Analysis of activity patterns, physiological demands and decision-making performance of elite Futsal referees during matches

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International Journal of Performance Analysis in Sport Vol. 17 , Iss. 5, Pages 737-751, 2017

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Abstract

The aims of this study were to examine Futsal referee match activity profile, decision making performance, and whether these correlate with fitness test performance. Eighteen elite Futsal referees (mean ± SD: age, 34.1 ± 3.2 years) participated. Total distance covered (5943.6 ± 414.7 m: 3374.0 m ball in play) low-, moderate-, high-intensity and sideways running distances were similar to previous research, walking (1741.4 ± 225.1 m) was lower, sprinting (149.0 ± 59.2 m), jogging (754.9 ± 162.5 m) and backwards distances (654.7 ± 149.3 m) were higher. Total distance (3093.5 m vs. 2850.1 m) and average heart rate were higher ($p < 0.05$) in the first compared to second half but lactate and session RPE were similar. The proportion of correct decisions decreased in the second half (91 ± 14.9% correct vs 73 ± 17.4%, $p = 0.002$). No correlations were evident between FIFA fitness tests and activity profile but Yo-Yo IET-2 performance and total distance (clock time) were correlated ($r = 0.720$, $p = 0.019$). Activity pattern differences compared to previous research could reflect the FIFA rule change (2010) and/or different study populations. Traditional FIFA tests seem less appropriate than intermittent (Yo-Yo IET-2) tests for assessing Futsal referee-specific fitness.

1. Introduction

Futsal is an indoor sport, characterized as an intermittent sport played between two competing teams of five players per team. It is officiated by two referees whom are required to stay outside of the pitch parallel to the touch line (FIFA, 2014), and implement the Futsal laws of the game. They move up and down the touch lines to keep up with play and also to keep the other referee within their field of vision. There are various studies of physiological profiling for Futsal players (Castagna, D'Ottavio, Vera, & Álvarez, 2009; Barbero-Alvarez, Soto, Barbero-Alvarez, & Granda-Vera, 2008 and Dogramaci and Watsford, 2006), however, there is little research on Futsal referees, with only one study to date (Rebelo et al., 2011) but this study was conducted before FIFA implemented new rules (2010), meaning it may no longer be as applicable to the demands of the game. No studies have been conducted since the rule change, but the rule change may have influenced the demand on referees and, hence, their activity profile. For instance when the ball goes out of play referees must now move to that location (e.g. where the kick-in or corner kick is to be taken: about 5 m from the point of taking), (FIFA, 2014, pp. 100 & 111).

Referees are expected to have a sufficient level of fitness to keep up with the game, therefore all national associations and confederations undertake and implement the FIFA fitness tests of referees before starting leagues/tournaments as part of the referee selection process. For match officials, such tests are used to ensure that they meet the minimum physical requirements deemed necessary to allow them to discharge their duties effectively during competition (e.g. keep up with play to allow good positioning to view incidents).

The fitness test for Futsal referees has recently changed (June 2016) from the traditional testing battery of a 1000 m run, 40 m sprint and 80 m agility tests (FIFA, 2014) to the new Fitness test (FIFA, 2016), which includes an intermittent test based on the Yo-Yo IET-2 test (modified Yo-Yo test, also named Assistant Referee Intermittent Endurance Test: ARIET). Previous research with Futsal referees has found significant relationships between performance on the Yo-Yo Intermittent Endurance Test (Yo-Yo IET-2) and physiological responses (Dixon, 2014a) and activity profile (Rebelo et al., 2011) during matches but not the traditional FIFA 1000 m endurance test.

Rebelo et al. (2011) observed a strong correlation ($r = 0.77$; $p < 0.05$) between High Intensity Running (HIR) in matches and the Yo-Yo IET-2 performance. Based on their findings, Rebelo et al. (2011) recommended that intermittent tests which involve changes of direction (such as the Yo-Yo IET-2) may have more relevance for Futsal referees than the (pre-2016) FIFA testing battery. More recently, Dixon (2014a) examined 58 officials (56 male and 2 female) at the FA National and Super Futsal League (who undertook the Yo-Yo IET-2, sprint (40 m) and agility (80 m) tests prior to the season). Dixon (2014a) also concluded that the Yo-Yo IET-2 is an appropriate test for Futsal referees, especially identifying differences in specific fitness between referees of different levels. Therefore the Yo-Yo IET-2 can be used to differentiate between different levels of futsal referees and it may be possible to use the test to identify those referees who show the fitness attributes for further development. Furthermore, Dixon (2014a) stated that further study is needed to understand the validity of the Yo-Yo IET-2 and its relationship with motion analysis of Futsal referees.

