Influence of the Ambient Temperature over the Tactic, Technical and Physical Performances of National Teams

Influencia de la temperatura ambiente sobre la táctica, el desempeño técnico y físico de los equipos nacionales

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Abstract

Soccer is a sport practiced in an open environment and is under the interference of the local environmental conditions of the game. Different environmental conditions, such as heat, relative humidity, cold and altitude can cause changes in the players' body homeostasis. Thus, this study aimed to verify the effect of different ambient temperature on the tactical, technical and physical performances of national teams in World Cup. The sample was composed by FIFA World Cup games played in Brazil/2014 (n=64; 24.98±4.51°C), and South Africa/2010 (n=61; 14.69±4.70°C). The data were obtained from FIFA website. Temperature was categorized in four ranges: ≤10°C; 11–20°C; 21–30°C; ≥31°C. The tactical (% ball possession time in each sector of the field), technical (% successful conclusions, % successful short, medium, long and total passes) and physical (distance covered) performances of the teams were compared based on temperature ranges. Kolmogorov-Smirnov test, ANOVA One-Way and Kruskal-Wallis (p<0,05) were used to compare the averages by temperature range, in addition to the Tukey and Mann-Whitney tests (post-hoc). The results showed that the ambient temperature had an influence on the time of possession of the ball in the defensive (p<0.001), midfield (p<0.004) and offensive (p<0.001). In addition, in relation to technical performance, warmer temperatures positively influenced the percentage of correct passes for short (p<0.028), medium (p<0.014), long (p<0.001) and total (p<0.001), in addition to the percentage of correct shots on goal (p<0.001). On the other hand, with regard to physical performance, warmer temperatures negatively influenced the total distance covered (p<0.001). The ambient temperature influenced the tactical, technical and physical performance of the national teams. In the World Cup, in matches played in warmer temperature ranges, the teams suffered a change in tactical performance, showed improvement in technical performance, and losses in relation to physical performance.

Keywords: Soccer, heat, thermoregulation, world cup.

Resumen

El fútbol es un deporte practicado en un ambiente abierto y está sometido a las interferencias de las condiciones ambientales locales del partido. Diferentes condiciones ambientales, como el calor, la humedad relativa del aire, el frío y la altitud pueden causar alteraciones en el organismo de los jugadores. Esas alteraciones en la homeostasis corporal influencian el desempeño deportivo de los jugadores de fútbol. Asimismo, el objetivo del presente estudio es verificar el efecto de diferentes temperaturas ambientales sobre el desempeño táctico, técnico y físico de equipos nacionales en Copas Mundiales. La muestra estuvo compuesta por partidos disputados en el Mundial de Brasil de 2014 (n=64; 24,98 ±4,51°C) y de Sudáfrica de 2010 (n=61; 14,69 ± 4,70°C). Los datos fueron obtenidos a través de la web de la *Fédération Internationale de Football Association* (FIFA). La temperatura se clasificó en cuatro rangos: ≤10°C; 11–20°C; 21–30°C; ≥31°C. Los desempeños tácticos (% del tiempo en posesión del balón en cada rango del campo), técnico (% acierto en remates, % acierto en pases cortos, medios, largos y totales) y físico (distancia media recorrida de los equipos) fueron comparados entre los rangos de temperatura ambientales descritos. Se utilizó el test Kolmogorov-Smirnov para verificar la normalidad de los datos. Se aplicó un ANOVA de un factor y Kruskal-Wallis (p<0,05) para comparar el promedio por rango de temperatura, además de los tests de Tukey y Mann-Whitney (post-hoc). Los resultados han mostrado que la temperatura ambiental presentó una influencia sobre el tiempo de permanencia en posesión del balón en el sector defensivo (p<0,001), medio campo (p<0,004) y ofensivo (p<0,001). Además, en relación al desempeño técnico, temperaturas más cálidas influyeron de forma positiva el porcentaje de acierto en pases cortos (p<0,028), medios (p<0,014), largos (p<0,001) y totales (p<0,001), además del porcentaje de acierto en remate a portería (p<0,001). Por otro lado, en lo que se refiere al desempeño físico, temperaturas más cálidas influyeron de forma negativa la distancia total recorrida (p<0,001). La temperatura ambiental influyó el desempeño táctico, técnico y físico de los equipos nacionales. En los partidos disputados en rangos de temperaturas más cálidas durante los Mundiales, los equipos sufrieron alteraciones en el desempeño táctico, una mejora en el desempeño técnico, y una pérdida en relación al desempeño físico.

