Paper : Technical Analysis

# Assessment of Soccer Referee Performance during Games

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**This study examined the objective assessment of 6 aspects of physical fitness of referees. The first experiment assessed Japan football association (JFA) referees. We measured distance of movement, speed of movement, heart rate and distance of movement out of the diagonal system of control. The second experiment assessed both international-level referees and JFA referees. We measured distance from the points where fouls occurred to where the referee stood.**

**Results revealed significant differences between Class 1 and Class 2 JFA referees in distance moved outside the diagonal system of control. Moreover a significant difference was found between international-level and JFA referees as to distance from points where fouls occurred to where the referees stood.**

**Referees were assessed by distance of movement, distance from points where fouls occurred to where the referees stood, and heart rate. Speed and distance of movement out of the diagonal system of control may be new criteria to evaluate referees objectively.**

**Keywords:** Soccer, Referee, Distance of movement, Speed of movement

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## 1. Introduction

Since the establishment of the first professional soccer league in Japan (J League) in May 1993, the quality of soccer players and coaching staff in Japan has improved rapidly through the early identification of players with the potential to develop into top-level athletes, the introduction of age- and region-appropriate training centers for improved training environments, and systematic activities designed to cultivate soccer coaching staff. Such progress resulted in the participation of Japan National Soccer Team in four successive World Cup tournaments and the progression of all age categories to international-level competition within the lost few years. The continuous development of Japanese soccer also requires the cultivation of referees and the enhancement of their ability (Japan Football Association (JFA), 2007, 277). The four referees, which are a referee, two assistant referees, and a fourth official, play an important role in bringing out the characteristics and enjoyment of soccer through fair judgment and safe and smooth game control. As such, the cultivation and improvement of referees are considered distinctively important factors for the cultivation and enhancement of players (JFA, 2004, 248; 2007, 277).

The JFA implemented a professional referee system in 2002, and established a referee college in 2004, implementing an instructor system for the systematic cultivation and education of referees in each class, and started a referee training center system in 2007 to facilitate the enhancement of the entire system. As a result, many international-level Japanese soccer referees have participated in international tournaments and have been assigned to important matches, such as the final matches at major tournaments etc. (JFA, 2002, 217; 2004, 242; 2005, 256; 258; 259; 2006, 272). In stark contrast to these impressive achievements, however, many players' complaints have registered against referee judgments and there have been reports of dissatisfaction with official matches in Japan. This highlights the prompt need for further improvement in the quality and quantity of referees.

In the current system the quality of soccer referees is assessed in three ways:

(1) Rule testing to assess the referee's understanding of game rules,
(2) Physical fitness testing to assess whether the referee is sufficiently fit to function effectively during matches (JFA, 2005, 259), and
(3) The evaluation of performance during matches through assessment reports completed by qualified referee assessors (JFA, 2007/2008).

Assessment reports on referees, whose role and authority in matches exert a significant impact on the outcome, are of essential importance due to their use in determining promotions, demotions, and assignments (JFA Referee Committee, 2006). Assessors are required to have the following 5 qualities: 1. experience as a referee; 2. the ability to observe matches from the perspective of a referee; 3. the ability to recognize the level and quality of referees; 4. the ability to evaluate referees objectively; and 5. the ability to assess referees on the basis of unified standards of performance. Assessors evaluate the following 4 aspects of referees: 1. accuracy and consistency of calls; 2. game control; 3. physical fitness, movement and positioning; and 4. cooperation with assistant referees (JFA, 2007/2008). The subjective nature of the assessor's perspective, however, raises doubts about the ability to evaluate other referees effectively. Among these four factors, physical fitness is the only one that can be assessed objectively. Currently, two tests of physical fitness are performed; namely, tests to evaluate speed and endurance. The speed test requires referees to run 40 m within 6.4 seconds 6 times with 1.5-minute intervals between runs. The endurance test requires referees to run 150 m within 30 seconds and walk 50 m within a 40-second interval 20 times in succession. These tests can assess the physical fitness as objectively as the existing 12-minute run, while reproducing, conditions closer to actual games. In contrast to actual game conditions, the test movements are predetermined, and important factors for referee performance, such as ensuring a clear view, are not included in the assessment.

