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Influence of physical fitness on decision-making of soccer referees throughout the match

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ABSTRACT

The purpose of this study was to analyze the relationships between physical fitness and physical performance in competition and the decision-making (successes and errors). A sample of 22 male national-level soccer referees (weight: 72.7 kg; height: 178.0 cm; age: 23.4 years) participated in this study. Physical fitness was assessed through 6 series of 40 m (velocity) and Yo-yo (aerobic) test in annual exam by Soccer Committee, physical performance was performed through the total distance covered in competition (Experiment 1), and decision-making was registered through a simulated Video Assistant Referee system (VAR) with the consensus of 2 national referees evaluating only warnings (yellow cards), expulsions (red cards), established penalties and obvious goal actions (called and no called) (Experiments 2 and 3). Results showed that physical fitness test was related with total distance ($rho = 0.63$, $p < .01$) and success rate percentage ($rho = 0.74$, $p < .05$) registered during competition. The success rate percentage, in the first half, was observed 44% successes, and in the second half, 59% successes. The number of events called was related with the physical fitness test score ($R^2 = 0.71$, $p = .035$; $R^2 = 0.64$, $p = .056$, respectively). As conclusion, the main finding of this study has provided insight into decision-making behavior in real competitive matches and the physical fitness was the predictor of the successful decision-making being able to determine the permanency, promotion or decrease of category.

1. Introduction

Soccer is the most practiced sport in the world that is characterized by explosive actions of short duration and incomplete recovery, where aerobic resistance predominates [1]. There is a wide variety of agents directly and indirectly involved in the game such as soccer players, coaches, referees, and fans. The function of the soccer referees (SRs) is fundamental since they are in charge of making decisions to apply the rules of the game [2]. To do this, they must position themself properly to make decisions correctly, since they are final and influence the outcome of a match [3]. Soccer is a sports modality that has a low score [4] and, in addition, the continuous decrease in the number of goals scored during matches, due to the improvement of the physical condition of the players [5], and the tactical attitude that coaches adopted when the score was favorable [6,7], shows that refereeing decisions are more relevant. Likewise, the SRs need to make decisions under stressful conditions, with high physical demands and throughout a 90-min competition [8]. In

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this sense, many researchers have taken this into consideration, resulting in a rapid growth of the interest on the links between decision-making and sports in the last years.

1.1. Exercise and performance psychology on soccer referee

The performance of the SR is based on physical, theoretical, and psychological factors [9]. These factors can be trained to increase the physical condition and performance of the SR in the competition, reducing the probability of error in decision-making during the match, due to better positioning to have the best view of the game and its actions [10]. However, although physical condition is not the only influential factor in correct decision-making by SRs, it is a very relevant component for them [11]. It is important that SRs are trained to improve their ability to cover large distances during a match and to repeat high-intensity efforts [12]. SRs must be able to actively follow the game, as being close to the play will make it easier for them to make the right decision. To do this, they must have good aerobic resistance and speed, since they cover distances between 9 and 13 km per match, occupying high-speed sprints between 4 and 8% of their actions [13].

In this way, the SRs carry out several physical tests throughout each season, characterized by performing 6 series of speed of 40 m, and an intermittent resistance test, known as the YO-YO test [14]. For these reasons, the SRs must train and maintain optimal physical condition to face each match properly and pass these physical tests in order to continue being appointed in future competitive matches. One of the physical qualities that must be trained is strength [15], since speed, both linear and with changes of direction, is predicted by both the elastic component [16] as a reactive-elastic strength [17]. It is a fundamental physical quality to improve speed, with the aim of being able to reach maximum values in acceleration, amplitude, and frequency of their movements [10].

1.2. Physical performance and decision-making on soccer referee

Aerobic resistance is predominant in this sport and helps postpone or withstand fatigue by prolonging organic work without reducing performance [18]. In the second half of matches, physical-physiological performance decreases [2], so it could negatively affect SRs in decision-making in these last minutes of the competition. A review of the literature reveals that SRs needs during the game a relevant cognitive capacity of selection on the desired information, required during a specific time-on-task (90 min) [19]. However, these refereeing demands request more resources demanding that could be affected or impaired by concurrent physical exercise [20]. In addition, the cognitive capacity is limited [21], for this reason, with the course of the competition and the increment of fatigue and anxiety (depending on the results and the importance of the competition) the deterioration of decision-making will appear [22].

