

# A systematic review of the literature on video assistant referees in soccer: Challenges and opportunities in sports analytics

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## ABSTRACT

Refereeing in sports is about fairness. The referee's job is to balance what the player with the ball thinks is fair with what the player trying to take the ball thinks is fair. Referees are judges on those two opposite opinions. Football (soccer) has massive global appeal and fan interest. Some football championships now use Video Assistant Referees (VAR) to help the referees make correct decisions. This study reviews the literature on VAR in football using the *Methodi Ordinatio*. *Methodi Ordinatio* is a methodology used to select and rank relevant scientific papers combining the impact factor, number of citations, and year of publication. We present a case study about the distance the VAR officials cover in the main Brazilian football championship (Brazilian Serie A). This study adopts the p-medians method to analyse the impact of opening VAR operation rooms in the distance covered by the professionals travelling to officiate matches. The locations of VAR operation rooms were obtained, and applying these locations in the first ten rounds of the Brazilian Serie A season 2021 would possibly reduce about 70% of the distance covered by the VAR officials travelling compared to the total distance performed.

## 1. Introduction

Brazil is a country located in South America with large territorial dimensions (8.516.000 km<sup>2</sup>), having 26 states as well as the Federal District, all these grouped into five regions. Travelling from one of these regions to another can be long distance, consequently high costs. Football (soccer) is the most popular sport in the world and the most popular sport in the history of mankind [1,2]. In Brazil, football is the most practised sport and the one that moves the largest audience and income, with the Brazilian Serie A ("Brasileirão Série A"), Brazilian Serie B ("Brasileirão Série B") and the Brazil Cup ("Copa do Brasil") as the main football championships. Furthermore, some Brazilian clubs also compete in other regional and international championships.

With the advent of technology, football has also innovated and used new technologies, the most known being Video Assistant Referee (VAR). VAR emerged to assess decisions taken by the referee via video images and reduce possible errors in match-deciding plays in football matches. Its use, in Brazil, began effectively in the Season 2019 of

Brazilian Serie A, currently, it is also used in other Brazilian national and regional championships.

Studies have been carried out regarding the use of this technology in football matches. Lago-Penás et al. [3] studied the influence of VAR on the football elite, analysing 1024 matches in the Italian Serie A and in the Bundesliga (German league) during seasons before and after the use of VAR started. The authors noticed that there was a decrease in some match aspects, such as fouls and yellow cards, but an increase in the number of minutes added. Mather and Breivik [4] submitted 80 Premier League (English league) professional football referees to watch 60 plays videos (faults, yellow cards and red cards) with variations in playback speed, giving their opinion on the assisted move. The main objective was to verify some aspects, such as the influence of slow motion on the decision, and no data was found to prove this situation.

Other studies look at the fan side of VAR in football. Scanlon et al. [5] studied the Premier League football fans perception of VAR in the 2019/2020 season who were physically present at matches,

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with the data being collected in different areas of the stadiums. The study exposes the complexities between VAR and the fans experience on match days. Mather and Breivik [4] analysed what VAR decisions influence on people who are not involved in decision making. The use of Multi-group analyses showed that the effect of one of the analysed items (transparency) is significantly stronger at home, while social influence is stronger at stadiums.

Publications involving the use of VAR in football are still at an early stage, since its implementation is recent. According to a research carried out in 3 databases (Scopus, ScienceDirect and Web of Science) there are few studies involving “VAR” and “Football” published and the first publication was in 2018. Thinking about that, literature review can help to determine if a subject little studied or if there is a gap in the subject.

Literature reviews have already been applied about football referees, but no study found in database searches (ScienceDirect, Scopus and Web of Science) performed a literature review in relation to VAR officials and football. Bouzas-Rico et al. [6] carried out a systematic literature review regarding field tests to evaluate aptitude of referees, considering databases up to May 2020. The authors found a total of 13 works that analysed the psychometric properties of aptitude tests, while 7 investigations focused in field physical aptitude tests specifically designed to evaluate aerobic endurance. Aragão e Pina et al. [7] carried out a literature review on football refereeing considering the Web of Knowledge and Scopus databases and publications up to September 2016. The search resulted in a total of 267 articles, which were grouped into seven themes and 54 sub-themes, of which 82.4% were publications from the last decade. The results showed that there were few solid research lines for the development of football refereeing, despite the increasing diversification of research areas, and that most studies were about the physical and technical performance of referees.

This study was divided into two parts: the first part consists of a literature review regarding “VAR” and “Football”, based on the *Methodi Ordinatio* proposed by Pagani et al. [8]; and the second part is a case study of the application of an p-median adapted model for the possible creation of Regional Centres of VAR (RCVAR), one in each of the 5 regions of Brazil, with the objective of reducing the distance covered by the VAR officials and, consequently, in cost reduction for the Brazilian Serie A championship. VAR centres means a facility with VAR infrastructure, to perform VAR tasks for one or several matches that occur at a stadium whose location eventually differs from such facility. The communication by electronic devices make it possible to work separated by large distances. Currently, in Brazil there is only one VAR centre located at Rio de Janeiro, where all VAR officials go to perform their tasks in the matches, and we want to analyse the impact of creating others VAR centres in the total distance covered by VAR officials. Optimization is an essential and indispensable element [9] that can be applied to search the set of optimal locations for facilities [10,11].