Against this backdrop, the present study was carried out with the purpose of examining six aspects of physical fitness related to referee performance that allow objective assessment: history of movement during matches, distance of movement, speed of movement, heart rate, distance of movement outside the range of the diagonal system of control, and distance between the referee and the point where the foul occurred.

## 2. Methods

### 2.1. Experiment 1. History, distance and speed of movement, and heart rate

#### 2.1.1. Subjects

Subjects were 14 JFA-certified referees (seven Class 1 and seven Class 2 referees). The age, experience, height, and weight of Class 1 referees were 33 ± 5 years of age, with 12 ± 2 years experience, 172 ± 6 cm, and 65 ± 7 kg, respectively; and Class 2 referees were 23 ± 4 years of age, with 5 ± 2 years experience, 175 ± 4 cm tall, and 66 ± 5 kg in weight, respectively. Investigators provided both written and verbal explanations of study purpose and methods to the subjects on the day prior to or before the start of the game, and obtained written consent prior to the participation. This study was approved by the Ethical Committee, Graduate School of Health and Sports Science, Juntendo University.

#### 2.1.2. Subject investigated

Fourteen matches were investigated, including 10 Kanto University Soccer League matches and 4 Chiba Prefecture Adult Amateur League matches.

#### 2.1.3. Track, distance, and speed of movement

Methods developed by Ohashi et al.(1998) were employed to measure referee's track, distance, and speed of movement during matches by W-EYES (manufactured by DKH), a behavior analysis system that employs triangulation. Two investigators coordinated in positioning a target player at the crossing of high-precision sights loaded on potentiometers fixed at two spots parallel to the touch lines of the field. Investigators obtained coplanar coordinates from the measured angles by triangulation (**Figure 1**). Data on speed and distance of movement were obtained every 0.5 seconds. Speed of movement was calculated by dividing distance by time. Accidental error was minimized by assigning two measurers to each sight. Outliers were smoothed through the comparison with video images to visually check utilizing a 5-point moving average filter.

#### 2.1.4. Heart rate measurement

Heart rate was measured by WearLink31C chest transmitter (manufactured by POLAR, Japan), which