Palabras clave: Fútbol, calor, termorregulación, mundiales.

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Introduction

Soccer is played all over the world and, therefore, in several different environments (Reilly & Williams, 2003). Its formal practice frequently occurs in open areas, which exposes players to different environmental conditions according to the local characteristics of the game location. The environmental variables which cause the most physiological alterations are heat/humidity and cold/altitude (Dvorak & Racinais, 2010). In this way, thermic stress is an important factor to be studied and controlled to reach corporal homeostasis in the players during the game and avoid athlete's performance loss (Brewer & Warren, 2014; Grantham et al., 2010).

Historically, studies have highlighted the effects of environmental conditions on players' physical performance (Ekblom, 1986; Reilly & Williams, 2003; Trewin et al., 2017). One of the first studies to investigate the influence of ambient temperature on physical performance was conducted by Ekblom (1986), who observed a decrease in the total distance covered in high intensity in the games played in environmental temperature of 30 °C compared to games played in environmental temperature of 20 °C. Recently, new studies have been developed and observed that in high temperature environments (30°C), the performance in vertical jumps, the number of runs at high intensity, and the number of sequential sprints in short intervals of time dropped sharply at the end of the match (Mohr et al., 2010). Also, the research developed by Link and colleagues (2017) showed that in warm conditions (>14°C), there is a noticeable reduction in the distances covered by the players in the first and second divisions of Bundesliga. On the other hand, the study conducted by Carling, Dupont, and Le Gall (2011) found cold environments had no influence on the total distance run by players in three different speed zones (0-14.3 km/h; 14.4-19.7 km/h and ≥ 19.8 km/h). Based on these studies, hotter environmental conditions seem to make players more susceptible to losses in physical performance.

However, in relation to technical performance, the study developed by Mohr and colleagues (2012) showed an improvement in passing and crossing efficiency in temperatures above 41°C, in comparison to games played in temperatures of 21°C, in addition to the increase in ball possession time. In the same way, research developed by Nassis and colleagues (2015) in the 2014 World Cup indicated influence of environmental temperature on the technical fundamentals of passing, with an increase in the percentage of successful passes in environments with higher thermal stress.

Despite the findings' importance, interpreting the phenomenon of environmental temperature influence on the performance of soccer players based solely on physical and technical performance reduces the possibility of a deeper understanding of the subject, leaving some important points to be clarified. For example, the tactical component of the game still lacks further studies, although this is a very relevant aspect for the sports context (Teoldo et al., 2017). The tactical component is considered an essential aspect for the player to achieve higher performance, since each action of the game is based on a tactical objective (Garganta, 2009; Teoldo et al., 2017). Thus, the evaluation of the tactical performance of teams in different environmental conditions may support the decision making of coaches regarding appropriate positional and behavior adaptations to the specific environmental conditions that the teams will face.

In this scenario, the World Cup has presented itself as an important field of investigation of sports science, due to the fact that it brings together the main world teams and major players (Dvorak & Junge, 2015; Nassis, 2013; Nassis et al., 2015). The World Cup is a competition played at a four-year interval and in places previously defined by the *Fédération Internationale de Football Association* (FIFA). Thus, the environmental conditions between two World Cup editions can present great thermal variations according to the chosen location and, consequently, require different preparation and acclimatization strategies for each of the competitions. From this perspective, several strategies have been proposed to mitigate the effects of environmental stress on the player's body temperature and homeostasis, in order to protect him and minimize performance losses during the game. For example, for a match played in a hot environment, body cooling and constant hydration of the players have been proposed (Dvorak & Racinais, 2010; Grantham et al., 2010; Maughan et al., 2010). On the other hand, for games in cold environments, longer heating and reheating during the game interval has been proposed (Mohr et al., 2004). Such strategies demonstrate the importance of understanding the

effects of environmental temperature on soccer players' performance.

Therefore, the objective of the current study was to verify the effect of ambient temperature on the tactical, technical, and physical performance of national teams in World Cups.

Methods

Sample

The sample was composed of matches (n=128), from the 2014 World Cup in Brazil (n=64), and 2010 FIFA World Cup in South Africa (n=64). The matches extended until the extra time (4 games in the 2010 World Cup and 7 games in the 2014 World Cup) as well as those whose values of the ambient temperature at the venue were not provided by the FIFA website (3 games in the 2010 World Cup) were excluded. All matches in both tournaments were played in the local winter season, at the following local time: 1:30, 4:00 and 8:30 P.M.

