REVIEW

Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition

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The physical demands of modern basketball were assessed by investigating 38 elite under-19-year-old basketball players during competition. Computerised time–motion analyses were performed on 18 players of various positions. Heart rate was recorded continuously for all subjects. Blood was sampled before the start of each match, at half time and at full time to determine lactate concentration. Players spent 8.8% (1%), 5.3% (0.8%) and 2.1% (0.3%) of live time in high "specific movements", sprinting and jumping, respectively. Centres spent significantly lower live time competing in high-intensity activities than guards (14.7% (1%) *v* 17.1% (1.2%); $p<0.01$) and forwards (16.6% (0.8%); $p<0.05$). The mean (SD) heart rate during total time was 171 (4) beats/min, with a significant difference ($p<0.01$) between guards and centres. Mean (SD) plasma lactate concentration was 5.49 (1.24) mmol/l, with concentrations at half time (6.05 (1.27) mmol/l) being significantly ($p<0.001$) higher than those at full time (4.94 (1.46) mmol/l). The changes to the rules of basketball have slightly increased the cardiac efforts involved during competition. The game intensity may differ according to the playing position, being greatest in guards.

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Basketball is a sport that has undergone quite radical changes in the past decade. Coaches believe that the changes to the rules in May 2000, which consist of shortening the attack time from 30 to 24 s and the time allowed to cross the median line from 10 to 8 s as well as subdividing the duration of play into four 10-min quarters instead of two 20-min halves, have probably modified the tactical and physical demands of the game. Thus, identifying the physiological requirements of modern basketball is essential to prescribe and develop an appropriate physical training programme.

There are, however, no accurate parameters to assess the intensity involved in this sport, although measurement of the continuous heart rate might provide approximate information about the aerobic energy expenditure during match play.[1 2] Time–motion analysis of the movement patterns also seems to be a reliable method to describe the physical demands of basketball,[1] despite some problems related to the validity and reliability of the method. Furthermore, blood or plasma lactate concentration is often used as an indicator of anaerobic lactacid energy production during competition,[1 2] although it represents a poor indicator of muscle lactate.[3] Since 1995, no study has been made in the scientific literature in which both time–motion analysis and physiological responses of players are investigated, and therefore little is known about the intensity of modern competition. At the same time, there is no study on men's basketball that determines the position-specific physical demands of this sport. Therefore, the aim of this investigation was to estimate the activity patterns, heart-rate responses and plasma lactate of 38 Tunisian elite under-19-year-old players during six matches.

METHODS

Subjects

A total of 38 elite under-19-year-old basketball players belonging to six teams were studied during the competition. The samples comprise 8 guards, 18 forwards and 12 centres, and training on an average of five times a week on the basis of 90 min per session. In each match, six or seven elite subjects from various playing positions were investigated to determine the physiological responses, whereas only players who were not substituted during the game were examined to conduct a detailed analysis of the movement patterns of the three major playing positions. All subjects gave their informed consent to the procedures approved by the ethics committee of the National Institute of Nutrition, Tunis, Tunisia and the Tunisian Basketball Union.

Preliminary fitness tests

A few days before the competition, the anthropometric and physiological parameters were evaluated. The subjects' heights were measured to the nearest 0.1 cm with a portable stadiometer (Seca, Marsten, UK). Body mass and total body fat mass were measured by a bioelectric body composition analyser (Tanita TBF-300 increments 0.1%, Tokyo, Japan). Body mass index was calculated as the weight in kilograms divided by the square of height in metres. The subjects participated in a multistage 20 m shuttle-run test[4] to determine their maximal aerobic speed. Maximal oxygen uptake (VO_2max) was then estimated using the equation of Leger *et al*[5] based on the relationship between the maximum speed achieved in this test, age and VO_2max.

The matches

The matches investigated were in the play-off stage of the Tunisian under-19-year-old basketball

Abbreviations: HRmax, maximal heart rate; VO_2max, maximal oxygen uptake championship (May–June 2004). Each match consisted of four 10-min quarters with a 15-min break at half time and 2-min breaks between the first and second quarters as well as between the third and fourth quarters. The environmental conditions were similar in all matches (29–33℃).