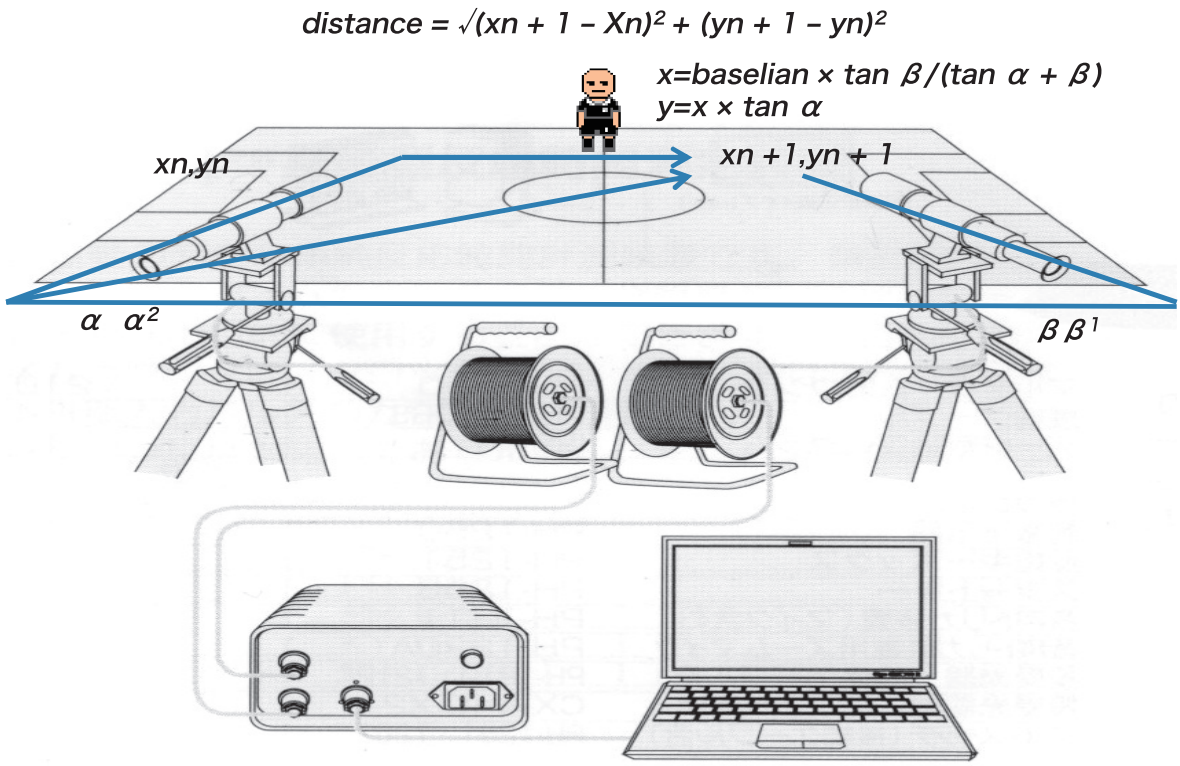


**Figure 1** High-speed movement Analysis-system

does not interfere with movement or judgment. Average heart rate data was recorded at 5-second intervals using RS400 (manufactured by POLAR, Japan). The estimated maximum value of the heart rate was set at 220-age.

### 2.1.5. Distance of movement out of the range of the diagonal system of control

Distance of movement out of the range of the diagonal system of control was measured by Digital Curvimeter CV-9Jr. (manufactured by Koizumi Sokki Mfg. Co., Ltd.) after setting the unit and scale size. We divided subject movement track obtained from W-EYES into five-second intervals in the first and second half. Distance of movement was then calculated based on the "Principle of the Diagonal System of Control (JFA, 2007/2008)." The unit of measurement was one meter and scale size was 500 (**Figure 2, 3**).

## 2.2. Experiment 2. Distance between the referee and the point where the foul occurred

### 2.2.1. Subjects

Subjects were 45 referees (15 international referees who refereed at the 2006 FIFA World Cup Germany, 15 Class 1 referees who refereed at the 2007 J League

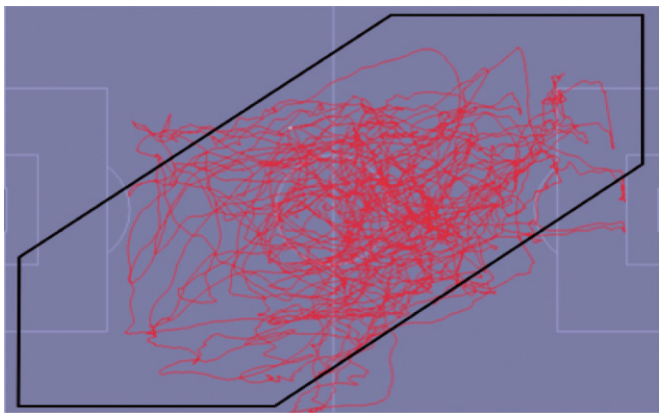

**Figure 2** History of Movement of 1st class refree and diagonal system of control (1st half : Typical example)

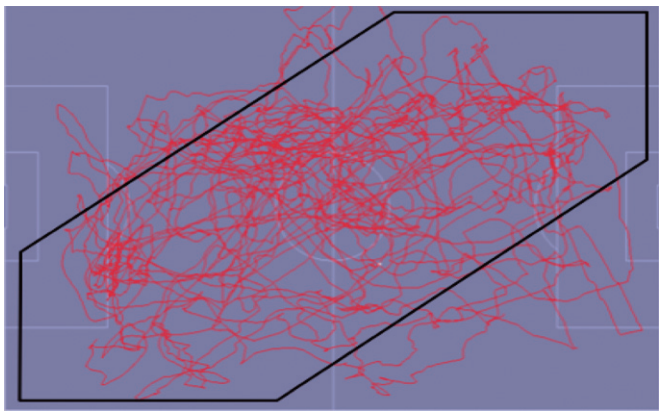

**Figure 3** History of Movement of 2nd class refree and diagonal system of control (1st half : Typical example)

Divisions 1 & 2, and 15 Class 2 referees who refereed at the 81st Kanto University Soccer League Division 1 and 2.