One can think that if it is wanted to reduce the distances covered by VAR officials to work, all of them should rather stay home and secure they have good internet or TV connection as to perform their task. But, in practice there are other more operational reasons which make it convenient that the whole referee team is together at one place, like the task done shorter and better.

In the Brazilian Serie A, there are 20 teams, so there are 10 matches in each round, all teams playing as home and away, so there are 38 rounds, totalizing 380 matches by season. In this way, for each round, it is necessary 10 referee crews (each crew consists of a main referee, assistants and VAR officials) from the total of 108, chosen by sortition. In the Season 2021 there were in this championship 2 teams from midwest, 4 from northeast, 5 from south, 9 from southeast but none from north, wherein the home team stadium usually is located in the city of the team head office. Since there are 20 teams in the championship, each team play 19 games as home team, thus, in the season 2021 of the Brazilian Serie A, 171 matches were played in southeast, 95 in south, 76 in northeast and 38 in midwest.

**Table 1**

Researches in three databases (Scopus, ScienceDirect and Web of Science).

Keywords combinations	Web of Science	Scopus	ScienceDirect
“Video Assistant Referee” and “Football”	19	28	2
“VAR” and “Football”	32	31	2
“VAR” and “Soccer”	16	32	1
“Video Assistant Referee” and “Soccer”	9	17	0

**Table 2**

Filtering procedure.

Filtering procedure	
Initial number of papers	189
Duplicate papers deleted	118
Papers without data deleted	0
Deletion of articles outside the theme	32
Deletion by document type	5
Total papers deleted	155
Final portfolio	34

Even that, from one season to the next one, there are 4 teams that rise from Serie B to Serie A and an equal number that are relegated from Serie A to Serie B, the distributions of teams by region changes just a little, most teams are always from southeast followed by south.

There is a great number of works in traditional bibliographic research. However, in order to know current trends in a theme, those methodologies do not have accessible tools for carrying out a more specific analysis. In this way, the *Methodi Ordinatio* helps to make this analysis [12].

## 2. Methodology

This research was divided in two stages: the first aims to carry out a literature review on publications involving “VAR (Video Assistant Referee)” and “Football (Soccer)”, based on the *Methodi Ordinatio*, created by Pagani et al. [8,13]; in the second stage, is presented a proposal for the creation of Regional Centres of VAR (RCVAR), aiming the minimization of distances covered by VAR officials to do their tasks in football matches of Brazilian Serie A football Championship.

### 2.1. Literature review by *Methodi Ordinatio*

Literature reviews are important in order to map articles already published and to find possible gaps in the literature. The *Methodi Ordinatio*, proposed by Pagani et al. [8] and widely applied in systematic review of the literature, is based on an index (*InOrdinatio*) to create a ranking with the most important articles. This method takes 9 steps shown in Fig. 1.

Initially there were 189 articles. The results obtained in the filtering procedures are shown in Tables 1 and 2.

The *InOrdinatio* index and the portfolio description are presented in Section 3.

Ranking the papers using the *InOrdinatio* Eq. (1), proposed by Pagani et al. [8], is applied in the step 6 shown in Fig. 1, resulting in a ordered scientific articles portfolio.

$$\text{InOrdination} = (\text{IF}/1000) + \alpha [10 - (\text{ResearchYear} - \text{PublishYear})] + \text{Ci} \quad (1)$$

where IF is the impact factor of the journal the paper was published,  $\alpha$  is a value ranging from 1 to 10 to be defined by the researcher according to the importance of the theme newness (due to the importance of the subject the value used was 8), ResearchYear is the year in which the research was carried out, PublishYear is the year in which the paper was published and Ci is the number of times the paper has already been cited.

As can be seen in Table 2, the final portfolio resulted in only 34 articles, so we decided to keep all articles. After reading the paper one can see that it is not about the subject studied and some results can be excluded by not being research articles (like book chapters and conference papers).