1.3. Current study

SRs receive a general planning of physical training in a standard way, excluding individual aspects and specific needs such as pelvic asymmetries, dynamic deviations of the lower limbs and even the overload of some weaker muscle groups, which can cause injuries [23]. Therefore, this study pretends to demonstrate that decision-making is predicted by physical condition (initial hypothesis [H1]). Furthermore, the decision-making could be predicted by the training time of physical qualities (H2) and the physical condition could be related with match performance (H3). The current study aimed to analyze the relationships between physical condition and physical performance in competition (total distance) and strength, resistance, and speed training time of national SRs (experiment 1); to analyze the relationship between the decision-making (successes and errors) during the match with physical condition, physical performance in competition, and strength, resistance, and speed training time (experiment 2); and to analyze the descriptive data of successes and errors throughout the match and the relationship between the decision-making and the physical condition (experiment 3).

Table 1
Anthropometrical measures, physical fitness, and behavior of SRs.

	Mean ± SD	95% LCI	CI	95% UCI
Anthropometrical measures (n = 22)				
Age (years)	23.35 ± 3.99	21.48	1.87	25.22
Height (cm)	177.95 ± 6.27	175.02	2.93	180.88
Weight (kg)	72.72 ± 7.54	69.19	3.53	76.24
Physical Fitness (n = 22)				
STT (hours)	3.53 ± 3.02	2.11	1.41	4.94
RTT (hours)	2.35 ± 1.48	1.66	0.69	3.04
VTT (hours)	1.65 ± 2.14	0.65	1.00	2.65
PFTS (UA)	1.60 ± 0.94	1.16	0.44	2.04
Referee Behavior (n = 22)				
Satisfaction	0.85 ± 0.75	0.50	0.34	1.20
Total distance (km)	8.67 ± 2.10	7.50	1.16	8.66
Cards mean (number)	5.16 ± 0.80	4.78	0.37	5.53

Note: Strength training time (STT); Resistance training time (RTT); Velocity training time (VTT); Physical Fitness test score (PFTS); Min: Minimum; Max: Maximum. CI: Confidence Interval; LCI: Lower *Confidence* Interval; UCI: Upper Confidence Interval.

2. Method

2.1. Participants

Twenty-two male SRs of national category, corresponding to the South of Spain, whose body characteristics are shown in Table 1, participated in this study. In total, there are approximately 70 SRs in this location, which represents a participation of 31% of the total for the first phase (Experiment 1), and 8.6% participation for the second phase (Experiments 2 and 3). Considering a statistical power of 80%, a type 1 error or alpha of 0.05 and effect size of 0.82 (this is the value equivalent to a $R^2 = 0.45$, which was the maximum prediction coefficient found in the literature for similar studies), we would need a minimum sample size of 16 subjects. For these reasons, experiments 2 and 3 could be considered as pilot study or case study, so in the conclusion it will be account.

Among the inclusion criteria established, a maximum age of 30 years was estimated in order to make the sample more homogeneous within the same category. A rationale for a maximum age of 30 years would be appropriate considering Helsen and Bultynck [24] reported that the field officials in charge of the final round of Union of European Football Associations (UEFA) 2000 Championship were an average age of 40 ± 4 years. Other criteria were to have more than 2 years of experience in the national category, not to have had any injuries in the last 3 months, and to train consistently on a weekly basis. For experiment 3, matches in which there were at least 3 yellow cards called, 1 red card called, or at least one goal scored as a penalty were included.

This study has followed the rules of the Helsinki Declaration (2013) and has been approved by the Ethics Committee of the University of Granada (471/CEIH/2018). The participants were informed about the aims, methods, and actions of the study. They have given written informed consent to the inclusion of material pertaining to themselves, they cannot be identified via the paper, and they have been fully anonymized.

