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Physiological Profile and Correlations between VO_{2max} and Match Distance Running Performance of Soccer Players with Visual Impairment

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Abstract: Aerobic capacity is crucial for the performance of soccer players; however, the relationship between VO_{2max} and the running performance of soccer players with visual impairment is not known. Possibly finding relationships would help in the training process, as training would be more targeted. Additionally, both bodyweight and relative VO2max are factors that affect people's health and wellness. From the literature, it appears that there are no studies that present the normal profile of soccer players with visual impairment. The aims of this study were to (a) determine the differences in VO_{2max} between soccer players and sedentary men with visual impairment; (b) to assess the relationship between the VO_{2max} of players with visual impairment and the distance covered in a soccer match and (c) to describe a profile of physiological parameters and distance running during a soccer match. Six male soccer players with VI and six male sedentary people with VI participated in this study. Anthropometric characteristics (age, height, bodyweight, body fat (BF), body mass index (BMI), cardiorespiratory markers (VO_{2max}, maximum heart rate (HRmax), respiratory exchange ratio (RER)) and the running performance of soccer players during matches were measured, and the VO_{2max} of all the participants was measured in a laboratory. Mann–Whitney U test was used to evaluate differences between sedentary and soccer players' anthropometric characteristics and performance. A correlation analysis by Spearman's' method was used to examine relationships between VO_{2max} and the rest of the physical values during the match. The level of statistical significance was set at $p < 0.05$. The soccer players' weight was 33% lower, and their BMI was 23% lower than that of sedentary men ($p = 0.023$, $\eta^2 = 0.457$ and $p = 0.048$, $\eta^2 = 0.394$, respectively). The relative body mass VO_{2max} of the athletes was 42.9% higher in comparison with sedentary men with VI ($p = 0.002$, $\eta^2 = 0.755$). No correlations were found between VO_{2max} and match running performance ($p = 0.957$, $r = -0.029$) or other parameters during the match in soccer players with VI. In conclusion, relative VO_{2max} is not related to the match running performance of soccer players. The tactics applied by the team, the style of play and the position of the player may affect the distances covered. Also, as expected, the soccer players showed lower bodyweight and higher relative VO_{2max}. However, this is the first study to observe the level of these differences.

Keywords: physiological profile; visual impairment; VO_{2max}; soccer match distance running

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1. Introduction

Visual impairment is a sensory disability that affects about 36 million people worldwide [1]. For equal participation in sport, people with visual impairment are categorized

under three sections (B1, B2, B3). The B1 category includes people who have or do not have light perception and cannot recognize any items. Visual acuity is also stated with logMAR, which stands for the logarithm of the maximum angle of resolution (International Blind Sports Federation (IBSA), 2018), and it presents more than 2.6 points according to the IBSA classification system [2].

Previous studies have shown that visual impairment is associated with a low quality of life [3], as it causes a variety of difficulties in daily activities and limits interactions and independence. One significant problem that this particular population has faced is a sedentary lifestyle due to difficulties in transportation and mobility [4].

According to researchers [5], people with visual impairment who participated in sporting activities had a higher quality of life compared with those who had a sedentary lifestyle. Participation in sporting activities seems to reduce the sense of pain and, at the same time, improve mental health [3,5]. Generally speaking, the improvement of physiological variables can help people with disabilities be healthier and more satisfied with their life [1]. Furthermore, the physical activity of people with visual impairment improves their social lives because, in most sports, and especially team ones, they socialize with other people [6]. As a result, this has a positive impact on their life satisfaction.

There are many sports designed with rules adapted for this particular disability (visual impairment) (judo, wrestling, cycling and blind soccer five-a-side), but there are also sports that have their own unique set of rules, like goalball and beep baseball [6,7].

There is a dearth of literature dedicated to people with visual impairment playing soccer. This can be concerning because of a variety of issues, for instance, the occurrence of injuries, the physical profile of soccer players, cardiorespiratory function, the effect of training on body composition, the internal and external workload that soccer players receive and the analysis of technical elements of the sport [6,8,9]. There are no specific data regarding all these issues, and generalizations are often made by other populations. Moreover, information on the maximum oxygen uptake of soccer players with visual impairment is very limited.

