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MAS and MANS Predicts Repeated Sprint Ability in Youth Soccer Players

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ABSTRACT

International Journal of Exercise Science 16(6): 846-854, 2023. The study investigated the impact of maximal aerobic speed (MAS) and maximal anaerobic sprint (MANS) on repeated sprint ability (RSA) in soccer. Methods: 17 amateur-to semi-professional soccer players, age 19 (± 4) years, were tested for maximal oxygen consumption (VO_{2max}), oxygen cost of running (C_r), RSA consisting of 15·20m sprint each divided by a 100 seconds dribble track, and 40-meter sprint performance. MAS was calculated as $VO_{2max} \cdot C_r^{-1}$, and MANS was defined as the highest velocity in the 40-meter sprint. Results: There was a strong correlation between MAS and average 20-meter RSA velocity ($r = 0.760$; $p < 0.01$), and between MAS and performance decrement ($r = -0.648$; $p < 0.01$). The product of 0.5MAS + 0.5MANS exhibited the strongest correlation with RSA ($r = 0.813$; $p < 0.01$). Conclusion: The combination of MAS and MANS strongly predicted RSA. High-intensity aerobic interval training (HIIT) and maximal strength training (MST) are recommended to improve MAS and MANS, and could thus lead to better RSA on the soccer field.

KEY WORDS: Repeated sprint ability, soccer, maximal aerobic speed, maximal anaerobic speed.

INTRODUCTION

Sprint capacity is one of the most critical physiological attributes in soccer (6, 10). A male soccer player sprints on average every 60- to 90 seconds during a soccer match, and each sprint lasts approximately 2-3 seconds (11). This indicates that the intermediate sprint is shorter than 20-meters (10). Sprinting distance during a soccer game has been shown to deteriorate in the last 15 minutes of the game compared to the first 15 minutes (4). It has been estimated that phosphocreatine (PCr) contributes with 55%, and that glycolysis contributes with approximately 35% of the total energy expenditure in a 3 second sprint with maximal effort (26). To rebuild PCr, the body needs oxygen (32). Yoshida et al. (32) showed that distance runners with high maximal oxygen consumption (VO_{2max}) had faster rebuild of PCr compared to subjects with lower VO_{2max}. Athletes with higher VO_{2max} thus seem to have better prerequisites to repeat explosive movements frequently (14). Improved VO_{2max} may therefore result in more sprints during a football game, as shown in Helgerud et al. (12). Athletes with high maximal aerobic speed (MAS), calculated as $VO_{2max} \cdot C_r^{-1}$, have been shown to be able to both maintain a higher aerobic running speed (27), and repeat explosive movements more frequently (12, 14). Aerobic capacity has been reported to correlate with repeated sprint ability (RSA) (11). Another important factor for performance in repeated sprints is logically maximal anaerobic speed (MANS) (5), as MANS sets the upper limit for sprint velocity. This indicates that athletes with higher MAS and MANS will have higher average sprint velocity during repeated sprints.

Anaerobic sprint reserve (ASR) can be defined as the difference between MAS and MANS in either absolute or relative terms (25). Athletes with a high ASR have been shown to either have the lowest MAS, or the highest MANS (25, 27). Therefore, ASR cannot indicate the performance of a soccer player, if not put in context with the actual level of MAS and MANS (25, 27). Ortiz et al. (22) and Støren et al. (27) found a positive correlation between MANS and ASR, and a negative correlation between MAS and ASR.

This cross-sectional study aimed to investigate the importance of MAS and MANS on repeated sprint performance in young male soccer players. A second aim was to assess whether the formula of 0.5 MANS + 0.5 MAS could predict the average sprint speed through a repeated sprint course.

METHODS

Participants

22 amateur- to semi-professionals soccer players were recruited for participation, of which 17 completed the study. Characteristics of the participants are presented in table 1. The participants signed a written informed consent form and a self-declaration form for individual health before participation. The study was performed in accordance with the declaration of Helsinki and approved by the Norwegian Centre for Research Data (ref nr 100648). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (20). Inclusion criteria required the players to be 16 to 40 years old and registered in a football club within the Norwegian football federation (NFF). In addition, the participants had to complete each lap in the 15·20m repeated sprint track within 100 seconds. Mean sprint velocity in the 15·20m repeated sprint track was used as a measure of RSA (tables 1 and 2).

The participants were divided into two groups to compare sprint velocity between the players with low MAS and players with high MAS. Group 1; MAS < $15 km \cdot h^{-1}$ (LowMAS). Group 2; MAS > $15 km \cdot h^{-1}$ (HighMAS). The participants first (1-5), second (6-10), and third runs (11-15) of the RSA test were compared for sprint velocity (Table 3).