Time–motion analysis

Video recordings were collected using one immobile camera (SONY, DSR-PD170P, Tokyo, Japan) positioned 4–5 m away from the sideline at halfway, at an elevation of 10–12 m to allow full coverage of the court. The software[6] adopted in this time–motion analysis (PC foot 4.0) made it possible to automatically detect the players' positions in each image. The used algorithm relies on the subtraction of the background through the use of statistic modelling, and consists of three important steps: initialisation, movement extraction (foreground) and model updating. The video recording was analysed frame by frame to an accuracy of 0.04 s. Each video sequence could be viewed at any chosen speed, permitting analysis of the movements. Based on the descriptions of McInnes *et al,*[1] nine movement categories were used to classify the form and intensity of activity during competition (standing still, walking, jogging, running, sprinting, jumping and low, moderate, high-specific movement). "Specific movement" in this study principally means shuffling as well as any foot action that is different from ordinary walking or running (roll, reverse and cross-over run). The movement categories were then arranged in high, moderate, low-intensity activities and recovery. Frequency and mean duration of, and live time spent in, each movement category were calculated. Live time in this study refers to the time during which the game clock was running and the subject was on court, and to the short moments in which the player was active during out-of-bounds. Total time refers to all of the time that the subject was on the court, including all stoppages in play, but excluding breaks between quarters. The distances travelled by the subjects during match play were not measured because it has been reported that this parameter would underestimate the physiological requirements of competition and possibly lead to incorrect conclusions regarding the overall demands of basketball.[1]

The reliability of the time–motion analysis was determined by repeating two trials at each speed for each player investigated, and by testing all players by three different experimenters.

Match heart rates

During the entire game, heart rate was recorded in 5-s intervals using Sport-tester S610 heart rate monitors (Polar, Kempele, Finland). The stopwatch on the heart rate recorder was synchronised with the starting time. Heart rate for time not spent on court was removed (breaks at half time, between the quarters and the time when the subject was substituted).

Blood collection and lactate analysis

Blood samples were drawn from the antecubital vein before the start of each match, at half time and at full time. In each sampling, 2 ml of blood was collected and placed in tubes containing EDTA for the determination of lactate concentration by enzymatic oxidation analysis (Kit Randox LC2389, Crumlin, UK). These assays were performed by the Clinical Biology Laboratory of the Tunisian National Nutrition Institute (Tunis, Tunisia).

Statistical analysis

Mean (SD) was calculated for each of the dependent variables. The reliability of the time–motion measurement was established using a coefficient of variation for the difference between repeated measurements.[7] Analysis of variance was used to compare the three positional groups for anthropometric and physiological characteristics, heart rate, plasma lactate concentration and movement patterns variables. If significant differences were observed, a Bonferroni reanalysis was carried out to locate those differences. The mean duration of the various activities was so short that we thought a statistical comparison would be unnecessary. Data for the four quarters were compared using a dependent samples t test and a non-parametric analysis (Wilcoxon's test). Pearson's correlation coefficient was used to examine the relationship between the variables. The statistical package SPSS-11.0 was used for statistical calculations. Significance was set at $p<0.05$.

RESULTS

Preliminary fitness tests

Table 1 presents the principal anthropometric and physiological characteristics of the subjects. Maximal oxygen uptake is comparable for players of the three playing positions, whereas higher values were found in centres for anthropometric parameters.

Time–motion analysis

Table 2 illustrates reliability of the time motion measurements.

Table 3 presents the total time, live time and stoppage time for all positional groups in the different quarters.

The mean (SD) frequency for all activities performed during a game was 1050 (51) movements (range 985–1141), with a significant difference ($p<0.01$) between guards and the other two positions. This difference is maintained after adjusting weight and height. The mean duration of the movement categories did not exceed 3 s (table 4). Approximately 41%, 5.3% and 22% of live time were spent competing in "specific movements", sprinting and low to moderate-intensity running, respectively, whereas 29.9% was spent standing still and walking.