Several studies have investigated football referees' decisions (including consideration of positioning of referees in relation to the incident) (Harley, Tozer, and Doust 2001; Oudejans et al. 2005; Gilis, Helsen, Catteeuw, & Wagemans, 2008; Catteeuw et al., 2010; Mallo et al., 2012; Al Hazmi, 2016), and proportions of correct and incorrect decisions of football referees and assistant referees during matches (Van Meerbeek, Van Gool, and Bollens, 1987; Helsen and Bultynck 2004; Oudejans et al., 2000; Oudejans et al., 2005; Helsen, Gilis, and Weston, 2006; Elsworthy, Burke, and Dascombe, 2014; Catteeuw et al., 2010). However, there is no previous research that has examined decision making for Futsal referees.

Hence, the aims of the current study were: 1) to examine the match activity profile of Futsal referees, 2) to examine decision making performance, and 3) explore relationships between FIFA fitness tests, Yo-Yo IET-2 test performance and match activity.

2. Materials and methods

2.1. Participations

Eighteen male elite referees in Iraq Futsal Premier League (IFPL) matches (mean ± SD: age 34.1 ± 3.2 years; height, 171.2 ± 5.3 cm; weight 72.0 ± 3.6 kg) volunteered to participated in this study. They all had over 5 years of experience as top level referees and were all officiating on IFPL 2013/2014. All participants were provided with information sheets and verbal explanations of the study procedures and possible risks before giving their written informed consent. Ethical approval was granted from the University Research Ethics Committee of the lead author (in the UK) in advance of study commencement. All referees were required to undertake a series of Fitness tests as part of the Iraqi Football Association (IFA) requirements to officiate, which were conducted independently from this but they also gave their consent for this data to be used for analysis in the present study (but records were only available for 10 referees for these tests: see further details below).

2.2. Study design

The present study recorded nine competitive matches with eighteen (2 per match) Futsal referees during IFPL 2013/2014. Referees were monitored during the match by video capture of the whole match for motion analysis; heart rate was recorded throughout the match; lactate samples collected at rest (pre-match), half-time and post-match and session RPE for the first and second half expressed. In addition, ten of the referees undertook two fitness tests with IFA: the FIFA Fitness tests were undertaken 8 days before the match and the Yo-Yo IET-2 was completed 3 days before the match.

2.3. Analysis of referees movement patterns and physiological responses to matches

Two GoPro Hero3 digital video cameras were used to record each match (each camera covering one side of the Futsal pitch). The cameras were placed on opposite sides of the pitch at the level of the halfway line, at a height of 3.5 m, and at a distance of 4.5 m from the touch line. The video data was analysed using Kinovea software (0.8.15)

(www.kinovea.org). The software was calibrated using measured distances between markers on the pitch which were visible in the camera frame and speed was calculated from distance covered and duration of each activity. Based on Rebelo et al. (2011), Krustrup and Bangsbo (2001) and Bangsbo, Norregaard, & Thorso (1991) studies, movements of Futsal referees were classified into nine categories as follows: standing (0 $km.h^{-1}$), walking (up to 6 $km.h^{-1}$), jogging (up to 8 $km.h^{-1}$), low intensity running (LIR) (up to 12 $km.h^{-1}$), moderate intensity running (MIR) (up to 15 $km.h^{-1}$), high intensity running (HIR) (up to 18 $km.h^{-1}$), sprinting (above 18 $km.h^{-1}$), backwards (BW) and sideways (SW) movements.

The Futsal referees were analysed in two separate ways: 1) during clock-time, containing all movement activities performed from kick-off until the half-time interval, and from the second half kick-off until the end of play with the exception of when the ball goes out or play is stopped by one of the referees; 2) at match-time analysis level, which (in addition to above) also includes all movements when the ball is out of play; however, the half-time and time-outs were excluded from the analysis.