2.2. Measures

For the first experiment, an ad-hoc record sheet was used where the hours of weekly training specifically dedicated to strength, resistance and velocity were recorded. In addition, the results of the physical tests were recorded as not fit (0), fit (1), bonus (2), or maximum bonus (3). These qualifications are those established by the Referees Committee in Spain. For example, the yo-yo test is scored with 0 if the record is less than or equal to 16.7 or 15.4 km/h, in the male or female category respectively, and 2 if the speed is 19, 2 or 16.8 km/h, in the male or female category respectively. Match evaluation reports are also added where decision-making in randomly chosen matches is evaluated. In addition, the total distance covered in the two matches following the physical tests was recorded, evaluated through POLAR RC3 GPS devices (Polar©, Finland); the perception of satisfaction with the qualifications of the physical tests through the Likert scale, where 0 is the lowest value (totally disagree) up to 3 points as the highest value (corresponding to totally agree).

For the second and third experiments, 6 competitive matches were chosen, and 48 events were evaluated corresponding to the analysis of successes or errors in plays of possible warnings (yellow cards), expulsions (red cards), established penalties and obvious goal actions. The Nac Sport® system (NAC Sport S.L., Spain) was used to view the matches. The observation was direct through 2 observers, active national SRs, making decisions by consensus.

2.3. Procedure

In the first experiment, the duration of weekly training in the last 8 weeks prior to the physical tests of the SRs carried out in March 2022 has been analyzed. The SRs must overcome 6 series of 40 m, with a rest of 1 min between series, below a fixed time; and a resistance test, called the Yo-yo test [14,25], which consists of performing 40 m at a certain speed, which increases progressively, until reaching the minimum required speed of 16.8 km h^{-1}, with the possibility of bonuses if they reach the speed 19.2 km h^{-1}. These bonuses are awarded when there are positive evaluation reports made by Committee inspectors who develop evaluations in "random" matches without prior notification.

Data were collected on the strength, velocity, and resistance training performed on the participating SRs, through the analysis of the weekly planning carried out. The training attendance rate in those 8 weeks had to be greater than 95%, that is, those SRs whose absence was greater than 2 training sessions were excluded. In addition, the result of the physical tests, the satisfaction level, and the average distance covered in the two matches following the physical tests were collected. In the second and third experiments, 48 events pertaining to the decision-making analysis (both successes and errors) were analyzed, in actions involving possible warnings (yellow cards), expulsions (red cards), penalties called, and overt goal actions. The rest of the fouls shown have not been taken into account because most were found without the opportunity to score, produced in the midfield. These decisions were assessed by two active national SRs, by consensus and through video recording.

2.4. Statistical analysis

Descriptive statistics were calculated for each variable. Normal distribution and homogeneity tests (Shapiro-Wilks and Levene's, respectively) were conducted on all metrics. In the present study three different experiments were performed.

i) The experiment 1 was performed with a total of 22 SRs and a Spearman's correlation coefficient (*rho*) was used to examine the relationship between physical fitness test score and strength training time, resistance training time, and velocity training time in

hours. Second, a Pearson's correlation coefficient was used to examine the relationship between showed cards and total distance performed by the SR.

ii) The experiment 2 was performed with a total of 6 SRs and a Spearman's correlation coefficient was used to assess the relationship between success rate (success and errors) and total distance, strength training time, resistance training time, and velocity training time.

iii) The experiment 3 was performed with a total of 6 SRs and try to clarify the behavior of the SRs thought the match time.

In all cases, we adopted the following criteria to interpret the magnitude of these correlations: $rho \leq 0.1$, trivial; $0.1 < rho \leq 0.3$, small; $0.3 < rho \leq 0.5$, moderate; $0.5 < rho \leq 0.7$, large; $0.7 < rho \leq 0.9$, very large; and $rho > 0.9$, almost perfect. All analysis were conducted using statistical software Statistica (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and Microsoft Excel software (Microsoft Corp., Redmond, Washington, DC, IL, USA). The significance level was set at $p < .05$.