Table 5 shows the percentage of live time spent in high-intensity activity by players of various positions in each quarter. A profound decrease in the time involved in intense activities was observed in the last quarter. The VO_2max for players were significantly correlated with the live time spent in high-intensity activity ($r = 0.55$, $p<0.05$) during the game.

Heart rate

The mean (SD) heart rate during the match was 171 (4) beats/min that equates to 91% (2%) of the maximal heart rate attained during match play, with a significant difference ($p<0.01$) between guards and centres (174 (4) *v* 169 (3) beats/min, respectively). Table 6 shows the values of the heart rate in each quarter. There was no significant relationship between the percentage of live time spent in high-intensity activity and the heart rate responses during competition ($r = 0.31$, $p>0.05$).

Blood lactate

The mean (SD) plasma lactate concentration during the match was 5.49 (1.24) mmol/l, with a significant difference ($p<0.001$) between values observed at half time and those at full time (6.05 (1.27) *v* 4.94 (1.46) mmol/l, respectively). According to playing position, the mean (SD) plasma lactate concentration was significantly higher for guards ($p<0.05$) than for centres (6.36 (1.24) *v* 4.92 (1.18) mmol/l, respectively). Figure 1 shows the plasma lactate concentrations for players of various positions at each sampling time. A significant correlation ($r = 0.50$, $p<0.05$) was found between lactate concentration and the percentage of time spent in high-intensity activity 5 min before sampling.

Table 1 Principal anthropometric and physiological characteristics of the subjects

Variable	All subjects (n = 38)	Guard (n = 8)	Forward (n = 18)	Centre (n = 12)
Age (years)	18.2 (0.5)	18.2 (0.2)	18.2 (0.5)	18.2 (0.5)
Height (m)	1.89 (0.05)	1.83 (0.04)*†	1.88 (0.04)‡	1.93 (0.03)
Body mass (kg)	80.3 (6.7)	76.2 (3.4)†	77.4 (5.1)†	87.2 (5.3)
Body fat (%)	8.2 (5.6)	6.1 (3.7)	7.8 (4.1)	10.4 (7.8)
Fat free mass (%)	91.7 (5.6)	93.9 (3.7)	92.2 (4.1)	89.6 (7.8)
BMI (kg/m^2)	21.7 (1.9)	22.7 (1.0)	21.8 (1.1)§	23.6 (1.8)
VO_2max (ml/kg min)	52.8 (2.4)	53.8 (1.9)	53.4 (2.3)	51.4 (2.4)

BMI, body mass index.
Data are mean (SD).
*Values are significantly different from those obtained by forward, $p<0.01$.
†Values are significantly different from those obtained by centre, $p<0.001$.
‡Values are significantly different from those obtained by centre, $p<0.05$.
§Values are significantly different from those obtained by centre, $p<0.01$.

DISCUSSION

This study is the first to investigate the kinematical and physiological demands of basketball after the changes in the rules in 2000. The total duration of time spent in intense movements was slightly higher than that reported previously.[1] The live time spent in high-intensity activity decreased significantly during the last quarter of each half. Heart rate responses indicate an important degree of efforts for guards in particular and plasma lactate values show a large contribution from the anaerobic energy systems towards the end of the first half.

Time–motion analysis

This study shows that the subjects performed a mean (SD) of 1050 (51) movements/game, resulting in a change of action every 2 s, which shows the highly intermittent nature of basketball. This is more than reported previously for senior professional Australian players,[1] and may be related to the "8–24 s rule". Shortening the attack time-limit has probably led to a decline in the adoption of long offensive tactical systems in favour of a further exploitation of players' individual creativity. Thus, the categories and intensities of movements were probably varied more often. The large number of actions performed by guards compared with other positional groups may be explained by the possibility that guards are usually more involved in ball possession during a match.

