

# Comparison of maximal aerobic speeds of team-sport athletes and investigation of optimal training loads\*

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Research article

**Keywords:** Endurance, Maximal Aerobic Speed, Team Sports, High School, Student Athlete

**Posted Date:** November 2nd, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-1039187/v1>

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## Abstract

**Objective:** To investigate maximal aerobic speed (MAS), participants of team sports in terms of certain variables and to determine relationship team sports.

**Design:** Screening research.

**Setting:** Elite soccer, basketball and handball players.

**Participants:** 44 athletes.

**Main Outcome Measures:** 20-meter shuttle run test (20MSRT) was used.

**Results:** There was a positive relationship between age,  $VO_{2max}$  and speed scores ( $p < 0.05$ ). Besides, significant difference between  $VO_{2max}$  distance and speed also  $VO_{2max}$  distance and speed were found to be significantly different according to types of sports ( $p < 0.05$ ). When distance and speed scores of athletes were examined, it was determined that mean scores of football players were higher compared to basketball and handball. Heart rate and MAS scores of participants were not significantly different according to type of sport played.

**Conclusions:** This study will contribute to strength and strength coaches, trainers and physiotherapists in terms of training programs that they will apply to athletes of various sports.

## Introduction

Many studies are carried out to identify characteristic qualities of competitors in different sports. Thanks to the developing technology, sports science renews itself day by day and tries to discover training techniques that increase success. In this context, contemporary training methods consider effects of high-intensity aerobic running speed training on physiological and performance values in team sports. Moreover, research is conducted on individual training applications related to different types of sports (Özen et al., 2020). MAS is defined in the literature as the speed of movement produced by an athlete at maximal aerobic power or 100% of  $VO_{2max}$  (Bosquet et al., 2002; Ermanno Rampinini et al., 2009). MAS measurements are made in km/h. It is more important to know the MAS, which is mandatory to adjust the running speed, which in turn facilitates physiological development, than to know  $VO_{2max}$  (Karatosun, 2012). It is thought that being able to adjust running speed of the athletes according to needs of the sports that they play will have an important role in their performances. On the other hand, it is thought that these running speeds may differ between sports, players' positions, and even genders. It is known that MAS are determined optimally according to type of sport and comparisons can be made accordingly. In this way, it becomes easier and more efficient to follow the physiological development of athletes (Baker & Heaney, 2005). This process is attracting more interest day by day from sports scientists. Furthermore, looking at the current literature on MAS, it is seen that it is next to this (Edis et al., 2007; Mülazımoğlu, 2012). On the other hand, when examining studies conducted outside of Turkey, it is seen that there is slightly more research available in the literature (Baker, 2015; Baker & Heaney, 2005; Dellal et al., 2008; González-Badillo et al., 2015).

As a result, this study will contribute to the existing literature in terms of relationships between types of sports and age of athletes and maximal aerobic speed. Therefore, the purpose of this research is a comparison of maximal aerobic speed (MAS) of young athletes and investigation of optimal training loads.

## Materials And Methods

### Participants

The research group comprised football ( $n=16$ ), basketball ( $n=12$ ) and handball players ( $n=16$ ) who were active in team sports in the 2018-2019 season in Trabzon, Turkey. There were 44 male participants in total. Current average age was  $17.20 \pm 1.0$  years, average height was  $178.6 \pm 6.6$  cm and average weight was  $73.1 \pm 11.2$  kg. Average age, height, weight and body mass index of football players were  $18.00 \pm 0.0$  years, height  $175.03 \pm 7.17$  cm, weight  $68.53 \pm 9.33$  kg and  $22.22 \pm 1.80$  kg/m<sup>2</sup>. Average age, height, weight and body mass index of basketball players were  $16.41 \pm 1.31$  years, height  $181.33 \pm 5.10$  cm, weight  $75.16 \pm 12.15$  kg and  $22.80 \pm$

3.10 kg/m<sup>2</sup>. Average age, height, weight and body mass index of handball players were 17.00 ± .63 years, height 180.18 ± 5.95 cm, weight 76.18 ± 11.47 kg and 23.42 ± 2.98 kg/m<sup>2</sup>.

