Activity profile and physiological responses of Korean amateur football referees during matches

YOUNGIN CHOI1), JUNGSUK ROH2)*

1) Department of Physical Therapy, Ansan College, Republic of Korea
2) Department of Physical Therapy, Hanseo University: 46 Hanseo 1 ro, Hami-myon, Seosan, Chungchungnam-do 356-706, Republic of Korea

Abstract. [Purpose] The present study aimed to analyze and compare the activity profile and physiological responses of amateur football referees during competitive matches of high school and college students. [Subjects and Methods] Thirty referees (high school, 15; college, 15) were included in this study. The total distance covered, movement speed, and heart rate were measured using a global positioning system-enabled wireless heart rate monitor. The blood lactate concentration was measured immediately after the first and second half. [Results] College football referees covered a higher total distance than did their high school counterparts (7,547 m vs. 6,719 m). The maximal heart rate of college football referees was low in the first half alone, and the percentage of the heart rate within the “maximum” range was low throughout the game. [Conclusions] Refereeing imposes a significantly high physical load on the body while tracking player and ball movement. The present study suggests the need for developing and distributing physical training programs tailored for refereeing.

Key words: Physiology, Heart rate, Football

INTRODUCTION

Official football matches are typically controlled by a match referee, an assistant referee, and a fourth official, according to the rules of the game; there can be an additional assistant referee and reserve assistant referee, depending on the importance of a match.

The referee moves simply in an attempt to be in the best position for making a correct decision. However, the referee is required to make sudden direction changes or accelerate and deaccelerate speed under unexpected circumstances, thus, expending more energy compared with that in ordinary movements performed for the same distance covered1, 2). In addition, the referee has to constantly move to keep up with the movement of players and the ball without rest, thereby increasing physical burden3).

The referee’s physical fitness, an influential factor for cognition, is indirectly related to the correctness of decision-making during matches2, 4). Therefore, it is important to analyze the activity profile and physiological responses of football referees to measure their physical capacity and quantify the physical demands required for refereeing. Krustup and Bangsbo5) investigated the physical capacity of soccer referees in two leading Danish leagues: the Danish Superliga and first division. In their study, the former group covered a total distance of 10,190 m and had a mean heart rate of 162 beats per minute (bpm), maximal heart rate of 190 bpm, and mean blood lactate concentration of 4.8 and 5.1 mmol after the first and second half, respectively. Moreover, the first division covered a total distance of 9,940 m and had a mean heart rate of 164 bpm; maximal heart rate of 184 bpm; and mean blood lactate concentration of 4.8 and 5.0 mmol after the first and second half, respectively5).

Korean studies have investigated the total distance covered and coverage time as well as the movement speed of referees.
using a global positioning system (GPS), without analyzing physiological responses, providing limited information on the physical burden on referees\(^5\). Moreover, these studies have mostly involved top-class referees, indicating that no attempt was made to examine the physical capacity of amateur referees, although they constitute a large proportion of referees in each country. Therefore, the present study aimed to examine the physical requirements for performing refereeing by analyzing and comparing the activity profile and physiological responses of amateur referees officiating specific high school and college football games in 2017. This study also intended to underline the importance of physical training for referees and to provide fundamental data necessary for the development of such programs.

**SUBJECTS AND METHODS**

This study involved 15 referees who officiated the 13th KBS N Football Game of College Students (freshmen and sophomores) and 15 referees who officiated the 50th National Football Game of High School Students for the President Award; both games were held in 2017 (Table 1). The participants were fully informed of the study purpose, and those who provided informed consent underwent measurements. Participants were excluded if they were taking medications or had a medical problem or other variables that could affect the study results.

The activity profile and movement speed were measured by a GPS-enabled Polar watch (RC3 GPS, Finland) worn by each participant. The data were automatically stored in the watch and were analyzed using website-based statistical software to record the total distance covered and maximum and mean movement speed.

The heart rate was measured using a wireless Polar heart rate monitor. A monitor sensor was attached to the area identified at the two-thirds of the chest circumference, and the measured data were wirelessly recorded by the wristwatch. The participants wore the sensor and watch at least 1 hour before each game and were given time to get used to the sensor. Physical activities were measured during the first and second half, which lasted 45 minutes each, and were partially recorded. Specifically, the mean and maximum heart rate and heart rate distribution (in percentage) were measured. The blood lactate concentration was measured using an automatic lactate analyzer (Lactate PRO, LT-1730, Japan). Peripheral blood was collected from the area 4–5 mm superior to the fingertip and injected into the lactate analyzer for measurement. Alcohol was used for disinfection before and after blood sampling. The measurements were recorded immediately after the first and second half.

The collected data were statistically analyzed using SPSS 21.0 (IBM, Armonk, NY, USA), and the mean and standard deviation were calculated for each variable. The independent sample t-test was used to compare measured variables between the two groups, and the paired t-test was used to compare the differences in measured variables between the first and second half in each group. \(p<0.05\) was considered statistically significant.