Aerobic capacity can be improved with both continuing endurance training and high-intensity interval training [10]. Aerobic capacity is particularly important for the performance of soccer players. Previous studies have reported a correlation between the distance covered during the match and maximum oxygen uptake [11]. Nonetheless, in a recent study using global positioning system (GPS) technology, studies have shown that there is no correlation between the running distance covered by soccer players during the match and maximum oxygen uptake [12]. It has also been reported that an improvement of VO_{2max} by 6% may increase running performance during the match, the number of sprints and the number of actions with the ball [13]. In addition, high levels of aerobic capacity help soccer players cope with the demands and physical challenges of the match [14] and have faster recovery between intense actions during the match [15].

The studies that focus on the aerobic capacity of visually impaired people (soccer players and sedentary) are limited, and there are not enough data to compare these two populations. Also, a positive relationship (between VO_{2max} and match running performance) could affect soccer players' training and would help trainers estimate players' match running performance via laboratory measurements. However, no research to date has dealt with the relationship between the VO_{2max} index and covered distances of soccer players with visual impairment. Therefore, it is assumed that soccer players with higher VO_{2max} will cover longer distances during soccer matches.

The aims of this study were to (a) determine the differences in VO_{2max} between soccer players and sedentary men with visual impairment; (b) to assess the relationship between the VO_{2max} of players with visual impairment and the distance covered in a soccer match; and (c) to describe a profile of physiological parameters and distance running during a soccer match. The hypotheses of the study were that (a) players with visual impairment will have higher VO_{2max} than nonathletes, and (b) there will be no relationship between VO_{2max} and running performance in matches of soccer players with visual impairment.

2. Methods

2.1. Participants

Twelve participants with visual impairment (B1 category) agreed to participate in this study. This included six soccer players practicing for 13 to 20 years and six sedentary men who had not participated in any kind of physical exercise for at least 6 months. Six participants had congenial visual impairment, and six had acquired visual impairment (three = athletes, three = sedentary) (Table 1). For the players who had developed blindness of an acquired nature, the age of onset was 9.3 ± 2.1 years, but they had not played soccer prior to their loss of sight. The evaluation of the severity of vision loss was based on an ophthalmological examination. The inclusion criteria were as follows: visual impairment (less than 20/200 and the field of vision limited to 20° legal visual impairment [2]; no medical contraindications to participate in the research; and male sex. The exclusion criteria were as follows: the coexistence of other disabilities and diseases and taking medication that could affect the results of the analyses. All participants met their daily obligations for the study.

Table 1. Participants' characteristics.

	Soccer Players (n = 6)			Sedentary People (n = 6)				
		Percentiles			Percentiles			
	Median	25th	75th	Median	25th	75th	p	η^2
Age (y)	27.0	21.0	35.5	24.5	21.5	34.0	0.936	<0.001
Height (cm)	169.5	164.0	176.5	173.0	167.0	178.8	0.173	0.169
Weight (kg)	70.0	64.4	78.3	81.1	69.9	93.2	0.023	0.457
BMI	25.5	22.5	27.7	29.2	27.1	37.2	0.048	0.394
Body Fat (%)	21.0	19.8	22.3	24.5	20.5	27.8	0.002	0.766
Lean body mass (kg)	54.6	51.5	62.5	61.8	53.4	69.3	0.032	0.282
Congenital/Acquired		3/3			3/3			

Level of significance $p < 0.05$; η^2—partial eta square; partial eta squared classification as small (0.01 to 0.058), medium (0.059 to 0.137) or large (0.138 or higher).

The sample of the study did not result from power analysis but from their voluntary participation. The participation of people with visual impairment in the sport of soccer is very limited, which made it difficult to enlarge the sample.