Reliability: All activity analyses in this study were conducted by the same operator (HA). However, in order to give an indication of method variability a different operator performed the same analysis on 1 match for comparison. The variation between operators ranged between -0.02% and 0.16% for distance covered (walking -0.14%, jogging 0.06%, LIR 0.05%, MIR 0.16%, HIR -0.12%, sprinting -0.14%, BW -0.02%, SW -0.02%, and total distance -0.02%). For activity duration variation between operators ranged between -0.06% to 0.03% (standing -0.01%, walking -0.05%, jogging -0.06%, LIR -0.05%, MIR -0.01%, HIR -0.01%, sprint -0.05%, BW 0.03%, SW 0.00%, and total duration -0.02%).

2.4. Decision making by observer panel assessment

Three independent expert Futsal qualified observers (two FA Futsal Assessors and one IFA Futsal Assessor) assessed decisions made by the referees by independently reviewing the footage from each match from the motion analysis recordings. Each observer independently watched and assessed the match videos and rated each refereeing decision (e.g. correct, incorrect, contentious) in line with the methods of Lovell (2014) so that a

decision making performance score (i.e. % correct decisions) could be calculated (if all 3 referees did not rate the decision the same the majority was taken: there was agreement between all 3 assessors on 71.5% of all ratings and at least two of the observers agreed on 99% of the ratings). Observers were allowed to watch the video/incident as many times as necessary for them to reach a decision (foul, no-foul or missed foul) and evaluated whether referee decisions were correct, contentious or incorrect.

2.5. Physiological measurement during fitness tests and matches

4.2.1. Heart Rate and Blood Lactate concentration:

Heart rate (HR) was measured and recorded continuously throughout the matches using a short range radio telemetry chest strap and wrist watch receiver (POLAR, S5800, Kempele, Finland) with data captured at 5 s intervals. The HR monitor was attached to the referees 45 minutes before the kick-off and removed 10 minutes post-match. Blood samples were collected from finger-pricks for the determination of lactate concentration at 3 times: rest (pre-match), and within 2 min of the end of the first half (half-time) and second half (post-match). Blood samples were analysed immediately to determine blood lactate concentration using a portable electroenzymatic device (Lactate Pro Portable Lactate Analyser, Japan). Clinical waste was then disposed of at the nearby University of Sulaimani via commercial clinical waste disposal operators.

2.6. Session Rating of Perceived Exertion (RPE)

Session RPE has been used as an effective tool for physical activity load in team sports for athletes (players and officials) (Weston, Castagna, Impellizzeri, Rampinini, & Breivik, 2010; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004 and Foster, 1998). Therefore, each referee was asked to express the session RPE (relating to the half just completed) after 10 min at half-time and post-match by using the scale of Borg's CR10-scale modified by Foster et al. (2001).

2.7. Fitness Tests

2.7.1. FIFA fitness tests (pre-June 2016 battery):

FIFA recommended a fitness test for Futsal referees to all member associations in the world. The pre-2016 FIFA test contained a 1000 m run ("Endurance" test), a 40 m ("Sprint" test) and an 80 m agility test (FIFA, 2014).

2.7.2. Yo-Yo Intermittent Endurance Test Level 2 (Yo-Yo IET-2):

This test requires intermittent exercise consisting of repeated 20 m shuttle runs (Bradley et al., 2011) and it was performed indoors (on a Futsal pitch). After each 40 m (2 × 20 m runs) participants have a 5 s rest of jogging around a marker placed 2.5 m behind the starting/finishing line. The pace of each shuttle is dictated by an audible tone played through a loud speaker. The speed is increased regularly until the participant is unable to continue with the required pace.

3. Statistical Analysis

Statistical analyses were carried out using SPSS (23 Amonk, NY: IBM Corp). Data are presented as means ± standard deviation (SD) and significance was accepted when $p < 0.05$. For comparison between the first and second halves for each activity (distance, duration and activity frequency) and also for comparison between match-time and clock time, values were compared using paired samples t-tests (and decision making performance [missed fouls] between 1st and 2nd halves) (or Repeated Measures ANOVA for blood lactate due to 3 repeated time points) when parametric assumptions were met.

If data were not normally distributed they were first normalised with log transformation using the natural log (comparisons for the total activity frequency between match-time and clock time among activities and also comparisons the FIFA endurance test and the Yo-Yo IET-2 with all activities at clock time) or square root transformation (distance from incident).

