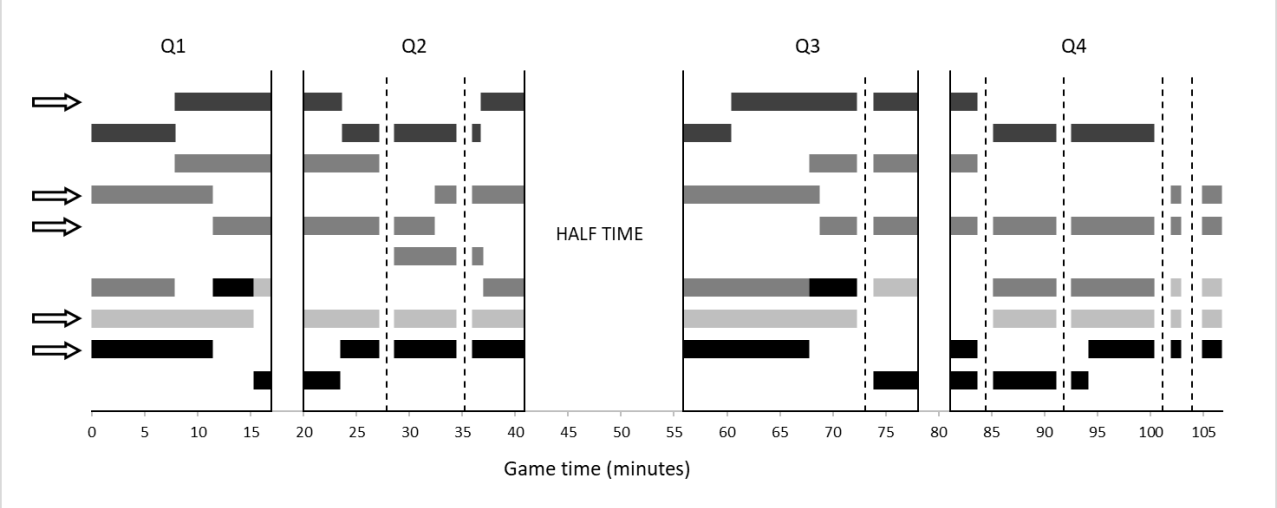
Results

The anthropometric and demographic characteristics of each player and the number of games played are shown in Table 1.

Table 1. Anthropometric and demographic characteristics of players.

N.	Position	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Games played (n)
1	Point guard	19	180	80	24.7	9
2	Point guard	29	183	82	24.5	14
3	Guard	26	188	88	24.9	13
4	Guard	28	194	87	23.1	7
5	Guard	24	199	94	23.7	15
6	Guard	36	187	83	23.7	1
7	Forward	20	205	100	23.8	15
8	Forward	29	202	96	23.5	15
9	Forward	26	198	93	23.7	15
10	Forward	24	210	105	23.8	13
11	Forward	25	202	100	24.5	4
12	Center	26	211	112	25.2	14
13	Center	28	208	115	26.6	15
Mean ± SD		26.2 ± 4.3	197.5 ± 10.3	95.0 ± 11.2	24.3 ± 0.9	11.5 ± 4.8

Figure 2:



Representative game in which ten of the thirteen players participating in the study played. The graph shows the time played by each player by position and quarters of the game: the five players on the court are represented by the only five bars converging at the same time point. Different colors represent the four positions: black, point guards; silver, guards; gray, forwards; dark gray, centers. Player substitutions and position changes are detectable by the change in color and bars, breaks from quarters are delimited by solid vertical lines while time outs are represented by the empty spaces filled with dashed lines. Finally, the arrows point to the players who played in the position for the longest time during the game.

Our results show that in the last quarter of the game, players covered significantly more ground ($p<0.001$) than in the other quarters, as shown in Figure 3. Moreover, looking at the distance covered by position (Figures 4 and 5), we found that on average in each quarter of the game, the guard and point guard covered significantly more meters than the center (guard = 1140.24 ± 331.7 and point guard = 1100.61 ± 293.92 vs center = 869.50 ± 342.85, $p<0.001$), while only the guard covered more meters than the forwards (forwards = 974.50 ± 274.08 $p<0.05$). Our analyses of distance, measured in average total meters covered per game by each position, yielded a similar difference: where the guard (4560.97 ± 632.36 m) and the point guard (4402.44 ± 771.70 m) covered significantly more meters than both the forwards (3592.01 ± 478.44 m) and the center (3478.03 ± 589.76 m); see Figure 4 and 5.