2.2. Procedures

All the players who participated in the present research completed the full time of the match, which lasted 2 × 25 min, while all goalkeepers were excluded from the study. The soccer players participated in five matches. The soccer players participated in two training sessions with the team on the field (for 75 min each training). Each of the training involved physical conditioning exercises, technical exercises, and tactical exercises. Also, they participated in two strength training sessions in the gym every week (for approximately 90 min per training session).

All measurements were conducted under field conditions on natural or artificial grass of the 5th generation. Also, the matches were performed on nonrainy days where the wind speed did not exceed 1 m/s.

All procedures and any possible risks and discomforts were fully explained in detail to participants before the start of the study. There were no caffeine beverages, smoking consumption or meals for at least 3 h before the testing. All the participants signed a consent form for their participation. This study was approved by the Ethics Committee of the Department of Physical Education and Sports Science, according to the ethical standards in exercise and sports research with disabilities. Participants' characteristics are shown in Table 1.

2.3. Experimental Approach to the Problem

A cross-sectional protocol was employed to approach the problem of the study. The VO_{2max} was measured in a lab, whereas running and cardiorespiratory parameters were measured during five soccer matches. Of the 12 participants, 6 were soccer players, while 6 were nonathletes. The nonathletes did not have to participate systematically (<2 times/week) in sports activities. All of them performed anthropometric and VO_{2max} measurements. The players participated in five soccer matches where physiological indicators (HR) and match running distance (covered distance (m) and velocity (km/h)) were measured.

One week before the beginning of the study, the participants familiarized themselves with the tests. Testing was incorporated within the laboratory. Soccer matches were performed on the team's field. More specifically, the anthropometric and VO_{2max} measurements were completed during the first visit to the laboratory after familiarization. At the beginning of the VO_{2max} measurement, all participants performed a 10 min warm-up and stretching, followed by a 10 min cool-down period. VO_{2max} measurements were performed under the same conditions in the laboratory. All participants avoided any strenuous activity the day before the measurements.

In the field, before each soccer match, the soccer players performed a standardized 25 min warm-up consisting of 5 min submaximal running, 5 min of stretching exercises, ball-handling exercises for 5 min, three repetitions of 15 m run-outs at approximately 90% of maximal speed and 4 min of active recovery.

2.4. Anthropometric Measurements

Body mass was measured using an electronic digital scale with the participants in their underclothes and barefoot. Their height was measured to the nearest 0.1 cm (Seca 220e, Hamburg, Germany). Body mass index (BMI) was calculated (kg/m^2). To assess body fat, a Lafayette skinfold caliper (Lafayette, Ins. Co., Lafayette, IN, USA) was used to measure the thickness of the soccer players' subcutaneous fat in four of their skinfolds (biceps, triceps, suprailiac, subscapular). All skinfold measurements were taken on the right side of the body to calculate the body fat percentage. The estimation of body density was calculated according to Durning and Rahaman [16].

$$\text{Density} = 1.161 - [0.0632 \times (\log\Sigma 4)],\ \Sigma 4 = \text{sum of 4 skinfolds}$$

The percentage of body fat was estimated by the equation of Siri (1956) [17]:

$$\text{BF (\%)} = [(4.95/\text{D}) - 4.5] \times 100$$

2.5. Maximal Oxygen Consumption (VO_{2max}) Assessment

This test was carried out in the laboratory, and its results show the level of aerobic capacity of the athlete. The most accurate measurement of $VO_{2max,}$ which is referred to as the "gold standard", consists of maximal laboratory testing on the treadmill [18]. The measurement of VO_{2max} is performed on a treadmill, because this kind of motion (walking–running) is similar to the movements in soccer matches. This index is used in assessing players' aerobic capacity. The VO_{2max} of participants was assessed in the morning. The room temperature was around 23 °C, and the relative humidity was 50%. The cardiorespiratory VO_{2max} test was performed on a treadmill (Pulsar; h/p/Cosmos, Nussdorf-Traunstein, Germany) using a continuous protocol until exhaustion, consisting of eight two-minute stages. The initial grade was 0%, and the speed was 4 km/h for warm-up. In the basic phase of the test, the grade was set to 3%, and the speed was set at 5 km/h. The speed was constant throughout the test, while the grade was increased by 2% every 2min. After the final stage, a cool-down session took place for 2 min at 2 km/h and 0% grade. Before studying the measurements, a pilot study was conducted. VO_{2max} and cardiorespiratory indices were measured via a breath-by-breath ergospirometric system (Oxycon Pro; Jaeger, Wurzburg, Germany). The analyzers were calibrated before the