3. Results

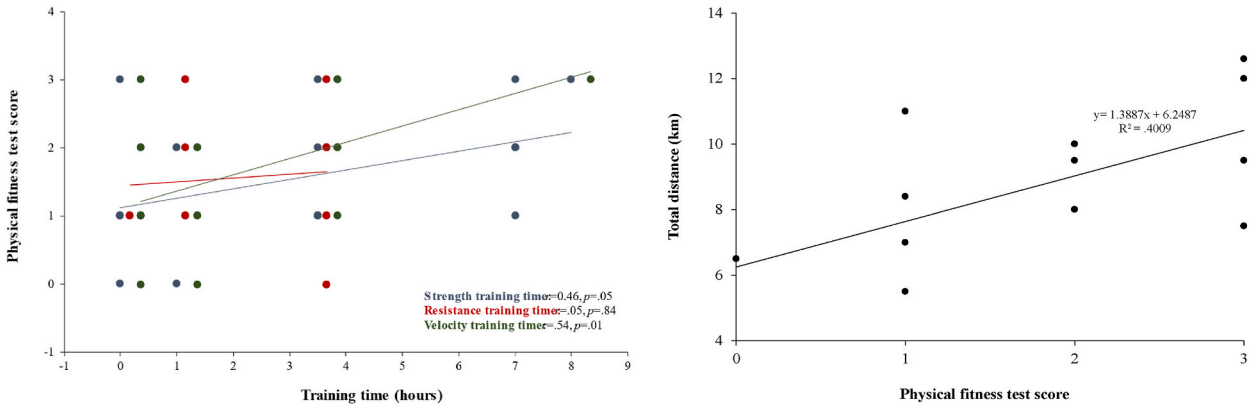
Descriptive statistics were calculated for anthropometrical characteristics, physical fitness training and test, and referee behavior (Table 1).

3.1. Experiment 1

Correlation analysis tests were performed between physical fitness test score and strength, resistance, and velocity training times. Positive moderate correlations ($rho = 0.46$, $p = .05$; $rho = 0.54$, $p = .01$) were found between physical fitness test score and strength and speed training times, respectively (Fig. 1a). Linear regression tests have been carried out, obtaining moderate determination coefficients between physical fitness test score with the strength ($R^2 = 0.207$, SEE = 0.829, $p < .05$) and speed training times ($R^2 = 0.294$, SEE = 0.782, $p < .01$), whose prediction equations resulted: physical fitness test score = 0.1389*strength training time + 1.1238 (equation 1); and physical fitness test score = 0.238*speed training time + 1.2231 (equation 2). These equations are not validated, but they are proposals based on the presented data. Subsequently, another correlation analysis was run between total distance covered in a match and number of cards shown in a match. However, dataset did not reveal any correlation ($rho = 0.17$, $p = .47$). Thus, the relationship analysis performed between total distance and physical fitness test score showed significant effects ($rho = .633$, $R^2 = 0.40$, SEE = 1.61, $p = .006$, Fig. 1b).

3.2. Experiment 2

A new correlation analysis was performed between success rate percentage and strength, resistance, and speed training times (Fig. 2a) and revealed correlations between success rate percentage and strength training time ($rho = 0.907$, $p = .006$) and speed training time ($rho = 0.732$, $p = .049$). Linear regression tests have been carried out, obtaining moderate and marginal determination coefficients with the success rate percentage and strength and speed training time respectively ($R^2 = 0.82$, SEE = 26.34%, $p < .05$; $R^2 = 0.54$, SEE = 19.06%, $p = .098$), whose prediction equations resulted in success rate percentage = 30.119*strength training time + 7.245 (equation 3); success rate percentage = 41.308*speed training time + 10.626 (equation 4). Subsequently, another correlation analysis was run between success rate percentage and total distance covered in a match. However, dataset did not reveal any correlation ($rho = 0.497$, $p = .20$). Finally, a positive moderate-large correlation analysis was found between success rate percentage and



a. b.