#### 2.2.2. Analyses

Games refereed by international and Class 1 referees were recorded on DVDs from videos broadcast on SKY PerfecTV. Live games refereed by Class 2 referees were recorded on digital video tape. Videos were recorded using the method described by Kobayashi, et al. (1998). The accuracy of this method is considered to be high because images can be stopped and marked. In order to obtain the most accurate positions possible, we recorded with reference to the lines of grass on the pitch, advertisements, and field lines. Class 2 referees marked videos with an "F" at the spot where a foul occurred and an "R" at the spot where the referee was standing on the field at the time the foul occurred. The scale was reduced to 1/370 and the distance between the referee and the spot where the fouls occurred was calculated.

### 2.3. Statistical processing

Stat View version 5.0 was used for all statistical analyses. All measurement data were shown as average value ± standard deviation. In Experiment 1, unpaired t-test was applied to differences in distance of movement, speed of movement, and heart rate of Class 1 and Class 2 referees and differences in the distance of movement out of the range of the diagonal system of control. In Experiment 2, one-way analysis of variance was used to determine the statistical significance among international, Class 1, and Class 2 referees. Multiple comparisons were carried out by Scheffe method for all items showing significant differences. Level of significance was set at less than 5 %.

## 3. Results

### 3.1. Distance and speed of movement

Distance of movement recorded per match for Class 1 referees was 12,029 ± 522 m and 12,031 ± 1186 m for Class 2 referees. In the first half, Class 1 referees moved 6,131 ± 338 m, and Class 2 referees moved 5,898 ± 325 m. In the last half, Class 1 referees moved 5,996 ± 594 m and Class 2 referees moved 6,035 ± 634 m. There was no significant difference in the distance of movement per match between Class 1 and Class 2 referees. The speed recorded for Class 1 and Class 2 referees in matches was 2.2 ± 0.1 m/sec. Speed of movement in the first half for Class 1 referees was 2.3 ± 0.1 m/sec and 2.2 ± 0.1 m/sec for Class 2 referees. In the last half, speed of movement for Class 1 referee was 2.2 ± 0.1 m/sec and 2.2 ± 0.2 m/sec for Class 2 referees. No significant difference was observed between Class 1 and Class 2 referees. Then, we divided the 45-minute first and last halves into 15-minute segments to compare and analyze Class 1 and Class 2 referee speed of movement. The first half was divided into 0-15 minutes, 15-30 minutes, and 30-45 minutes. The speed of movement per segment for Class 1 referees was 2.3 ± 0.1 m/sec, 2.3 ± 0.2 m/sec, and 2.2 ± 0.2 m/sec, respectively, while the speed of movement per segment of Class 2 referees was 2.3 ± 0.2 m/sec, 2.1 ± 0.1 m/ sec, and 2.0 ± 0.2 m/sec, respectively. Similarly, the last half was divided into 45-60 minutes, 60-75 minutes, and 75-90 minutes, with Class 1 referee speed of movement measured at 2.2 ± 0.1 m/sec, 2.2 ± 0.1 m/sec, and 2.2 ± 0.1 m/sec, respectively, and Class 2 referee speed of movement being 2.2 ± 0.2 m/sec, 2.2 ± 0.2 m/sec, and 2.2 ± 0.2 m/sec, respectively. No significant difference between Class 1 and Class 2 referees was revealed. The most frequent speed of movement among Class 1 referees in the first half was 3-4 m/sec, and the distance of movement was 1424 ± 67 m. The most frequent speed of movement among Class 2 referees was 2-3 m/sec, and the distance of movement was 1365 ± 171 m. In the last half, the most frequent speed of movement for both Class 1 and Class 2 referees was 2-3 m/sec. The distance of movement was 1398 ± 109 m for Class 1 and 1379 ± 164 m for Class 2. The distance of movement at each speed revealed no significant difference between Class 1 and Class 2 referees.