measurements. The highest VO_{2max} value recorded was accepted as the VO_{2max}, after achieving the stabilization of VO_{2max} for at least five measurements (steady-state 5 breaths). Moreover, during the testing, the following parameters were recorded: heart rate (HR), maximal HR and respiratory exchange ratio (RER).

The VO_{2max} was achieved when at least two of the following four criteria were met: (a) HR exceeded 95% of the expected maximal HR predicted by formula 220-age; (b) leveling-off (plateau) of VO_{2max} despite the increase in treadmill grade; (c) a respiratory exchange ratio (RER) higher than 1.1; and (d) the subject was no longer able to continue walking/running despite verbal encouragement [19].

During the measurement, the participants moved on the treadmill with normal arm movements.

2.6. Global Positioning System (GPS) Analysis

HR data from the match was recorded using the Polar Team Pro (10Hz) (Polar Electro Oy, Kempele, Finland). The recording of the HR began when the athletes wore their monitors. All the values were taken directly from the Polar Team2 Pro software. In matches, each player wore the same GPS device to avoid any existing interunit variation, and at the end of the match, data were analyzed; four indices were used for the total match (total distance (m), mean and maximum movement speed (km/h), mean heart rate (b/min)).

2.7. Statistical Analysis

All statistical analyses were performed using SPSS (version 24.0; SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to examine the normal distribution of the sample. The results show that the data of the study did not follow the normal distribution; so, the next statistical tests were used. Descriptive statistics were used to calculate percentages, medians and percentiles for the variables. Mann–Whitney U test was used to evaluate differences between sedentary and soccer players' anthropometric characteristics and performances. Effect sizes were estimated by calculating partial eta squared and were classified as small (0.01 to 0.058), medium (0.059 to 0.137) or large (0.138 or higher) according to Cohen (1988) [20]. Finally, the correlation analysis by Spearman's' method was used to examine relationships between VO_{2max} and the rest of the physical values during the match. The interpretation of the observed correlations was performed according to Hopkins' ranking: correlations between 0.3 and 0.5 were considered moderate, between 0.51 and 0.7 large, between 0.71 and 0.9 very large and above 0.91 almost perfect [21]. The level of statistical significance was set at $p < 0.05$.

3. Results

The correlations observed in this study are presented in Table 2. The total distance covered by the soccer players was 1820 m (median = 993 m, Percentiles: 25th—767 m, 75th—1049 m). The median speed was 2.03 km/h (Percentiles: 25th—1.65 km/h, 75th—2.38 km/h), while the median of maximum speed was 8.35 km/h (Percentiles: 25th—7.40 km/h, 75th—9.68 km/h). The median HR during the match was 161 beats/min (Percentiles: 25th—151 beats/min, 75th—168 beats/min).

Table 2. Correlation between VO_{2max} and physiological parameters.

	Total Distance		**Median HR**		**Median Velocity**		**Max Velocity**	
	r	***p***	**r**	***p***	**r**	***p***	**r**	***p***
VO_{2max} Relative to body mass (mL/kg/min)	−0.029	0.957	−0.200	0.704	0.314	0.544	−0.257	0.623

Level of significance $p < 0.05$; interpretation of correlations: between 0.3 and 0.5 were considered moderate, between 0.51 and 0.7 large, between 0.71 and 0.9 very large and above 0.91 almost perfect.