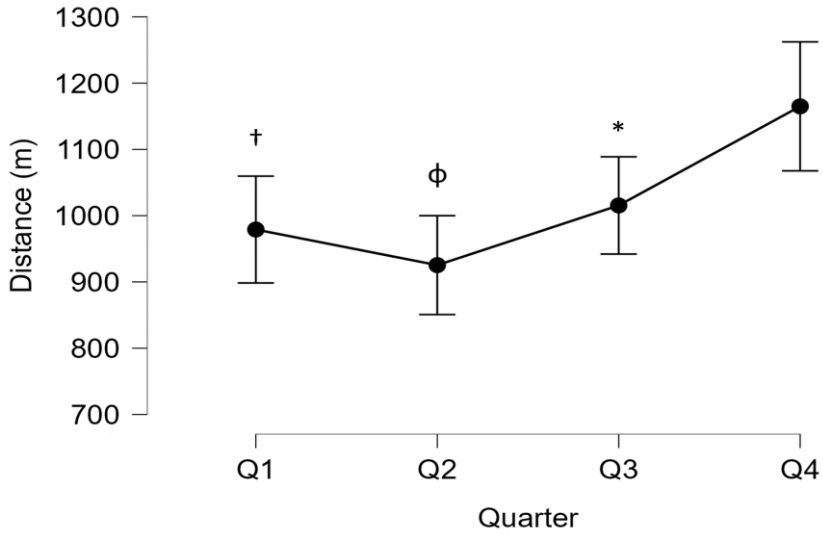


Figure 3. Mean differences between the total distance covered by all players in each quarter of the game (mean ± 95% confidence interval). Values are significantly different from those obtained in the fourth quarter. *: $p<0.05$; †: $p<0.01$; ϕ: $p<0.001$

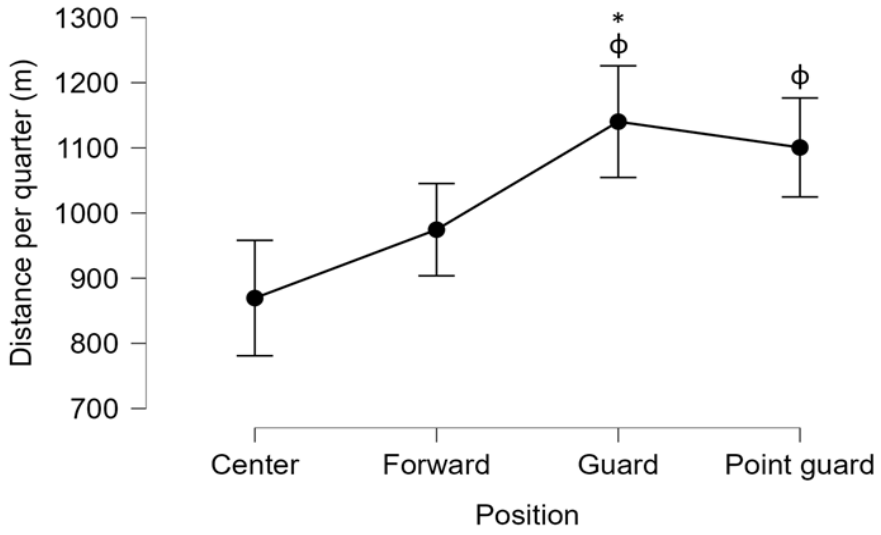


Figure 4. Mean differences between the total distance covered by all players in each quarter of game (mean ± 95% confidence interval). Values are significantly different from those of the center, ϕ: p<0.001
Values are significantly different from those of the forwards, *: p<0.05

