Variability of Soccer Referees' Match Performances

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Abstract

The aim of the present study was to determine the between-match variability in soccer referees' match performances. 1269 individual match observations were undertaken on 59 referees (range 2-79 games per referee) officiating in the English Premier League and Championship from 2003/2004 to 2007/2008 using a computerised tracking system (Prozone®, Leeds, England). Between-match coefficients of variation (CV) were calculated for all games and then compared between referee age and experience groups. High mean CVs were observed for high-speed running distance (25.9 ± 10.1%), recovery time (32.7 ± 13.8%), explosive sprints (34.3 ± 16.6%), total number of sprints (54.0 ± 20.7%) and number of match fouls (28 ± 4.6%). Smaller CVs were observed for total distance covered (3.8 ± 1.5%), top sprinting speed (5.6 ± 10.9%), distance from the ball (4.2 ± 1.9%) and the distance from fouls (9.9 ± 4.3%). Variability in match activities was not influenced by referee age or experience. The present study's findings demonstrate that variability in soccer referees' match performances is high in some variables and not dependant on referee age or experience. Such variability means that research requires large sample sizes to detect real systematic changes in a number of performance characteristics when studied during matches.

Key words: Between-match variation, physical performance, age, experience

Introduction

Referees are pivotal to the game of soccer; their physical and cognitive performance being an inevitable influence on match outcomes. Therefore, it is important that their physical performance is given due consideration by sports scientists [6]. Consequently, the match physical performances of soccer referees have received an increasing amount of attention in the literature. Previous researchers have reported that the match distances covered by English Premier League referees are similar to those of the players they are officiating [23,20], thereby illustrating the high level of physical strain imposed upon the referees during competitive match-play. It is the amount of high-speed activity that appears to be the best measure that discriminates between levels of physical performance in soccer refereeing [17,18]. However, like all measures of sporting performance high-speed efforts undertaken by referees during match-play may be subject to variation between successive matches. Indeed one of the key factors that have been reported to influence the amount of high-speed activity performed by soccer referees is the overall match intensity, as determined by the amount of high-speed activity performed by the players [21]. A recent analysis undertaken on 485 elite outfield players across three competitive seasons, reported that match-to-match variability was generally high across all high-speed running variables with a mean +/- SD coefficient of variation (CV) of 16.2 ± 6.4% (95 % CI = 15.6–16.7%) and 30.0 ± 11.3% (95% CI = 29.9-30.9%) reported for high-speed running and total number of sprints during a game, respectively [13]. Such large within-subject (player) or between-match variation in high-speed activity could be a consequence of changes in the players' tactical roles [20] along with changes in the physical condition of the player [19], environmental conditions [11] and the self-imposition of physiological stress [10]. Given that soccer referees' match physical performances are related in part to those of the players on the same matches [21], the magnitude of the between-match variability reported in players suggests that the variability in referees' physical performance is likely to be relatively large.

Soccer referees are required to keep up with play at all times despite occupying an age bracket on average 10-15 years older than their playing counterparts. Along with previously reported age-related impairments in referees' fitness levels [5] Weston and colleagues [24] reported an age effect for referees' physical match performances, with older referees (43-48 years) covering significantly less total match distance, high-speed running and performing less sprints when compared to the younger (31-36 years) referees. However, the decreased match physical performances did not impact upon the older referees' ability to keep up with play, as determined by average distances from the ball and from fouls. Consequently, Weston et al. [24] proposed that the older, more experienced referees may well be more economical with their movements due to their many years of practice. If indeed older, more experienced referees are able to better regulate their own workloads this may result in a lower match-

to-match variability of activities in comparison to younger, less experienced referees. Therefore, the influence of referee age and experience upon match-to-match variability warrants investigation.

The description of performance variability is important for predicting statistical power in research as well as how worthwhile a certain intervention is for performance [3], yet to date relatively few attempts have been made to provide a detailed analysis of the match-to-match variation of key match performance activities in soccer referees. Krustrup & Bangsbo [17] reported mean intra-individual coefficients of variation (n=8) in total distance covered and high-speed running of 4% and 6%, respectively. Whereas, from a total of 88 matches played within a 7-day period Weston et al. [21] demonstrated a match-to-match variation for total distance covered and high-speed running in referees (n=16) of 15% and 47%, respectively. These values, however, were for a limited number of physical performance indices and were calculated from only two successive matches. Therefore, a more detailed examination utilising a greater number of performance measures, along with an assessment of how sampling over different lengths of time might influence variability is warranted if the match-to-match variability in referees' match performances is to be fully understood.