If data could not be normalised then non-parametric tests were used: Wilcoxon matched pairs test (1st vs 2nd half activity profile results for walking, jogging, LIR, MIR, HIR, sprint, BW and SW; HR and RPE, and decision making [correct, contentious, incorrect decisions]).

Pearson correlation was used to compare FIFA endurance test and the Yo-Yo IET-2 performance with total distance at match-time and clock time, and also compare fitness tests with total distance of all activities (walking, jogging, LIR, MIR, HIR, sprint, SW and BW) at match-time (FIFA endurance test and the Yo-Yo IET-2 were compared with all activities at clock time after log transformation of the variables to normalise data distribution). Pearson correlation was also used to compare the FIFA endurance test and the Yo-Yo IET-2 performance with decision making performance.

4. Results

4.1. Motion analysis

Total match duration was on average 79.58 ± 6.34 min. Overall duration and frequency information for both match time and clock time are shown in Table 1.

***** Please insert Table 1 near here *****

Total distance, distances for each activity type, percentage of total distance and percentage of total time for each activity is also shown in Tables 1-2.

***** Please insert Table 2 near here *****

4.2. Physiological and perceptual responses during the match

***** Please insert Table 3 near here *****

4.3. Assessment of referee decision making performance

***** Please insert Table 4 near here *****

There were 178 situations in total across all 9 matches. This included 151 referee decisions and 27 missed fouls. The proportion of correct, incorrect and contentious decision are shown in Table 4. On average, referees were further away from the incident for incorrect (13.3 ± 5.4 m) compared to correct decisions (9.2 ± 4.6 m, $t = -3.36$, $p = 0.001$).

4.4. FIFA Fitness Tests and Yo-Yo IET-2

Mean performance in the endurance test was 3.51 ± 0.04 min and Yo-Yo IET-2 distance was 1160.0 ± 147.3 m. There was a significant correlation between the Yo-Yo IET-2 performance and total match distance covered at clock time ($r = 0.720$, $p = 0.019$) but not match time ($r = 0.076$; $p = 0.834$). There was a significant correlation between the Yo-Yo IET-2 performance and clock time jogging distance ($r = 0.658$, $p = 0.038$) and match time jogging distance ($r = 0.827$; $p = 0.003$). There was no correlation between the endurance test (1000 m) and total distance covered at match time ($r = -0.54$, $p = 0.883$) or at clock time ($r = -0.295$, $p = 0.409$). There was no correlation between the endurance or the Yo-Yo IET-2 and the HIR during match time ($r = -0.174$, $p = 0.630$) or clock time ($r = -0.110$, $p = 0.762$), respectively ($n = 10$). There was no correlation between the endurance or the Yo-Yo IET-2 and any other activity profile measures (all $p > 0.05$). There were no correlations between the endurance test ($r = -0.16$, $p = 0.650$) or the Yo-Yo IET-2 ($r = 0.09$, $p = 0.795$) and proportion of correct decisions. There was also no correlation between the endurance test ($r = 0.32$, $p = 0.35$) or the Yo-Yo IET-2 ($r = -0.009$, $p = 0.980$) and the change incorrect decisions percentage from the 1st to 2nd half.

5. Discussion

The main findings of the present study were that total distance was similar (2013/14 season, after the FIFA rule change) to the previous study (2005/6 season, before the FIFA rule change, Rebelo et al., 2011) but distribution of activity types/activity profile differed. The total number of activities performed in the present study (1539 ± 130) is slightly higher than the previous study and total match duration is similar to previous Futsal studies (Dixon, 2014b; Rebelo et al., 2011 and Doğramacı and Watsford, 2006). There was a higher amount of jogging, sprinting and backwards running, and less walking in the present study (compared to Rebelo et al., 2011) whereas the amount of LIR, MIR, HIR and sideways running were similar. This could be a result of changes to the match activity profile that have occurred since the FIFA rule change as referees' activity is directly influenced by match play.