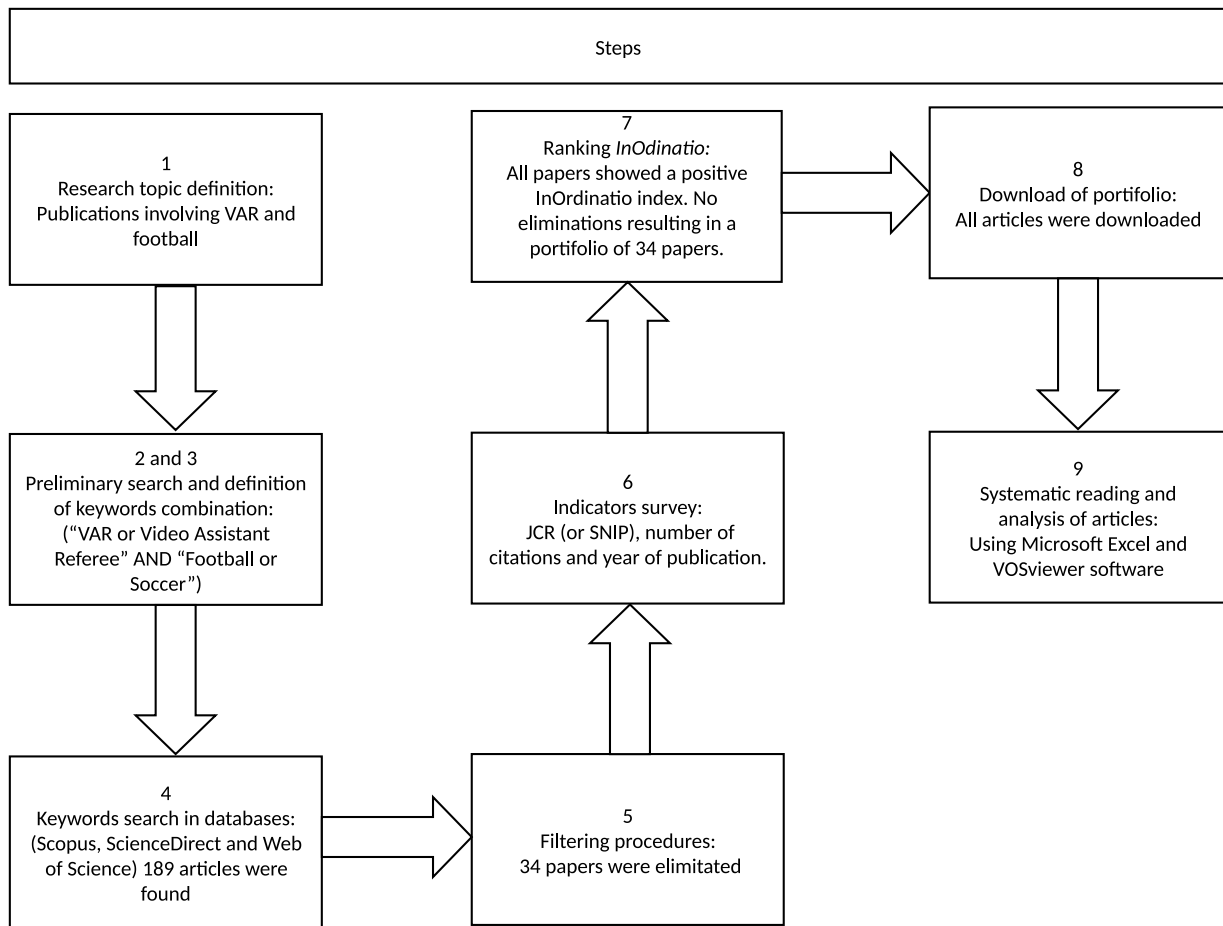


Fig. 1. Summary of the Methodi Ordinatio application.

## 2.2. Minimization of total distance covered by the VAR officials

The second step of this work is an application of an adaptation of p-median problem for the possible creation of VAR centres based on the reduction of distances covered by VAR officials to do their tasks in the matches of the Brazilian Serie A. This study proposes the use of one, two, three or five VAR centres distributed in Brazil, evaluating the possibility of keeping the already existing VAR centre in Rio de Janeiro. The most complete proposition is the creation of regional centres in each of the 5 regions of Brazil (South, Southeast, Midwest, Northeast and North). For the construction of this problem was considered the 5 regions of Brazil, its 27 capitals (states) and 108 referees able to work in a match of the season 2021 of the Brazilian Serie A. The 26 states, the federal district and their respective capital and abbreviations used in Brazil are presented in Table 3.

The possible locations for the VAR centres, are the state capitals because the most football matches of the championship studied take place in these cities and the displacement for these cities are easier than for inland cities.

For the definition of an adapted p-median problem one must consider the decisions variables  $x_{ij}$  and  $y_j$ . Where  $y_j$  is a binary variable indicating whether the VAR centre  $j$  is selected and  $x_{ij}$  is a binary variable indicating whether the VAR official is served by regional centre  $j$ .

$$x_{ij} = \begin{cases} 1, & \text{if the VAR official } i \text{ is served by regional centre } j \\ 0, & \text{otherwise} \end{cases}$$

$$y_j = \begin{cases} 1, & \text{if the VAR centre } j \text{ is selected} \\ 0, & \text{otherwise} \end{cases}$$

Table 3

Regions, states and their respective capitals.