The soccer players with visual impairment's weight and BMI were 33% and 23% lower than those of the sedentary men with visual impairment ($p = 0.023$, $\eta^2 = 0.457$ and $p = 0.038$,

η^2 = 0.394, respectively). Also, the soccer players' body fat was lower than the equivalent body fat of the sedentary men (p = 0.002, η^2 = 0.766). Additionally, the relative body mass VO_{2max} and the relative lean body mass of athletes were 42.9% and 24.1% higher, respectively, than the sedentary men (p = 0.002 and p = 0.032, respectively). The participants' cardiorespiratory parameters are presented in Table 3.

Table 3. The values of participants' cardiorespiratory parameters.

	Soccer Players			Sedentary People				
		Percentiles			Percentiles			
	Median	25th	75th	Median	25th	75th	p	η^2
HRmax (b/min)	161	144	186	162	147	176	0.995	<0.001
RER	1.05	1.00	1.10	1.05	0.98	1.10	0.841	<0.001
VO_{2max} (L/min)	2.90	2.63	3.17	2.77	2.60	3.05	0.157	0.149
VO_{2max} (mL/kg/min) Relative to body mass	41.15	36.93	43.93	33.95	30.18	41.78	0.002	0.755
VO_{2max} (mL/kg/min) Relative to lean body mass	51.06	47.48	55.29	44.97	41.82	51.66	0.004	0.674

Level of significance $p < 0.05$; η^2—partial eta square; partial eta squared classification as small (0.01 to 0.058), medium (0.059 to 0.137) or large (0.138 or higher).

4. Discussion

The results of the present study confirm the hypothesis that soccer players with visual impairment have higher VO_{2max} than nonathletes. Also, the second hypothesis was confirmed, as no correlation of VO_{2max} with the running performance of the players in the matches was observed.

4.1. Relationship of VO_{2max} with Total Match Running Distance and Other Physiological Parameters

This is the only study that investigates the relation of VO_{2max} to the distance covered during a soccer match for people with visual impairment. The findings showed that there were no correlations with the total running distance covered in soccer matches by athletes. In the literature, there is no study to compare with this study's findings in soccer players with visual impairment (about the correlation between VO_{2max} and match running performance). However, in a study performed on soccer players without visual impairment [12] that tested the relationship between VO_{2max} and match running performance (measured by GPS), no correlations were mentioned. At all levels and kinds of soccer matches, the tactical role, individual playing position, opponent and stimulus degree of motivation can affect the correlation between VO_{2max} and match running performance. It has been shown that some contextual variables can affect external load, such as match running distance [6]. However, Gamonales et al., (2020) [22] in a tournament for individuals with visual impairment showed a similar match running distance (1416 to 1877 m). The position played by the players and the tactics applied by the team affect not only the distance covered by the players but also the characteristics of these distances. For example, it is well known that lateral midfielders perform more and bigger sprints than central midfielders. In soccer players without visual impairment, the values of VO_{2max} are between 55 and 65 mL/kg/min [23]. These values are high since players must be able to cope with the demands of the sport, but they are not like the values in endurance sports that exceed 70 mL/kg/min [24]. Coaches do not seek to maximize VO_{2max}, as they prefer to devote the time they would spend for this purpose to training technical–tactical elements.

Additionally, no correlations were observed between VO_{2max} and other physiological parameters like heart rate or median and maximum velocity of the players during a soccer match. However, a study by Gamonales, et al. (2020) [22] on soccer players with visual impairment from three different countries (Spain, Italy and Czech Republic) showed lower heart rate average values (~145 beats/min) during matches than the present study. Similar results were presented in a more recent study by the same laboratory [6] that was performed

on 50 soccer players with visual impairment. The average heart rate was 38 beats/min. These values are well below the values observed in the present study, with participants in the three studies having similar ages.

4.2. Differences in Anthropometric Characteristics between Soccer Players and Sedentary People

It should be mentioned that the targets of the present study were to examine the differences in anthropometric characteristics and VO_{2max} between sedentary men and soccer players with visual impairment and the possible relationship between VO_{2max} and parameters during a soccer match. In general, the findings of the present study showed that soccer players had a lower weight and a lower BMI than sedentary men. The obesity of people with visual impairment may be partly connected to a lack of habitual physical activity [25]. Habits related to physical activity during childhood are also adopted during adulthood. Also, an obese child is very likely to be an obese adult [26]. It is crucial for youth with visual impairment to adopt an active lifestyle and participate in any kind of sport. The BMI of the participants (soccer players) in the present study was similar to the values mentioned in a previous study [22].