Our results suggest that referees suffer fatigue in the second half, which differs from players. Players have been seen to cover similar distances in each half (Dogramaci,

Watsford, and Murphy, 2011 and Castagna et al., 2009) although high intensity running was reduced in the second half (Castagna et al., 2009). This can be explained by the fact that unlimited rolling substitutions are allowed in Futsal with players typically covering 3-5 km per match (Makaje, Ruangthai, Arkarapanthu, & Yoopat, 2012; Dogramaci et al., 2011; Castagna et al., 2009 and Doğramacı and Watsford. 2006) whereas Futsal referees must officiate the whole match continually (and may cover double this distance). However, we must acknowledge that we did not analyse the players within the present study. Since the activity of referees is dictated by the activity of the game, and previous research on Futsal players has shown that greater distance covered is observed in higher level (i.e. elite vs amateur) players (Makaje et al., 2012 and Dogramaci et al., 2011) along with the fact that players seem to cover less distance and also show less evidence of decreasing towards the end of matches shows the importance of conducting analysis on referees rather than making assumptions based on analyses of players. The physiological and perceptual measures in the present study lend some support to this and the referees' motion analysis data (suggesting referee fatigue).

Rebelo et al. (2011) observed that the mean HR for Futsal referees was lower in the second (143 bpm) compared to first half (149 bpm). For football many report that performance intensity and tempo of play is reduced in the second half (Krustrup et al., 2009; Da Silva, Fernandes and Fernansez. 2008; Mallo, Navarro, Garcia-Aranda, Gilis, & Helsen, 2008; Weston, Drust, & Gregson, 2011; Krustrup and Bangsbo, 2001 and Catterall, Reilly, Atkinson, & Coldwells, 1993) and it is possible that similar patterns occur in Futsal. However, in football this can be attributed to increased fatigue of players and changes in the velocity of the game (Barbero-Alvarez et al., 2012) but Krustrup et al. (2009) report it could be influenced by the referee's fitness (e.g. they become less able to "keep up" with play). For Futsal, given the smaller decrements reported in players' activity, and unlimited rolling substitutions, player fatigue may be less of a factor and the results observed here may be more related to referees' fitness. This information may aid fitness coaches to optimise training and, perhaps most importantly, for associations to determine the best methods and tests to assess referees' fitness. However, it will be valuable for future research to collect data from referees and players during the same

matches to further advance understanding of the relationship between match profile and physical performance of referees.

The decrease in decision making performance and increase in missed fouls in the 2nd half are in line with research on football referees and assistant referees, whereby the likelihood of incorrect decisions was increased towards the end of a match (Krustrup and Bangsbo, 2001 and Mallo et al., 2012). This may be related to fatigue (physical and mental) in the latter stages of the match. However, this was not confirmed by a correlation between fitness measures and 1st-to-2nd half changes in decision making, but the relationship between fitness and decreases in measures of performance (that are likely influenced by both mental and fatigue in synergy) are likely to be more complex and will require further research, which is beyond the scope of the present study.

In the present study the results for referee position showed that referees were on average ~4 m further away from the infringement for incorrect compared to correct decisions. This may be a result of referees failing to be in the optimal position (i.e. keeping up with play) due to fatigue (physical and/or mental). In the study of Mallo et al. (2012) less incorrect decisions were made when referees were between 11 to 15 m from the incident compared to being further away and similar findings have been reported in other football research (Krustrup and Bangsbo (2001). Although those findings were in football and not Futsal it demonstrates the importance of positioning (or keeping up with play) and supports the findings of the present study. It must also be noted that this relationship was not evident in football assistant referees (Gilis et al. 2008).

5.1. Relationships between fitness tests performance and match activity profile

FIFA recently changed the fitness testing battery for Futsal referees and have replaced the old test (which included a 1000 m "endurance" run, 40 m sprint and 80 m agility run) with a new test battery that includes a modified version of the Yo-Yo (ARIET). Dixon (2014a) and Rebelo et al. (2011) pointed out that the 1000 m test does not seem an appropriate reflection of the referee's ability and lacks external validity or sports-specificity for Futsal refereeing. Both authors have suggested the Yo-Yo IET-2 as more appropriate. Our findings support the notion that this new testing battery is better suited

