

Analysis of the Physical Performance and Decision-Making of Football Referees in Hot and Humid Environments

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Abstract: The aim of the present study was to assess the acclimated central referee's activities during matches conducted under hot and humid conditions. The physical activity and number, the rightness or error of decisions taking was determined during Official matches of the 2018-2019 Djibouti's Football Championship. All matches were filmed with a digital camera. The movements were quantified as previously described by Da Silva protocol walking ($5.8\text{ km}\cdot\text{h}^{-1}$), backwards and agility movements ($8.9\text{ km}\cdot\text{h}^{-1}$), jogging ($11.4\text{ km}\cdot\text{h}^{-1}$), fast running ($18.3\text{ km}\cdot\text{h}^{-1}$) sprint ($25.2\text{ km}\cdot\text{h}^{-1}$). Polar V800 was used to quantify the distance covered, LongoMatch® to count the number of decision-making and also Kinovea® free software to measure the distance between central referee position and the offence emplacement (Location). The referee's group sample characteristic were: mean age of 29 ± 6.2 years, body mass of 66.3 ± 6.9 kg, stature of $1.76 \pm 0.1\text{ m}$, body mass index of $21.6 \pm 2.4\text{ kg}\cdot\text{m}^{-2}$ and a percentage of fat of $15.9 \pm 3\%$. Results showed that central referees covered during a match an average distance of $10113 \pm 820\text{ m}$. The patterns of total distances by acclimated Football referees in this study are lower with previous results observed under temperate conditions by other study. 122 ± 4.6 decisions per match have been made by referee. Compared to the first half, more decisions were taken in the second half ($P = 0.037$), with a significant decrease in decision making under-15m and an increase in decision making over 15m during the last 15min of the match ($P = 0.008$). Consequently, the distance separating the central referee position and the whistled action emplacement increased over time ($P = 0.005$) with qualities of decision. The number of decision-making was also comparable to the previous results observed during the Euro 2000 Football matches. In conclusion, acclimated referee's physical performance shows lower physical performances in the heat comparable to referees physical performance observed in temperate zone.

Keywords: African Football Referee, Physical Performance, Decision-Making, Location

1. Introduction

Sometimes football matches are played in hot and humid environment where temperatures exceed 30°C and relative humidity reached 50-70% [1]. Also, according to indeed in the current decade, no less than 5 main International Federation of Football Association (FIFA) competitions have been or will be organized in a hot environment with or not a high degree of humidity [2]. Football is an intermittent sport characterized by repeated high intensity activities with short recovery time.

Therefore, the physical and physiological demands are more important than a simple continuous physical activity such as walking or running [3]. It is commonly known that the physical requirements of the central referee are similar to that of a football player in terms of high-speed running and distance covered [4]. These authors have shown that high intensity activities are negatively affected in the heat [4]. During the World Cup 1994 in Brazil, Nassis and al. [5] observed a decrease in the number of sprints during the matches played under the heat conditions. In contrast, the

acclimatized subjects to the heat environment showed either maintenance of the performance level or an increased sprint during exercise [6].

In addition to these physical constraints, the referee must have also to face the mental fatigue induced by the pace of the game and due to the stressful conditions of the match [7]. Catterall and al. [8] have observed that physical fatigue can lead to situations where the referee might be located far from the offense place, which could affect his ability to make an appropriate decision is away from whistled action emplacement the scene of the infringement and therefore impairs his ability to make an appropriate (right) decision. They reported that the percentage of error increased (23%) during the last 15 minutes of the match [9]. Given that the last 15 minutes of each halt-time are crucial moments in the match, maximum decision-making is reached has been observed during these periods of the game [7]. In addition, exercise in the heat has been shown to induce an increase in the core temperature thus affecting cognitive function [10]. In view of these considerations, referees are in complicated situations to ensure their tasks appropriately.

Accordingly, the aim of this investigation is to study the physical performances, to quantify the decision-making and to measure the distance between the referee location and the offence emplacement (decision-making) of acclimatized central referee's during matches conducted under hot and humid conditions.

