



Original Research

Aerobic Capacity is Related to Repeated Sprint Ability with Sprint Distances Less Than 40 Meters

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ABSTRACT

International Journal of Exercise Science 10(2): 197-204, 2017 Research is inconclusive regarding the association between aerobic fitness (objectively measured VO_{2max}) and repeated sprint performance when the sprints are less than 40 meters. Soccer athletes must be able to repeat sprints without significant decreases in speed and strength and conditioning coaches need to better understand if aerobic fitness is related to repeated sprint ability (RSA). Twenty (10 male, 10 female) Division I soccer athletes first completed a graded maximal treadmill test to measure VO_{2max} . Then on a separate day, athletes completed the RSA test. The RSA test consisted of 10, 30-meter sprints which athletes repeated every 30 seconds. There were significant negative correlations ($r \leq -0.69$, $P < 0.001$) between VO_{2max} and all 10-sprint times and average sprint time. More aerobically fit Division I soccer athletes were faster at all time points during the RSA test. Aerobic fitness is associated with faster sprint times during a more anaerobic RSA test when sprint distances are less than 40 meters.

KEY WORDS: Oxygen uptake, sprinting, performance

INTRODUCTION

Aerobic fitness is essential for soccer athletes to perform at an optimal level (15, 17). In addition to aerobic fitness, repeated sprint performance is also a critical component of game performance in soccer. The ability to reproduce sprints without significant reductions in sprint speed is known as repeated sprint ability (RSA). Athletic performance at a high level requires soccer athletes to train both their oxidative phosphorylation (aerobic) system and their phosphocreatine-adenosine triphosphate (PCr-ATP) (anaerobic) system (7, 16). While the PCr-ATP system is the primary system to fuel athletes during the anaerobic (i.e., burst of sprints lasting less than 6 seconds) portions of a game, the aerobic system also plays an important role

to assist with PCr replenishment (7, 9, 21). The relationship between the aerobic and anaerobic variables on an athlete's ability to reproduce sprints is debatable and the current research is discordant due to the varying forms of a repeated sprint test (1, 2, 5, 16). A better understanding about the relationship between aerobic fitness and brief anaerobic work in the form of repeated sprints that are less than 40 meters is needed to improve strength and conditioning recommendations for soccer athletes.

Prior research has yet to show a relationship between aerobic fitness (e.g., VO_{2max}) and RSA when the repeated sprint distances were less than 40 meters and when the work-to-rest ratios are 1:4 to 1:5 (6, 21). A study by Aziz et al. (1) concluded that aerobic fitness measured via VO_{2max} was not associated with RSA sprint performance in young elite soccer athletes. The RSA test implemented used a RSA running test that consisted of six, 20 meter sprints with a 20 second recovery between each sprint (~1:5 work-to-rest ratio). Another RSA study increased the distance by 10 meters with the same recovery time and also suggested that RSA is not related to aerobic fitness (14). A limitation to the findings from Pyne et al. (14) was that VO_{2max} was not objectively measured, but estimated using a shuttle run. Contrary to studies suggesting no relationship between VO_{2max} and RSA, some research has provided evidence that VO_{2max} is related to RSA (5, 12). For example, results from Bishop and Spencer (5) suggest that aerobic fitness, in addition to anaerobic power, is related to RSA performance in well-trained adult athletes when using a wind-braked cycle ergometer protocol consisting of 5 repetitions, 6 seconds of work with a 24 second recovery between repetitions (1:4 work-to-rest ratio) (5). Additionally, Jones et al. (12) implemented a RSA test consisting of 6, 40-meter sprints with 20 seconds of recovery between each sprint and found that VO_{2max} is associated with RSA. A potential reason for the discrepancies between these studies could be due to the different sprint distances (20-30 meters versus 40 meters), modes of exercise (i.e., running compared to cycling) employed for the RSA tests and even possibly the age and level of athletes (i.e., young versus adult and elite versus vs. non-elite) tested. To better assess the relationship between VO_{2max} and RSA in soccer athletes, a running sprint test should be utilized with shorter sprint distances than 40 meters. It is reasonable to suggest that soccer athletes frequently engage in sprint distances of less than 40 meters and it is imperative to assess if aerobic fitness is still related to a soccer athletes RSA when shorter sprint distances are utilized. The potential relationship, or lack thereof, between sprint times and VO_{2max} could alter optimal training recommendations.