to determine referees' suitability (in terms of fitness). We observed a significant positive correlation between Yo-Yo test performance and jogging distances (clock time and match time) and between Yo-Yo test performance and total clock time distance, which is in agreement with the findings of Rebelo et al. (2011). There was no correlation, however, between Yo-Yo test performance and total match time distance and we observed significant differences between match time and clock time motion analysis results. This could be explained by the fact that match time includes many periods of rest and non-active periods (including stoppages in play) so a greater proportion of match time is spent in activities that are less physically demanding and/or related to fitness. We believe that this highlights the importance of studying clock time and our data provide preliminary evidence that clock-time statistics may be more important (i.e. this contains the periods when referees are exposed to most physiological demands, and must keep up with play, view and make decisions on incidents). We also found no correlation between the 1000 m run performance and match activity, further supporting the suggestion that this test lacks relevance and sport-specificity although the lack of correlation between the Yo-Yo test and many other parameters of the motion analysis may suggest that, although this test is better it is still not ideal in this context. Further studies directly examining the relationships between performance on this new testing battery and match activity and/or performance of referees are still needed. It is also worthy of note that Futsal referees ran backwards 654.7 ± 149.3 m in the present study and the latest FIFA fitness tests for Futsal referees does not include backwards running, highlighting the scope for further development and improvement (sport-specificity) of the testing battery. It is also important to note that a referee's activity profile may be influenced not only by their fitness but also by their experience, skill, game awareness and effective positioning. These factors may influence the nature of any relationships between activity profile and fitness levels, which is a limitation when using simple correlations between such measurements.

6. Practical Applications

- Futsal referees suffer fatigue in the second half, which may have practical implications for their ability to perform optimally (e.g. keep up with play in order to make decisions).

- Futsal referees made a greater proportion of incorrect decisions in the second half.
- The 2nd half decrements may be related to sports-specific fitness levels (and although this did not correlate with fitness test performance, sport-specific fitness for referees may also include resistance to physical and mental fatigue combined).
- Fitness coaches can use the above information to optimise training with the aim of improving sports-specific fitness in referees.
- The new FIFA testing battery for Futsal referees seems better suited to determine sport-specific fitness due to better relationships with match activity profile. However, this battery still lacks any assessment of backwards movements, which could be incorporated in the future to increase specificity further.

7. Conclusion

In conclusion, the present findings show that the referees covered a similar total distance to that previously reported (pre 2010 rule change). However, there appears to be some differences in activity types/patterns, which could be a result of the rule change and/or could reflect the different study populations (i.e. Portuguese vs Iraqi). There were reductions in second half parameters (total distance and heart rate) and an increase in the percentage of incorrect decisions and missed fouls, which could be due to changes in the tempo/intensity of the game (i.e. player fatigue), referee fatigue (combined mental and physical), or a combination all factors. Further motion analysis studies are needed to collect data for referees and players during the same matches. The present study also suggests that the traditional FIFA fitness test (and 1000 m run) were poor for assessing Futsal referee-specific fitness, and tests that involve intermittent and/or direction changes, such as the Yo-Yo test or ARIET, may be more appropriate, although further research is needed on the ARIET in this context.

8. Acknowledgements

The authors would like to thank Iraqi Football Association, Iraqi Futsal Committee for giving permission to collect the data.