The mean (SD) frequency of high-intensity running averaged by Tunisian under-19-year-old players was 55 (11) (range 36–74), resulting in a sprint once every 39 s. This is less than previously recorded,[1] and may be attributed to the fitness levels of the samples. The higher VO_2max for senior professional Australian players (60 ml/kg/min) compared with that estimated for our players (52 ml/kg/min) was likely to enhance repeated high-intensity running performance during competition. It has been shown that the distance covered at high intensity in soccer is closely related to the aerobic fitness of the players.[8 9] Several observations also show that VO_2max is an important determinant of the ability to perform high-intensity intermittent exercise.[10–12] Therefore, as intermittent sprint training improves aerobic and anaerobic metabolism,[13 14] it would enable younger basketball players to perform more frequent high-intensity run efforts during a game. Previous researches have shown the beneficial effects of intense interval training on repeated sprint performance.[15–17] Analysis by playing position shows that guards averaged more sprints and spent greater live time in this activity than forwards and especially centres. This may be because guards are usually the first players who assure the fast transitions from defence to offence and vice versa.

This study shows that players from various positional groups spent approximately 11% of live time in moderate-intensity running, similar to that recorded by other authors.[1] Run efforts in basketball are likely to be performed in all directions, including running backwards and even sideways. Since they accentuate the metabolic loading,[18] such movements require greater physical demands than running forwards.[19] Therefore, increasing the muscular efficiency of these movements through agility training would be beneficial.[20]

On average, players performed 44 (7) jumps per game (range 30–54), which is close to the 46 jumps reported previously.[1] However, although not statistically significant, the number of jumps averaged by centres tended to be appreciably higher than forwards and guards. This is probably attributed to their major role in both offensive and defensive rebounds.

Table 2 Reliability of time–motion measurement

Movements	Frequency CV (%)	Average time CV (%)	% Live time CV (%)
Walk	1.8	2.2	2.9
Jog	1.9	1.9	2.6
Run	2.5	2.9	2.7
Sprint	2.7	3.6	3.4
Low-specific movement	1.5	2.5	2.9
Medium-specific movement	2.1	2.8	3.2
High-specific movement	3.9	3.1	3.8
Jump	0.9	1.4	1.6

CV (%), coefficient of variation for the difference between repeated measurements in percentage.

Table 3 Total time on court, live time played and stoppage time in the different positions and quarters of the matches

Position	Total time (s)	Live time (s)	Stoppage time (s)
All positions	4520 (130)	2122 (54)	2398 (126)
Guard (n = 8)	4474 (143)	2103 (58)	2370 (161)
Forward (n = 18)	4498 (127)	2105 (48)	2393 (135)
Centre (n = 12)	4588 (123)	2155 (51)	2434 (92)
1st Quarter	990 (97)	502 (39)	488 (32)*
2nd Quarter	1080 (115)	526 (43)	554 (44)*
3rd Quarter	1100 (88)	510 (45)	590 (46)*
4th Quarter	1350 (66)	584 (66)	766 (55)

Data are mean (SD).
*Values are significantly different from those obtained in the 4th quarter, $p<0.001$.