## Research Design

The aim of this study is to compare the MAS of young athletes participating in team sports and to determine the optimal training loads. In this study, a quantitative research approach was used. As a methodological approach, the screening method was preferred in order to determine the most obvious characteristics of the participants, such as their skills and attitudes (E. Rampinini et al., 2007). The 20-meter shuttle run test was applied as a data collection technique by the researchers to the athletes forming the working group after obtaining the necessary permissions. Athletes voluntarily participated in the implementation of the data collection tool, and informed consent forms were obtained from them or their families.

## Statistical Analysis

Before proceeding to the analysis stage, the data of the research were tested to determine whether they were suitable for normal distribution with the Shapiro-Wilk W test and kurtosis and skewness values. Parametric techniques were used because the distributions were observed to be normal. The data were analysed with the SPSS 23 package program. In this context, information about the research group and various research variables were evaluated using descriptive statistics techniques. As data analysis techniques, one-way analysis of variance (ANOVA) and Pearson product-moment correlation coefficients were used. In the analysis of the data, significance levels were taken as 0.05.

## 20-Meter Shuttle Run Test

Within the scope of this research, the Trabzonspor Kadir Özcan Youth Development Centre's synthetic field was used for the 20-meter shuttle run test. Active male athletes from football, basketball, and handball voluntarily participated in the study. Six running tracks, consisting of a flat area of 20 meters, were used for the test. The starting and ending points of the created areas were determined by marking them with training funnels. The command signals necessary for the test were transferred from a computer environment to the athletes via a sound system. Before starting the test, the athletes were allowed to acclimate to low-intensity shuttle running exercises. In addition, the athletes were encouraged to run at the maximum level during the test and to complete the test at the maximum level. "The running speed at the start of the test is 8.5 km and the running speed is gradually increased by 0.5 km per minute. The test ended with two faults occurring repeatedly or when athletes reached their burnout levels" (Tamer, 2000).

## Heart Rate Measurement Equipment

A heart rate monitor (Polar RS 800, Finland), which can measure heart rate instantly, was used to determine the heart rate and save it to the computer.

## Calculation of Maximal Aerobic Speed

There are many different formulas and test models to calculate MAS directly and indirectly (Baker and Heaney 2015). Baker and Heaney obtained some normative aerobic fitness data for MAS scores for athletes competing in field sports. In this sense, they used the following tests to determine MAS: laboratory tests, Multistage Montreal Beep, VAMEVAL, YoYoIR1, Carminatti's test, Multistage Shuttle Beep, Set Time Trial, Set Distance Trial, and 1200-m Shuttle. The test model applied in the current study is the Multistage Shuttle Beep (20-m shuttle run test). The formula for calculating MAS in this test is as follows: (MAS=Latest speed (km/h)×1.34-2.86) [13]. The result of this formula gives us MAS in km/h. It should then be converted to m/s so that training running distances can be more easily calculated. For example, the MAS of an athlete whose test is completed at the 13th shuttle level is calculated as follows: 13th shuttle speed=14.5 km/h. We need to put it into the formula and convert it to m/s as follows: MAS= 14.5×1.34-2.86=16.5 (km/h)×1000/3600=4.6 m/s. There is also a general correction formula for calculating MAS with estimated VO<sub>2max</sub> (MAS=Estimated VO<sub>2max</sub>/3.5), which gives us the result in kilometres per hour (Eyüpoğlu, 2016).

## Results

In this section, the appropriateness of the variables for normal distribution is examined with skewness and kurtosis values, and demographic information and descriptive values related to the research variables are shown both on a general basis and according to the type of sport played. Afterwards, information about the test results is included. The arithmetic averages of test performance parameters (HR, VO<sub>2max</sub>, distance, speed, and MAS) of the football, basketball and handball players are presented in Table 1.