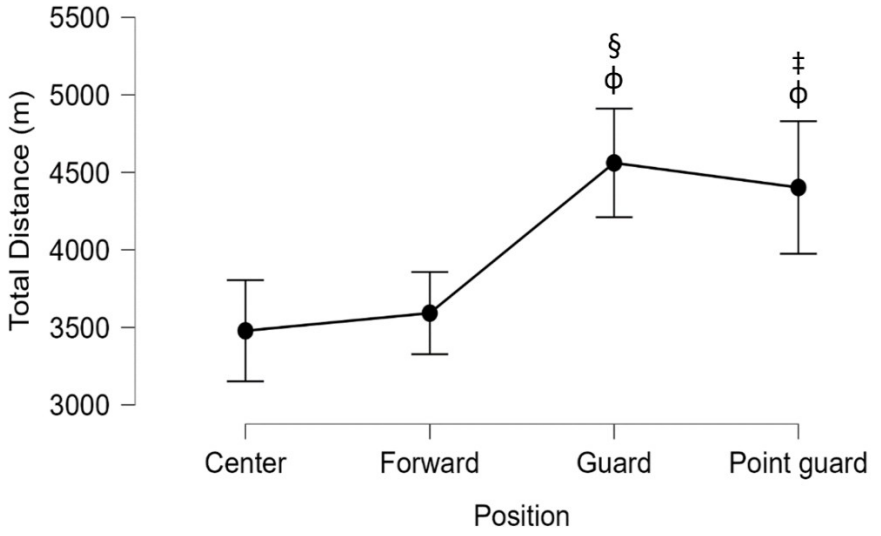


Figure 5. Mean differences between the total distance traveled by all players in all the game (mean ± 95% confidence interval). Values are significantly different from those of the center, ϕ: p<0.001.
Values are significantly different from those of the forwards, §: p<0.001; ‡: p<0.01.

Table 2 shows the results regarding the variation of the *%distance* and total time in each speed range and in the different quarters of the game. With respect to the *%distance*, we found at least a significant difference between Q1 and Q2 and between Q3 and Q4 in all speed ranges. Specifically, in the *standing* range, we noted a significant increase (p<0.001) between Q1 and Q2 and between Q3 and Q4, while in the walking range, there was a significant increase between the first three quarters and the last quarter (p<0.05). The jogging range decreased only from Q2 to Q4. while the remaining ranges decreased between Q1 and Q2 and between Q3 and Q4. Analyzing instead the *%time* spent in

the different speed categories and in the different quarters of the game, we found that in each speed range, there was at least a significant difference between Q1 and Q2 and between Q3 and Q4. It can also be noted how the *%time* spent in each speed range decreases significantly ($p<0.05$) between Q1 and Q2 and between Q3 and Q4, while only the *standing* range tends to increase between Q1 and Q2 and between Q3 and Q4.

Table 3 shows the results regarding how *%distance* and *%time* spent varies in the different speed ranges according to position. The analysis showed that in the walking range, *%distance* covered differs significantly ($p<0.05$) between point guard and center (37.8% and 40%, respectively). The *%time* spent in this range by the point guard and guard differs significantly from the center position ($p<0.05$ and $p<0.01$, respectively). Thus, the center spends a higher *%time* (55.5%) than the point guard (52.6%) or guard (53.4%) in the walking range. The center spends a lower *%time* (16.1%) and covers a lower *%distance* (31.9%) than the point guard, guard or forwards ($p<0.001$) in the jogging range, while the point guard spends a higher *%time* (19.9%) and *%distance* (37.8%; $p<0.05$) than the other positions. In the moderate speed range, we find a significant difference only in *%distance* traveled, where the center covers a significantly greater distance than the other positions (center 8.4% vs forwards 7,5%, point guard and guard 6.9%; $p<0.001$). Moreover, the center spends a greater *%time* (0.8%) and *%distance* (3.5%) than the point guard and guard (0.6% and 2.6%; $p<0.05$) in the high-speed range. The center also covers a greater *%distance* than the point guard (1.5% vs 1.0% $p<0.05$) and a greater *%distance* and *%time* than the forward (0.3%; 1.5% vs 0.2%; 1.0%, respectively) in the max speed range. Regarding accelerations, we also quantified both *%time* and %*distance*. However, since the two dependent variables assumed the same significance, we decided to report only the *%time* values for each quarter of the game and for each position (see Table 4). Specifically, regarding accelerations in different quarters of the game (Table 4: total time per quarter), it was found that as much as $22.8 \pm 0.7\%$ of total playing time is spent performing major accelerations (max, high and intermediate acceleration and decelerations). Interestingly, examining accelerations over the four quarters of a game, we can observe a significant decrease between Q1 and Q2 and between Q3 and Q4 in major accelerations and a parallel decrease between Q1 and Q2 and between Q3 and Q4 in low accelerations and decelerations. Analyzing accelerations according to player position (Table 4: Total time by position), we found that the point guard spends a higher percentage of total time performing major accelerations than the guard. On the other hand, the forwards and center spend the least time performing accelerations.