Table 4 Frequency and duration of different activities during the matches

Activity	All players	Guard (n = 6)	Forward (n = 6)	Centre (n = 6)
Frequency (n)				
Sprint	55 (11)	67 (5)*†	56 (5)‡	43 (4)
High-specific movement	94 (16)	104 (19)	94 (13)	85 (8)
Jump	44 (7)	41 (7)	41 (6)	49 (3)
Total high intensity	193 (24)	211 (24)§	190 (22)	177 (10)
Run	97 (14)	103 (11)	88 (5)	101 (19)
Medium-specific movement	197 (33)	230 (37)*‡	186 (13)	176 (9)
Total moderate intensity	294 (40)	332 (44)*§	274 (12)	277 (25)
Jog	113 (8)	113 (8)	110 (10)	117 (6)
Low-specific movement	175 (10)	176 (14)	173 (6)	175 (11)
Total low intensity	288 (11)	289 (11)	283 (10)	292 (13)
Walk	129 (10)	130 (8)	126 (15)	130 (8)
Stand	147 (11)	141 (15)	149 (9)	150 (10)
Total recovery	275 (16)	271 (18)	275 (23)	280 (3)
Total of all movements	1050 (51)	1103 (32)¶‡	1022 (45)	1026 (27)
Average time (s)				
Sprint	2.1 (0.2)	1.9 (0.2)	2.1 (0.1)	2.2 (0.1)
High-specific movement	2.0 (0.2)	1.9 (0.3)	2.1 (0.2)	2.0 (0.2)
Jump	1.0 (0.1)	0.9 (0.1)	1.0 (0.1)	1.1 (0.1)
Total high intensity	1.8 (0.1)	1.7 (0.2)	1.8 (0.1)	1.8 (0.1)
Run	2.3 (0.3)	2.1 (0.4)	2.4 (0.2)	2.4 (0.4)
Medium-specific movement	1.9 (0.2)	1.8 (0.1)	2.0 (0.2)	1.9 (0.1)
Total moderate intensity	2.1 (0.2)	1.9 (0.2)	2.2 (0.2)	2.1 (0.1)
Jog	2.2 (0.2)	2.1 (0.1)	2.2 (0.2)	2.3 (0.1)
Low-specific movement	1.7 (0.1)	1.6 (0.1)	1.7 (0.1)	1.8 (0.1)
Total low intensity	1.9 (0.1)	1.8 (0.1)	1.9 (0.1)	2.0 (0.1)
Walk	2.4 (0.3)	2.3 (0.2)	2.4 (0.3)	2.6 (0.1)
Stand	2.3 (0.2)	2.2 (0.3)	2.2 (0.2)	2.4 (0.2)
Total recovery	2.3 (0.2)	2.2 (0.2)	2.3 (0.2)	2.5 (0.1)
Live time (%)				
Sprint	5.3 (0.8)	5.9 (0.7)‡	5.4 (0.3)§	4.5 (0.4)
High-specific movement	8.8 (1)	9.3 (0.9)†	9.2 (0.6)§	7.9 (0.8)
Jump	2.1 (0.3)	2.0 (0.4)	2.0 (0.3)	2.3 (0.1)
Total high intensity	16.1 (1.4)	17.1 (1.2)‡	16.6 (0.8)§	14.7 (1.0)
Run	10.4 (0.8)	10.2 (1.0)	10.1 (0.4)	10.8 (0.9)
Medium-specific movement	17.7 (2.5)	19.8 (2.3)‡	17.9 (2.0)	15.5 (0.9)
Total moderate intensity	28.1 (2.3)	30.0 (1.8)‡	28.0 (2.1)	26.3 (1.5)
Jog	11.6 (0.8)	11.0 (0.5)‡	11.4 (0.7)§	12.4 (0.6)
Low-specific movement	14.2 (1.0)	13.4 (1.1)‡	14.4 (0.6)	14.7 (1.0)
Total low intensity	25.8 (1.5)	24.5 (1.1)‡	25.8 (1.0)	27.2 (1.1)
Walk	14.4 (1.1)	13.9 (1.0)†	14.0 (0.8)	15.4 (0.8)
Stand	15.5 (1.2)	14.5 (1.2)†	15.6 (0.6)	16.4 (1.1)
Total recovery	29.9 (2)	28.4 (1.9)‡	29.6 (1.4)§	31.8 (0.8)

Data are mean (SD).
*Values are significantly different from those obtained by forward, $p<0.05$.
†Values are significantly different from those obtained by forward, $p<0.001$.
‡Values are significantly different from those obtained by centre, $p<0.01$.
§Values are significantly different from those obtained by centre, $p<0.05$.
¶Values are significantly different from those obtained by centre, $p<0.01$.

Table 5 Percent of live time spent in high-intensity activity by various positional groups in the different quarters of the matches

Position	Q1	Q2	Q3	Q4
All positions (n = 18)	17.58 (1.76)*	16.53 (1.58)	16.73 (1.40)†	13.64 (1.33)
Guard (n = 6)	19.18 (1.10)‡§	17.49 (1.41)¶	17.50 (1.57)**†	14.29 (1.48)**
Forward (n = 6)	17.97 (0.69)¶§	17.08 (0.82)**	17.14 (0.88)††	14.13 (0.83)
Centre (n = 6)	15.61 (1.00)§	15.01 (1.25)‡‡	15.54 (0.90)††	12.49 (0.89)

Q, quarter.
Data are mean (SD).
*Values are significantly different from those obtained in the second quarter, $p<0.001$.
†Values are significantly different from those obtained in the fourth quarter, $p<0.001$.
‡Values are significantly different from those obtained by centre, $p<0.001$.
§Values are significantly different from those obtained in the second quarter, $p<0.05$.
¶Values are significantly different from those obtained by centre, $p<0.01$.
**Values are significantly different from those obtained by centre, $p<0.05$.
††Values are significantly different from those obtained in the fourth quarter, $p<0.05$.
‡‡Values are significantly different from those obtained in the third quarter, $p<0.05$.