Fig. 1. a. Relationship between physical fitness test score and strength training time, resistance training time and velocity training time. b. Relationship between physical fitness test score and total distance.

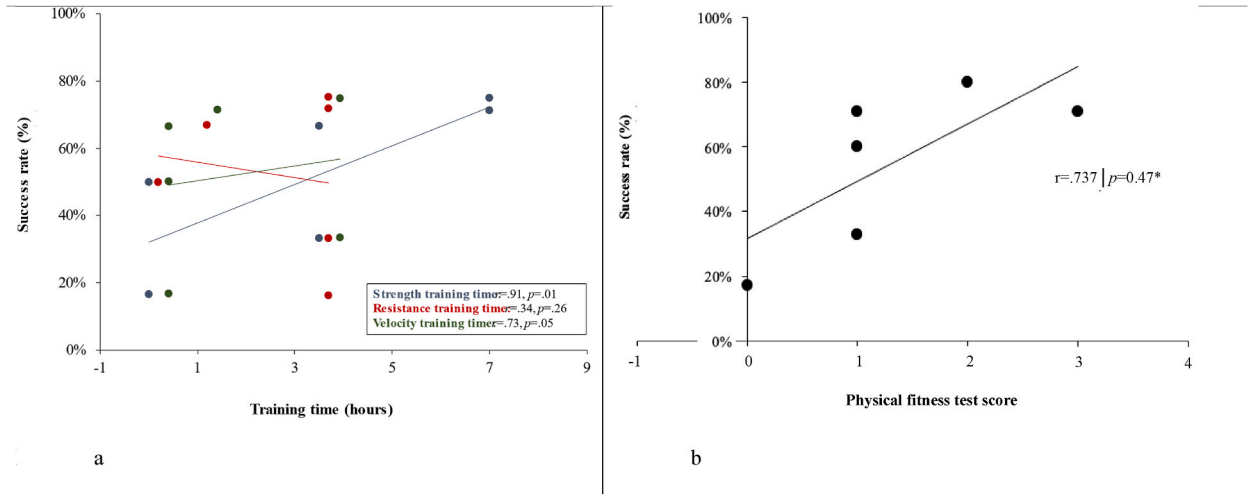


Fig. 2. a. Correlation between success rate percentage and strength training time, resistance training time and velocity training time. b. Correlation between success rate percentage and physical fitness test score.

physical fitness test score (*rho* = 0.737, $p = .047$). However, the linear regression between these metrics showed a marginal significance ($R^2 = 0.54$, SEE = 18.88%, $p = .094$; Fig. 2b).

3.3. Experiment 3

In the 6 matches analyzed, the number of events (in absolute values) was carried-out in the minutes of the match (absolute values) and, furthermore, categorized into ranges of 15 min and evaluating the success rate percentage (relative values) were quantified (Fig. 3). In the first half, 56% errors and 44% successes were observed, and in the second half, 41% errors and 59% successes were observed. A higher number of decisions was observed in the second half (32 decisions), compared to the first half (16 decisions).

A new analysis was performed separating the events and success rate according to the half of the match. Thus, correlation and linear regression tests were carried out between number of events in the first half and the physical fitness test score showed (*rho* = −0.843, $p = .018$; $R^2 = 0.71$, SEE = 0.621, $p = .035$) (Fig. 4a). In the same line, the same analyses were performed in the second half, and showed the contrary direction in the correlation between the same metrics (*rho* = 0.799, $p = .028$; $R^2 = 0.64$, SEE = 0.694, $p = .056$) (Fig. 4b).