Table 2. Percentage of total distance and total time spent in each speed range in each quarter over fifteen games

	Standing	Walking	Jogging	Low speed	Moderate Speed	High speed	Max Speed
Total distance (%)							
Q1	1.0 ± 0.5	36.9 ± 5.4 §	35.1 ± 4.4	13.4 ± 3.3 #	8.5 ± 2.9	3.6 ± 2.0	1.5 ± 1.6 ‡
Q2	1.6 ± 1.0 ϕ	38.0 ± 5.5 §	35.6 ± 5.7 #	12.8 ± 3.2	7.4 ± 3.0 †	3.2 ± 2.0 ‡	1.4 ± 1.6 ‡
Q3	1.2 ± 0.6 §	40.0 ± 5.9 #	35.3 ± 4.0	12.5 ± 3.1	7.1 ± 2.6 †	2.9 ± 1.8 †	1.1 ± 1.3
Q4	1.9 ± 1.4	42.0 ± 7.6	33.9 ± 5.5	12.3 ± 3.5	6.7 ± 2.9 †	2.3 ± 1.9 ϕ	0.8 ± 0.9
Total time (%)							
Q1	17.1 ± 7.3 ϕ	54.4 ± 6.5 †	19.9 ± 4.5 ϕ	4.8 ± 1.7 ϕ	2.5 ± 1.0 ϕ	0.9 ± 0.5 †	0.3 ± 0.3
Q2	23.3 ± 11.5	51.7 ± 8.4	18.0 ± 5.0	4.1 ± 1.5	2.0 ± 1.1	0.7 ± 0.5	0.3 ± 0.3
Q3	19.6 ± 8.0 §	55.1 ± 7.1 #	18.2 ± 3.2 §	4.1 ± 1.3	1.9 ± 0.8	0.6 ± 0.5 ‡	0.2 ± 0.3 #
Q4	25.4 ± 10.6	52.5 ± 7.3	16.1 ± 4.8	3.7 ± 1.5	1.6 ± 0.9	0.5 ± 0.4	0.1 ± 0.2

Total distance (%): Values are significantly different from those obtained in the first quarter, †: $p<0.01$; ϕ: $p<0.001$. Values are significantly different from those obtained in the fourth quarter, #: $p<0.05$; ‡: $p<0.01$; §: $p<0.001$

Total time (%): Values are significantly different from those obtained in the second quarter, †: $p<0.01$; ϕ: $p<0.001$. Values are significantly different from those obtained in the fourth quarter, #: $p<0.05$; ‡: $p<0.01$; §: $p<0.001$

Table 3. Percentage of total distance covered and total time spent in each speed range according to position in fifteen games.