Data collection procedures

The data were collected through the Castrol Performance Index and obtained through the *Fédération Internationale de Football Association* official website (FIFA - ***http://www.fifa.com/index.html***) from the match reports provided by the entity. The Castrol Performance Index uses data obtained through real-time kinematic analysis, based on data recorded through semi-automated cameras, with frequency rate of 25 frames per second. After consult and collection from the website, data were registered in a *Microsoft Excel* 2016 spreadsheet for further analysis.

Analyzed variables

Ambient Temperature

The ambient temperatures (°C) were categorized in four ranges (≤ 10°C; 11-20°C; 21-30°C; ≥ 31°C).

Table 1. Number of matches in each temperature range.

Temperature ranges	Number of matches
≤ 10 °C	10
11 - 20 °C	48
21 - 30 °C	53
≥ 31 °C	3

Tactical performance

To analyze the tactical performance, we measured the percentage of time of ball possession in each sector of the field. The field was divided into three spaces parallel to the goal lines to collect the data, namely the sectors of defense, midfield, and attack.

Technical performance

In this study, the percentage of successful passes was used as a measure of technical performance, being separated in: short (0.1 - 9.99 m), medium (10 - 29.99 m), and long (above 29.99 m); total passes (u.a); and the percentage of shots on goal.

Physical performance

The variable used to measure the physical performance was the average total distance covered by the team (m).

Data analyses

In order to describe the values of the variables regarding tactical, physical and technical performance, measures of central tendency and dispersion (means and standard deviation, respectively) were used. The *Kolmogorov-Smirnov* normality test was carried out.

To compare the variables regarding the physical, technical and tactical dimensions according to the temperature ranges, the ANOVA *One-Way* test was used, for the parametric data, and for the non-parametric data, the *Kruskal-Wallis* test was used. Tukey's and *Mann-Whitney* test were used *as post hoc*, respectively. Effect sizes were obtained using Cohen's *d* and η^2 – subsequently transformed in Cohen's *d* through the Psychometrica website (https://www.psychometrica.de/effect_size.html) and magnitudes were classified as: null (< 0.20), small (0.21 to 0.60), medium (0.61 to 1.20) and large (> 1.20) (Cohen, 1992).

All statistical procedures were performed through IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. The significance level was set to $p<0.05$.

Results

Table 2 displays the values for the teams' tactical, technical and physical performance compared between four temperature ranges.

Tactical performance

In matches played in the temperature range 21 - 30 °C, the teams kept ball possession longer in the defensive sector compared to the temperature range 11 - 20 °C (z= -5.33; p<0.001; d=0.76; medium effect), and kept ball possession longer in the midfield sector compared to the temperature range ≤ 10 °C (z= -2.77; p=0.04; d=0.76; medium effect). In the temperature range ≤ 10 °C, the teams had longer ball possession in the offensive sector compared to the temperature range 21 - 30 °C (z= -4.88; p<0.001; d=1.56; large effect) and ≥ 31 °C (z= -2.28; p=0.023; d=1.40; large effect). In addition, in the temperature range 11 - 20 °C, the teams kept ball possession longer in the offensive sector compared to the temperature ranges 21 - 30 °C (z= -6.92; p<0.001; d=0.97; medium effect) and ≥ 31 °C (z= -2.13; p=0.034; d=0.86; medium effect).

Technical performance

Regarding the percentage of successful short passes (z= -2.03; p=0.028; d= 0.57) and medium passes (z= -2.79; p=0.014; d=0.77; medium effect), a significant difference was found between the temperature ranges ≤ 10°C and 21 - 30°C. In addition, significant differences were found with respect to the percentage of successful short passes (z= -1.34; p=0.028; d=0.65; medium effect) and medium passes (z= -1.08; p=0.014; d=0.63; medium effect) between the ranges ≤ 10 °C and ≥ 31 °C. Likewise, there was a significant difference in the percentage of successful short passes (z= -2.30; p=0.021; d=0.44; small effect) between the temperature ranges 11 - 20 °C and 21 - 30 °C. Finally, the percentages of successful short passes (z= -1.02; p=0.028; d=0.52; small effect) at the temperature range 11 - 20 °C and ≥ 31 °C were also significantly different.