Table 1  
Descriptive statistics for performance variables

Parameter	n	Mean	SD	Min.	Max.	Sport branch	Parameter	Mean	SD	Min.	Max.
						Football (n=16)	HR (b.min <sup>-1</sup> )	193,81	6,69	180,00	203,00
					VO <sub>2max</sub>  (ml. kg <sup>-1</sup> min <sup>-1</sup> )		55,47	5,98	44,60	62,60	
					Distance (m)		2176,25	487,83	1420	2800	
HR (b.min <sup>-1</sup> )	44	196,77	7,62	180,00	212,00		Speed (km/h)	13,81	0,99	12,00	15,00
							Mas (m/sn)	3,92	0,60	3,11	4,79
VO <sub>2max</sub>  (ml. kg <sup>-1</sup> min <sup>-1</sup> )	44	49,70	7,28	37,23	62,60	Basketball (n=12)	HR (b.min <sup>-1</sup> )	196,58	6,96	188,00	207,00
					VO <sub>2max</sub>  (ml. kg <sup>-1</sup> min <sup>-1</sup> )		49,59	4,41	43,00	56,60	
Distance (m)	44	1647,00	613,73	680,00	2800,00		Distance (m)	1548,33	412,92	940	2220
					Speed (km/h)		12,45	0,96	11,00	14,00	
Speed (km/h)	44	12,65	1,34	10,50	15,00		Mas (m/sn)	3,84	0,35	3,30	4,42
						Handball (n=16)	HR (b.min <sup>-1</sup> )	199,87	8,16	83,00	212,00
Mas (m/sn)	44	3,76	0,48	3,11	4,79		VO <sub>2max</sub>  (ml. kg <sup>-1</sup> min <sup>-1</sup> )	44,01	5,65	7,23	54,77
					Distance (m)		1192,0	435,0	680,0	2060,0	
					Speed (km/h)		11,65	0,99	0,50	13,50	
					Mas (m/sn)		3,54	0,37	0,11	4,23	

Relationships between participants' heights, weights, ages, Bmi and HR, VO<sub>2max</sub>, distance, speed, MAS scores was analysed through Pearson correlation. The relationships of the variables with the dependent variables is shown in Table 2. Accordingly, a positive significant relationship was found between the dependent variable of MAS and age, VO<sub>2max</sub>, distance, and speed. According to these relationships, MAS increases as the age, VO<sub>2max</sub>, distance, and speed of the athletes increase. When other variables were examined, a positive correlation was observed between age scores and VO<sub>2max</sub> and speed. A significant positive correlation was found between VO<sub>2max</sub>, another variable, and distance and speed. When Bmi scores are analysed, a negative relationship was observed between Bmi and VO<sub>2max</sub> and speed.

Table 2  
Relationships between height, weight, age, and Bmi and HR, distance, speed, and MAS values

Parameter	1	2	3	4	5	6	7	8	9
Height (cm)	1	,67**	-,13	-,25	-,18	-,27	-,27	-,26	-,18
Weight (kg)		1	-,09	,89**	-,04	-,40**	-,36*	-,37*	-,27
Age (years)			1	-,04	-,12	,42**	,55**	,56**	,32*
Bmi (kg/m <sup>2</sup> )				1	,06	-,36*	-,37*	-,33*	-,25
HR (b.min <sup>-1</sup> )					1	-,27	-,24	-,27	-,16
VO <sub>2max</sub> (ml. kg <sup>-1</sup> min <sup>-1</sup> )						1	,98**	,99**	,70**
Distance (m)							1	,99**	,68**
Speed (Km/h)								1	,69**
Mas (m/sn)									1

The relationships between some parameters and the MAS values of participants of different sports were tested with ANOVA. The results are given in Table 3. As a result of this analysis, VO<sub>2max</sub>, distance, and speed were found to differ according to type of sport. In the LSD test performed to find source of difference, VO<sub>2max</sub> scores favour football, basketball and handball. In favour of football and handball scores showed a significant difference in favour of basketball. Among the distance values of the athletes, the average of football players was highest ( $\bar{X}$  = 2176.25, SD = 487.83) compared to basketball ( $\bar{X}$  = 1548.33, SD = 412.92) and handball ( $\bar{X}$  = 1192.50, SD = 435.72). The average distance score of the basketball players was higher than that of handball players. In terms of speed values, basketball players had the highest average among the three types of sports. There were no significant changes in HR or MAS scores of the participants according to type of sport. In the MAS scores of the athletes, a significant difference was found in favour of football between football and handball players. While there was no significant difference in the ANOVA test, the significant difference seen in the LSD test may be due to the precise measurement of the LSD test.