**RESULTS**

The overall activity profile of the referees during the high school and college football games is shown in Table 2.

The total distance covered by the referees officiating high school games was 6,719 m (first half, 3,180 m; second half, 3,539 m). Their mean movement speed was 3.6 km/h and 3.4 km/h in the first and second half, respectively, while their maximum movement speed was 23.0 km/h and 22.3 km/h, respectively.

The total distance covered by the college football referees was 7,547 m (first half, 3,625 m; second half, 3,922 m). Their mean movement speed was 3.4 km/h in both periods, while their maximum movement speed was 23.7 km/h and 23.4 km/h for the first and second half, respectively.

The overall physiological responses of the referees during the high school and college football games are shown in Table 3.

The high-school football referees had a mean heart rate in the first and second half of 150 bpm and 148 bpm, respectively, and a maximum heart rate of 177 bpm and 175 bpm, respectively. The heart rate distribution was 20% maximum, 30% hard, 24% moderate, 17% light, and 7% very light in the first half, and 18% maximum, 24% hard, 24% moderate, 22% light, and 9% very light in the second half. The blood lactate concentration was 5.0 and 5.9 mmol after the first and second half, respectively.

| Table 1. General characteristics of the subjects |
|------------------------------------------------|
| HRG | CRG |
| Class 1 (n=6) | Class 2 (n=9) | Class 1 (n=14) | Class 2 (n=1) |
| Age (yrs) | 36.81 ± 7.74 | 38.74 ± 6.51 |
| Height (cm) | 174.98 ± 3.89 | 172.66 ± 5.89 |
| Weight (kg) | 71.44 ± 8.02 | 68.15 ± 7.48 |
| Refereeing experience (yrs) | 5.92 ± 1.97 | 9.64 ± 2.25 |

HRG: high-school referee group; CRG: college referee group.
The college football referees had a mean heart rate in the first and second half of 146 bpm and 145 bpm, respectively, and a maximum heart rate of 169 bpm and 170 bpm, respectively. The heart rate distribution was 6% maximum, 31% hard, 29% moderate, 22% light, and 10% very light in the first half, and 6% maximum, 29% hard, 29% moderate, 22% light, and 12% very light in the second half. The blood lactate concentration was 5.2 and 6.4 mmol after the first and second half, respectively.

### DISCUSSION

The referee follows players' action by moving inside the football pitch with no restrictions, with the aim of regulating the game according to the rules\(^1\). An optimal position for making a correct decision is defined as a spot where the referee can oversee both the players and assistant referees, and the referee has to move constantly to take such an appropriate position in a timely manner\(^6\). Therefore, the referee’s movement capability is a key element for improving the accuracy of decision making. In this study, we measured the total distance as well as the mean and maximum movement speed for evaluating the movement patterns of football referees. The results revealed that the college referees covered greater distances than the high-school referees. However, in both groups, the total distance covered was much greater in the second half than in the first half. The greater distances covered by the college group can be attributed to external factors associated with the movement capability of players. Given that the referee’s movement is positively correlated with the speed of players and the ball\(^7\), the college referees must have been required to move more quickly to deal with college players who perform better and have a physical capacity that is higher than that in high school students. Generally, towards the end of the game, the locomotive activity of the referee is expected to decline due to accumulated fatigue\(^8\). However, we found that the total distance covered in the second half was significantly high in both groups. Two hypotheses may explain this finding: the referee demonstrated strong physical fitness in the game or the referee’s movement was affected by frequent long-passing techniques, used as one of the game strategies for the second half.

The heart rate is an indicator of physiological responses triggered by physical activities and increases during exercise to accelerate oxygen supply to active muscles\(^3,7\). Therefore, heart rate monitoring is essential for assessing human energy expenditure and metabolic function and the ability to perform exercise, and may be used to prescribe training programs. In the present study, the major results were that the maximum heart rate of the college referees was significantly lower during the first half and that the percentage of the heart rate in the “maximum” range was low throughout the game. The range was highest when heart rate variations were divided into five categories and presented as a percentage of the total time in the first

### Table 2. Activity profile of the referees during games of high school and college football students

|                | HRG        | CRG        |
|----------------|------------|------------|
|                | First half | Second half| First half | Second half |
| Total distance covered (m) | 3,180 ± 0.6 | 3,539 ± 0.3\(^*\) | 3,625 ± 0.3\(^*\) | 3,922 ± 0.3\(^*\) |
| Mean movement speed (km/h)  | 3.6 ± 1.1  | 3.4 ± 1.2  | 3.4 ± 1.3  | 3.4 ± 1.1  |
| Maximum movement speed (km/h) | 23.0 ± 3.1 | 23.0 ± 3.4 | 23.7 ± 2.5 | 23.4 ± 3.4 |

\(^*\)Significantly different compared to first half (p<0.05).