Therefore, the purpose of the present study was to 1) evaluate the longer- and shorter-term between-match variability in elite soccer referees' match performance activities, and 2) examine the influence of referee age and experience upon match-to-match variability.

Methods

Referees and match data

A total of 1269 individual match observations were undertaken on 59 referees (median of 9 games per referee; range = 2-79 games) competing in the English Premier League (n=919 observations) and Football League Championship (n=350 observations) from 2003/2004 to 2007/2008 (5 seasons). The study conformed to the ethical standards of the International Journal of Sports Medicine [14].

Data collection and analysis

Each match was examined using a computerised, semi-automatic video match-analysis image recognition system (ProZone®, Leeds, England). Recent findings have demonstrated that the ProZone® match-analysis system provides valid and reliable analyses of movement patterns of footballers during match-play [8,9]. To examine the effect of age on match-to-match variability the referees were assigned to one of three different age-group categories [23]; young (22-36 years, n=23; match observations = 338), intermediate (37-42 years, n=24; match observations = 420) and older (43-49

years, *n*=12; match observations = 511). Referee experience was recorded at the beginning of each respective season. To determine the effect of referee experience on match-to-match variability the referees were divided into two groups [21]; a low experience group (*n*=46; match observations = 571), with 4 seasons or less refereeing on either the Premier or Football League, depending upon which competition the referee's data were recorded, and a high experience group (*n*=13; match observations = 698) with more than 4 seasons refereeing.

The objective measures of match physical performance selected for analysis were: 1) total distance covered (m); 2) high-speed running distance (m; running speed >19.8 km.h); 3) mean recovery time between high-speed bouts (s); 4) total number of sprints (>25.2 km.h); 5) top sprinting speed (km.h); 6) % of explosive sprints (characterised by a rapid acceleration) defined as the attainment of sprint speed (>25.2 km.h) from either standing, walking [7.2 km.h], jogging [< 14.4 km.h] or running [< 19.8 km.h] with time spent in the high-speed run category [19.8 to 25.2 km.h] less than 0.5 s). These speed thresholds are the current ProZone® default thresholds. A recent study has demonstrated that running distances based on individualised speed thresholds are substantially lower than distances recorded when the ProZone® classifications are used [1]. Therefore, we acknowledge that the thresholds used fail to individualise match activities relative to each referee's specific movement speeds or physiological capacity. As such the inability to determine this relationship makes it difficult to relate any speed of movement to the specific range of intensities that can be performed by the referees. However, the use of the ProZone® speed thresholds is consistent with previous studies analysing the match physical performances of English Premier League referees [22,24] and players [8,9,20].

Objective measures of the referees' technical performances were also selected for analysis, with these measures being the mean number of match fouls, mean distance from fouls (m) and mean distance from the ball (m).

Evaluation of shorter-term between-match variability

To determine the magnitude of the variability in referees' physical performance measures between matches played within a short time frame, match data from 15 referees were analysed across an 8-week period for any of the seasons included within the present study. Only those referees completing a minimum of 4 (median = 5, range = 4-8) consecutive games across the time period were included for analysis.

Statistical analysis

Data were explored for parity with a normally distributed population using histograms. All data, including the large data-set for number of sprints in a match, were found to be reasonably normal in

distribution. Therefore, data are presented as the mean ± SD. Between-match coefficients of variation (CV) and associated 95 % confidence intervals (CI) were calculated for each variable and compared between referee age-groups and referee experience using a one-factor (between group) general linear model. The residuals from this statistical model were found to be reasonably normal in distribution. Specific significant differences in estimated marginal means between age-groups and experience-groups were explored using independent *t*-tests incorporating the Bonferroni correction for control of type I error rate. Coefficients of variation were calculated by dividing the standard deviation of repeated performance data by the corresponding mean value for each referee. These coefficients of variation were found to follow an approximate normal distribution.

Results

Longer-term between-match variability in match performance activities

The referees' mean match performance measures across 1269 matches are presented in Table 1. The longer-term match-to-match variability (independent of referee age and experience) and associated 95 % CI interval for each match performance indicator is also presented in Table 1. A high match-to-match variability was observed for high-speed running distance, recovery time, % of explosive sprints, the total number of sprints and the number of match fouls. Less match-to-match variability was observed for total distance covered, top sprinting speed, distance from the ball and the distance from fouls. Match-to-match variability in match performance activities was not influenced by referee age (Table 2) or referee experience (Table 3).

