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Energy Demands and Metabolic Equivalents (METS) in U-19 Basketball Refereeing During Official Games

Mohamed Ali Nabli[1,2*], Nidhal Ben Abdelkrim[1], Carlo Castagna[3], Imed Jabri[4], Tahar Batikh[4] and Karim Chamari[5]

[1]Tunisian Research Laboratory Sports Performance Optimization, National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia

[2]Department of Biology, Faculty of Sciences of Bizerte, University of Carthage, Bizerte, Tunisia

[3]School of Sport and Exercise Sciences, Faculty of Medicine and Surgery, University of Rome Tor Vergata, Rome, Italy

[4]Higher School of Sciences and Techniques of Tunis, University of Tunis, Tunis, Tunisia

[5]Athlete Health and Performance Research Centre, Qatar Orthopedic and Sports Medicine Hospital, Doha, Qatar

*Corresponding author: Mohamed Ali Nabli, Faculty of Sciences of Bizerte, University of Carthage, Tunisia, Tel: +974 6651377 / +216 55 947040; E-mail: nablimedali@live.fr

Abstract

The metabolic demands among U-19 basketball players were studied; however, physical and physiological demands of U-19 basketball refereeing during competition are rather scant. The aim of this study was to analyze the energy expenditure (EE) and the exercise intensity of basketball refereeing during official game and determined as Metabolic Equivalent (METs). Sixteen elite level basketball referees were studied during U-19 basketball games (n=8) for time motion analyses (TMA). The EE data were calculated, using specific equations, from the time spent by the referee in each exercise-intensity zone. During game, referees spent a mean EE of 504.4 ± 77.7 kcal. A significant difference was observed between 113.5 ± 18.2 kcal in the 1st quarter (Q1) and 137 ± 27.5 kcal in the Q4 (p=0.007). The averaged EE (~5 kcal.kg^{-1}.h^{-1}) corresponded to "moderate energy intensity" (~5 METs) with a large contribution of the aerobic energy pathway. In all, during 88% of game the intensity was equal or lower than 3.8 METs and in 12% it was higher than 9.8 METs which were considered as low to high-intensity thresholds, respectively. The energetic profile studied in this research confirms that basketball refereeing may be regarded as a clearly intermittent-activity mode with a predominantly aerobic metabolism solicitation. Referees officiating in U-19 basketball games should carry out a physical conditioning regime that prepares them for such an effort.

Introduction

Interest in quantifying energy expenditure (EE) in a variety of sports has increased dramatically in recent years. In fact, EE monitoring could provide information on energetic and metabolic demands during official competition. In basketball, the EE of players during a game is considered to range between 360 and 660 kcal h^{-1} [1]. In this context, the recommended energy intake is 4500-5000 kcal for male basketball players [2]. Moreover, Salarkia et al. [3] reported that professional basketball player's energy requirement may equal to 3900 kcal day^{-1}. But it's recognized that basketball player's energy requirement is not stable; EE could vary according to the changes in the frequency and intensity of training sessions, exercises and games [4].

The EE is the metabolic energy equivalent of the physical activity [5]. EE during activity could be measured to determine a diet that appropriately restores the athlete's EE during training and/or game [5]. Perfectly, EE should be quantified by measuring oxygen uptake (VO$_2$) in continuo during the game using indirect calorimetry [5]. However, this is not possible during official games, due to evident practical constraints. Even during training, the eventual use of metabolimeters is hardly considered for obvious reasons. Consequently, other variables, either tightly or basely related to EE and physical activity, have been considered and used. The heart-rate (HR), body-temperature [6],

estimated VO$_2$ [7], nutritional assessment and food intake [3], muscular creatine-phosphate and blood-lactate concentration [8], could be listed as a substitute variables. Osgnach et al. [9] relatively recently applied to the time motion analyses (TMA) values a computational approach to calculate EE during official soccer competitions. Nevertheless, compared to the amount of details collected on players, there is a deficiency of information describing the physical activity of referees during game [10].