2. Materials and Methods

2.1. Participants and Procedures

15 national and international referees were used in this study. Their mean age, height, body mass and a percentage of Fat were: (29 ± 6.2 years, 66.3 ± 6.9 Kg, 176 ± 0.1 cm, and $15.9 \pm 3\%$). Anthropometric measurements were made according to the published guidelines [11]. With the agreement of the Djibouti Football Federation, all participants have signed consent after a verbal explanation of research activities to be carried out. The referees who participated in this study have all undergone standard medical tests and validated the official tests of FIFA to officiate the matches of the national championship and the international matches. The performances of the matches (physical and decision-making) of football referees in hot and humid zones were quantified by Polar V800 and a video analysis method using LogoMatch and Kinovea software. All the matches were filmed according to the protocol of Da Silva and al. [12], using a digital camera (Sony cam model CCD-TRV 128, Japan) mounted on a tripod positioned off the ground, perpendicular to the center line, at a height of approximately 15 m and at a distance of about 15 to 20 m from the area. All the matches of the first division national championship took place from 16:00 to 18:00.

2.2. Explanation of Experimental Procedures

When analyzing the matches with the LongoMatch®

software, we have quantified the types of displacements (number of steps, number of slow running, number of fast running, number of sprints, number of back running, number of agility movement) and also quantification of the number of decision-making. For to analyze the decision making qualities, an observation table was submitted to the technical instructors. An advanced analysis with video recoded matches was conducted by FIFA/CAF technical instructors. Polar V800 and using Kinovea® software we determined the distance traveled for each activity (Total Distance, Running Distance, Slow running Distance, fast running Distance, Sprint Distance) and also the distances between central referee position and the offence emplacement (Location). To quantify these results, we categorized the physical activities according to the study of Da Silva and al. [12] walking (5.8 km.h^{-1}), jogging (8.8 km.h^{-1}), backwards and sideways movements (8.9 km.h^{-1}) running (11.4 km.h^{-1}), fast running (18.3 km.h^{-1}), sprint (25.2 km.h^{-1}), were quantified. The number of decisions taken and the distance between the referee the offence emplacement were measured with the software LongoMatch® and Kinovea®. Statistical Analysis Descriptive statistics (mean \pm SD) were calculated for all the data collected. The data collected was processed by XLSTAT 2009.3.02. The data are compared using the "Student T" test for matched samples when the variables follow the same distribution law. Otherwise, the non-parametric "Wilcoxon" test and the Kruskal-Wallis test were used. The significance limit is set at $P < 0.05$.

3. Results and Analyses

Study was conducted under hot ($30 \pm 0.8^\circ\text{C}$) and humid ($67 \pm 3.5\%$) conditions. The total distance covered by referees during matches in hot and humid zones are 10113m and the high intensity running distance (Fast running distance + Sprint distance) are 1051m.

Table 1 present the distance and percentage of time covered by African Football referees in different activities such as (walking, jogging, high intensity: running, sprinting and agility movement: backward, sideways movement). The game are sequenced by 15mn time period. The average distance covered during the last 15 minutes of the first period is 1616 m ($P=0.020$) was significantly higher compared the distance during the last 15 minutes of the second period is 1558m. The average walking distance during the last 15mn periods of the second period is 864 ± 63 m ($P=0.022$) was significant compared the average walking distance in the last 15 minutes of the first period was 749 ± 39 m. The average distance in fast running during the last 15mn periods of the first period is 152 ± 3 m ($P = 0.005$) with a significant difference compared to the last 15 minutes of second period was 130 ± 1 m (see figure 1). The average distance of agility movement (Backward and unorthodox movement) during the 15-minute periods of the first period is 187 ± 15 m ($P = 0.017$) with a significant difference compared in the last 15 minutes of the second period was 156 ± 17 m. The percentage of time devoted to walking during the match is $50 \pm 0.7\%$ of the total time of the match. The jogging, fast running, the percentage of time is

respectively $26.3 \pm 1.6\%$, $5.4 \pm 0.4\%$ of the total duration. For Agility movement (Backward and sideways movement) the percentage of time is $5 \pm 0.6\%$ of the total duration of the

match. In addition, the field referee in hot and humid zone performs on average 1128 changes of activities of which 606 in low intensity and 140 in high intensity.

Table 1. Distance and percentage of the time covered by Football referees in different Locomotive categories.