Shorter-term between-match variability in match performance activities

The variability between matches played over an 8-week period is presented in Table 1. All match performance activities, with the exception of the number of fouls, showed a tendency to be reduced over the shorter period compared with the equivalent values reported across the five seasons. However, match-to-match variability remained high for the variables high-speed running distance, recovery time, % of explosive sprints, the total number of sprints and the number of match fouls. Less match-to-match variability was again observed for total distance covered, top sprinting speed, distance from the ball and the distance from fouls.

Discussion

The aim of the present study was to determine over different lengths of time the match-to-match variability in soccer referees' match physical performances, whilst also examining the influence of referee age and experience upon this variability. Utilising a longitudinal data collection period which encompassed a large sample size we were able to report that match-to-match variability in

performance characteristics of soccer referees is high (CVs ~20-54%) for high-speed running distance, recovery time, % of explosive sprints, the total number of sprints and the number of match fouls and is not dependant on referee age or experience. The match-to-match variability was slightly reduced when observed over a shorter time period but generally remained high. In-line with a recent investigation into the match-to-match variability in high-speed activities in soccer players, such extensive data have implications for the interpretation of match physical performances and also the use of certain measures of physical performance, namely high-speed activities, as indicators of performance in applied research studies [13].

Previous research that has examined match-to-match variability in soccer referees' match physical performances used two successive matches, relatively small sample sizes and examined only two aspects of physical performance; total distance covered and high-speed running [17,21]. However, the use of semi-automated match analysis systems now permits more detailed evaluations of the specific elements of a player's or referee's match physical performances over an extended period of time [9]. Consequently, our study provides the most precise estimates of match-to-match variability in soccer referees to date due to its large sample size and also longer- and shorter-term data collection periods. It also provides the most extensive estimates of the variability in more variables of match physical performance than previously examined as a number of discrete components of match activity were examined as opposed to composite measures previously examined [17,21]. Specifically, we are able to confirm that variability is high not only for high-speed running distance but also high for total number of sprints, the time in between high-speed activities and the type of sprints performed by soccer referees. These findings are consistent with the data reported previously by Weston et al. [21] for a composite measure of high-speed running, and higher than the high-speed running match CVs reported by Krustrup and Bangsbo [17]. Substantial differences in the methodologies used to classify high-speed running may well account for the observed differences. In addition, given that the most important aspect of soccer refereeing is the decision making process [15] a further novel aspect of our study was that we were able to examine variability in key facets of the referees' technical performances: most notably their ability to keep up with play and the number of fouls awarded during a match, with the variability being lowest for distance from the ball and highest for the number of match fouls.

Soccer referees' match physical performances have been demonstrated to be in part related to those of the players on the same matches [21]. Recently, Gregson et al. [13] reported that the match-to-match variability in performance characteristics of English Premier League players is high, with coefficient of variation values of 16.2% and 30.0% for high-speed running and total number of sprints, respectively. The authors attributed the majority of this variation to the tactical and technical requirements of the game. Given that the amount of high-speed running performed by English Premier

League referees correlates to the amount of high-speed running performed by the players on the same matches [21] the players' high CVs may account for the high match-to-match variability for high-speed running (25.9%) and sprint frequency (54.0%) presently observed. Interestingly, Castagna et al. [6] reported that soccer referees' physical performances seem to parallel that reported for midfield players, given that midfielders act as the link between defence and attack and the referee's requirement is to keep up with the game. This may ultimately impact upon the large variability observed in the referees' match-to-match high-speed running performances given that Gregson et al. [13] reported that the largest variation in high-speed activity tended to be observed in players who operated in central roles (CVs ~22-39%). Therefore, the greater variability observed in referees, even relative to central midfielders, is unsurprising given that referees are required keep up with play at all times to ensure correct judgments [25] as well as responding to a variety of players and playing styles.