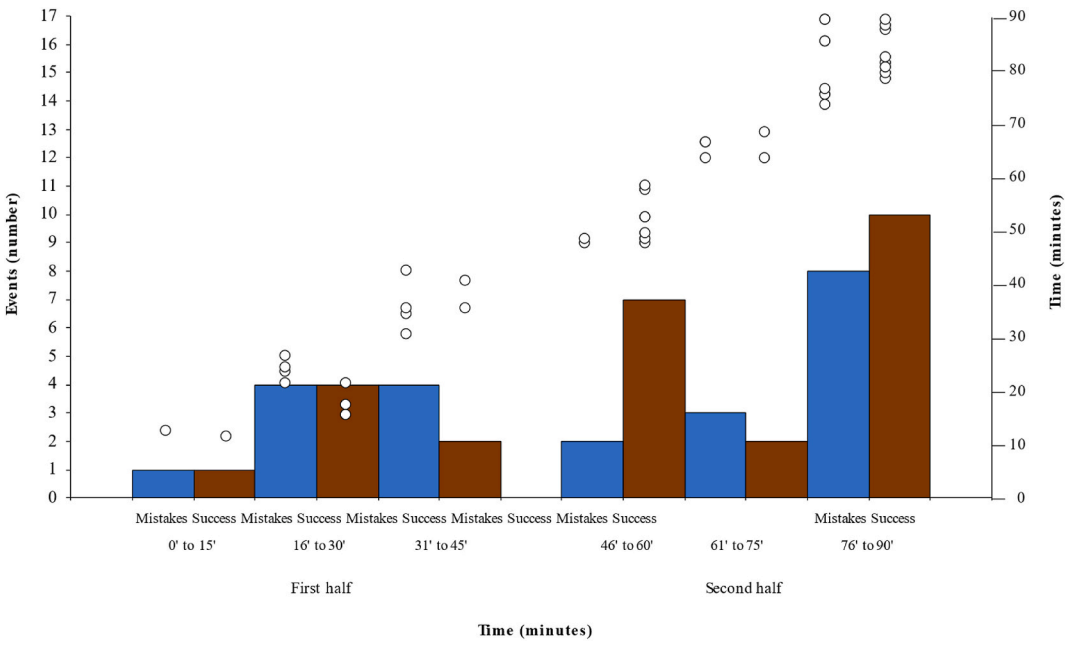


Fig. 3. Decision-making (errors and success) during the match time.

4. Discussion

The aims of this study were to know the relationship between physical condition, evaluated through the annual physical tests that SRs undergo, weekly dedication to training classified by physical qualities, physical performance during the competition and decision making (successes and errors) in national SRs. The findings obtained have revealed that, in the case of this study, the physical condition of the SRs was directly related to the hours of SR training, specifically in the amount of specific training linked to strength and speed. In addition, the previous findings also have a relationship with physical performance during sports competition (experiment 1). Subsequently, it was observed how specific strength and speed training was related to decision making (percentage of success), which was related to the physical condition (experiment 2). For all these reasons, these results showed that physical qualities, specifically those linked to strength and speed, moderated the behavior of the SR and could be decisive in general preparation, as has been shown in previous studies [26]. In this sense, these findings seem decisive in SRs committees and are keys when it comes to promoting or keeping SRs. In addition, the results obtained suggest that the performance in the physical tests could be a good predictor of success in the rest of the behaviors of the selected referees.

The experiment 3 results showed a high percentage of errors both in the first and in the second half (56% and 41%, respectively), values much higher than the average of 14% of errors in professional SRs [27], and 20–26% in assistant SRs [20,28,29]. However, the results obtained showed great relevance due to the effect of time on game behaviors. Thus, the evaluated actions that could determine the course of the match could be decisive in its result, since the differences in the result were minimal and some notable actions (i.e., yellow cards, red cards, penalties, or fouls that occurred in dangerous situations whistled or not whistled, in the games analyzed) could determine the outcome of the match [4]. Considering the previous results, we could highlight this fact as an added value, since the SRs proceed differently throughout the course of the match and showed different decision-making behaviors that were reflected in a lower number of decisions in the first half of the match with respect to the second half [27]. Despite this, the error rate was higher in the first half, with a low number of errors being notable during the first 15 min of each half of the game, accentuating a higher proportion of errors from minute 76 until the end of the match. These data are agreeing with the previous research carried out [27,30–34] and that indicated a decrease in precision at the end of the match. These results could suggest that the appearance of fatigue caused by the physical demands of the match [35] and the characteristic intensity of this type of competition, could affect the correct assessment, subject to individual cognitive abilities [36]. In fact, if to the previous statement, we add as potential stress factors the high physical stress during the matches to which the main and assistant SRs [37] are subjected and the high pressure to make decisions in front of large crowds could be explained by the previous suggestions. In any case, these two stressors could affect high-level cognitive functions such as: i) cognitive control, ii) attention and iii) perception, among others, and therefore, added to physical condition and individual vulnerability (resistance to situational pressure) condition the decisions of the SRs. A novel treadmill-based Soccer Referee Simulation (SRS) protocol has been developed in which highly reproducible physiological and perceptual responses are produced that are consistent with those of competition. This protocol would help to develop controlled intervention programs with referees to determine physiological thresholds in which the attentional elements involved in decision making decrease [38].