Table 6 Absolute heart rate in the different positions and quarters of the matches

Position	HR (beats/min) Q1	Q2	Q3	Q4
All positions (n = 38)	173 (4)	173 (5)	173 (4)*	167 (4)
Guard (n = 8)	176 (4)†	176 (5)†	176 (4)†‡	170 (4)
Forward (n = 18)	173 (5)	173 (5)	174 (4)*	167 (4)
Centre (n = 12)	171 (3)	170 (3)	171 (4)§	165 (4)

HR, heart rate; Q, quarter.
Data are mean (SD).
*Values significantly different from those obtained by centre, $p<0.0001$.
†Values are significantly different from those obtained in the fourth quarter, $p<0.05$.
‡Values are significantly different from those obtained in the fourth quarter, $p<0.05$.
§Values are significantly different from those obtained in the fourth quarter, $p<0.01$.

Forty-one percent of live time was spent in "specific movements" (table 4). This is greater than the 32% reported for Australian professional players,[1] suggesting a more direct style of play in junior Tunisian competition. Results according to playing position show that guards averaged more "specific movements" at medium intensity than the other positions. Such movements required a great deal of energy expenditure during competition when playing under the "8–24 s rule", and consequently it should form an integral part of physical conditioning for basketball.

In this investigation, players spent 16.1% and 29.9% of live time in high-intensity activity and both walking and standing still, respectively (table 4). When comparing these results to the 15% and 35% reported for Australian professional players,[1] the high-intensity nature of the Tunisian elite under-19-year-old match play is highlighted. Centres spent more live time in recovery, but were involved in less high-intensity activity than guards and forwards. This may be because centres usually spend most of the time close to the basket whether in attack or defence, and thus represent the focus of their partners' movements. The fact that centres were considerably taller and heavier than the other groups, also noted in recent observations,[21 22] may have limited their performance during competition. Furthermore, although not of statistical significance, the lower VO_2max of centres, compared with guards and forwards, could also explain their impaired performance as a positive relationship was noted between the live time spent in high-intensity activity and VO_2max ($r = 0.55$, $p<0.05$).

A decrease in the amount of high-intensity activity in all playing positions was observed during the second and fourth quarters (table 5) compared with those recorded during the first and third quarters. In soccer, impaired work intensity is reported towards the end of the match due to the low quadriceps muscle glycogen concentrations in a considerable number of individual muscle fibres.[3 23 24] Recent research has also shown that a decline in both core and quadriceps muscle temperature at half time is associated with an inhibited soccer players' ability to perform maximally at the onset of the second half.[25] This, however, has not been observed in this study as all players averaged moderate-intensity activities in the interval between the halves (re-warm-up), which even allowed centres to increase their amount of high-intensity activity during the third quarter. Tactical strategies can also explain the decline in high-intensity activity in the fourth quarter as during the last minutes of a game, teams are likely to manage a further control of ball possession. Consequently, the proportion of straight play and fast breaks decreases, causing the whole pace to slow down.

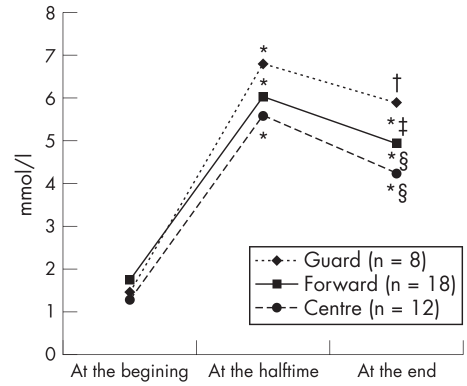

Figure 1 Plasma lactate concentration in the different positions at the beginning, at half time and at the end of the matches. *Values were significantly different from those obtained at the beginning, $p<0.01$. †Values were significantly different from those obtained by centre, $P<0.05$. ‡Values were significantly different from those obtained at the half time, $p<0.01$. §Values were significantly different from those obtained at the half time, $p<0.05$.