	Standing	Walking	Jogging	Low speed	Moderate Speed	High speed	Max Speed
Total distance (%)							
Point guard	1.2 ± 0.8	37.8 ± 7.5 *	37.8 ± 5.1 ϕ	12.7 ± 3.9	6.9 ± 3.3 ϕ	2.6 ± 1.8 †	1.0 ± 1.0 *
Guard	1.5 ± 1.0	38.7 ± 5.1	35.8 ± 4.0 ‡ϕ	13.1 ± 2.8	6.9 ± 2.6 ϕ	2.6 ± 1.8 †	1.2 ± 1.4
Forward	1.5 ± 1.2	39.4 ± 6.6	35.0 ± 5.1 ‡ϕ	12.2 ± 3.3	7.5 ± 3.0 ϕ	3.2 ± 2.0	1.0 ± 1.4 *
Center	1.4 ± 1.0	40.0 ± 6.5	31.9 ± 4.3 ‡	13.1 ± 3.2	8.4 ± 2.9	3.5 ± 2.3	1.5 ± 1.7
All players	1.4 ± 1.0	39.1 ± 6.0	34.9 ± 4.5	12.8 ± 2.8	7.4 ± 3.0	3.0 ± 2.0	1.2 ± 1.4
Total time (%)							
Point guard	20.4 ± 11.8	52.6 ± 9.1 *	19.9 ± 5.8 ϕ	4.3 ± 2.1	1.9 ± 1.3	0.6 ± 0.4 *	0.2 ± 0.2
Guard	21.1 ± 9.8	53.4 ± 6.9 †	18.4 ± 4.0 ϕ#	4.3 ± 1.3	1.9 ± 0.9	0.6 ± 0.4 *	0.2 ± 0.3
Forward	22.4 ± 10.0	52.4 ± 7.4	18.2 ± 4.4 ϕ#	4.0 ± 1.5	2.0 ± 1.0	0.7 ± 0.5	0.2 ± 0.3 *
Center	21.0 ± 8.8	55.5 ± 6.7	16.1 ± 3.7 #	4.1 ± 1.3	2.2 ± 0.9	0.8 ± 0.6	0.3 ± 0.3
All players	21.4 ± 0.8	53.4 ± 7.5	18.1 ± 5.1	4.2 ± 1.5	2.0 ± 1.0	0.7 ± 0.5	0.2 ± 0.3

Total distance %: Values are significantly different from those of the center, *: $p<0.05$; †: $p<0.01$; ϕ: $p<0.001$. Values are significantly different from those of the point guard, ‡: $p<0.01$;
Total time %: Values are significantly different from those of the center, *: $p<0.05$ †: $p<0.01$; ϕ: $p<0.001$. Values are significantly different from those of the point guard, #: $p<0.05$.

Table 4. Percentage of time spent in the different acceleration ranges and variations according to quarters and positions.

	MA	HA	IA	LA	LD	ID	HD	MD
Total time per quarter (%)								
Q1	1.0 ± 0.5 †§	3.0 ± 0.8 §	8.7 ± 1.6 *	36.5 ± 3.8 §	38.2 ± 3.9 ‡	8.9 ± 2.5 †	2.7 ± 1.0 *	0.8 ± 0.4 #
Q2	0.8 ± 0.4	2.7 ± 1.1 §	8.1 ± 2.0	37.2 ± 4.9 ‡	39.6 ± 6.4	8.2 ± 2.3	2.4 ± 0.8	0.8 ± 0.4
Q3	0.8 ± 0.4 ‡	2.6 ± 0.7	8.1 ± 1.3 §	37.9 ± 4.1	39.1 ± 4.3	8.2 ± 1.4 §	2.3 ± 0.7 ‡	0.7 ± 0.4
Q4	0.7 ± 0.3	2.3 ± 0.9	7.3 ± 1.7	39.2 ± 5.7	40.5 ± 6.5	7.2 ± 1.8	2.0 ± 0.7	0.7 ± 0.3
Total time per position (%)								
Point guard	1.1 ± 0.4	3.0 ± 1.1	8.1 ± 2.2	37.6 ± 5.2	38.3 ± 6.1	8.3 ± 2.5	2.7 ± 1.1	0.9 ± 0.5
Guard	0.9 ± 0.5 †	2.6 ± 0.8 δ	7.8 ± 1.7	37.9 ± 4.2	39.9 ± 5.2	7.7 ± 1.6	2.4 ± 0.8	0.8 ± 0.4
Forward	0.7 ± 0.3 *	2.6 ± 1.0 *	8.3 ± 1.7 #	37.6 ± 5.0	39.5 ± 5.3	8.4 ± 1.8 ‡	2.3 ± 0.8 ϕ	0.6 ± 0.4 ϕ§
Center	0.9 ± 0.5 ϕ	2.5 ± 0.8 ϕ§	8.2 ± 1.5	37.8 ± 4.8	39.4 ± 5.5	8.3 ± 1.5 #	2.2 ± 0.7 ϕ	0.7 ± 0.4 ϕ
All players	0.8 ± 0.4	2.7 ± 0.9	8.0 ± 1.8	37.5 ± 4.9	39.7 ± 5.8	8.1 ± 1.9	2.3 ± 0.8	0.7 ± 0.4

Total time per quarter (%): Values are significantly different from those obtained in the second quarter, *: $p<0.05$; †: $p<0.01$. Values are significantly different from those obtained in the fourth quarter, #: $p<0.05$; ‡: $p<0.01$; §: $p<0.001$
Total time per position (%): Values are significantly different from those of point guard, *: $p<0.05$ †: $p<0.01$; ϕ: $p<0.001$. Values are significantly different from those of guard, #: $p<0.05$; ‡: $p<0.01$; §: $p<0.0$

Discussion

The main aim of this study was to assess differences in the distance covered by players, their accelerations and decelerations, and the various speed demands placed on them in a series of official elite men's basketball games, taking into account player position, quarter of the game and actual playing time.