There are many researches that tried to examine the EE on soccer referees during the match. Da Silva et al. [4] estimated the EE on Brazilian soccer referees during professional match. The soccer referee's estimated match energy demand varied from 3500 to 4000 kcal.day^{-1} [4]. Ardigò et al. [11] used the global positioning system (GPS) to quantify EE and physical activity variables during soccer refereeing. However, studies conducted on basketball referees are rather scant; the only available study [7] has analyzed the basketball referees' EE during the game by relating the HR response in the game to the laboratory-determined relationship between HR and VO$_2$. Determination of VO$_2$ requirement during the game permit the quantification of athlete's EE with thinkable accuracy [12]. Since, on average, 5 kcal are resulted for 1 liter of consumed oxygen, it is possible to express EE during the game in kcal [4]. Also, the intensity of basketball referee's physical activity during games has been evaluated by the recording of HR [7].

Another means of estimating EE during the physical activity implies the statement in terms of Metabolic Equivalent (METs). For defining, a

MET represents the resting VO_2 and is set as the EE (VO_2) as $mlkg^{-1}min^{-1}$ or $Lmin^{-1}$ in rest conditions [13]. Consequently, the EE of a physical exercise can be defined in multiples of resting VO_2, which simplifies the calculations of energy requirements during the effort. According to Wilmore et al. [14], all physical activity can be categorized by the intensity according to their requirements in oxygen. Therefore, through METs calculations, it is possible to categorize the intensity of different physical exercise [13]. Recent researches have showed that basketball refereeing is an activity model principally linked to the aerobic pathway [15,16]. However, it is also useful to convert this into an EE and the intensity of referee's physical activities performed during a game presented in METs to assist with conditioning and nutritional programs [4]. Therefore, the aim of the present study was to determine the EE and the intensity of the physical activity (expressed in METs) performed by U-19 basketball referees during a game.

Materials and Methods

Participants

This study included 16 male Tunisian referees (age: 35.7 ± 9.11 years, weight: 80.3 ± 7.54 kg, height: 1.80 ± 0.07 m and body mass index: 24.7 ± 1.51 kg m^{-2}), 4 were classified as international referees and 12 as national referees with an average experience of 12 ± 10 years as basketball referees. They have been referees at senior level. The participants were observed during official games and each referee was measured on one occasion only. All referees had medical clearance for the physical activity. Referees were aware of the experimental protocol and risks and benefits without being aware of the aim of this study. They signed an informed written consent, before starting the investigation. The study protocol was in accordance with the guidelines planned by the World Medical Assembly Declaration of Helsinki and was approved by the University Ethics Committee [17].

Study design

This study was conducted during the play-off phase of the Tunisian U-19 basketball championship (April–June 2013, the season started in October 2012). In this study, a total of 8 official games of the play-off phase were considered. Games were performed on separate Sundays (one game per week) but all were held at the same hour (i.e., starting at 4:00 pm) and under close warm environmental conditions (i.e., 28-31°C). The game-duration composed of four 10-min Q with a 15-min interval at half-time (between 1st half: Q1+Q2 and 2nd half: Q3+Q4) and a 2-min break between the Q of each half (e.g. Q1 to Q2).

Referees' activities were assessed using video TMA. EE values were determined, using fixed equations; from the duration spent in each physical activity (see methods).

The data here provided are part of a main project that examined the game performance and fitness status of North African elite level basketball referees. The TMA data in this study was re-used from the original source [18] to analyze the referee's energy expenditure. Other sub-set data such as the physiological measures of the participants (i.e., heart rate and blood lactate concentration) were published elsewhere [18].