Region	j	State (abbreviation)	Capital
South	1	Rio Grande do Sul (RS)	Porto Alegre
	2	Santa Catarina (SC)	Florianópolis
	3	Paraná (PR)	Curitiba
Southeast	4	São Paulo (SP)	São Paulo
	5	Rio de Janeiro (RJ)	Rio de Janeiro
	6	Minas Gerais (MG)	Belo Horizonte
	7	Espírito Santo (ES)	Vitória
Midwest	8	Mato Grosso do Sul (MS)	Campo Grande
	9	Mato Grosso (MT)	Cuiabá
	10	Goiás (GO)	Goiânia
	11	Distrito Federal (DF)	Brasília
Northeast	12	Bahia (BA)	Salvador
	13	Alagoas (AL)	Maceió
	14	Ceará (CE)	Fortaleza
	15	Maranhão (MA)	São Luís
	16	Paraíba (PB)	João Pessoa
	17	Pernambuco (PE)	Recife
	18	Piauí (PI)	Teresina
	19	Rio Grande do Norte (RN)	Natal
	20	Sergipe (SE)	Aracaju
North	21	Acre (AC)	Rio Branco
	22	Amazonas (AM)	Manaus
	23	Pará (PA)	Belém
	24	Rondônia (RO)	Porto Velho
	25	Roraima (RR)	Boa Vista
	26	Tocantins (TO)	Palmas
	27	Amapá (AP)	Macapá

The definition of the linear integer programming is [14]

$$\text{Min } Z = \sum_{i=1}^n \sum_{j=1}^m d_{ij} x_{ij} \quad (2)$$

subject to

$$\sum_{j=1}^m x_{ij} = 1 \quad \forall i = 1, \dots, n \quad (3)$$

$$y_j - x_{ij} \geq 0 \quad \forall i = 1, \dots, n \text{ and } \forall j = 1, \dots, m \quad (4)$$

$$\sum_{j=1}^m y_j = p \quad (5)$$

$$x_{ij} \in \{0, 1\} \quad \forall i = 1, \dots, n \text{ and } \forall j = 1, \dots, m \quad (6)$$

$$y_j \in \{0, 1\} \quad \forall j = 1, \dots, m \quad (7)$$

where  $d_{ij}$  is the distance between the city of VAR official residence  $i$  and the VAR centre  $j$  that were determined using Google Maps,  $n$  is the total number of VAR of officials (108),  $m$  is the number of possible VAR centres (27) and  $p$  is the total number of VAR centres to be selected.

The objective function, Eq. (2), is the total distance covered by all needed VAR crews to the nearest VAR centre. As they are chosen by sortition (according to Brazilian Football Confederation), all VAR officials has the same probability to officiate in a match. The restriction of Eq. (3) ensures that all video referees will be assigned to only one VAR centre, while the restriction of Eq. (4) ensures that a VAR official will only be assigned to a selected VAR centre (the nearest one). The restriction of Eq. (5) guarantee that there will be selected exactly  $p$  VAR centres. The restrictions of Eqs. (6) and (7) condition the decision variables to have binary values.

In the case of an VAR centre that already exists (like that one in Rio de Janeiro), it is also necessary to use an restriction like Eq. (8)

$$y_q = 1 \quad (8)$$

where  $q$  represents the VAR centre that already exists.

In the case that it is desired to create one VAR centre in each of five Brazilian region ( $p = 5$ ), the restriction of Eq. (5) must be replaced by

$$\sum_{j \in R_k} y_j = p_k \quad \forall k = 1, \dots, n_R \quad (9)$$

and

$$\sum_{k=1}^{n_R} p_k = p \quad (10)$$

where  $p_k$  is the number of VAR center selected for region  $k$  ( $p_k = 1$ ),  $R_k$  is the  $k$  subgroup from all possible VAR centres (one subgroup for each region) and  $n_R$  is the total number of subgroups (regions,  $n_R = 5$ ).

A VAR official from the one region can be assigned to officiate in a VAR centre in another one, since the displacement is shorter. After the VAR centres were selected, the total distances covered by VAR officials to officiate in the first 10 matches of Season 2021 of Brazilian Serie A where calculated and compared to each one of the possibilities proposed for creation of VAR centres.

### 3. Results and discussions

The results and the proper discussion are presented in two parts as same as presented in Section 2.

#### 3.1. Literature review by Methodi Ordinatio

There are 34 paper in the portfolio, since the application of the *InOrdinatio* index did not result in a negative value. Whereby, there are very few studies about the subject addressed in this work, so all papers were considered. In Table 4 it is possible to verify the results and the ranking for the *InOrdinatio* index.

**Table 4**

Final portfolio.