Distance

We found that the guard and the point guard covered the greatest distance both over the entire game and per quarter , with the center covering the shortest distance (Figures 4 and 5). Although most previous studies considered players of different levels, ages and genders than those analyzed in our study, our results are in line with investigations suggesting that frontcourt players (centers and forwards) cover a shorter distance than the backcourt players (point guards and guards). [14,16,22–24] In addition, as shown in Figure 3, we found that in the last quarter of the game, players covered greater distances ($p<0.001$) than in the other quarters, a finding which is in contrast with previous findings based on non-elite female basketball players. [16] This result could be due to several factors. First, the differences in the methods used: unlike other investigations, in our investigation, players were tracked for the entire game, including all stoppages in play, and all movements, such as walking on the court and positioning at the free throw, were included. Secondly, Italian professional basketball rules allow substitutions to be made by the team that has conceded a basket only in the last two minutes of the fourth quarter, which leads to coaches making more tactical substitutions to adjust their team's offensive or defensive capabilities in the final quarter (Figure 2). All these factors result in players covering more distance in the fourth quarter, especially at very low speeds due to these inactive phases.

One of the most important findings of this study was that the average total distance played by individual players ranged from 3478 m by the center to 4561 by the guard on average per game, against the current literature indicating a range of 4.4-7.5 km.[20] Notably, Ben Abdelkrim (2010) [8] reported an average of 7558 ± 575 m traveled by Tunisian junior players, but only players who were not substituted and played the 40 minutes of the game were analyzed.

Similarly, Scanlan (2011) [14] found that elite backcourt and frontcourt players covered 6390 m and 6230 m respectively, but their data was cumulated within each position across 48-minute games. Finally, it is often incorrectly reported that Erčulj et al. (2008) [25] found that elite Slovenian players covered 4.4 km per game, but this is just an extrapolation from the actual playing time and distance of the full 40-minute game. Without that extrapolation, the actual distance traveled by the players averaged 3506 m (2476.47 m during the active phase of the game and 1029.57 during the passive phase), which is much closer to our data. Although we did not split the data between active and

passive phases, our distance results show the actual distances covered by individual players for each position and quarter, which more realistically reflects the physical demands of elite basketball.

Speed range

Regarding speed range trends over the course of the game, in agreement with the above-mentioned results regarding distance, we found a progressive increase in *%distance* and *%time* from Q1 to Q4 in the lowest speed ranges, namely standing and walking, while *%distance* and *%time* in the medium-high speed ranges decreased. These results are in line with previous studies on soccer, futsal [26–28] and basketball [9], which showed that the amount of activity in the high intensity and max intensity speed ranges progressively declines during the game, in particular between the first and second half in soccer and during Q2 and Q4 in basketball. This may be explained by an increase in fatigue in parallel with a decrease in muscle glycogen levels. [29,30] However, it could also depend on tactical strategies, which in last few minutes of the game often result in teams seeking to maintain possession of the ball, and hence there is a decrease in the proportion of continuous play and fast breaks and a general slowing of the pace of the game. [9] Our results show that only 2.9 ± 0.3% of the total playing time is spent running at speeds over 15 km/h, accounting for 11.6% of the total distance. In this regard, a previous study showed that high-intensity activities in elite basketball were performed for 10% of total playing time and 15% of actual time. [10] In contrast, another study [13] showed that only 6.1% of total time was spent at high intensity, with a 1:4:5 ratio of high:medium:low intensity activities. However, it is important to note that these studies, due to their use of inferior technologies, did not use speed ranges based on measured speed. Instead, the activity was observed by an operator who categorized it based on his or her perception, indicating whether the player was exhibiting maximal effort or high-speed movements, including sprints, defensive slides, throws, jumps, physical drives in the post, and under the basket. Analyzing the speeds according to the different positions, we note how speeds up to 12 km/h and those over 18 km/h apparently differ among the different positions. In particular, the center spends a greater percentage of his time in the walking, moderate, high and max speed ranges than the other positions as a percentage of total distance covered (see Tables 2 and 3), while spending a smaller percentage in the jogging range. However, it is important to consider that the center covered significantly less distance than the guard and point guard and that, although the individual percentage of moderate, high, and maximum speed is higher, all positions cover a similar distance at moderate high and maximum speed in terms of the total amount. It is worth noting, however, that this result might suggest that the center, probably because of the characteristics of his position during plays, tends to move in a straight line (running basically smoothly) and this, particularly evident during fast breaks, might explain how he manages to achieve high top speeds.