Mohr et al. [19] and Rampinini et al. [20] reported a seasonal effect for match running distances in soccer players, with the distance covered being higher at the end of the season than at the start. Consequently, factors such as the time of season when the data are collected and also changes in referee and player fitness levels may influence the between-match variability. With this in mind the analysis of a sub-set of the data collected across a relatively short time period enabled an examination of the influence of time of season and referee fitness on match-to-match variability given that fitness levels would not be expected to vary when referees perform four consecutive matches over a short period. When examined over an 8-week period the referees' match-to-match CV's were slightly reduced but generally remained high. These data are consistent with Gregson et al. [13] who performed an analysis of their data collected across a relatively short period of time (8 weeks), indicating that the influence of time of season upon the inherent variability in players' high-speed activities is relatively small. Therefore, referee fitness and the stage of the season in which the data were collected does not fully explain the variability observed in measures of referees' match physical performances. As such it is likely that the main factors driving the referees' match-to-match variability are the technical and tactical changes in match-play and variation in the self-imposition of physical stress [13].

Another unique aspect of this study was that we were able to examine the influence of referee age and experience upon the match-to-match variability of soccer referees' physical performances. Previous research has demonstrated that older referees cover significantly less total match distance, high-speed running and perform fewer sprints when compared to the young referees [24]. Referee experience is considered as a fundamental prerequisite to officiate at the elite level [12] and Weston et al. [24] proposed from their research that older, more experienced referees may well be more economical with their movements due to their many years of practice. However, we found that match-to-match variability in the match physical performances of soccer referees is not dependent on age or

experience. Consequently, it may well be that the referees' match physical performances are a response to the overall match intensity as determined by the amount of high-speed running performed by the players. This important finding suggests that those involved in the fitness preparation of older referees in particular ensure that their referees are able to meet the varying physical demands of all of their matches through a trained capacity to perform repeated bouts of high-speed running and sprinting.

Variability for total distance covered in a match was low (CV 3.8%), suggesting that this measure would be a stable indicator of physical performance in soccer referees. However, in applied sports science research it is important that a sports-specific dependent variable is selected [2]. With this in mind, it is the amount of high-speed running that is a more crucial element of soccer refereeing performance. This is evidenced in soccer referees by Krustrup and Bangsbo [17] and Mallo et al. [18] who reported the distance covered by high-speed running seems to be the best physical performance discriminator in referees. Consequently, studies that have evaluated the match physical performances of soccer referees have used this measure as the sports-specific dependent variable. However, the high match-to-match variability reported for referees' high-speed activities suggests that this variable may not be a stable enough indicator of physical performance [16].

The high CVs reported for high-speed running and total number of sprints have serious implications for sample size estimation for studies examining referee match physical performance pre- and post-intervention. For example, using a nomogram to estimate the effects of measurement repeatability error Batterham & Atkinson [4] reported that to detect a meaningful difference of 10% using a measure with a coefficient of variation of 30% would require a sample size of approximately 200 referees. Consequently, such high CVs make it very difficult to detect any worthwhile changes due to an intervention [7]. Furthermore, high-intensity activity does not provide an accurate indication of an individual's capacity if it is based on a single observation [13].

Match-to-match variability for distance from fouls and from the ball was much lower when compared to the variability observed for high-speed activities. Consequently, the detection of any worthwhile changes due to an intervention would be easier to detect. However, the relationship between these measures with viewing angle and ultimately correct decision making has yet to be determined [24] and changes in distance may be of limited practical significance if they do not alter a referee's viewing angle.

In conclusion, match-to-match variability in performance characteristics of soccer referees is high in some variables. This inherent variability means that research requires large sample sizes to detect real systematic changes in a number of performance characteristics, namely high-speed running activities. As such, our data provide useful information to researchers and practioners alike who may wish to

examine referee's physical or technical match performances pre and post experimental interventions. Despite previous research demonstrating reduced match physical performances in older referees, neither age nor experience influenced the referees' match-to-match variability. Such a finding suggests that those involved in the fitness preparation of older referees in particular ensure that their referees are physically trained to be able to meet the varying physical demands of their matches.

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Table 1 Longer- and Shorter-Term Between-Match Variation for Referees' Match Activities (Mean ± SD).