ID	Ref.	Paper title	InOrdinatio
1	[3]	How does Video Assistant Referee (VAR) modify the game in elite soccer?	98.002488
2	[15]	Video assistant referees (VAR): The impact of technology on decision making in association football referees	65.003943
3	[16]	The effects of the Video Assistant Referee system (VAR) on the playing time, technical-tactical and physical performance in elite soccer	47.002488
4	[17]	The influence of the video assistant referee on the Chinese Super League	45.002029
5	[18]	The training of soccer assistant referees beyond onfield experience: The use of the Interactive Video Test	36.000813
6	[19]	One image segmentation and discrimination method of live video system applied in sport game	24.000110
7	[20]	The Moral Gatekeeper: Soccer and Technology, the Case of Video Assistant Referee (VAR)	20.004232
8	[21]	Implementation of the Video Assistant Referee (VAR) as a Career Change-Event: The Israeli Premier League Case Study	20.004232
9	[22]	Is the perception of intent by association football officials influenced by video playback speed?	20.003653
10	[23]	The effect of the Video Assistant Referee on referee's decisions in the Spanish LaLiga	20.002029
11	[4]	A Step to VAR: The Vision Science of Offside Calls by Video Assistant Referees	19.001695
12	[24]	Football on the net: an analysis of twitters on the use of video arbitration in the Brazilian championship of 2019	16.000040
13	[25]	The influence of var in the final result of the 2019 Brazilian championship	16.000040
14	[26]	The new technology in football: dialogues on the influence of the var	16.000040
15	[27]	The impact of video assistant referee (VAR) on match performance variables at men's FIFA World Cup tournaments	12.001281
16	[28]	Video assistant referee's effect on football: Turkish super league case	12.000004
17	[29]	VAR implementation and soccer team performance: a comparison between the 2014 and 2018 World Cups	12.000000
18	[30]	Sports fans and innovation: An analysis of football fans' satisfaction with video assistant refereeing through social identity and argumentative theories	10.010969
19	[31]	Fans' Perceptions towards Video Assistant Referee (VAR) in the English Premier League	10.000950
20	[32]	The significant role of scoring from set plays in the 2018 FIFA World Cup	9.001669
21	[33]	Analysis of perceptions of Turkish fans of video-assistant-referees in elite soccer	9.000450
22	[34]	An integrated conceptual framework of decision-making in soccer refereeing	8.004048
23	[35]	Soccer in the classroom: dynamic geometry and the interpretation of a polemic move	8.000060

(continued on next page)

Fig. 2 shows the analysis performed concerning the keywords of the articles.

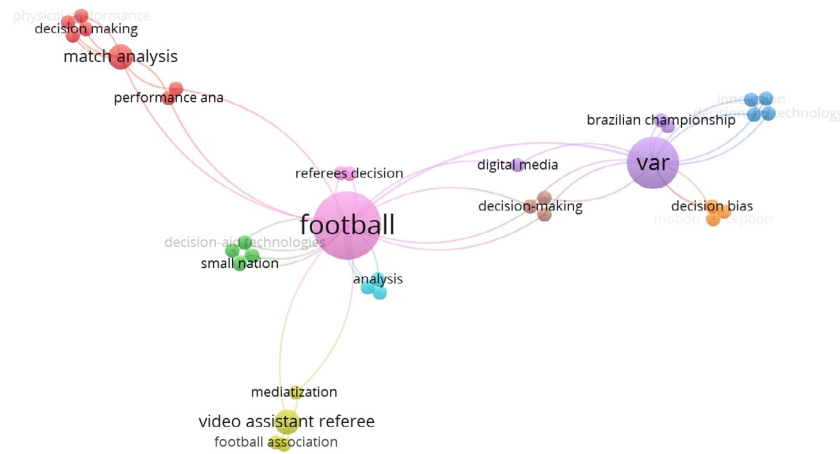


Fig. 2. Keywords map.

Table 4 (continued).

ID	Ref.	Paper title	InOrdination
24	[36]	Rules, Standards, and the Video Assistant Referee in Football	6.000400
25	[37]	English Premier League manager perceptions of video assistant referee (VAR) decisions during the 2019–2020 season	3.000360
26	[38]	Monitoring experts: insights from the introduction of video assistant referee (VAR) in elite football	2.001500
27	[5]	‘It’s not football anymore’: perceptions of the video assistant referee by english premier league football fans	1.000360
28	[22]	Affected but not involved: Two-scenario based investigation of individuals’ attitude towards decision support systems based on the example of the video assistant referee	1.000290
29	[39]	The Effect of the Video Assistant Referee System Implementation on Match Physical Demands in the Spanish LaLiga	0.004614
30	[40]	Mediatized Engagements with Technologies: “Reviewing” the Video Assistant Referee at the 2018 World Cup	0.003183
31	[41]	Video Assistant Referee in a Small-Nation Context: Intensified Mediatization	0.003183
32	[42]	Development of the Effect of Video Assistant Referee Application on Football Parameters	0.002838
33	[43]	The video assistant referee (VAR) as neo-coloniality of power? Fan negative reactions to VAR in the 2018 FIFA Men’s World Cup	0.001578
34	[44]	Influence of the video assistant referee (VAR) on the Brazilian Men’s Soccer Championship	0.000750

Among the main keywords, we can highlight: “football”, with 7 occurrences, “var” with 3 occurrences and “match analysis” and “video assistant referee” with 2 occurrences. Table 5 shows the number of publications and the number of citations per year.

The first publication dates from 2018, year in which it was registered 4 citations of papers of final portfolio. 2021 and 2022 (year of this study) have the highest numbers of publications, 12 and 11, respectively. The publications from 2021 have the highest number of citations, 99. As the VAR had its first tests applied in 2016 in the United States of America, the studies are recent. Fig. 3 shows the distribution of articles by country.