Heart rate

The range of mean match heart rates (87–95% maximal heart rate (HRmax)) reported previously in basketball[1 2 26] shows that the physical demands of this sport may vary according to many factors, such as the level of competition, tactical strategies and the physical capacity of players. In this study, the mean (SD) heart rate during total time was 171 (4) beats/min (91% (2%) of HRmax), which reflects the considerable demands placed on the cardiovascular capacity of the players in competition. These values and those observed during recent investigation in women[2] are greater than that noted in the work of McInnes *et al*,[1] and we may assume that modern basketball matches are probably played at higher exercise intensity than before the "8–24 s rule".[1]

The mean heart rate during the match seems to be higher than that expected from the live time spent in high-intensity activity. This may be related not only to the large physiological requirements associated with specific movements,[1] acceleration, deceleration and changing directions during running,[18] but also to the rapid turnover of the 168–242 brief intense actions and the upper-body demands of shooting, passing and rebounding.[1] Analysis by playing position shows that the heart rate for guards was greater than that for centres in the first three quarters and consequently during the entire game. Such finding agrees with that of national and international women's basketball,[2] and is supported partially by the time–motion analysis showing a significant difference between players for these positions in the live time spent in low- to high-intensity activities and recovery. However, the comparable heart rate for forwards and centres was in disagreement with forwards' greater involvement in high-intensity exercise (table 4), and this could be explained in different ways. Firstly, heart rate is not only influenced by exercise intensity and duration but also by other factors such as psychological arousal and anxiety.[27] No significant relationship was noted in this study between the heart rate responses and the percentage of time spent in high-intensity activity. Secondly, some bouts of static work in which centres are usually involved such as screening, blocking and maintaining position against physical resistance from a competitor, which we could not investigate for methodological reasons, may also have contributed to the high heart rate responses of the centres. During such activities, nearly all the muscles are involved in isometric and dynamic work, which has a noteworthy effect on the heart rate values reached.[28] Activities of static exertion deserve further investigation as they probably contribute to the demands of basketball.

Previous studies in field sports[29] showed that the heart rate values decreased in the second half, and this has been associated with the decreased percentage of live time spent in intense activities. Although the intensity of exercise in this investigation decreased markedly in all playing positions during the second and fourth quarters, heart rate values declined only during the last quarter (table 6), which reflects that they represent an indirect estimation of exercise intensity.[30] The increase in stoppage time in the fourth quarter can also explain this result. McInnes *et al*[1] reported that the major reduction in heart rate responses occurred during free throws and time-outs, when they decreased approximately to 70–75% and 60% of HRmax, respectively.

Blood lactate

Blood lactate concentration in basketball[1 2] has been reported to be between 3.7 and 13.2 mmol/l, with a large variability between players and standards of competition. The mean (SD) plasma lactate concentration of 5.5 (1.3) mmol/l recorded in this study did not allow us to have an accurate estimation of the anaerobic glycolytic contribution to metabolism during the entire match because of the limited lactate determinations. It has been shown that blood lactate measurements in basketball[1] is related to the incidence of high-intensity activity 5 min before blood sampling. A similar correlation was observed in our work, and the interpretation of lactate values is limited to giving an indication of the type of activity that has been carried out towards the end of each half.

Our plasma lactate results seem to be lower than those observed immediately after a high-intensity intermittent exercise,[31] and this may be associated with the short duration of any high-intensity activities (<3 s). Price and Halabi[32] observed that after 10 min of sprint intermittent exercise at different work–rest durations, blood lactate concentration was considerably lower in the short work–rest trial (6–9 s) than in the medium (12–18 s) and long (24–36 s) trials.