Performance Measure	Overall Mean Value	Longer-term Coefficient of Variation (%)	Longer-term 95% Confidence Intervals	Shorter-term (*n*=15) Coefficient of Variation (%)	Shorter-term 95% Confidence Intervals
Total Distance (m)	11770 ± 808	3.8 ± 1.5	3.5 – 4.2	3.1 ± 1.4	2.3 – 3.8
High-Speed Running (m)	889 ± 327	25.9 ± 10.1	23.6 – 28.2	22.9 ± 13.4	15.5 – 30.2
Recovery Time (secs)	45.1 ± 14.2	32.7 ± 13.8	29.5 – 35.8	25.3 ± 11.1	19.2 – 31.4
Total Number of Sprints	30.5 ± 21.3	54.0 ± 20.7	49.3 – 58.6	44.5 ± 31.9	27.0 – 62.1
Top Sprint Speed (km.h)	31.8 ± 1.40	5.6 ± 10.9	3.2 – 8.1	5.1 ± 2.6	3.7 – 6.6
Explosive Sprints (%)	47.4 ± 11.4	34.3 ± 16.6	30.6 – 38.0	28.4 ± 10.3	22.7 – 34.0
Number of Fouls	28 ± 4.6	20.4 ± 7.5	18.7 – 22.1	22.0 ± 8.1	17.5 – 26.4
Mean Distance from Fouls (m)	14.6 ± 1.7	9.9 ± 4.3	8.9 – 10.8	8.0 ± 3.3	6.2 – 9.8
Mean Distance from the Ball (m)	19.4 ± 1.0	4.2 ± 1.9	3.7 – 4.5	4.0 ± 3.6	2.0 – 6.0

Table 2 Influence of Referee Age on Between-Match Variation for Match Performance Measures (% CV and 95 % CI).

	Total Distance (m)	High-Speed Running (m)	Recovery Time (secs)	Total Number of Sprints	Top Sprint Speed (km.h)	Explosive Sprints (%)	Number of Fouls	Distance from Fouls (m)	Distance from Ball (m)
Young	3.7 ± 1.2	25.8 ± 18.5	33.9 ± 13.4	51.2 ± 9.4	7.8 ± 12.4	32.5 ± 18.5	19.9 ± 6.7	8.5 ± 3.3	3.8 ± 1.8
	(3.2-4.2)	(21.9-29.8)	(28.8-39.1)	(43.5-60.0)	(3.8-11.7)	(26.9-38.1)	(17.1-22.7)	(7.2-9.9)	(3.1-4.6)
Intermediate	4.1 ± 1.2	26.1 ± 18.5	31.4 ± 13.4	53.6 ± 9.4	4.8 ± 12.4	34.5 ± 18.5	19.3 ± 6.7	9.9 ± 3.3	3.9 ± 1.8
	(3.6-4.5)	(22.3-30.0)	(26.3-36.5)	(46.0-61.2)	(0.9-8.6)	(29.0-40.0)	(16.6-22.0)	(8.6-11.3)	(3.2-4.6)
Older	3.8 ± 1.2	24.2 ± 18.7	27.3 ± 13.6	50.9 ± 9.5	4.9 ± 12.5	28.3 ± 18.7	20.6 ± 6.7	9.0 ± 3.3	3.8 ± 1.8
	(3.1-4.4)	(18.8-29.6)	(20.2-34.5)	(40.2-61.6)	(-0.6-10.4)	(20.6-36.1)	(16.8-24.5)	(7.1-10.9)	(2.7-4.8)

Table 3 Influence of Referee Experience on Between-Match Variation for Match Performance Measures (% CV and 95 % CI).

	Total Distance (m)	High-Speed Running (m)	Recovery Time (secs)	Total Number of Sprints	Top Sprint Speed (km.h)	Explosive Sprints (%)	Number of Fouls	Distance from Fouls (m)	Distance from Ball (m)
High	3.9 ± 1.2	24.3 ± 9.4	28.2 ± 13.5	51.1 ± 9.3	5.2 ± 12.4	33.8 ± 18.4	18.5 ± 6.6	8.7 ± 3.3	3.3 ± 1.7
	(3.3-4.6)	(19.1-29.5)	(21.3-35.1)	(40.9-61.3)	(-0.1-10.5)	(26.4-41.3)	(14.9-22.2)	(6.9-10.6)	(2.4-4.3)
Low	3.8 ± 1.2	26.0 ± 9.5	32.5 ± 13.5	52.4 ± 9.4	6.2 ± 12.4	32.1 ± 18.4	20.2 ± 6.6	9.4 ± 3.3	4.0 ± 1.7
	(3.5-4.2)	(23.2-28.7)	(28.9-36.2)	(47.0-57.8)	(3.4-9.0)	(28.1-36.1)	(18.2-22.1)	(8.4-10.3)	(3.5-4.5)