Brazil and the United Kingdom are the ones contributed the most to the portfolio, 6 articles each one, followed by Spain, 5 articles,

Table 5

Citation over the years.

Year	Number of papers	Number of citations
2018	1	4
2019	2	74
2020	8	71
2021	12	99
2022	11	13

Table 6

Main authors.

ID	Authors	Number of papers
1	Lago-Peñas, C.	4
2	da Silva, D. C.	2
3	Galily, Y.	2
4	Mather, G.	2
5	Samuel, R. D.	2
6	Tenenbaum, G.	2

and Israel and Turkey, 3 articles each one. A total of 14 countries are present in the portfolio. Fig. 4 shows the numbers of articles per journal.

The Brazilian Journal of Futsal and Football is the one with most publications, 4 in the total. Others six journals presents two papers each one, making a total of 25 journals in the composition of the portfolio. Table 6 presents the main authors.

The author Lago-Peñas, C. has participated in four articles, either as author or co-author. Five researchers appear in two publications and 101 have participation in at least one paper.

Most publications involving VAR and football deal with the influence of VAR in football. Lago-Peñas *et al.* [3] examined how the employment of VAR influenced the football, analysing 1024 matches in the Italian Serie A and Bundesliga (German league) in relation to 9 different aspects. A paired z-test and a linear model were used to compare the before and after the insertion of VAR in the matches, verifying that, after the implementation of VAR, there was an increase in the number of minutes added and a decrease in the number of offside, fouls and yellow cards. Spitz *et al.* [15] verified the impact of VAR on referee decision-making by analysing 2195 football matches in 13 countries. A total of 9732 checks with possible game-changing plays were analysed, with an average duration of 22 s. The chance for making the correct decision after the VAR intervention were found to be significantly higher than the referee’s initial decision, with the accuracy increasing from 92.1% to 98.3%. Errekagorri *et al.* [16] evaluated the effects of the VAR during a match, technical-tactical and physical performance of teams in the Spanish league in the 2018–2019 season. A total of 375 matches were evaluated, grouped according



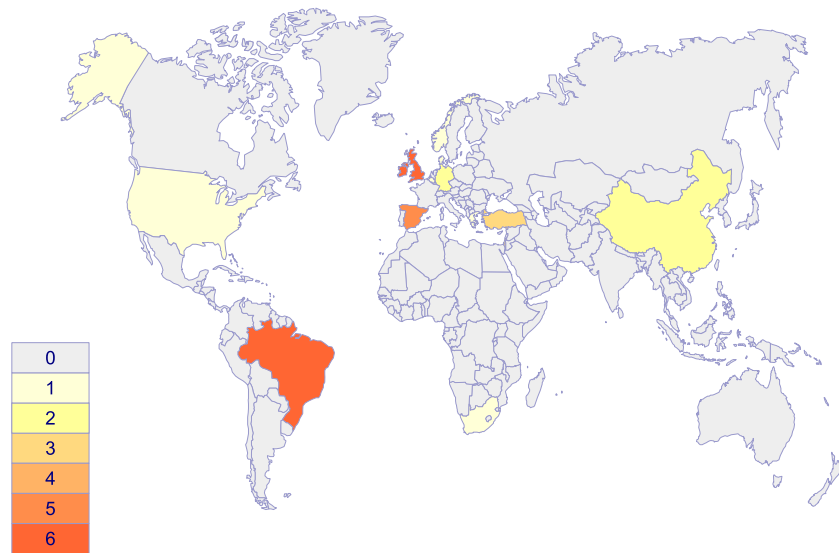


Fig. 3. Number of papers by country.