Testing protocol

The physical tests were performed on two different days with 48 to 96 hours in between for complete recovery. Body weight, height, oxygen cost of running (C_r) and VO_{2max} were tested on the first day, RSA and 40-meter sprint were tested on the second day.

The C_r test was performed as part of the warm-up before the VO_{2max} test, and a two-minute break was given between the two tests. C_r and VO_{2max} were performed on a treadmill (Woodway PPS 55, Waukesha, WI, USA), and VO_2 was measured with the ergospirometry test system Jaeger Vyntus CPX (CareFusion, GmbH, Hoechberg, Germany). The C_r test consisted of two submaximal workloads of four minutes each at 0% incline, with a one-minute break between each workload. VO_2 was measured after 3:20, 3:40, and 4:00 minutes. The C_r value was calculated as the average VO_2 measurements divided by the speed and expressed as $ml \cdot kg^{-1} \cdot m^{-1}$. The best result of the two intervals was registered as C_r, if within 70- to 90% of VO_{2max} (15).

The incline on the treadmill was set to either 2 or 5% throughout the VO_{2max} test. The starting speed and incline were based on the subject's performance on the C_r test. After every 30 seconds, the speed increased by 0.5 $km \cdot h^{-1}$ until voluntary exhaustion. The criteria used to determine if VO_{2max} was reached were; respiratory exchange ratio (RER) above 1.1, peak heart frequency (HF_{peak}) above 95% of maximal heart frequency (HF_{max}), and a plateau of the VO_2 curve (8).

A 30-minute progressive warm-up was performed before a 40-meter maximal sprint test, and then a three-minute break was given before the RSA test started. MANS was defined as the highest velocity in the 40-meter sprint. The 40-meter sprint was repeated three minutes after the RSA test was completed.

A repeated sprint track simulating football-related movements was designed to measure RSA, based on the dribbling track in Hoff et al. (16). At the start of each lap, the maximal 20-meter sprint was performed. The time limit for each lap was 100 seconds, and the total number of laps was 15.

Statistical Analysis

All statistical analyses were performed using the Statistical package for social sciences (SPSS) (Version 28.0. Armonk, NY: IBM Corp, USA. The material was tested for normal distribution in the variables MAS, MANS and average time in 20-meter sprint, by use of QQ plots and Shapiro-Wilk tests. The data showed normal distributions, the results are therefore presented as mean ± standard deviation (SD). Pearson's bivariate correlation test was used to determine the correlation between the variables, while the standard error of estimate (SEE) was found by use of linear regressions. To investigate the differences between players with high or low MAS, independent sample *t*-tests were used. The level of significance was set to $p < 0.05$. A power analysis prior to the study revealed that given a hypothetical difference between the high and the low MAS group of 4%, a standard deviation of difference of the same size, a power of 80% and a significance level of 0.05, 16 participants would be needed.

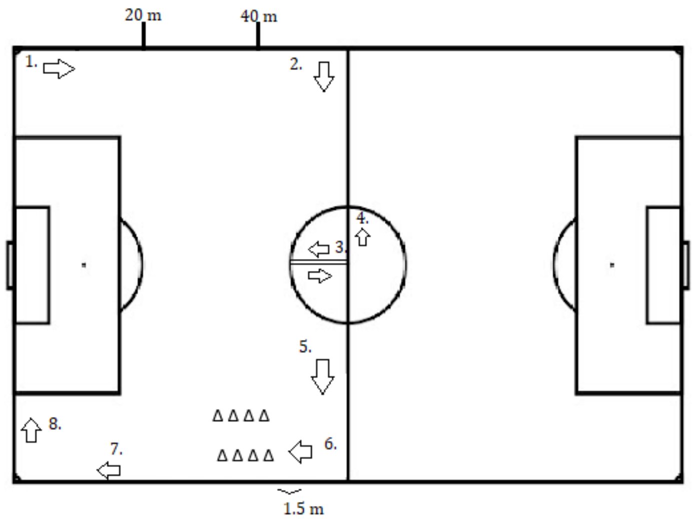

Figure 1. 1. 20m maximal effort sprint up the sideline. 2. Jog until to the middle circle in the midfield. 3. Sideways run from the midfield to the end of the circle and back. 4. Run backward to the end of the circle. 5. Run forward towards the sideline. 6. Dribble the ball between eight cones with 1.5m space to each other down the sideline. 7. Run with the ball to the deadline and leave the ball there. 8. Run back to start, and if the subject has spare seconds left, a pause before the new lap.