Time–motion analysis (TMA)

Game activities were monitored by means of a device using a technology similar to that reported by Ben Abdlekrim et al. [19]. Video recordings were collected using a fixed camcorder (Sony®, model Handycam CCD-TRV 128) tied to a tripod, installed ~5 m far away from the sideline at half-court, at a height of ~12 m (depending on the sport hall concerned) to permit full coverage of the court. The software adopted in this time–motion analysis (PC-foot® 4) allowed the detecting of the referees' positions in each frame [20]. The court calibration was made by the same software using the dimensions that applied by the FIBA rules. The adopted algorithm was based on the subtraction of the background applying a statistic modelling, and comprises the following proceedings: initialization, motion-extraction and update of the model [19].

The video registration was analyzed frame by frame to a precision of 0.04 second. The video series could be visualized at any selected speed, allowing analysis of the motion. The following locomotive categories were used: standing/slow motion (0-2.92 km h^{-1}), walking (>2.92-7.34 km h^{-1}), jogging (>7.34-10.11 km h^{-1}), running (>10.11-14.83 km h^{-1}) and sprinting (>14.83 km h^{-1}), while the mean speed for each category was calculated after analysis of the video series. The time for the participant to pass known distances pre-markers in the court was used to calculate the speed for each motion activity. These categories were chosen in accordance with a previous study on soccer refereeing, in absence of any study on basketball [4]. Then these categories were classified in: (1) low-intensity activities; including standing/slow motion and walking (2) moderate to high intensity activities; including jogging, running and sprint.

A total-time refers to all of game-time comprising all play-stoppages, but excluding breaks between Q/half times. The frequency and time spent in each motion category was digitally registered by the same experienced observer. These data were used to determine the referees' distance covered in each motion category. The total distance covered during each moment of the game was determined by adding the distances covered in each motion category. Reliability of TMA was studied by repeating the analysis of two games by the same experimenter one month apart. For each game the complete analysis of the 2 referees was performed and then reliability analysis was conducted. Game analysis and reliability assessments were performed by the same experimented investigator. According to Hopkins [21] the analyses of relative and absolute reliability of TMA have shown similar and good reliability (Table 1). These results of reliability were alike to that found in previous studies that involved soccer referees [4,20,22] and basketball players [19].

	ICC	%SEM
Walking	0.99	0.005
Jogging	0.99	0.52
Running	0.74	0.58
Sprinting	0.97	0.63
ICC: Intra-class-coefficient; %SEM: Standard error of measurement in percentage		

Table 1: Relative and absolute reliability of time-motion measurement (n=4).

Energy expenditure (EE)

EE values were determined from the time referees spent in each physical activity zone. The following equations were used to estimate the oxygen uptake (VO_2) during: (i) running and sprinting: $VO_2 = 3.5 + (0.2 \times m\ min^{-1})$, (ii) walking: $VO_2 = 3.5 + (0.1 \times m\ min^{-1})$, both proposed by the American College of Sport Medicine [23]. VO_2 during jogging was estimated by the equation proposed by Bubb et al. [24] $VO_2 = 3.5 + (km\ h^{-2} \times 0.394)$. EE during the time participants stayed standing-still was estimated multiplying the basal metabolism constant 3.5 ml kg^{-1} min^{-1} by the average body mass. Then, the value of estimated VO_2 was transformed in kcal, multiplying it by 5 [14].

The quantification of referee's EE throughout the game in METs was possible by estimating the VO_2 expended in each motion category [4]. For an adult, 1 MET is equal to ~3.5 ml of oxygen uptake, for kilogram of body mass per minute (1 MET = 3.5 $mlkg^{-1}$ min^{-1}). For example, a two MET activity request two times the metabolic EE of standing still. Therefore, the EE was estimated by dividing the estimated VO_2 of each motion category by the constant 3.5 [4].