### Table 3. Physiological responses of the referees during high school and college football games

|                | HRG        | CRG        |
|----------------|------------|------------|
|                | First half | Second half| First half | Second half |
| Mean heart rate (bpm) | 150 ± 18.9 | 148 ± 22.4 | 146 ± 6.6 | 145 ± 8.9 |
| Max. heart rate (bpm) | 177 ± 14.7 | 175 ± 15.9 | 169 ± 9.1\(^†\) | 170 ± 11.9 |
| Heart rate distribution (%) | Maximum 20 ± 16.8 | 18 ± 18.9 | 6 ± 10.6\(^†\) | 6 ± 8.2\(^†\) |
|               | Hard 30 ± 15.9 | 24 ± 14.9 | 31 ± 20.1 | 29 ± 18.5 |
|               | Moderate 24 ± 13.6 | 24 ± 11.7 | 29 ± 10.5 | 29 ± 11.2 |
|               | Light 17 ± 13.8 | 22 ± 16.2 | 22 ± 15.7 | 22 ± 14.9 |
|               | Very light 7 ± 8.0 | 9 ± 12.4 | 10 ± 12.5 | 12 ± 17.1 |
| Blood lactate concentration (mmol) | 5.0 ± 3.2 | 5.9 ± 3.4 | 5.2 ± 3.0 | 6.4 ± 2.9 |

\(^*\)Significantly different compared to first half (p<0.05).
\(^†\)Significant difference between the groups (p<0.05).

HRG: high-school referee group; CRG: college referee group; bpm: beats per minute.
and second half. Overall, the college referees seemed to show superior characteristics compared to the high-school referees in terms of the ability to overcome the burden of the game’s physical requirements, and they showed less cognitive load and stress\(^8\). This means that high-school referees are more likely to make decision errors in relation to their lower physical capacity and cognitive response to stress\(^4\). Such findings were interesting, considering the fact that the mean age of the college referees was high. Since college tournaments are also competitions where future professional athletes are identified based on their capabilities, most referees are highly qualified individuals with class 1 certification. Therefore, the attitude of the referees in preparing for the tournament and their approach to games may have been significant. It is believed that such factors may have contributed to good physical fitness, as indicated by the findings in this study.

Blood lactate concentration indicates the level of lactic acid accumulated in blood after high-intensity exercise and reflects anaerobic energy production\(^2\). Sporadic sprinting by the referee is considered high-intensity movement for which the muscles exert force, and the shift from aerobic to anaerobic energy generation occurs in the referee\(^2\). Therefore, high blood lactate levels mean that high-intensity activities have been frequently performed\(^2\). In the present study, both groups demonstrated higher blood lactate levels in the second half than in the first half. This result is expected given that high-speed running increases toward the end of the game and implies that the physical load on the referees markedly increases as the game progresses\(^8\).

This study has certain limitations. Because of its small sample size \((n=30)\), it may be difficult to generalize the study results. Further limitations include problems involved in clearly identifying the activity profile and physiological responses of the referees, with the time period divided into the first and second half, and relating blood lactate levels to only activities performed several minutes before blood sampling\(^2\).

In conclusion, this study showed that the physical demand on football referees is significantly high because of the nature of their task, which requires continuous movement to track players and the ball without a rest period. Hence, regular physical training including specialized sprinting is necessary for referees to maintain the level of physical fitness required to effectively perform their duties\(^3,8\). Further studies are needed to investigate the effects of physical training programs designed for referees on physical stress imposed on them during matches.

**Funding**

This research was supported by Hanseo University.

**Conflict of interest**

None.

**REFERENCES**

1) Castagna C, Abt G, D’Ottavio S: Physiological aspects of soccer refereeing performance and training. Sports Med, 2007, 37: 625–646. [Medline] [CrossRef]

2) Krustrup P, Mohr M, Bangsbo J: Activity profile and physiological demands of top-class soccer assistant refereeing in relation to training status. J Sports Sci, 2002, 20: 861–871. [Medline] [CrossRef]

3) Helsen W, Bultynck JB: Physical and perceptual-cognitive demands of top-class refereeing in association football. J Sports Sci, 2004, 22: 179–189. [Medline] [CrossRef]

4) Krustrup P, Bangsbo J: Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. J Sports Sci, 2001, 19: 881–891. [Medline] [CrossRef]

5) Jang J, Hur S: Analysis of physical match performance in football referees using GPS. Korean J Sports Sci, 2014, 23: 1433–1441.

6) Mallo J, Frutos PG, Juárez D, et al.: Effect of positioning on the accuracy of decision making of association football top-class referees and assistant referees during competitive matches. J Sports Sci, 2012, 30: 1437–1445. [Medline] [CrossRef]

7) Catterall C, Reilly T, Atkinson G, et al.: Analysis of the work rates and heart rates of association football referees. Br J Sports Med, 1993, 27: 193–196. [Medline] [CrossRef]

8) Krustrup P, Helsen W, Randers MB, et al.: Activity profile and physical demands of football referees and assistant referees in international games. J Sports Sci, 2009, 27: 1167–1176. [Medline] [CrossRef]