Time	Activity	Standing	Walking	Jogging	High intensity running		Agility		Total
	Time				Fast Running	Sprint	Backward Running	Unorthodox movement & (Sideways)	
0-15mn	% time	5.4 ± 0.5	50.8 ± 1.4	26.4 ± 1.7	5.7 ± 0.6	0.3 ± 0.1	6.5 ± 0.1	4.5 ± 1.2	100
	Distance		1021 ± 32	556 ± 59	165 ± 5	20 ± 6	130 ± 8	96 ± 11	1988 m
15-30mn	% time	6.2 ± 0.6	48.7 ± 0.6	26.5 ± 2.7	5.5 ± 0.5	0.3 ± 0.1	6.2 ± 0.4	4.8 ± 0.8	100
	Distance		776 ± 98	451 ± 96	167 ± 8	19 ± 6	102 ± 10	87 ± 8	1602 m
30-45mn	% time	6 ± 0.9	50.3 ± 0.6	26.3 ± 0.6	5.1 ± 0.2	0.3 ± 0.1	6 ± 0.1	5.3 ± 0.2	100
	Distance		749 ± 38	521 ± 94	152 ± 3	17 ± 6	93 ± 10	94 ± 5	1626 m
45-60mn	% time	6.5 ± 0.1	50.7 ± 0.6	26.3 ± 1.5	5.5 ± 0.5	0.3 ± 0.1	6.2 ± 0.7	5.1 ± 0.9	100
	Distance		872 ± 34	473 ± 95	166 ± 6	19 ± 6	105 ± 17	87 ± 8	1722 m
60-75mn	% time	5.6 ± 0.7	49.3 ± 0.6	26.3 ± 1.2	5.6 ± 0.4	0.2 ± 0.1	5.8 ± 0.7	5.3 ± 0.9	100
	Distance		796 ± 39	454 ± 39	163 ± 2	17 ± 5	95 ± 6	92 ± 5	1617 m
75-90mn	% time	6 ± 0.5	50 ± 0.7	26 ± 1.8	5.1 ± 0.2	0.3 ± 0.1	6 ± 0.1	4.9 ± 0.8	100
	Distance		864 ± 38	382 ± 44	130 ± 1	16 ± 5	89 ± 11	77 ± 6	1558 m
Total	distance		5078 m	2777 m	943 m	108 m	614 m	531 m	10113 m

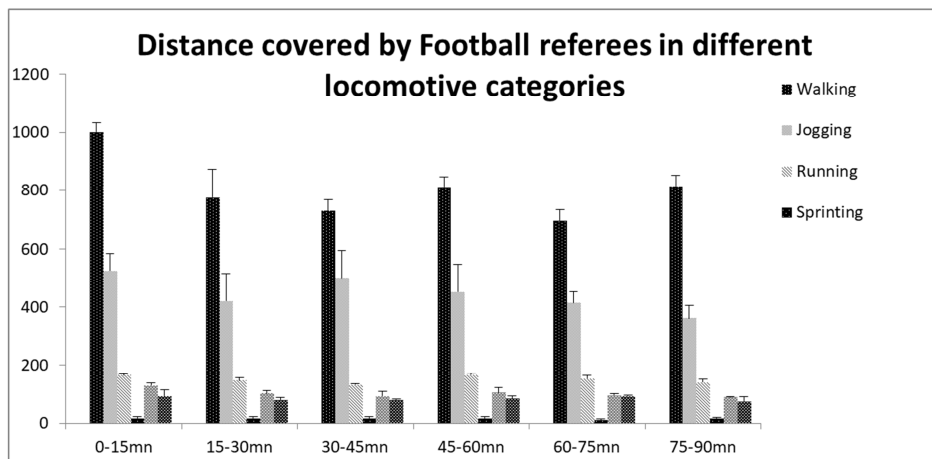


Figure 1. Percentage of the time covered by Football referees in different locomotive categories during the first and second half of the game by 15mn period.