### 3.2. Heart rate

Heart rate of the Class 1 referees was 163 ± 16 beats per minute (bpm) and the heart rate of Class 2 referees was 168 ± 9 bpm. In the first half, the Class 1 referee heart rate was 162 ± 16 bpm and Class 2 referee heart rate was 168 ± 8 bpm. In the last half, Class 1 referee heart rate was 164 ± 16 bpm and Class 2 referee heart rate was 169 ± 10 bpm. Results revealed no significant difference between Class 1

and Class 2 referees. The maximum heart rate of Class 1 referees was 87 ± 7% and the maximum heart rate for Class 2 referees was 86 ± 4%. In the first half, Class 1 referee heart rate was 87 ± 7% and Class 2 was 86 ± 4%. In the last half, Class 1 was 88 ± 8% and Class 2 was 86 ± 4%. There was no significant difference between Class 1 and Class 2. Dividing both first and last halves into 15minute segments as we did for speed, we observed changes in referee heart rate. As a result, in the first half, Class 1 referee rates were 156 ± 16/min, 165 ± 15/min, and 166 ± 16/min, respectively, and Class 2 heart rates were 165 ± 14/ min, 168 ± 13/min, and 171 ± 16/min, respectively. In the last half, Class 1 rates were 160 ± 18/min, 165 ± 15/min, and 167 ± 16/ min, respectively, while Class 2 rates were 166 ± 17/ min, 169 ± 14/min, and 171 ± 15/min, respectively. Results showed no significant difference by 15-minute segment between Class 1 and Class 2.

### 3.3. Distance of movement out of the range of the diagonal system of control

Class 1 referee distance of movement out of the range of the diagonal system of control was 689 ± 236 m while Class 2 referee distance was 1126 ± 391 m. In the first half, Class 1 showed 364 ± 138 m and Class 2 showed 509 ± 189 m. In the last half, Class 1 showed 325 ± 127 m and Class 2 showed 617 ± 233 m. As a result, Class 1 showed significantly lower values in the distance of movement out of the range of the diagonal system of control than Class 2 did ($p>0.05$) (**Figure 4**).

### 3.4. Distance between the referee and the point where the foul occurred

The distance between referees and the point where the foul occurred was 12 ± 3 m for international referees, 14 ± 4 m for Class 1 referees, and 14 ± 5 m for Class 2 referees. Comparison among the three groups revealed significantly lower values for international referees than the two other groups ($p<0.05$). Comparison of referees by 15-minute match segment showed significantly different values ($p<0.05$) for international and Class 1 referees during the 75-90 minute time segment of the game. However, there were no significant differences during the other time segments (**Figure 5**).