Table 3  
HR, VO<sub>2max</sub>, distance, speed, and MAS values of athletes according to type of sport

Parameter	Football (n=16)		Basketball (n=12)		Handball (n=16)		F	p	Sig.
	Mean	SD	Mean	SD	Mean	SD			
HR (b.min <sup>-1</sup> )	193.81	6.69	196.58	6.96	199.87	8.16	2.73	.76	1-3
VO <sub>2max</sub> (ml.kg <sup>-1</sup> min <sup>-1</sup> )	55.47	5.98	49.59	4.41	44.01	5.65	17.48	.00	1-2, 1-3, 2-3
Distance (m)	2176.25	487.83	1548.33	412.92	1192.50	435.72	19.53	.00	1-2, 1-3, 2-3
Speed (km/h)	13.81	.99	12.45	.96	11.65	.99	19.39	.00	1-2, 1-3, 2-3
Mas (m/sn)	3.92	.60	3.84	.35	3.54	.37	2.94	0.64	1-3

## Discussion

In this research, relationships between athletes' height, weight, age, and Bmi and HR, VO<sub>2max</sub>, distance, speed, and MAS scores were examined with Pearson correlations. A positive correlation was found between age, VO<sub>2max</sub>, and speed and MAS values.

According to this relationship, MAS scores increase as the age,  $VO_{2max}$  distance, and speed of the athletes increase. It can be said that the MAS score will increase as the age variable increases. This can be described as a developmental process and it shows parallelism with other studies performed (Baquet et al., 1999). However, no study investigating the relationship between  $VO_{2max}$  distance, and speed variables and MAS scores was found. In this sense, when the relationships of these variables are interpreted, according to the formula MAS is calculated as  $(MAS = \text{Latest speed (km/h)} \times 1.34 - 2.86)$ . The higher the speed variable, the higher the MAS value will be indirectly. According to the protocol of the 20-meter shuttle run test, when the relationship of MAS with distance is interpreted, distance covered must be increased in order to obtain the speed value of participants or to obtain next speed level. According to the  $VO_{2max}$  formulas used in the calculations in our study, for the  $VO_{2max}$  value to be high, the speed score should also be high (Baker, 2015).

The relationship between athletes' HR,  $VO_{2max}$  distance, speed and MAS values and the type of sport was tested with ANOVA. As a result of this analysis, it was found that  $VO_{2max}$  distance and speed differ according to type of sport. In the LSD test conducted to find the source of the difference, there was a significant difference in  $VO_{2max}$ . Scores of football players were highest in comparisons of football, basketball and handball, while basketball scores were higher than those for handball. In this sense, when studies on footballers are examined, had similar findings for  $VO_{2max}$  values (Crisp et al., 2013; Eyüpoğlu, 2016; Helgerud et al., 2001). In studies of basketball players, similar  $VO_{2max}$  findings (Crisp et al., 2013). Finally, when studies of handball players are examined, lower  $VO_{2max}$  values were calculated in a previous study (Parlak, 2018). For this reason, the training and conditioning of athletes can be predicted.

The average distance of those who played football was higher compared to basketball and handball. The average distance score of basketball players was higher than that of handball players. When similar previous studies are examined, which examines the distance between 8619 - 10,335m, the distance travelled about basketball, the average distance of athletes is 5587m, and the distance covered in handball found distances covered in their study as 3627m (Crisp et al., 2013; Helgerud et al., 2001; McInnes et al., 1995; Oba & Okuda, 2008). In this sense, it is thought that reason for the difference in distances between different types of sports is due to structural differences. In this sense, what separates games from each other, that is area measures or the playing time of the games. Based on these differences, it can be said that when the data in our study are compared, the same parallelism is revealed.