Another important finding of the present study was that soccer players showed greater values of VO_{2max} than sedentary men. A crucial ability of soccer players is aerobic capacity. The most useful index to assess this capacity is VO_{2max}, which is the ability of the body to maximize the use of oxygen during maximal effort. Despite the adjustments to the rules for soccer players with visual impairment, the sport is especially demanding of aerobic capacity. In the present study, the VO_{2max} of the soccer players was higher than that of the sedentary men. Although the absolute value of VO_{2max} between players and nonplayers differed only by 8.6%, the relative value of VO_{2max} differed by 42.9%. This indicates the significant influence of weight on VO_{2max}. The studies that were performed on people with visual impairment used different methods to measure cardiorespiratory, muscle strength and body fat, and it is difficult to compare their results [26]. This was the first study that compared the VO_{2max} of soccer players and sedentary men with visual impairment. The soccer players showed a higher absolute and relative value of VO_{2max} in comparison with the visually impaired sedentary men.

From the above, it seems that soccer players with visual impairment maintain their bodyweight closer to normal levels than nonathletes with visual impairment. The relative VO_{2max} that is important for soccer players is affected by their bodyweight. This observation is evident in the present study, as soccer players and nonathletes showed similar absolute VO_{2max} values but differed significantly in relative VO_{2max} values. It is known that a higher relative VO_{2max} generally reflects better cardiovascular endurance and efficiency, as it signifies an individual's ability to transport and utilize oxygen for energy production. Individuals with higher relative VO_{2max} levels often exhibit lower risks of chronic diseases like heart disease, obesity and type 2 diabetes. This relationship is grounded in the principle that a strong cardiovascular system enhances oxygen delivery to tissues, improves metabolism and helps maintain healthy bodyweight [27–29]. Thus, striving to improve and maintain a higher relative VO_{2max} level through regular physical activity contributes significantly to promoting overall health and well-being.

However, people with visual impairment are likely to have lower physical activity levels than their peers with physical or chronic disabilities [30,31]. Social and self-imposed barriers are the main issues preventing people with visual impairment from participating in any sporting activity [32]. Previous studies have mentioned that physical activity may reduce the risk of developing depression, improve the quality of life and generally improve the mood of people [33]. It is very important to encourage people with visual impairment to participate in team sports. Soccer is a team sport in which a player is part of a group. It has been mentioned in a previous study that life satisfaction increases when people join exercise groups [34]. In another study, researchers revealed that Torball practice improves the emotional well-being and social abilities of people with visual impairment [35]. Therefore, the participation of people with visual impairment in soccer may help them maintain their

bodyweight and improve their aerobic capacity. Both of the above factors are related, as mentioned above, to indicators of health and life satisfaction.

As far as the limitations of the study are concerned, a larger sample size would be better for safer conclusions. Also, all the participants belong to the B1 category of visual impairment; so, the results of this study are representative of this group of participants and cannot be generalized to all people with visual impairment. Additionally, in the present study, the demographic characteristics of the sample were not taken into account. Finally, the cross-sectional study design cannot indicate a causal relationship between soccer participation and physical condition. Reducing these limitations in future research will create a clearer picture of the VO_{2max} of visually impaired soccer players and the distance they cover during a soccer match.

5. Conclusions

In conclusion, the results demonstrate that players' match running performances do not depend on the index of VO_{2max}, and none of the study's variables can predict the match running performance of soccer players with visual impairment. Additionally, soccer players with visual impairment have significantly greater relative VO_{2max} than sedentary men. Finally, sedentary men presented with a higher BMI index than soccer players. As mentioned above, both bodyweight and relative VO_{2max} are factors that affect people's health and wellness. Therefore, people with visual impairment should be encouraged to participate in sporting activities such as soccer.

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