For the results of the percentage of long passes (z= -5.75; p=0.003; d=0.76) and total completed passes (z= -3.47; p=0.001; d=0.69; medium effect), differences were found between the temperature ranges ≤ 10 °C and 21 - 30 °C. In addition, there were significant differences in the percentage of long passes (z= -5.75; p=0.015; d=0.90; medium effect) and completed total passes (z= -2.98; p=0.003; d=0.55; small effect) between the temperature ranges ≤ 10 °C and ≥ 31 °C.

Table 2. Values of tactical, technical and physical performance indicators based on the four temperature ranges.

Performance	Temperature ranges				
	≤ 10 °C	11 - 20 °C	21 - 30 °C	≥ 31 °C	*p*
Tactical					
Defensive sector	24.00 ± 6.35	22.43 ± 5.94	26.88 ± 5.82	26.33 ± 5.78	<0.001‡
Medium sector	49.21 ± 5.27	52.34 ± 5.36	53.09 ± 4.95	53.00 ± 6.72	0.004*
Offensive sector	26.89 ± 3.66	25.28 ± 5.58	20.20 ± 4.82	20.67 ± 5.08	<0.001*†‡§
Technical					
% successful shots on goal	34.46 ± 11.48	40.80 ± 18.32	55.85 ± 15.56	60.18 ± 5.41	<0.001*†‡§
% successful total passes	70.45 ± 7.88	71.10 ± 7.33	75.26 ± 6.00	74.17 ± 5.31	<0.001*†
% successful short passes	71.88 ± 8.45	72.72 ± 8.77	76.04 ± 6.02	76.75 ± 6.41	0.028*†‡§
% successful medium passes	73.77 ± 8.27	76.68 ± 7.45	79.37 ± 6.01	78.05 ± 4.90	0.014*†
% successful long passes	47.38 ± 11.66	51.19 ± 9.22	55.75 ± 10.24	55.67 ± 5.90	<0.001*†
Physical					
Total average distance covered (m)	9423.20 ± 559.44	9800.85 ± 879.92	9324.72 ± 801.36	9150.00 ± 368.41	<0.001‡§

* – Significant difference between ≤ 10 °C and 21 – 30 °C (p<0,05).
† – Significant difference between ≤ 10 °C and ≥ 31°C (p<0,05).
‡ – Significant difference between 11 – 20 °C and 21 – 30 °C (p<0,05).
§ – Significant difference between 11 – 20 °C and ≥ 31 °C (p<0,05).

With regard to the percentage of successful shots on goal, a significant difference was found between the temperature ranges ≤ 10 °C and 21 - 30 °C (z=19.74; p<0.001; d=1.56; large effect), and between ≤ 10 °C and ≥ 31 °C (z=19.74; p=0.007; d=2.87; large effect). Furthermore, the results indicated a difference in the percentage of shots on goal between the ranges 11 - 20 °C and 21 - 30 °C (z=19.74; p<0.001; d=0.89; medium effect). Finally, there were significant differences in the percentage of successful goal shots between 11 - 20 °C and ≥ 31 °C (z=19.74; p<0.029; d=1.43; large effect).

Physical performance

A significant difference was observed in relation to the total average distance covered by the teams when comparing the temperature ranges 11 - 20 °C and 21 - 30 °C (z= -4.62; p<0.001; d=0.57; small effect), and between 11 - 20 °C and ≥ 31 °C (z= -2.45; p<0.001; d=0.96; medium effect).

Discussion

The objective of this study was to verify the effect of ambient temperature on the tactical, technical and physical performance of national teams in World Cups. According to the results, the tactical performance of the national teams changed in the different temperature ranges analyzed. In addition, the results indicated an improvement in the technical performance of the national teams in matches played in environment conditions with higher temperature (21 - 30 ºC and ≥ 31 ºC). On the other hand, the results showed that higher temperature (21 - 30 ºC and ≥ 31 ºC) had negative effects on the physical performance of the national teams.