When looking at the speed values, a difference was observed in favour of football when comparing the scores for all three studied sports and in favour of basketball when comparing handball and basketball. When studies on football are examined, performance values related to the shuttle run test applied to football players in his study (Arslan, 2009). In that study, speed reached by young football players in the shuttle run test was found as 13.7 km/h, which is very close to speed obtained in our study (13.8 km/h). When we look at studies about basketball, results of shuttle tests to determine maximal oxygen consumption among basketball players. The study stated that basketball players were able to run an average of 2152 m in the 20-meter shuttle run test (Gürses & Akalan, 2018). This result corresponds to a speed of approximately 14 km/h in the test protocol. When this result is compared with current research (12.45 km/h), it is seen that previous speed score was higher. It is thought that such a difference may be due to athlete age, training, and conditioning levels. Finally, looking at work on handball, reported that handball players had an average speed of 13.25 km/h in the 20-meter shuttle run test. In this study, it was found that handball players had an average speed of 11.65 km/h. This speed is lower. Such a difference may be due to athlete age, training, and conditioning levels, as mentioned above (Suna et al., 2016).

No significant changes were observed in the HR and MAS scores of participants according to types of sports. However, in the LSD test, a significant difference was observed in the HR scores of the football and handball players in favour of handball. When we examine maximal HR results in studies on basketball, reported that HR of basketball players in 20-meter shuttle run test as 198.46 beats/min (Gürses & Akalan, 2018). In the current study, it was found to be 196.58 beats/min. When we examine other studies, found that average heart rate during basketball competitions to be  $169 \pm 9$  beats/min (McInnes et al., 1995).

When we examine studies about football players, found that maximal heart rate to be 196.92 beats/min in a shuttle run test applied to young footballers (Arslan, 2009). Analysed HR of footballers and reported an average of 162 beats/min (Çiçek et al., 2004). Examining other sources, (Bangsbo et al., 1991) reported 164 beats/min for Danish players and different study reported that 171 beats/min for professional players (Ali & Farrally, 1991). As a result of the study, it was found to be 193.81 beats/min. When we examine works on handball, reported that HR of 180 beats/min for handball players in 20-meter shuttle run test. In the current study, it was found to be 199.87 beats/min. In addition, in a study testing physiological and physical capacities of elite male handball players, found maximal HR of handball players in the Yo-Yo test to be 191 beats/min. (Michalsik et al., 2015; Suna et al., 2016)

For the MAS scores of athletes, a significant difference was found between football and handball players in favour of football. While there was no significant difference in ANOVA test, significant difference in LSD test may be due to precise measurement of LSD test. As a result of our current study, MAS of football players was 3.92 m/s, while that of basketball players was 3.84 m/s and that of handball players was 3.54 m/s. When we examine studies in literature, it can be seen that there is very limited research on MAS. The value for Italy Series A footballers was reported as 4.91 m/s with rampinini test (Rosenblatt, 2014). The value for English Premier League football players was 4.85 m/s (test unknown) (Büyüköztürk et al., 2017), for France's 1st League players was 4.75 m/s (VAMEVAL test) (Dellal et al., 2008), for Spain's professional U16 club footballers was 4.5 m/s (Montreal test), for Spain's professional U18 club footballers was 4.44 m/s (Montreal test), and for Spain's professional U21 club footballers was 4.41 m/s (Montreal test) (González-Badillo et al., 2015).