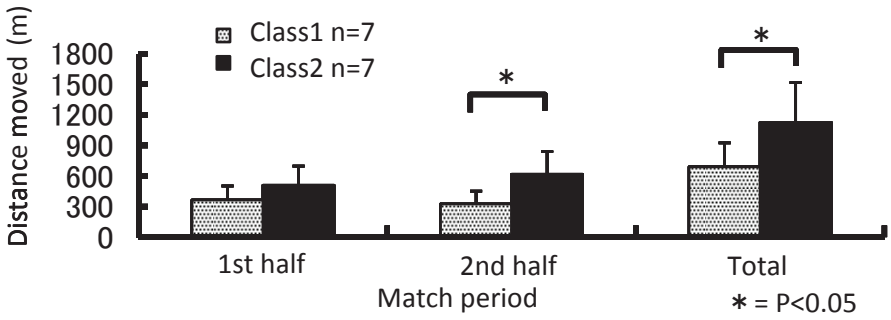


**Figure 4** Distance of movement out of the range of the diagonal system of control

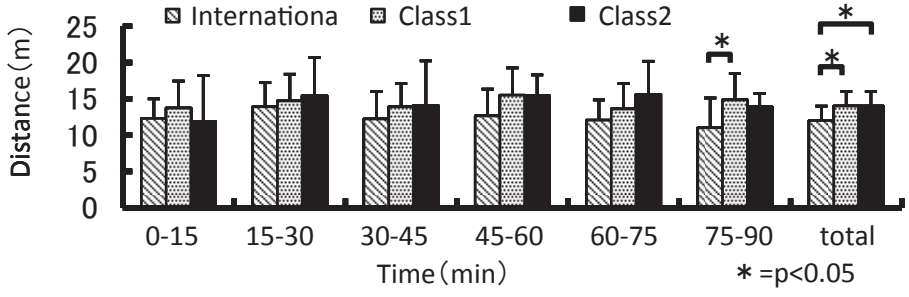


**Figure 5** Distance of movement between the referee and the point where the foul occurred for every 15-min segment

## 4. Discussion

### 4.1. Distance and speed of movement, and heart rate

#### 4.1.1. Distance of movement

The referees require sufficient physical fitness to referee effectively throughout a match. We employed W-EYES to compare the physical fitness of Class 1 and Class 2 referees in the first and last halves, and the entire match. The results revealed no significant difference between the two groups. There was also no significant difference in the distance of movement in the first or last halves, with results showing that both Class 1 and Class 2 referees moved more than 12 km during matches. Although distance of movement during matches is closely associated with endurance, it is also greatly influenced by the dynamic relationship between the two opposing teams, static factors, motivation, and weather (Ohashi et al., 1985). The results of investigations by Castagna and other researchers (Castagna & D'Ottavio, 2001; Catterall et al., 1993; D'Ottavio, & Castagna, 2001) were consistent with this study in revealing no extreme difference in distance of movement during matches between Class 1 and Class 2 referees. However, in their studies, it was recognized that referees require the endurance necessary to run approximately 12 km in soccer matches. Measuring the distance of movement allows the objective assessment of the referees' endurance. It is considered important for Class 3 and Class 4 referees as well as Class 1 and Class 2 referees to develop sufficient endurance for movement throughout matches.

#### 4.1.2. Speed of movement

While many studies of soccer players' speed of movement have been published, no studies have examined referees' speed of movement during matches. Players' speed of movement fluctuates irregularly within the range of 1 m/ sec to 4 m/sec, rarely reaching a top speed of 8-9 m/sec (Ohashi et al., 1983, 1985). This study employed W-EYES to obtain data for a comparison of the speed of movement of Class 1 and Class 2 referees during the first and last halves as well as entire matches. The results revealed no significant difference between these two groups. Indeed, results indicated trends similar to the results obtained in previous studies of the speed of movement of soccer players during matches (Miyazaki et al., 2001; Ohashi et al., 1983). In other words we confirmed that there was no difference in speed between referees and players. These results show the possibility of objectively assessing the speed of movement required for referees to perform effectively throughout an entire match. Because the speed of movement of both players and referees during matches is irregular and the existing physical fitness test employs the 12-minute run for assessment, a speed test has been developed which employs six 40-m runs within 6.4 seconds and an endurance test which employs a 50-m run within 40 seconds, repeated 20 times. These tests showed that referees also require sprinting ability and the same physical fitness as players. However, the validity of the tests has not been confirmed and requires further study.

#### 4.1.3. Heart rate

Five factors were compared : heart rate of referees in the first and last halves, average heart rate, the ratio to maximum heart rate and heart rate every 15 minutes. No difference was found between Class 1 and Class 2 referees, consistent with previous studies. In spite of the fact that Class 1 referees are 10 years older than Class 2 referees, the comparison revealed no difference in heart rate between Class 1 and Class 2 referees, which showed that Class 1 referees maintained a high level of physical fitness. Koshiyama (1992) reported that both distance of movement and heart rate for referees were lower in the middle of the last half of matches. However, the present study revealed no significant difference in heart rate between the first and last halves, which contradicts previous studies that reported an increase of heart rate in the last half. According to the FIFA World Youth Championship UAE 2003 report, an important factor for referees in modern soccer games is sufficient physical fitness to manage 90-minute matches, and the present study showed that in fact physical fitness has increased. There was no significant difference between the heart rate for each 15-minute segment and speed of movement. However, Class 2 referee heart rate exceeded the heart rate of the Class 1 referees throughout matches, and Class 1 referees had greater speed of movement than Class 2 during the 15-30, 30-45, and 45-60 minute segments. In addition, while Class 1 moved at 3-4 m/ sec the majority of the time, Class 2 moved at 2-3 m/ sec the majority of the time. These results make clear

the need for cardiorespiratory capacity which allows repeated sprints in the modern soccer games.