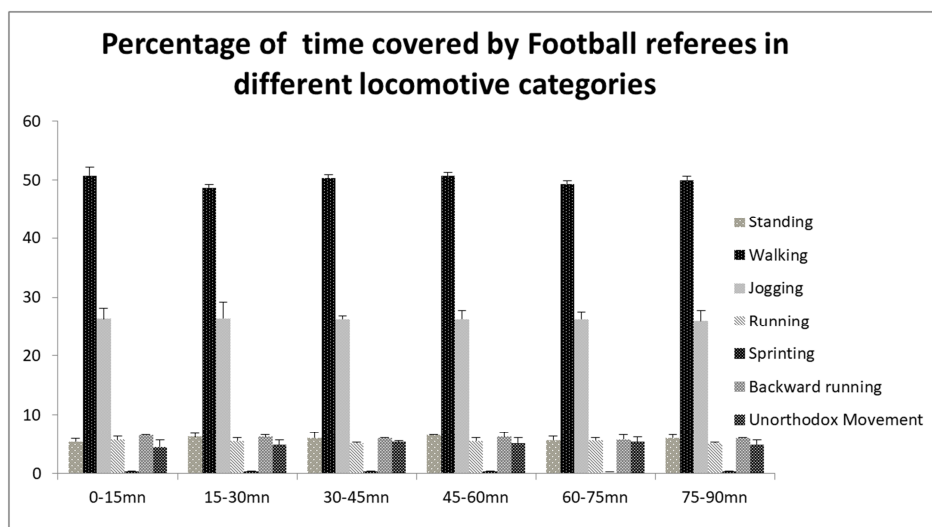


Figure 2. Percentage of the time covered by Football referees in different locomotive categories during the first and second half of the game by 15mn period.

Table 2 shows the average distance between the referee location and the offence emplacement (decision-making),

and the numbers of decision-making during the match. During the hot and wet zone, the referee takes an average of

122 observable decisions. The average of the distances where the distance between the referee location and the offence emplacement was less than 15m during the decision-making was 13.5 ± 0.2 m. The average of the distances where the referee was more than 15m from the offence of emplacement during the decision-making is 15.9 ± 0.5 m. In the last 15 minutes of the second period, the average of the distances where the referee is more than 15m from the

scene of the incident when he whistles is 17 ± 1.1 m with a significant difference ($P = 0.091$) and number of means 13 ± 1 decision making (see figure 2). In hot and humid zones, during the match the referee takes 42 decision-making where he was at a distance of more than 15m from the offence emplacement, this represents 1/3 of the total decision-making observed during the match (122 observable decisions).

Table 2. Number and distance of decision-making by referees lower or upper 15m in the place of infraction.

	Number decision-making < 15m	Number of decision-making > 15m	Distance of decision-making < 15m	Distance of decision-making > 15m	Total of number decision-making
0-15mn	15 ± 1	3 ± 1	11.6 ± 2.3 m	15.6 ± 0.2 m	18
15-30mn	13 ± 1	5 ± 1	13.6 ± 1.4 m	15.7 ± 0.3 m	18
30-45mn	11 ± 1	10 ± 1	14.2 ± 0.7 m	16.2 ± 0.4 m	21
45-60mn	16 ± 1	4 ± 1	12.9 ± 1.5 m	15 ± 0.5 m	20
60-75mn	13 ± 1	8 ± 1	13.7 ± 1 m	16.1 ± 0.7 m	21
75-90mn	11 ± 1	13 ± 1	14.7 ± 0.2 m	17 ± 1.1 m	24
Average	13.2 ± 1	7 ± 1	13.5 ± 0.2 m	15.9 ± 0.5 m	122

Table 3 showed that errors do not increase with increasing distance between referee's location and the offence emplacement. Not difference between C1 average: 0.7 ± 0.5 (error when the distance Less than 15m) and C2 average 0.8 ± 0.4 (error when the distance more than 15m).