## Conclusions

1. It was found that as age,  $VO_{2max}$ , and distance and speed scores of athletes increased, the MAS also increased.
2. A positive correlation was found between age and  $VO_{2max}$  and speed scores.
3. A positive correlation was found between  $VO_{2max}$  and distance and speed.
4. A negative relationship was found between Bmi and  $VO_{2max}$  and speed. It was found that  $VO_{2max}$ , distance, and speed differed according to types of sports. In the LSD test conducted to find the source of difference, there was a significant difference in  $VO_{2max}$  in favour of football compared to basketball and handball scores, and in favour of basketball compared to handball scores. For the distance values of the athletes, it was observed that average of football players was higher compared to basketball and handball. Similarly, the average score of basketball players was higher than that of handball players.
5. When speed values for different types of sports were analysed, a difference was found in favour of football compared to basketball and handball, and scores for basketball were higher than those for handball.
6. No significant changes were observed in HR and MAS scores of the participants according to types of sports. However, in LSD test, a significant difference was found between football and handball in favour of football in MAS scores of the athletes.

## Recommendations Based On Research Results

### MAS program with long interval method for football, basketball, and handball

1st day (92% MAS, 6 x 3 minutes) x 2 sets. 2nd day (96% MAS, 5 x 2 minutes) x 2 sets. 3rd day (4 x with 90% MAS, 90 seconds) x 2 sets. Between sets, rest time is given with 40% MAS for 2 minutes [8]. Program is shown in Table 4.

Table 4  
MAS program with long interval method for football, basketball, and handball players

Days	1st day		2nd day		3rd day	
MAS %	%92	%40	%96	%40	%100	%40
Distance (m)	UZ	KK	UZ	KK	UZ	KK
Time	6 x 3dk	2dk	5 x 2dk	2dk	4 x 90sn	2dk
Football	649,15m	188,16m	451,58m	188,16m	352,8	141,12m
Basketball	653,90m	184,32m	442,36m	184,32m	134,6m	138,24m
Handball	584,22m	169,92m	407,80m	169,92m	318,6m	127,44m
UZ; Long edge, KK; Short edge, MAS; Maksimal aerobic speed						

### MAS program with grid method for football, basketball, and handball

1:1 Running/Rest-Active (15 s: 15 s). Long edge run with 100% MAS. Short edge run with 70% MAS, work starts with 6 minutes, 2-4 sets if 8 minutes run time is preferred. If 10 minutes is preferred, 1-2 set method can be used. 2-4 minutes rest time should be given between sets. Accordingly, the grid training model for football players, basketball players, and handball players is presented visually in Figure 1. [8].

## **MAS program with Eurofit method for football, basketball, and handball**

1:1 Running/Rest-Passive (15 s:15 s) with 120% MAS. The total distance of departure and return can be applied as shown in Table 4. The work starts with 5 minutes; the intensity can be increased up to 8 or 10 minutes. It can be applied in the form of 1-2 sets and a rest period of 2-4 minutes can be given between sets. Accordingly, the Eurofit training model for football players, basketball players, and handball players is presented visually in Figure 2. [8].

## **MAS program with Tabata method for football, basketball, and handball**

2:1 Running/Rest-Passive (20 s:15 s), with 120% MAS. The total distance of departure and return can be applied as shown in Figure 1. The intensity of working from 5-6 minutes to 8 minutes can be increased. 2-5 sets can be applied and 4 minutes rest time can be given between sets. Accordingly, the Tabata training model for football players, basketball players, and handball players is presented visually in Figure 3. [8].

## **Declarations**

### **Ethical statements**

Trabzon University internal ethics committee (81614018-30/22-10-2018).

### **Funding**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### **Declaration of competing interest**

None declared.

### **Acknowledgments**

The authors would like to thank all the teams involved in this study who registered their data.