The analysis of the 6 SRs for experiment 3 started from the initial sample of 22 studied in experiments 1 and 2. As indicated in the procedure, the assessment was carried out by 2 national SRs through observation by means of video recording and acting in a similar way as it is currently carried out by the "Video Assistant Referee" system, commonly called "VAR" [39], determining each arbitration decision by agreement. We considered that an incorrect decision could be due to a distant position on the field of play and, therefore, not suitable for the correct perception of the action. This has been demonstrated in the physical condition tests, which, it has

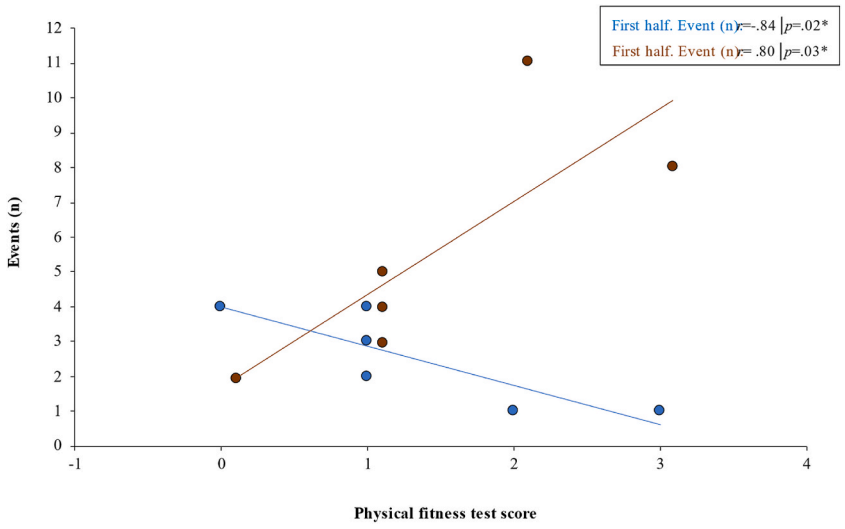


Fig. 4. a. Correlation between number of events in first half and physical fitness test score. b. Correlation between number of events in second half and physical fitness test score.

subsequently been verified, that some of the SRs have minimally achieved or have failed said annual physical tests, resulting in a drop in category. This fact suggests that the choice of the analyzed matches could be inappropriate. Although it is true that this choice was determined by matches in which there were at least 3 yellow cards, 1 red card or one of the goals scored was from a penalty, that is, for experiment 3, they chose games in which it was known in advance that there were important decisions. In a study, we observed specific decision biases based on motor experience, being those referees without this experience the ones who penalized fewer fouls, unlike those with motor experience, so it would be important to know his past as a footballer to make an assessment or homogenization of the participants [40]. In any case, qualitative studies showed the desire to referee correctly without making any type of error [41,42]. However, the SRs show a number of stressful factors that influence their decisions: i) Individual factors: opinion, concentration, control; ii) experience factors: personality, personal life and experience and iii) situational factors: cross factors, player region, environmental factors and crowd interaction. Specifically, in Italian SRs it has been shown that their age negatively influences both their physical condition and the performance reports they obtain from superior officials [43]. However, in this study we could not investigate any of them as the main factor influencing decision-making. We can suggest direct links between the level of physical condition and decision making and therefore, we could attribute the findings found in the second half of the match to factors related to muscle fatigue and this physical condition, as occurs in studies that analyzed decision making in SRs [11,27,44–46]. Specifically, in the last 15 min, the accuracy rates in the referees were lower compared to the rest of the match time [27].