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Table 1: Overall match motion analysis results for clock-time and match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Distance (m)	Clock-time (Ball in play)	0 ± 0	901.0 ± 157.0	392.4 ± 103.1	443.5 ± 65.4	403.6 ± 88.5	170.6 ± 88.9	97.6 ± 45.2	372.4 ± 74.4	593.0 ± 111.0	3374.0 ± 215.3
	Match-time	0 ± 0	1741.4 ± 225.1	754.9 ± 162.5	774.0 ± 100.9	635.9 ± 103.1	275.5 ± 91.5	149.0 ± 59.2	654.7 ± 149.3	958.1 ± 230.9	5943.6 ± 414.7
	Statistical analysis values (t/z,p)	0	t = 17.59, p < 0.001	t = 15.59, p < 0.001	t = 19.59, p < 0.001	z = -3.72, p < 0.001	z = -3.72, p < 0.001	t = 8.45, p < 0.001	t = 11.21, p < 0.001	t = 10.09, p < 0.001	t = 33.59, p < 0.001
% of total distance	Clock-time (Ball in play)	0 ± 0	26.8 ± 5.0	11.5 ± 2.7	13.1 ± 1.8	11.9 ± 2.1	5.1 ± 2.7	2.9 ± 1.3	11.0 ± 1.9	17.6 ± 3.3	100.0 ± 0.0
	Match-time	0 ± 0	29.4 ± 4.3	12.7 ± 2.3	13.1 ± 1.9	10.7 ± 1.2	4.6 ± 1.4	2.5 ± 0.9	11.0 ± 2.3	16.1 ± 3.5	100.0 ± 0.0
Duration (s)	Clock-time (Ball in play)	493.8 ± 95.3	805.3 ± 128.7	210.5 ± 60.9	160.0 ± 25.7	108.4 ± 23.3	38.1 ± 19.8	17.1 ± 7.5	234.5 ± 39.2	332.4 ± 65.0	2400.0 ± 0.0
	Match-time	1225.3 ± 221.1	1626.2 ± 255.5	402.9 ± 89.9	279.1 ± 39.0	171.8 ± 28.0	61.7 ± 20.3	26.8 ± 10.8	413.0 ± 96.4	568.1 ± 167.9	4774.8 ± 380.1
	Statistical analysis values (t/z,p)	t = 15.79, p < 0.001	t = 15.07, p < 0.001	t = 15.67, p < 0.001	t = 18.38, p < 0.001	z = -3.72, p < 0.001	z = -3.72, p < 0.001	t = 8.97, p < 0.001	t = 11.67, p < 0.001	t = 7.76, p < 0.001	t= 26.50, p < 0.001
% of total time (s)	Clock-time (Ball in play)	20.6 ± 4.0	33.6 ± 5.4	8.8 ± 2.5	6.7 ± 1.1	4.5 ± 1.0	1.6 ± 0.8	0.7 ± 0.3	9.8 ± 1.6	13.9 ± 2.7	100.0 ± 0.0
	Match-time	25.5 ± 3.2	34.0 ± 3.9	8.5 ± 2.0	5.9 ± 0.8	3.6 ± 0.5	1.3 ± 0.4	0.6 ± 0.2	8.7 ± 2.0	12.0 ± 3.5	100.0 ± 0.0
Frequency (n)	Clock-time (Ball in play)	275.3 ± 29.0	230.3 ± 48.4	51.2 ± 14.4	44.3 ± 7.1	32.3 ± 8.8	11.2 ± 3.9	6.4 ± 2.2	74.2 ± 16.2	128.2 ± 23.4	853.4 ± 76.4
	Match-time	505.1 ± 37.6	438.7 ± 77.0	99.4 ± 26.7	76.0 ± 9.0	51.5 ± 11.0	18.4 ± 5.0	9.9 ± 3.4	127.1 ± 26.4	213.2 ± 47.1	1539.2 ± 129.9
	Statistical analysis values (t/z,p)	t = 31.20, p < 0.001	t = 18.06, p < 0.001	t = 13.35, p < 0.001	t = 29.42, p < 0.001	t = 17.10, p < 0.001	t = 14.54, p = 0.001	t = 10.64, p < 0.001	t = 12.17, p < 0.001	t = 11.19, p < 0.001	t = 31.63, p < 0.001
% of total Frequency (n)	Clock-time (Ball in play)	32.4 ± 3.9	26.9 ± 4.4	6.0 ± 1.6	5.2 ± 0.8	3.8 ± 1.0	1.3 ± 0.5	0.8 ± 0.2	8.7 ± 1.5	15.0 ± 2.1	100.0 ± 0.0
	Match-time	33.0 ± 3.3	28.4 ± 3.8	6.4 ± 1.6	5.0 ± 0.6	3.3 ± 0.6	1.2 ± 0.3	0.6 ± 0.2	8.2 ± 1.4	13.8 ± 2.5	100.0 ± 0.0

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.
Statistical analysis values (t/z,p) show comparisons between Clock-time and Match-time (t when parametric, z when non-parametric tests used).