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## Figures

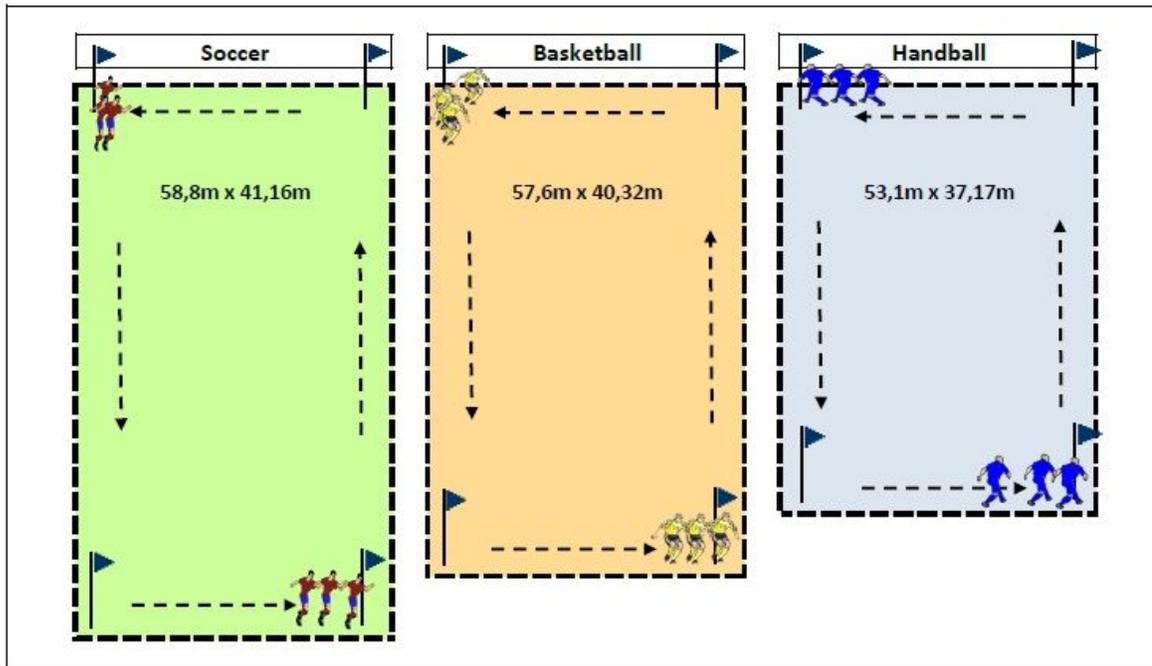


Figure 1

MAS program with grid method for football, basketball, and handball players

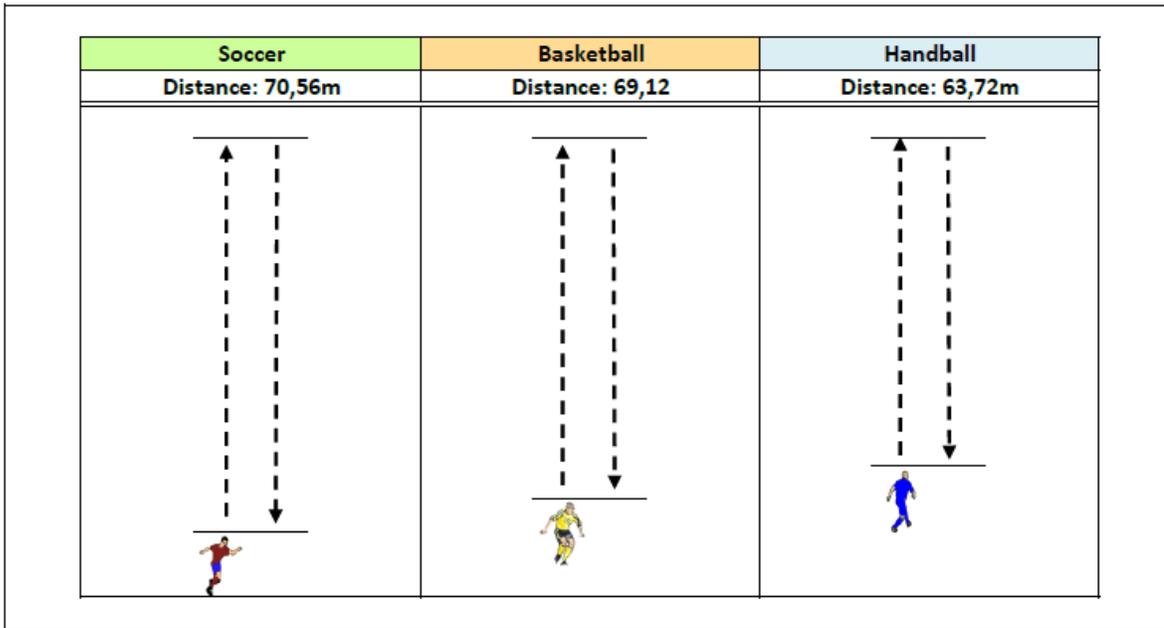


Figure 2

MAS running distances with Eurofit method for football, basketball, and handball players