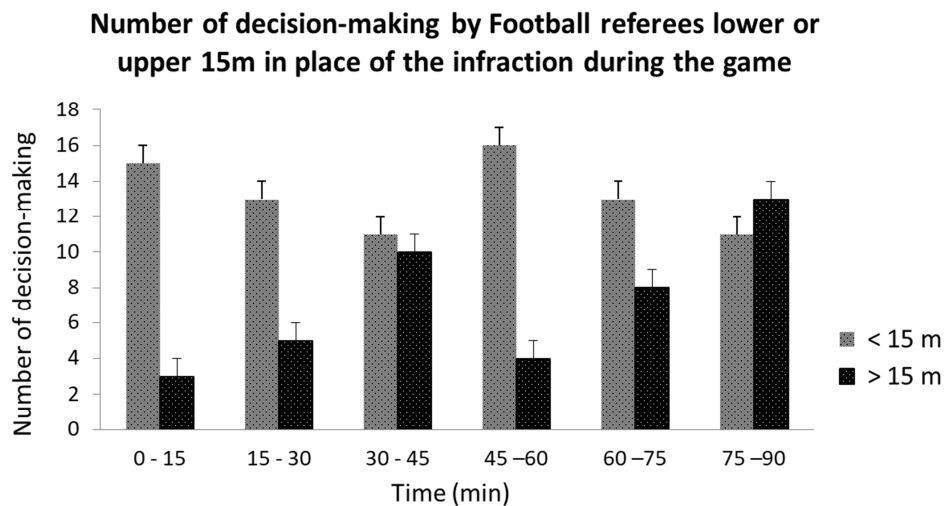


Figure 3. Number of decision-making by Football referees lower or upper 15m in place of the infraction during the first and second half of the game. Data are reported as means \pm SEM. $P < 0.05$ for the difference between the 15mn periods (Two-tailed Student t-test).

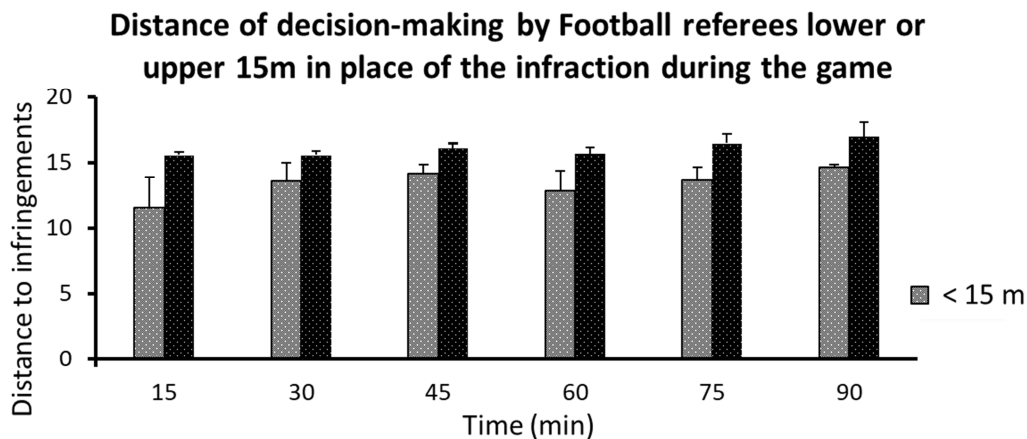
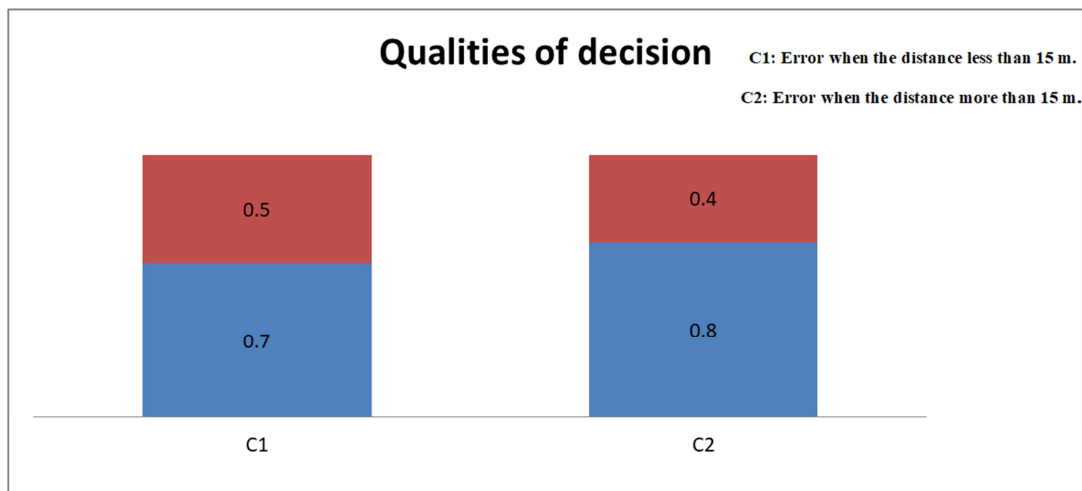


Figure 4. Distance of decision-making by Football referees lower or upper 15m in place of the infraction during the first and second half of the game. Data are reported as means \pm SEM in meters. $P < 0.05$ for the difference between the 15mn periods (Two-tailed Student t-test).