Statistical analysis

All data are presented as mean ± standard deviation (SD). The normality's assumption was tested using the Shapiro-Wilk test for each variable before conducting any statistical parametric test. To compare in between Q, analysis of variance (one-way ANOVA) was used. When necessary, the post-hoc Tukey's test was applied. To compare in between halves, an independent samples T-test was used. The relative and absolute reliability of the TMA were determined with Intra-class-coefficient (ICC) and using the standard error of measurement (SEM) [25], respectively. All statistical calculations were determined using SPSS 19 program for Windows (SPSS, Inc, Chicago, IL, USA). The significance level considered for all the statistical analysis was set at $p<0.05$.

Results

Absolute and relative reliability calculations are reported in Table 1. TMA showed acceptable relative (ICC 0.70–0.99) and absolute reliability (% SEM 0.005–0.63%). Table 2 introduces the total average time spent in each physical activity zone during the game. Referees expend more of the time walking, and high-intensity activities (running and sprinting) amounted for ~6 minutes. Table 3 shows the mean whole distances covered in each motion category during game. The mean whole distance covered was 3907 ± 848.5 m, referees spent 81% of game time by walking, 7% by standing/slow motion, 6% by jogging, 4% by running, and 2% by sprinting.

	Standing	Walking	Jogging	Running	Sprinting	Total
Game	5.5 ± 1.2	63.5 ± 2.1	3.6 ± 0.2	4.2 ± 0.3	1.4 ± 0.2	78.4 ± 4.2

The values represent the mean ± SD of the duration of each motion action expressed in minutes

Table 2: Time in minutes spent in each motion activity (n=16).

Table 4 shows the results for the EE in each motion category. The entire game EE was 504.4 ± 77.7 kcal with significant differences observed between 113.5 ± 18.2 kcal in Q1 and 137 ± 27.5 kcal in Q4

(p=0.007). A means of 127.4 ± 26.4 kcal and 126.6 ± 22.2 kcal, were observed as the referees' EE in Q2 and Q3, respectively. A non-significant (p=0.14) difference was observed between EE in the 1st and 2nd half 240.9 ± 42.4 and 263.6 ± 42.9 kcal, respectively (Figures 1 and 2).
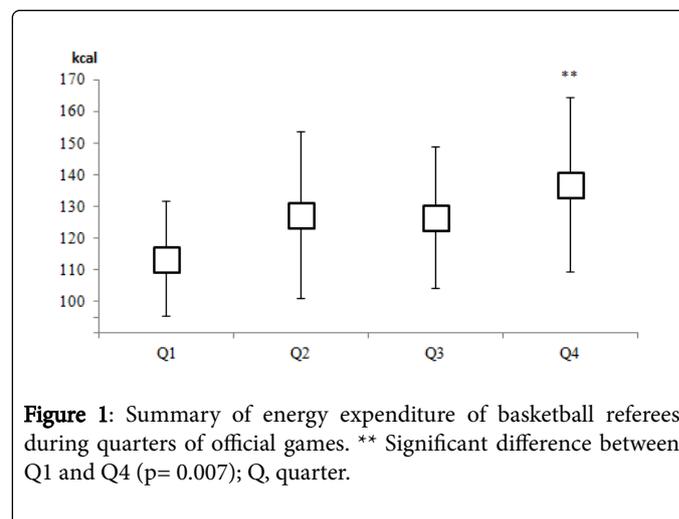
Figure 1: Summary of energy expenditure of basketball referees during quarters of official games. ** Significant difference between Q1 and Q4 (p= 0.007); Q, quarter.
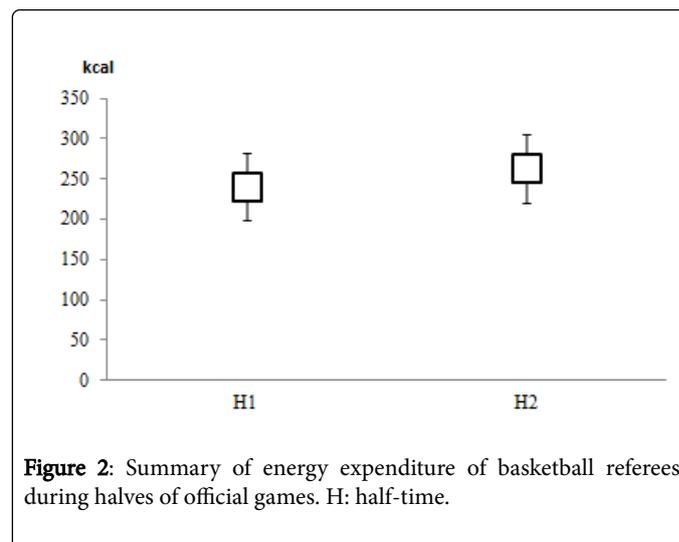
Figure 2: Summary of energy expenditure of basketball referees during halves of official games. H: half-time.