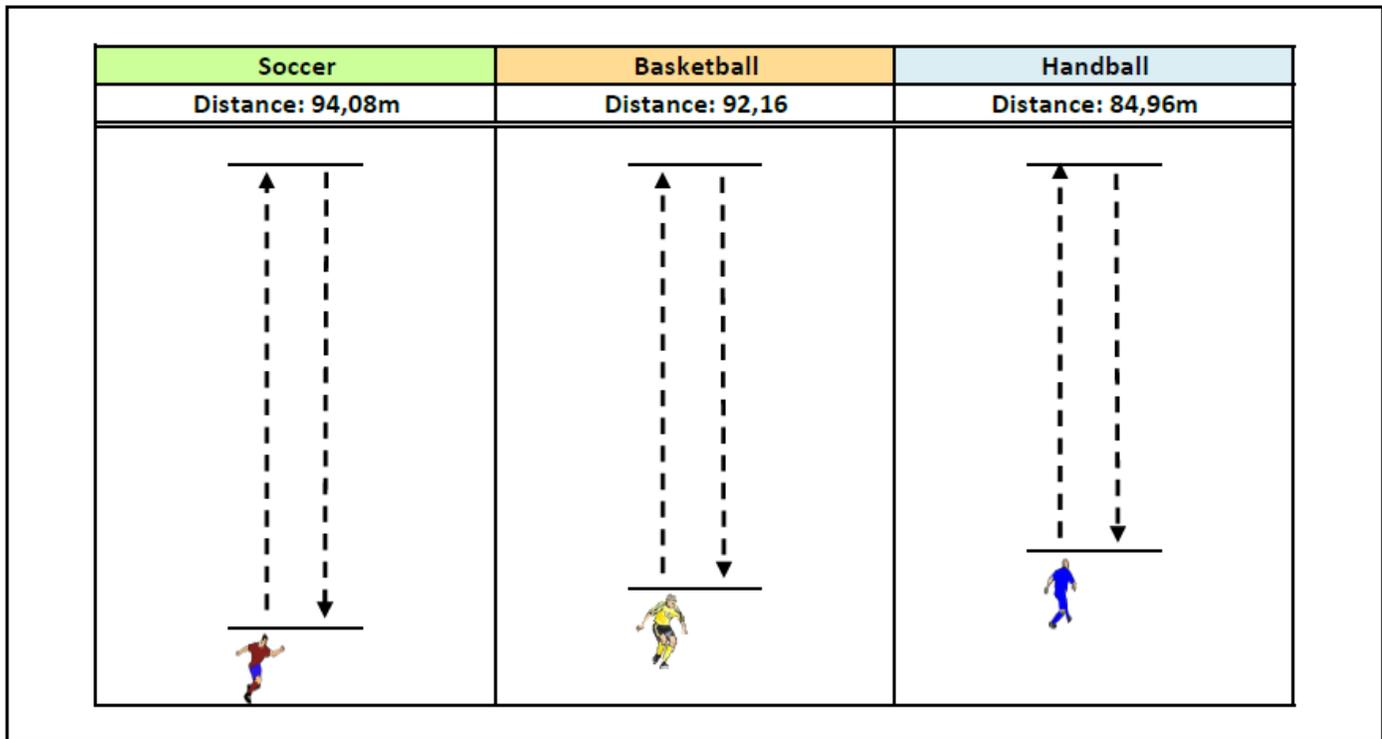


Figure 3

Mas running distances with tabata method for football, basketball and handball branches