Table 2: Match time motion analysis results

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Distance (m)	First Half	0 ± 0	812.4 ± 161.2	384.6 ± 118.7	425.9 ± 73.7	360.3 ± 63.8	161.1 ± 83.0	81.7 ± 30.7	327.2 ± 87.6	540.3 ± 152.0	3093.5 ± 271.3
	Second Half	0 ± 0	929.0 ± 117.1	370.3 ± 120.6	348.1 ± 78.3	275.6 ± 65.1	114.4 ± 33.2	67.4 ± 57.6	327.5 ± 93.6	417.8 ± 103.7	2850.1 ± 219.1
	Statistical analysis values (t/z,p)	0, 0	t = -2.91, p = 0.010	t = 0.34, p = 0.733	t = 3.16, p = 0.006	z = -3.20, p = 0.001	t = 2.52, p = 0.022	t = 1.94, p = 0.068	t = -0.012, p = 0.991	t = 4.58, p < 0.001	t = 3.87, p = 0.001
Duration (s)	First Half	555.4 ± 130.0	744.9 ± 155.8	206.6 ± 66.9	153.9 ± 29.6	97.8 ± 17.3	36.1 ± 18.3	15.3 ± 5.6	210.1 ± 64.6	315.1 ± 103.4	2335.2 ± 219.4
	Second Half	669.9 ± 125.2	881.2 ± 141.5	196.3 ± 62.3	125.2 ± 28.1	74.0 ± 17.4	25.6 ± 7.9	11.5 ± 10.3	202.9 ± 65.5	253.1 ± 81.7	2439.7 ± 185.4
	Statistical analysis values (t/z,p)	t = -3.80, p = 0.001	t = -3.78, p = 0.001	t = 0.47, p = 0.643	t = 3.11, p = 0.006	t = 4.88, p < 0.001	t = 2.53, p = 0.021	z = -1.63, p = 0.102	t = 0.34, p = 0.732	t = 3.62, p = 0.002	t = -3.09, p = 0.007
Frequency (n)	First Half	242.1 ± 19.6	207.7 ± 50.1	52.8 ± 18.9	43.2 ± 8.3	29.5 ± 5.8	10.5 ± 3.9	5.6 ± 1.4	64.4 ± 13.4	118.9 ± 30.8	774.6 ± 78.6
	Second Half	262.9 ± 29.1	231.0 ± 33.3	46.7 ± 17.2	32.8 ± 4.8	22.0 ± 6.4	7.9 ± 2.1	4.3 ± 3.0	62.7 ± 21.4	94.3 ± 20.9	764.6 ± 63.6
	Statistical analysis values (t/z,p)	t = -2.73, p = 0.014	t = -2.73, p = 0.014	t = 1.06, p = 0.303	z = -3.02, p = 0.002	z = -3.41, p = 0.001	t = 2.79, p = 0.013	t = 2.81, p = 0.012	t = 0.30, p = 0.764	t = 4.44, p < 0.001	t = 0.70, p = 0.488

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.
Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 3: Physiological and perceptual measures

Pre match	**Half-time / First half**	**Post-match / Second half**	Statistical analysis values (F/z, p)
Blood lactate (mM)			
1.27 ± 0.32	1.98 ± 0.53	2.12 ± 0.41	F = 22.86, p < 0.001 ** for post hoc details see legend
Heart rate (BPM)			
-	150.9 ± 1.9	144.5 ± 2.6	z = - 3.50, p < 0.001
Session RPE			
-	6.8 ± 1.3	7.1 ± 0.7	z = - 0.90, p = 0.365

Values are mean ± SD (n=18).
Statistical analysis values (F/z,p) show comparisons between Half-time/First Half and Post-match/Second Half (and pre-match for lactate), (F when parametric, z when non-parametric tests used).
**Blood lactate post hoc: pre-match vs half time ($p < 0.001$); pre-match vs post-match ($p < 0.001$); half-time vs post-match ($p = 0.42$).

Table 4: Assessment of referee decision making performance.

Decisions made	**1st half**	**2nd half**	**Whole match**	Statistical analysis values (t/z, p)
Correct	91.1 ± 14.9%	73.3 ± 17.4%	81.3 ± 11.8% (123/151 decisions)	z = -2.71, p = 0.007
Contentious	1.7 ± 5.3%	8.8 ± 14.8%	6.5 ± 9.3% (9/151 decisions)	z = -1.82, p = 0.068
Incorrect	7.2 ± 14.4%	17.9 ± 17.1%	12.2 ± 11.3% (9/151 decisions)	z = -2.04, p = 0.041
Total decisions (151)	46% (69)	54% (82)	100%	
Missed fouls	24.8 ± 18.4%	75.2 ± 18.4%	100% (27 incidents)	t = -4.56, p = 0.002

Values are mean ± SD (n=18). Statistical analysis values show comparisons between 1st half and 2nd half.