RESULTS

Participant characteristics and various test results are presented in table 1.

Table 1. Participant characteristics and test results (*N* = 17)

Age (yrs)	19 ± 4	19.1
Height (cm)	174.5 ± 10.7	6.1
BW (kg)	71.0 ± 9.4	13.2
VO_{2max} (mL·kg^{-1}·min^{-1})	53.3 ± 7.0	13.1
C_r (mL·kg^{-1} ·m^{-1})	0.212 ± 0.017	7.8
MAS (km·t^{-1})	15.1 ± 1.6	10.8
MANS (km·t^{-1})	27.9 ± 1.6	5.7
ASR (km·t^{-1})	12.8 ± 2.2	16.8
Avg. 20m sprint (km·t^{-1})	20.0 ± 0.96	4.8

Values are presented in mean ± standard deviations and coefficient of variation (%). Yrs: years, cm: centimeters, BW: bodyweight, kg: kilogram, VO_{2max}: maximum oxygen uptake, mL·kg^{-1}·min^{-1}: milliliters per kilo bodyweight per minute, C_r: oxygen cost of running, mL·kg^{-1} ·w^{-1} = milliliter per kilo bodyweight meter, MAS: maximal aerobic speed, km·t^{-1}: kilometer per hour, MANS: maximal anaerobic speed, ASR: Anaerobic sprint reserve, Avg: average, 20m sprint : average sprint speed on the sprint track, m: meter

There were significant correlations between the average 20-meter repeated sprint velocity and MAS. The strongest correlation was found between the average 20-meter repeated sprint and 0.5MAS + 0.5MANS (Table 2).

Table 2. Correlations with average 20-meter sprints

	R	R^2	SEE%
MAS	0.760**	0.578	3.2
MANS	0.451	0.203	4.4
0.5MAS+0.5MANS	0.813**	0.661	2.9
ASR	-0.244	0.345	4.8
ASR% of MAS	-0.455	0.210	4.4

MAS: maximal aerobic speed, MANS: maximal anaerobic speed, 0.5MAS + 0.5MANS: 50% maximal aerobic speed+50% maximal anaerobic speed, ASR: Anaerobic sprint reserve, ASR% of MAS, Anaerobic sprint reserve % of maximal aerobic speed, R: correlation, R^2: regression, SEE = Standard estimate of error
* $p < 0,05$
** $p < 0,01$

The high MAS group ($N = 9$) had better average 20-meter sprint in the RST than the low MAS group ($N = 9$), with 20.7 + 0.8 and 19.4 + 0.5 km.t-1 respectively ($p < 0.001$, Cohen's *d* 1.94).

The results presented in table 3 show that while there was no difference between the players with low or high MAS during the 5 first runs, differences did appear in the later runs.

Table 3. Repeated sprint ability divided by high or low MAS

		All ($N = 17$)	LowMAS ($N = 8$)	HighMAS ($N = 9$)	Diff SR	
5m	S1-5	1.24 ± 0.06	1.25 ± 0.06	1.24 ± 0.06		
	S6-10	1.27 ± 0.07	1.30 ± 0.07	1.25 ± 0.07	0.04 ± 0.05	1.02
	S11-15	1.26 ± 0.06	1.29 ± 0.05	1.23 ± 0.05	0.04 ± 0.04*	1.06
10m	S1-5	2.07 ± 0.08	2.09 ± 0.08	2.04 ± 0.08		
	S6-10	2.12 ± 0.09	2.19 ± 0.06	2.06 ± 0.09	0.07 ± 0.06	0.96
	S11-15	2.11 ± 0.11	2.20 ± 0.10	2.05 ± 0.08	0.10 ± 0.12	0.76
20m	S1-5	3.54 ± 0.14	3.62 ± 0.13	3.47 ± 0.11		
	S6-10	3.65 ± 0.19	3.81 ± 0.12	3.52 ± 0.13	0.14 ± 0.11*	1.13
	S11-15	3.64 ± 0.21	3.81 ± 0.17	3.50 ± 0.12	0.16 ± 0.15	0.94

Values are presented in seconds as mean ± standard deviations. Diff SR: differences in speed reduction between groups, with Cohen's *D* effect size. m: meter, MAS: maximal aerobic speed, S 1-5, the five first runs. S6-10, the next five runs. S11-15, the last five runs. Low MAS, MAS < 15 $km \cdot t^{-1}$. High MAS, MAS > 15 $km \cdot t^{-1}$
*$p < 0.05$ less speed reduction in High MAS than in Low MAS

Table 4. Correlation between MAS or MANS and ASR.