The mean EE was ~5 kcal kg^{-1} h^{-1} that corresponded to ~5 METs. This was considered as moderate energy intensity. The referees spent 88% of the game time at walking and standing/slow motion as low intensity (~3.8 METs) and 12% of the game time by jogging, running and sprinting as moderate to high intensity (higher than 9.8 METs).

The large to bass-intensity exercise ratio may be expressed as ~1: 12. This reflects that an important-intensity action occur every ~12 low-intensity actions. The basketball referees expend 4357 seconds at bass-intensity activities and 355 seconds at high-intensity.

Walking	Jogging	Running	Sprinting	Total
2036 ± 668	447 ± 139	927 ± 369	486 ± 186	3907 ± 848

The values represent the mean ± SD. The distances are described in meters

Table 3: Distance covered by referees during game-play (n=16).

	Speed (m s⁻¹)	Speed (m min⁻¹)	Estimated VO₂ (ml kg⁻¹ min⁻¹)	Estimated VO₂ (L min⁻¹)	Time (mm:ss)	kcal
Standing			3.5	0.3	5.5	8.2
Walking	1.6	97.5	13.3	1.1	63.5	338.9
Jogging	2.5	147.9	34.5	2.8	3.6	42.7
Running	3.2	189.8	41.5	3.4	4.2	72.2
Sprinting	5.1	304.8	64.5	5.2	1.4	42.5
Total					78.4	504.4
VO₂: Oxygen uptake						

Table 4: Calorific expenditure per motion action during game-play (n=16).

Discussion

This is the first research to investigate the energy expenditure (EE) of U-19 basketball referees during game after FIBA rule changes in May 2000. The latter changes consisted of reducing the attack duration from 30 to 24 s and the time permitted to get over the median-line from 10 to 8 s, as well as, the game consisted of four 10-min quarters (Q) in place of two 20-min halves [19]. In the present study, the total game EE was 504.4 ± 77.7 kcal with a significant improvement in EE was showed in the 4th quarter (Q) compared to 1st Q. It was observed that during games referees performed large periods of bass-intensity exercise interspersed with short sequences of intense-exercise. In all, during 88% of game-time the intensity was lower than 3.8 METs, in 12% it was higher than 9.85 METs. Overall the results show that basketball refereeing may be defined as an intermittent exercise mode with permanent aerobic source [17].

During the game, referees covered a mean distance of 3906.94 ± 848.5 m. This value was similar to that observed in Borin 'study [16] during the qualifying phase of the competition in the Brazilian Basketball League (3026-4770 m), which officiated by the 3 referees system and involved the FIBA rules (game was consisted of 4 × 10 min Q). But data were lower than those observed by Lončar et al. [26], who reported that basketball referees covered an average distance of 5921 m and 6773 m during a Slovenian Basketball League Play-off that officiated by 3 referees and 2 referees, respectively. These differences could be partially linked to different factors, such as; the competitive level of the analyzed games [4]. In fact, the distances covered by referees in a basketball game may be increased throughout competition phases [16].