In relation to physical performance, the national teams covered a greater distance when playing in the temperature range of 11 - 20 °C, reducing the average distance covered in environment conditions with higher temperature (21 - 30 ºC and ≥ 31 ºC). In soccer, research indicates that the increase in ambient temperature negatively affects the players' physical performance (Mohr et al., 2012; Özgünen et al., 2010). These results can be explained since in high temperature situations the players tend to sweat more, dissipating heat and maintaining body homeostasis (Maughan et al., 2010). As a result of this mechanism, there is a loss of water and nutrients through sweating, which can sometimes lead to fatigue, in which the player is unable to maintain a certain intensity or power level (Bangsbo et al., 2007; Gandevia, 2001). Finally, the present study indicates the temperature range 11 - 20 °C as the environmental condition in which the national teams performed the best in relation to physical performance. In this conjecture, playing in milder temperature ranges tends to be beneficial to the physical performance of the players with respect to their ability to travel long distances. Recent researchers have found results that agree with the present study (Chmura et al., 2017; Zhou et al., 2019). The study developed by Chmura and colleagues (2017) found that ambient temperatures below 22 °C are the most favorable and comfortable thermal conditions for soccer players' physical performance. Similarly, Zhou and colleagues (2019) indicated the temperature range of 10.6 – 22 ºC as a comfort zone to promote better soccer match performances.

With regard to technical performance, the results of this study indicate that in higher temperature ranges (21 - 30 ºC and ≥31 ºC) the national teams were more successful in the technical fundamental of passing, with improvement in the percentage of successful short, medium, long and total passes, and shots on goal. The findings of this study are corroborated by the literature, which has shown a higher percentage of successful passes at warmer temperatures (Mohr et al., 2012; Nassis et al., 2015). Likewise, regarding shots on goal, the study conducted by Brewer and Warren (2014) indicates that more goal opportunities are created and there is a higher percentage of successful shots on goal in higher temperature ranges. Interestingly, these results demonstrate that the physical fatigue more easily generated at higher temperatures (Mohr et al., 2010) seems not to interfere in the players' technical performance, so that technical losses may be associated with other stresses, such as mental fatigue that players normally experience during games. This hypothesis is based on studies that show a reduction in the percentage of successful technical fundamentals of passing after a mental fatigue protocol (Badin et al., 2016; Smith et al., 2016). Such reduction was not found in the analysis of the present study.

The environmental temperature of the match venue changed the tactical performance of the national teams. The results showed that the teams kept possession ball longer in the offensive sector at cooler temperatures (≤ 10 °C and 11 - 20 °C).

On the other hand, in matches played in higher temperature ranges (21 - 30 ºC and ≥31 ºC), the national teams spent more time with the ball possession in the defensive and midfield sector. The teams that keep the ball in these sectors tend to be more cautious and secure in passing, since the loss of the ball in one of these sectors increases the possibility of offensive success of the opposing team (Barreira et al., 2014). This seems a plausible hypothesis since the results indicate an improvement in the efficiency of the technical fundament of passing at warmer temperatures. Similarly, the difficulty in progressing to the offensive sector possibly induced the teams to use the long distance shot or deep pass to reach the opponent's goal. However, these inferences need to be tested in future heuristic work, since the present study did not control where the shots and passes were made.

Practical applications

Based on the findings of this study, coaches will be able to use appropriate strategic solutions, namely regarding positional and behavior adaptations, in order to minimize the interference of ambient temperature on the team's performance. Some of these possible strategies include the use of alternative tactical systems that generate less physical overload in the athletes and improve the percentage of passes (Bradley et al., 2011), besides the substitution of players of certain positions by teammates better adapted to higher temperatures. The acquisition of knowledge about the players' performance in different ambient temperatures can also contribute to the selection of more appropriate warm-up strategies. For example, during halftime in colder ambient, it is indicated to do low-intensity exercise to preserve muscle temperature. On the other hand, the warm-up in warmer ambient should be limited to 10 min in low intensity to prevent a potentially detrimental increase in internal body temperature (Grantham et al., 2010). However, despite the relevance of these findings in practical terms, the present work did not consider the relative air humidity and wind conditions, aspects that have also been pointed out as influencing sport performance (Brocherie et al., 2015; Özgünen et al., 2010). Finally, for future studies, sample grouping according to the competitive level of the performing teams is also suggested, including control variables over game quality, match score and level of opponent (Brocherie et al., 2015; Lago, 2009; Taylor et al., 2008).

Conclusion

The ambient temperature of the place where the match is played affects the sports performance of the national teams, especially in places where the temperatures are higher. In warmer environmental conditions, the national teams tend to adopt more secure behavior, presenting an improvement in the technical fundaments of passing and keeping ball possession longer in the defensive and middle sectors. In addition, this standard of technical and tactical performance can be interpreted as an attempt to compensate for the reduction in physical performance, by reducing the need to move a lot and granting greater efficiency.

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