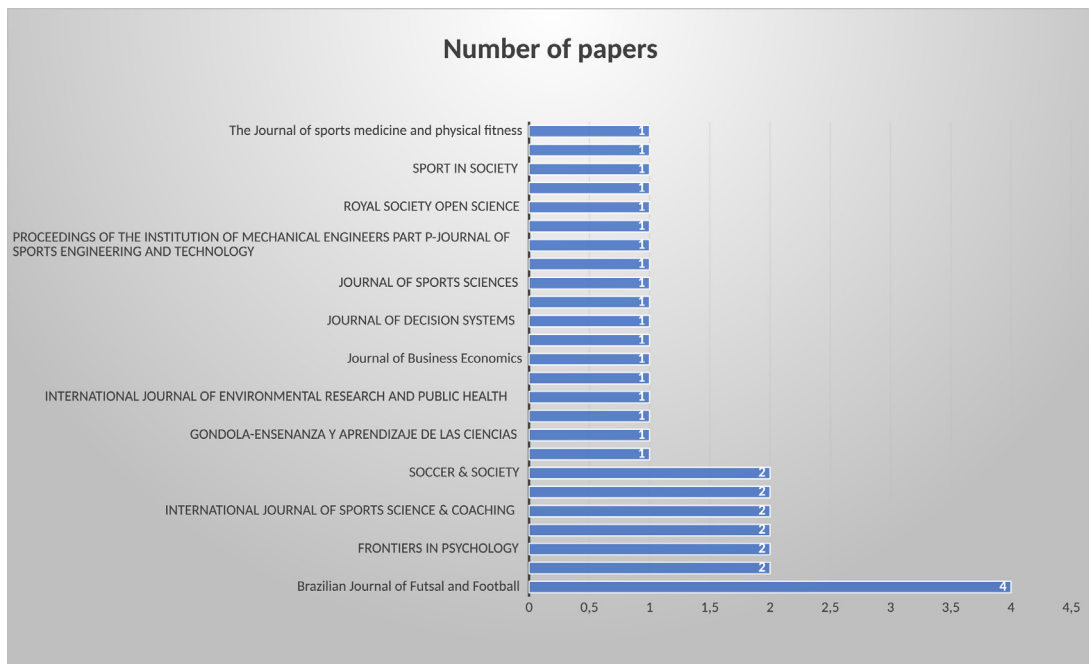


Fig. 4. Main journals.

to the number of interventions and analysing different aspects. There were fluctuations in relation to the results, with an increase in total playing time (TPT) in all groups. In general, the authors cite that VAR hardly changes the games. Han et al. [17] studied the impact of the introduction of VAR in the Chinese football Super League, comparing 240 matches without VAR in the 2017 season and 240 matches in the 2018 season in which the VAR was employed, using the Generalized Linear Model (GLM) and comparison of averages, with 9 variables. As a result, after the introduction of VAR, the number of offsides and fouls dropped significantly, the playing time in the first and second half and the total time increased and the home team advantage decreased slightly.

Armenteros et al. [18] carried out an analysis of the football assistant referees training using the Interactive Video Test (IVT). Assistant referees from the second and third Spanish divisions were chosen, dividing them into two groups, the Experimental Group (EG) and

the Control Group (CG). The EG referees were trained with the IVT analysing 720 offside decisions, after this both groups were evaluated in field tests involving the simulation of 326 possible offside situations. When compared, there was continuous improvement over time in the EG associated with the use of IVT, significantly better than the improvement in the CG. Laiguo [19] proposed a method of segmentation and discrimination of images from the live video system applied to sports matches through a fast algorithm, according to the characteristics of the football video and the VAR system. This method was applied comparing the normalized colour histogram of the targets to identify which team the players belong to. The experimental results shows that the tracking algorithm can solve the problem of object occlusion of different players in the football match, being able to constantly track players and be adopted by VAR.

Studies involving VAR are also being applied in relation to Brazilian football. Freitas Junior and Ferreira [24] analysed the tweets about

**Table 7**

Total distance (km) covered by VAR officials in the first 10 rounds of Season 2021 of Brazilian Serie A football championship, VAR centre in Rio de Janeiro (RJ).

Match	Round									
	1	2	3	4	5	6	7	8	9	10
1	688	2368	885	506	448	688	872	41	2631	1795
2	115	1400	41	1079	1196	1079	1400	541	448	1795
3	853	0	1032	688	115	541	0	144	115	0
4	1079	0	1400	1032	41	506	506	2368	688	541
5	1400	41	448	144	1400	144	885	1032	1400	506
6	1032	853	1079	2368	0	1032	0	853	872	853
7	2438	2438	115	1795	872	1400	86	1196	1032	144
8	448	506	872	853	885	853	448	2438	506	1251
9	1196	872	1196	2438	0	2368	2438	688	1079	41
10	0	1019	0	872	2368	2438	1079	1795	0	1196

the use of VAR in the Season 2019 of Brazilian Serie A. Initially, comments from this social network were collected and cataloged, verifying agreements and disagreements about the use of VAR. As a result, the authors verified that 66% of the opinions were against the use of VAR, while 34% were favourable, out of 604 analysed tweets. Guimarães and Costa [25] studied the influence of VAR on the final result of all matches of Brazilian Serie A Season 2019. There were interferences in 81 games, with 44 goals disallowed, 18 confirmed, 37 penalties signalled and scored, verifying that VAR was decisive for the final classification of the clubs in the championship. Meneguete et al. [44] evaluated the influence of VAR in the Brazilian Serie A comparing seasons 2018 and 2019, because in 2019 VAR was used for the first time in this championship. It was found that most of the analysed plays are related to penalties, followed by offsides and red cards. There was a reduction in the average number of fouls, yellow cards and offsides in the season 2019 compared to season 2018 and that VAR can influence referee decisions and match proceedings.

### 3.2. Minimization of total distance covered by the VAR officials

The minimization of the distances covered by VAR officials using the adaptation of p-median model for only one VAR centre resulted that São Paulo (SP) should be selected to be installed the VAR centre, instead of Rio de Janeiro (RJ) where it is actually installed. As a sample for comparison, it is shown in Table 7 the distances covered by VAR crews to officiate in each match of first 10 rounds of Season 2021 of Brazilian Serie A, a total of 91 081 km was covered by VAR officials. If there was only one VAR centre in São Paulo (SP), this distance could be reduced to 85 240 km (6.4% of reduction). In other words, in terms of distance, Rio de Janeiro (RJ) is not the best choice for allocation of VAR centre.