### 4.2. Distance of movement of referees out of the range of the diagonal system of control

In order for referees to perform effectively, it is essential for them to move flexibly to see each player's movements clearly. Referees adopt the diagonal system of control as a basic technique. There was no significant difference in the distance and speed of movement and heart rate among Class 1 and Class 2 referees. However, according to a comparison of the distance of movement out of the range of the diagonal system of control in the first and last halves, and throughout the match, Class 1 referees showed significantly shorter distances than Class 2 referees in the last half and throughout the match ($p<0.05$). As a result, Class 1 referees conformed more with the principles of the diagonal system of control than did Class 2 referees. In other words, Class 1 referees showed a longer distance of movement within the range of the diagonal system of control than Class 2 did. This may be a result of differences in years of experience and number of games refereed. Furthermore, when Class 1 referees are in charge of matches, assistant referees with higher skill are naturally assigned to the matches. Effective refereeing requires cooperation between the referee, two assistant referees, and the fourth official during matches. The referee has the right to make final decisions: However, if the assistant referee has a clearer view than the referee when a foul occurs, the assistant referee has the right to be involved in the judgment. Such cooperation between the referee and assistant referees makes it possible to reduce the distance of movement during matches. Based on these facts, Class 1 referees cooperate more with other referees compared with Class 2 referees and adjust their positions more than Class 2 referees do.

### 4.3. Distance between the referee and the point where the foul occurred

An examination of the distance between the referee and the point where the foul occurred showed 12 ± 3 m for international referees, 14 ± 4 m for Class 1 referees, and 14 ± 5 m for Class 2 referees. As a result, distances for international referees were similar to Class 1 and Class 2 referees ($p<0.05$). During the last 15-minute segment (75-90 minutes) in the last half, distances for international referees were similar to Class 1 ($p<0.05$), and international referees with higher skill refereed in locations closer to the ball than did Class 1 and Class 2 referees. In regard to the distance of movement out of the range of the diagonal system of control, Class 2 called fouls at locations closer to the ball than did Class 1 referees. However, there was no difference in the distance between referee and the point where the foul occurred between Class 1 and Class 2 referees. Therefore, it is considered that Class 1 referees cooperate closely with assistant referees, adjusting their positions while managing 90-minute games.

While the national teams of each country won the preliminary matches in each region to earn a place in the World Cup, referees also experienced many severe games, from domestic to six continental league matches. The top-level referees participating in World Cup games as international referees have higher skill levels and cooperate well with assistant referees, and this reduces the need for the referee to be close to players when they make fouls out of the range of the system of control. Toru Kawakami, the first Japanese referee to participate in a World Cup tournament and referee for the third-place match in the 2006 World Cup in Germany, expressed the opinion that the referee should not move along with the ball. In order to maintain good positioning, the referee needs to understand the tactics of teams and the characteristics of players to predict the progress of the match. He also stated that experience is of essential importance.

Matches involve two teams of eleven individuals. Four referees work together as a team during matches. Until 1996, assistant referees served as linesmen and had the responsibility of judging whether a ball was in or out of bounds or offside. After 1996, however, linesmen became assistant referees and came to provide greater support to the referee. Therefore cooperation among referees is essential. In many cases, only one or two out of 11 players are around the ball at any given moment; however, the referee is required to be close to the ball all the time, which demands that the referee have, in addition to endurance and speed, good cooperation with assistant referees. The referee is also required to read the intentions of each player and the flow of the game to quickly move to the next position.

## 5. Conclusions

This study showed that distance of movement and heart rate of referees, distance between the referee, and the point where a foul occurs can be used to objectively assess the skills involved in refereeing and the physical fitness required for matches.

This study suggested that speed of movement of referees and their distance of movement out of the range of the diagonal system of control could serve as new indices for the objective assessment of the skills involved in refereeing.

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