However, the whole distance covered during a game is an insufficient indicator of the referee's physical requirements during a game, since standing/slow motion and walking account for ~88% of total activity. In this context, the quantity of high-intensity exercise is a preferable informer of the demanding periods of the game and the evolution of fatigue [27].

An 81% of game time was performed by referees at a low intensity (i.e., walking). Also, they covered 52.1% of total distance by walking. The result in the present study was higher than that recorded previously [26] in Slovenian basketball referees during games officiated by 2 and 3 referees (32.4% and 37.5% of their total distance, respectively). Differences in game-tactics and game-intensity between

countries/teams are other reasons that should also be taken into consideration when comparing results [28,29]. The high percentage (81%) of exercise at bass-speed (walking) estimated in this study could be the consequence of an inferior game-intensity of the regional tournament where referees officiated, and/or differences in game character between North African and Europeans players. In addition, players' tactical strategies could also affect the referee's high-intensity exercise and especially in Q4 as during the last moments of a game, teams (i.e., U-19 basketball championship) are probably to manage a more dominance of ball possession [19].

Running at high (sprinting) and moderate-intensity velocities (running) are infrequently executed by basketball referees. In this study, running at high intensity (sprinting) didn't arise for more than 2% of entire time (Table 2). This was lower than what previously reported [25] in Slovenian basketball referees during games officiated by 2 and 3 referees (5.4% and 3.1% of their refereeing time, respectively).

In this research, a basketball referee's estimated EE during the game was 504.4 ± 77.7 kcal. In basketball, studies performed so far on EE of referees are relatively scant. Rupcic et al. [7] have estimated the energy consumption per min for each game period; energy consumption values were determined by HR–VO₂ relationship in laboratory conditions to estimate the EE. However, it is recognized that the treadmill protocol for determining HR-VO₂ could overestimate the game VO₂. For example, direct measurements of VO₂ in football referees during a game registered a value of EE of 1195 kcal, and the value quantified by the recording of HR was 1565 kcal, in average [30]. The equations applied in this study to estimate the VO₂ during physical activity used the average velocity for each category. Also, to estimate basketball referee's EE, TMA in this study did not take into account some referees' movements, such as acceleration, deceleration and changing of direction. However, Osgnach et al. [9] reported that an important metabolic load was imposed on players not only over the maximally intensive moments of the game (knowing as high running speed) but every time acceleration is high, even when reached velocity is low. Moreover, because of the acceleration and deceleration phases, the variability in EE for the same total distance is approximately 15%. But, researches on accelerated (or decelerated) running are very limited because of the difficulty in using an energy approach in examining these types of exercises.

The results of the present study revealed a significant difference observed between 113.5 ± 18.2 kcal in Q1 and 137 ± 27.5 kcal in Q4 (p=0.007). The EE was significantly increased in the 2nd half by ~4.5%, a fact that could reflect the increase in low (walking) and moderate (running) activities performed during this period. Indeed, in the 2nd half, the distance covered in running was higher than the 1st half (t=3.45, p=0.004), the referees spent significantly more time in walking and running than the 1st half (t=2.75, p=0.009 and t=3.95, p=0.0004, respectively). This result may be reached by a good referee's physical fitness. Indeed, a good physical preparation could improve the referees' ability to keep up with play [31]. Also, referee's thermoregulation and rehydration processes could affect their EE during last period of competition. Indeed, referee's rehydration during the half-time interval may contribute to enhance their performance towards the end of the game [32]. However, Rupcic et al. [6] haven't reported a significant differences in the EE between the 1st and 2nd half-time (14 ± 2 vs 13.7 ± 1.9 kcal min⁻¹), as well as between particular quarters of basketball games.