Table 3. Error of decision-making by referees lower or upper 15m in the place of infraction.

Nombre of referee's	C1: (error when the distance Less than 15m)	C2: (error when the distance more than 15m)
1	1	0
2	0	1
3	1	1
4	0	1
5	1	0
6	1	1
7	1	1
8	1	1
9	1	1
10	1	0
11	0	1
12	1	1
13	0	1
14	1	1
15	0	1
Average	0.7	0.8
Ecartype	0.5	0.4

**Figure 5.** Error of decision-making by Football referees lower or upper 15m in place of the infraction during the first and second half of the game.

4. Discussion

The aim of this study is to demonstrate the direct impact of heat on the physical performance of a central referee and the other hand to understand if the decrease in physical performance caused by heat can impact the distance between central referee position and the offence emplacement (decision-making) during matches. After analysis of the data collected, the most important results showed that the physical performance of the acclimated central referee decrease in the last 15 minutes of the second half of the match. At the same time the distance between central referee position and the offence emplacement (decision-making) increased during the second period of the game.

The total distances, the distances of fast running and in sprint covered by referees and football players don't show any differences [4]. In our study, the total distances and the distance of high intensity run covered by referee's (10113m; 1051m) in hot and wet zone are very close to that reported by the study with Brazilian Referee's under hot and humid conditions [12]. But our results are lower than the results of

Castagna and al. [13]. These authors have revealed that international Europeans soccer referees covered 11218m in total distance and 1277m in high intensity run in temperate zone. In this regard, others authors have shown that high intensity distances are negatively affected in the heat [4].

Also, the global intensity of the match is determined by the quantity of high speed running performed by the referees and players [14].

Other important aspect of refereeing is the capacity to follow the game. The referees must follow the game every time to ensure correct judgments. Therefore, the study of Weston and al. [4] on the referees of England championship in temperate zone has indicated that the average of the distances between the central referee and the place of incident was of 10.80m. Our results demonstrate that in hot and humid region during the last 15 minutes of each half time of the game, the distance between central referee position and the offence emplacement is in average of 15.9m. Nevertheless, it has been revealed that heat exposure affects negatively physical performance and also cognitive process [15]. In this title, some authors [8] indicate that the loss of physical performance due by the tiredness can lead to situations where the referee is

far from the place of incident. In addition, the study of Mallo and al. [9] have reported that the error percentage was low when the referee is at the distance of 11 to 15m of the place of incident. But the error percentage increased (23%) toward the last 15 minutes of the end of the match.

Although the quality of refereeing performance is characterized differently in each sport, the way of decision-making is always considered the most important aspect [16]. As for the way of decision-making, in our study, the referee takes in average 122 observable decisions during the match (see table and figure 2). The results in hot and wet zone are not far from the study of the Europeans referees in temperate zone during Europe championship in 2000 [7]. This study has showed that referees had taken approximately 137 observable decisions during a match [7].

To examine the precision of decision-making as the distance between central referee position and the offence emplacement is more than 15m [17]. This parameter is enabling to quantify the rightness (correct/incorrect) of decision-making during the last 15 minutes of each half-time of matches under hot and humid condition. Our study showed that the increasing distance between referee's location and the offence emplacement that's not caused a more errors during decision-making. Speed with change of direction in order to have a good angle of vision and experiences of referee's can be explaining these qualities of decision.

5. Conclusion

In conclusion, acclimated referees showed lower physical performances in the heat comparable to referees physical performance observed in temperate zone. In hot and humid zone, the distance between the referee location and the offence emplacement decreased the last 15 minutes. Our study showed that errors do not increase with increasing distance between referee's location and the offence emplacement.

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