Acceleration-Deceleration

Regarding accelerations, overall, 22.8 ± 0.7% of the total playing time was spent performing major accelerations (MA, HA, MD and HD). This interesting result is in line with a study on soccer that yielded a similar percentage (22.2%).[21] The percentage of time spent performing major accelerations (22.8±0.7%) is much higher than the percentage spent at high speed (2.9 ± 0.3%), highlighting why an assessment of metabolic load (work rate) based solely on distance covered or speed achieved underestimates the true performance pattern in a team sport such as basketball. In fact, even if total and relative distances are similar among positions, athletes might cover these distances in completely different ways - underscoring an intrinsic problem with this metric. It is important for sports scientists to understand this problem if they are going to monitor relative distance, as this variation in work rate can significantly alter the athlete's level of fatigue. In the present study, examining the pattern of accelerations in different quarters of the game, we note a decrease in major accelerations between Q1 and Q2 and between Q3 and Q4, followed by a parallel decrease in lower acceleration ranges between Q1 and Q2 and between Q3 and Q4. This pattern again shows a decrease in playing intensity over time, which may be due to tactical, physiological and psychological factors according to the multifactorial model of fatigue.[30] However, analyzing accelerations for different positions (Table 4, Total time per position %), we note that there are significant differences only in the major acceleration and deceleration ranges. Specifically, the point guard, followed by guard, spends a higher *%time* in major accelerations ranges, while the positions that spend the least time performing accelerations are the forwards followed by the center. In fact, unlike the center, the point guard and guard tend to make numerous changes of direction on the court (changing activities, moving to the lateral lines etc.). This could be the reason why the center was found to run more stretches at moderate, high and maximum speed, while playmakers and guards perform more accelerations, exhibiting a substantial difference in terms of biomechanical and metabolic demands. This result, in addition to showing the different work-rate and thus the need to diversify training according to positions, highlights that the positions most exposed to muscle and metabolic load due to constant acceleration and decelerations are the point guard and guard. This could also explain the higher number of injuries that occur in these two positions.[31] This study has some limits. For example, we analyzed only the home games of one particular team, and it is likely that tactical behaviors (and therefore also physical demands) may be different from those of away games. Moreover, our findings could be coach dependent, since different coaches may manage game situations using different tactics. However, the main strength of this study is that we analyzed all 15 home matches of the regular season, while previous research has studied a maximum of 6 games.[8] Moreover, we measured the actual distance and playing time by assessing

individual players for each position. Finally, this is the first study to calculate the time and distance percentage of speed and acceleration for each player.

Conclusion

The main findings of this study are that activity demands vary by position, with the center covering the least distance on average per game compared to the guard and point guard, but more distance at moderate, high, and maximum speeds with lower accelerations, while the point guard and guard cover the most distance by spending more time at higher accelerations. This implies that these positions require different physical conditioning programs. In particular, the center has a greater need to run for longer stretches at speeds close to maximum speed, while the point guard and guard must be able to cover greater distances by performing major accelerations and decelerations through movements with specific changes of direction. Moreover, the observation that the point guard and guard spend most of the time in the higher accelerations, together with the finding that the higher speeds and accelerations decrease from Q1 to Q4, provides valuable information to trainers who must focus on preventing musculotendinous injuries for these positions. In conclusion, the present investigation provides valuable information to coaches and athletic trainers to better manage position-related training loads in terms of quantity and quality in order to optimize playing strategies.

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