Evaluating the possibility of creating two VAR centres with minimum distances covered VAR officials resulted in the allocation in São Paulo (SP) and João Pessoa (PB). In this configuration, 82 VAR crews should be served by VAR centre allocated in São Paulo (SP) and the other 26 in João Pessoa (PB). Again, Rio de Janeiro (RJ) was not selected as a VAR centre. But, for comparison if one fix Rio de Janeiro (RJ) as a selected VAR centre, because it already exists, the two VAR centre should be in Rio de Janeiro (RJ) and João Pessoa (PB) with 83 VAR crews served in the first one and 25 in the other. In case São Paulo (SP) and João Pessoa (PB) were selected the total distance covered would be 53 568 km and in the case of Rio de Janeiro (RJ) and João Pessoa (PB) were selected, the distance would be 65 089 km. Comparing to the actual situation the distances reduction could be, respectively, 41.2% and 28.5%.

For the creation of three VAR centres, the selection should be São Paulo (SP), Maceió (AL) and Goiânia (GO) serving, respectively, 60, 22 and 26 VAR crews. Fixing Rio de Janeiro as one of the VAR centres, thinking of using the existing structure, the selected centres should be Rio de Janeiro (RJ), João Pessoa (PB) and Goiânia (GO) serving,

**Table 8**

Total distance (km) covered by VAR officials in the first 10 rounds of Season 2021 of Brazilian Serie A football championship, VAR centres in Rio de Janeiro (RJ), Curitiba (PR), Goiânia (GO), João Pessoa (PB) and Manaus (AM).

Match	Round									
	1	2	3	4	5	6	7	8	9	10
1	543	117	566	506	448	543	501	41	161	992
2	115	560	41	234	0	234	560	144	448	992
3	0	0	191	543	115	532	0	144	115	0
4	234	0	560	191	41	506	506	117	543	532
5	560	41	448	144	560	144	566	191	560	506
6	191	0	234	117	0	191	0	0	501	0
7	161	161	115	992	501	448	115	0	191	144
8	448	506	501	0	566	0	448	161	506	422
9	0	501	0	161	0	117	161	543	234	41
10	0	0	0	501	117	161	234	992	0	0

respectively, 54, 23 and 31 VAR crews. With 3 VAR centres the total distance covered by VAR crews is 52 307 km, and for 3 VAR centres fixing Rio de Janeiro (RJ) the total distance is 58 285 . Comparing to the actual situation (only one VAR centre in Rio de Janeiro (RJ)) the reduction are 42.6% and, 36.0% respectively.

The last case this study analysed is the creation of one regional VAR centres, one in each Brazilian region. In the South region the VAR centre should be allocated in Curitiba (PR), in the Southeast region, in Rio de Janeiro (RJ), and in the Midwest, Northeast and North regions, in Goiânia (GO), João Pessoa (PB) and Manaus (AM), respectively. Finally, there is a configuration that the existing VAR centre is selected.

In the RCVAR of South region, 31 referees were allocated and in the Southeast, Midwest, Northeast and North regions, 28, 23, 23 and 3 referees, respectively.

Considering the first 10 rounds of Season 2021 of the championship studied, the total distance covered by the VAR crews after the implementation of the five RCVARs would be 27 290 km (a possible reduction of 70.0%). The detailed distances by round and match is shown in Table 8.

Close numbers of VAR officials from the main referee crew were allocated in the South, Southeast, Midwest and Northeast Brazilian regions, only the North Brazilian region has very few VAR officials allocated. The North Brazilian region has a very large territory and few referee crews. As in each round there are 10 matches, it is possible that RCVAR of North region would not be used for some rounds in a row. For this reason, one can think that it is not interesting to create a facility with VAR infrastructure in North region, but in Manaus (where the CRVAR of North region should be located) was constructed the Amazon Arena as part of Brazil's hosting of the 2014 FIFA World Cup, and this stadium is very few times used because there is no football team of North region in Brazilian Serie A, so this structure could be used to install the VAR infrastructure for North region CRVAR.

## 4. Conclusions

In this work a literature review, about “football” and “VAR”, was carried out applying the *Methodi Ordinatio*. After the literature review, it was carried out a study about the reduction of the total distance covered by VAR officials to officiate in the matches of Brazilian Serie A football championship. There are few publications involving “Football” and “VAR” and most of them aim to describe the impacts of VAR and technologies in football, allowing new studies to evaluate other aspects. As a sample, among the many possibilities analysed, in 10 rounds of the Brazilian Serie A championship, the distance covered by VAR officials to do their tasks in the matches could have a reduction of about 70% (compared to the current situation that there is only one VAR centre in Rio de Janeiro) if one VAR centre were created in each region of Brazil, being that in Southeast the VAR centre already exists in Rio de Janeiro. The physical and mental health issues of referees is a study to be carried out in the future, as it can help to improve performances and reduce referees errors in matches.

## 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.

## Data availability

No data was used for the research described in the article

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