This study showed that players' plasma lactate concentrations at half time were greater than at full time (fig 1). It seems that the decline in live time spent in high-intensity activity and the increase in stoppage time in the fourth quarter have resulted in a high splanchnic blood flow, which seemed to ensure a larger uptake of lactate by the liver to resynthesise glycogen (gluconeogenesis). Thus, the later stages of the second half were probably played at lower intensity than those in the first half. Nevertheless, we cannot make any deductions about the muscle lactate concentrations. Krustrup *et al*[3] have lately reported that muscle lactate concentration was not correlated with blood lactate concentration during a soccer game. A scattered relationship has also been observed between muscle and blood lactate concentrations when participants performed repeated intense exercises using the yo–yo intermittent recovery test.[33] This has been explained by the higher rate of lactate clearance in muscle than in blood during recovery periods.[3 23] Analysis by playing position shows that plasma lactate concentration for guards at full time was higher than that for centres (fig 1). This finding was partially supported by the greater amounts of high-intensity activities in which guards were involved in the last quarter of the game.

This study, however, shows a need for lactic-acid-tolerance training for basketball players to improve intramuscular buffering capacity. Bishop *et al*[34] reported that the ability to buffer H^+ is important for maintaining performance during brief repeated sprints. Aerobic conditioning is also essential to improve lactate removal during recovery as reduction in oxygen availability during high-intensity exercise is associated with a higher accumulation of lactate in blood and an impaired ability to maintain a high-power output.[11]

To obtain accurate knowledge of the anaerobic energy production in basketball when playing under the "8–24 s rule", further investigation involving repeated analysis of blood and muscle lactate of subjects throughout several games would be necessary.

What is already known on this topic

- Competitive basketball entails intermittent exercise with bouts of short, intense activity punctuating longer periods of low-level, moderate-intensity exercise and recovery.
- It is characterised by involving a large number of discrete movements, each lasting <3 s, with frequent changes in intensity.
- The physiological requirements of men's basketball are high, placing considerable demands on the cardiovascular and metabolic capacities of players.
- The majority of play time is devoted to activities aerobic in nature. The glycolysis makes an important contribution to the energy demands of basketball.
- In women's basketball, it has been reported that the intensity developed in an official game is not reached in practice sessions. Different levels of intensity exist in the same game, and the physical demands in female competition vary according to playing position and standards of competition.

What this study adds

Four major findings emerged from this study:

- The changes to the basketball rules of May 2000, which consist of shortening the attack time from 30 to 24 s and the time allowed to cross the median line from 10 to 8 s, as well as subdividing the duration of play into four 10-min quarters instead of two 20-min halves, have lead to an increase in game intensity.
- The first and third quarters of a basketball game were played at higher exercise intensity than the second and fourth quarters. Indeed, impaired physical performance occurs during the second and fourth quarters for players in all positions.
- A large contribution from the anaerobic energy systems was concluded towards the end of halves, particularly in the first half.
- As for women, analysis by playing position in men's shows the greater cardiac and metabolic efforts in which guards were involved during competition compared with forwards, especially centres.

CONCLUSION

In combination with the time–motion analysis, the heart rate responses for Tunisian under-19-year-old players show that modern basketball matches are played at a slightly higher intensity than earlier—that is, before the changes to the rules in 2000. Plasma lactate determinations show a large contribution from the anaerobic energy systems towards the end of the halves. Analysis by playing position shows the greater cardiac and metabolic efforts in which guards were involved compared with centres. Reduced performance occurs during the second and fourth quarters for players in all positions. Finally, as this study is the first to focus on men's basketball competition when playing under the "8–24 s rule", further investigations are recommended to confirm these findings.

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COMMENTARY

Physiological demands imposed during a basketball game are dependent on the style of play. Although data on physiological responses during a competitive game are limited, several studies have examined heart rate and blood lactate response during competition. This study increases our knowledge on the position-specific physiological demands of basketball as well as the effect of the changes in the rules of basketball. Indeed, game intensity may differ according to the playing position—being greatest in guards. Also, in combination with the time–motion analysis, the heart rate response demonstrates an increase in game intensity owing to changes in the rules in 2000.

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