The intensity of the physical activity couldn't be determined, when the whole or partial EE of each motion enunciated in kcal. However, it is possible to create another way to express the EE and also of classifying the physical activity according to its intensity, using MET, when the estimated VO_2 of each motion action was assumed. As mentioned above referees spent 81% of the game-time at walking, an exercise with an estimated VO_2 of 13.25 ml kg^{-1} min^{-1}, which equivalents to an EE of 3.8 METs. Also, 7% of the game-time was spent in standing/slow motion, with an estimated VO_2 of 3.5 ml kg^{-1} min^{-1}, and an EE of 1 MET. Consequently, during 88% of the game, they execute physical activities that could be categorized as low-intensity, aerobics [13,33]. The rest 12% of game-time is expended performing the physical activity using energy deriving from the aerobic and anaerobic pathways (jogging, running and sprinting). In jogging, the estimated VO_2 was 34.5 ml kg^{-1} min^{-1}, which corresponds to 9.9 METs, an effort expressed as intense [33]. During 6% of the game time, referees performed running or sprinting motions, with an estimated EE of 41.5 VO_2 ml kg^{-1} min^{-1} (11.9 METs) and 64.5 VO_2 ml kg^{-1} min^{-1} (18.4 METs), respectively. Activities with energy consumption above 10 METs are classified as highly-intense [33]. Moreover, assessing energy intensity (i.e., MET) during games could provide information on referee's exercise load, with the related potential physiological adaptations. This study showed a specific ratio (~1:12) between high and low intensity exercises in basketball referees, which reflect their specific intermittent activity during official games.

The EE of basketball referees may vary according to many elements, such as (i) the level of competition (senior vs U-19). For instance, the games of the final phases could be played with a higher physical and physiological stress than qualifying or semi-final phases [16], (ii) tactical strategies; the ways how teams play their offensive or defense systems in each period of the game, may impact the referees' demands/responses. Indeed, during fast break action referees may require to perform a sprint to relocate themselves in strategical position with respect to player's action in the court, which impose a high EE, inversely to the zone offense playing style, where much less fast breaks are observed [19].

To get an objective measure of the average intensity of referee's physical activity during the game, the mediated average was used rather than the simple arithmetic average [4]. The amount of METs expenditure depends on the velocity, distributed in five categories in the present study. For instance, the part of METs spent in the condition "standing/slow motion" is far lower compared to sprinting. Besides, there is an important difference in the whole time of permanence in activities of high and low-velocity. Therefore, determination of the mediated average clearly decreases the possibility of obtaining biased outcomes by the highlighted reasons [4].

Based on the result of this research and using the classification adopted by Ainsworth et al. [13], it is feasible to identify the referee's physical activity as moderate energy intensity. This outcomes coincides with the values found in studies that estimated the intensity of referee's physical activity by means of HR [15,16].

The METs method was established to unify intensities of physical activity and improve comparison different researches [13]. The METs data found in this study, allows comparing the intensity of a referee's physical activity with the outcomes obtained in referees or athletes from other sports. The latter referees and athletes were indeed studied more precisely and their energy requirements were better established.

Specific nutritional programs for basketball referees should be appointed founded on physical and metabolic requirements tried during official games (~5 kcal kg^{-1} h^{-1}). The dietary habits must be suitable to their quotidian physical activities. Indeed, referees should develop a diet that relatively restores the referee's EE during training and/or official game. Therefore, the training session should focus on intermittent aerobic-exercise of low and moderate intensity and frequent maximal-intensity (sprints) bouts with a ~1:12 ratio of high intensity effort: recovery.

Conclusion

This study showed that during games from the Tunisian U-19 basketball championship referees covered on average, a distance of 3907 ± 848.5 m with a mean energy EE of 504.4 ± 77 kcal per game. Averagely, this physical activity corresponds to moderate energy-intensity (~5 METs) with large participation of the aerobic-energy pathway. However, during 88% of game-time the intensity was equal or lower than 3.8 METs (threshold of low intensity) and in 12% higher than 9.8 METs (threshold of high intensity). The character of activity observed in this statement justify that basketball referees, like players assume intermittent nature exercise.

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