	R	R^2	SEE%
MAS	-0,676**	0,457	12,8
MANS	0,654**	0,428	13,1

MANS: Maximal anaerobic speed, MAS: Maximal aerobic speed, ASR: Anaerobic sprint reserve, R: Correlation, R^2: Regression, SEE%: Standard estimate of error * $p < 0,05$ ** $p < 0,01$

Mean 40m times before and after RST were 5.94 ± 0.28 and 5.99 ± 0.29 respectively. The times were not significantly different.

DISCUSSION

The main finding of the present study was the strong correlation between 0.5MAS + 0.5 MANS and mean sprint time (r = 0.81, SEE = 2.9%). Also, a strong correlation was found with MAS alone and mean sprint time (r = 0.76, SEE = 3.6%). This indicates a strong impact from MAS on RSA, with an additional contribution from MANS. While MANS sets the upper sprint performance level, MAS seemed to determine the level of speed decrement throughout the repetitions. The latter was shown in the present study by the larger performance decrement among those with low MAS, compared with those with high MAS (Table 3).

The associations between aerobic capacity and RSA are in accordance with results from some previous studies investigating RSA (17, 18, 21, 24). High aerobic capacity is suggested to improve recovery during repeated sprints partly because athletes with high aerobic capacity may restore PCr faster (32).

Meckel et al. (18) have suggested that the contribution of the aerobic system increases with an increasing number of sprint repetitions. This is supported by the findings in the present study. While there was little or no differences between the high MAS and the low MAS groups in sprint velocity during the first five repetitions, differences increased from repetition six and forward. Contrary, Aziz et al. (1) found that improving MAS only marginally improved RSA. However, Aziz et al. (1) only used eight repetitions of sprints. In comparison, the present study consisted of 15 repetitions, with a more active and longer rest period.

The reduced RSA over time in the present study indicates some sort of muscle fatigue. Rampinini et al. (23) have suggested that muscle fatigue can be both temporary and more sustained. Temporary fatigue occurs in intensive game periods (19). Mohr et al. (19) reported reduced RSA during the first half of a soccer match, but the players had recovered their performance towards the end of the first half. An intensive game period could reduce the PCr levels, which deteriorates sprint ability (9). The PCr concentration in the muscle cell is usually restored after a 2-5 minutes break (30). Therefore, a total game break or an easy game period could restore the PCr concentration to normal. A more sustained muscle fatigue occurs towards the end of the game, as there have been reported fewer sprints in the last 15 minutes (3, 19). The finding in the present study that 40m times did not deteriorate after a three minute break post RST, thus indicate a temporary but not sustained fatigue after the RST. The RSA test only lasted for 25 minutes. The investigation of sustained muscle fatigue could have been tested more accurately through an extended test. Throughout an intensive game it has been reported muscle damage, reduced glucose levels, and accumulation of lactate (9). MAS could then have been an even more RSA determining variable towards the end of a full match game.

ASR was calculated as the difference between MAS and MANS in absolute terms, and as a percentage of MAS in relative terms in the present study. A positive correlation between MANS and ASR, and a negative correlation between MAS and ASR was found, supporting the results in Støren et al. (27) among runners and in Ortiz et al. (22) among soccer players. The present study found no significant correlation between ASR and the average time on 20-meter sprints (Table 2). Sandford et al. (25) stressed that focusing on only one element of the ASR is not the best for better performance. The athletes should focus on ASR relative to both MAS and MANS to increase their performance. We do not know with certainty if the association between MAS and RSA in the present study mostly relates to the sprints, the active breaks or the combination of both.

The 15·20m RSA test had a duration of 25 minutes, and is therefore hard to compare with a 90 minutes soccer game. However, a full 90 minutes RSA test may increase the risk of injuries and possibly lead to reduced motivation to complete the test. Although 17 players were a sufficient number in order to perform statistical analyses and detect associations, the number is too small for generalizing the results. With only 17 subjects, there is also a possibility for type II statistical errors.

This study underlines that MAS and MANS are important determining factors for RSA, and thus soccer performance. Hopefully, the results of this study can be helpful for coaches and athletes to understand the importance of MAS and MANS. Studies have shown that high-intensity aerobic interval training (HIIT) effectively improves VO_{2max} (13, 14). Maximal strength training (MST) has been effective in improving both C_r (28) and sprint performance (2, 14, 31). HIIT and MST may help athletes improve MAS and MANS and can be effectively trained during the season (7, 14, 29, 31).

Conclusion: RSA was to a large extent predicted by 0.5 MAS + 0.5 MANS, with MAS being the most important variable. We suggest a combination of HIIT and MST in order to improve MAS and MANS for better performance on the soccer field.

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