4.1. Limitations, strengths and opportunities

This study has some limitations. First, the sample size in experiment 3 is scarce, although at present, the simulation of creating a VAR system to make consensual decisions with professional SRs is very expensive. However, this limitation becomes a strength because this study is unpublished and decision making with training and physical tests of SRs has never been studied. Decision-making is objective, taking into account soccer rules, carried out in a room, with SRs seated and having the necessary time to determine whether each decision is correct or not. Decisions made and not made in midfield that have no direct impact on the match have been removed, as they could have unnecessarily affected the hit/miss ratio. This ratio was exclusively carried out in actions that do have an impact on determining the match, such as cards called and not called, as well as penalties and fouls in areas with the possibility of scoring (called and not called). Another limitation is being able to know the number of explosive actions with incomplete recoveries to which the referee is subjected, mainly due to the appearance of fatigue. This information could be relevant if contrasted with decision-making, the main topic of the study.

Despite its limitations, the current study is a step forward in that it reveals the relevance of physical condition on decision-making of SRs for enhancing the accuracy rates. The findings presented represent important practical contributions, namely regarding the suggestion that training strategies based on neuromuscular and velocity conditions and should be employed in the annual control by judges (i.e., using repeated sprint accumulated test or change of direction test, among others). To improve these practical implications, the SR preparation is essential for his continuity and permanence in the category, to promote new training automation, control, and management systems. It is desired to carry out an experimental study to verify the fluctuation in decision-making for 8 weeks, for example, in which physical qualities are affected, especially strength, which is the quality that is statistically related to successful decisions and also seems to be directly related to the results of physical tests, carried out annually. Once the positive effect has been verified, the training sessions that have favored both improving the hit ratio and improving physical condition could be described. This type of study not only contributes to the field of Sports Science, but also helps to improve the knowledge of these SRs who need information and training on both what happens in sports competition and in training. This study has other strengths. In the first place, a simulated VAR room has been carried out in which decisions in some competition matches have been analyzed, through the collaboration of 2 national SRs analyzing through recorded matches. This protocol is an added value of this study. Secondly, the analysis of match performance has been combined, along with decision-making and the hours dedicated to training, differentiated by physical quality (strength, resistance, and speed), carried out by a Physical Activity and of Sport professional, co-author of this study. This second fact makes the study more extensive, and they have been differentiated by experiments, which currently does not exist any study that addresses all these variables at the same time. Thirdly, real information from all the experiments is described, building recommendations and encourages the referees and professionals who advise them to reflect and improve their training plans.

5. Conclusions

This case report has provided insight into decision-making behavior in real competitive matches. The main findings of this study showed that the error rate increased in the final minutes of the competition in semi-professional SRs. In addition, strength and speed training time have been shown to be related to successful decision making and were the best predictor of success in the annual physical tests that SRs undergo to determine permanency, promotion or decrease of category. Physical condition moderates the decision making. The control of training hours could be mandatory to register it with the Referees Committee, taking into account that this variable is directly related to the improvement of physical condition and, in turn, to a higher rate of successes in decision-making. This study has allowed to know how some intrinsic characteristics of the SR influence decisions, having a margin for improvement thanks to the inclusion of physical activity and sports professionals for training planning aimed at improving qualities and physical condition, in general, in order to increase the match performance and decision-making, especially those that must be taken in the final minutes of the competition.

Author contribution statement

Alfonso Castillo Rodriguez: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Emilio José J. Alejo-Moya: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Antonio Figueiredo: Analyzed and interpreted the data; Wrote the paper.

Wanesa Onetti-Onetti: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Francisco T. González-Fernández: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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