In addition to VO_{2max} and sprint times, the previously aforementioned studies also assessed factors such as total sprint time (i.e., sum of all repeated sprint times in the protocol) and average sprint time (1, 2, 5, 10, 12, 16). It has been established that utilizing average sprint time is an effective measure to assess RSA performance (1, 13, 14, 21). RSA can be used to calculate an athletes fatigue using a fatigue index (i.e., percent reduction of sprint time from the fastest sprint) in relation to the aerobic capacity throughout a RSA test (21). While rate of fatigue is an intriguing calculation and assessment, it has been reported to be less reliable, relative to average sprint time, when analyzing RSA performance (13). However, a better understanding is needed to assess the relationship between aerobic capacity and rate of fatigue when

employing different RSA protocols, primarily with shorter sprint distance and more sprint repetitions.

To justify changes in RSA, longer sprint distances, quicker recovery times and additional sprints should simulate a more difficult test in an attempt to replicate a more realistic soccer-conditioning test. Therefore, the purpose of the study was to directly measure Division I collegiate soccer athletes VO_{2max} and then assess its relationship to RSA test performance, rate of fatigue and the age of the athletes when a more challenging sprint test is employed. Based on previous research, it is hypothesized that VO_{2max} will be related to rate of fatigue and age, but not RSA performance since each sprint distance was less than 40 meters.

METHODS

Participants

A total of 20 ($n = 10$ females, $n = 10$ males) division I soccer athletes volunteered to participate in the study. All athletes were cleared by the team physician and had no contraindications to physical activity or exercises. Prior to participation in the study, research personnel explained the VO_{2max} protocol (BRUCE Protocol) and the procedures for the RSA test. After explaining the research protocol, athletes read and signed an informed consent form. The university Institutional Review Board approved the study.

Protocol

The testing protocol for VO_{2max} included a validated, graded maximal treadmill exercise test (BRUCE protocol) (8) and the RSA test which consisted of 10 total 30-meter sprints, one sprint every 30 seconds. Since the RSA testing protocols in the literature vary from study to study, the RSA test employed in the current study required four more sprints (10, as opposed to 6) and a sprint distance of 30 meters. The combination of a 30-meter sprint distance, quicker recovery time and additional sprints simulated a more physiologically taxing soccer-specific conditioning test.

Upon arrival to the Human Performance Laboratory, trained research personnel measured each athlete's height and weight using a stadiometer and balance beam scale (Detecto®, Webb City, MO USA), respectively. After anthropometric measurements were recorded, athletes were fitted with a heart rate monitor (Polar, Kempele, Finland) and a full VO_2 mask and head strap for the VO_{2max} test (Hans Rudolph, inc, Kansas, USA).

Following initial measures, athletes completed a maximum of a ten-minute warm-up jog at a self-selected pace. Upon completion of the warm up, the VO_2 mask and head strap was appropriately secured to each athlete and was then connected to a calibrated metabolic cart with his or her heart rate monitor synced to the cart. Oxygen consumption was recorded using a gas and flow calibrated metabolic cart (Pravo Medics, Truemax 2400) and VO_2 was recorded as relative VO_2 in $ml \cdot kg^{-1} \cdot min^{-1}$. Each subject's respiratory exchange ratio (RER) was monitored to ensure maximum effort was exerted. Athlete's VO_{2max} was achieved if they discontinued to run and their RER was ≥ 1.15 . After completing the VO_{2max} test, athletes

performed a cool-down that consisted of a self-selected walking pace to reduce any risk of injury or syncope episodes. Heart rate was recorded as beats · min⁻¹ (BPM).

Athletes were advised to rest for a minimum of 24-48 hours after the VO_{2max} test. To avoid any influence from VO_{2max} testing, research personnel scheduled all RSA testing a week after subjects completed their VO_{2max} test. For the RSA test, each athlete completed a 10-minute active warm-up that was specific to the linear sprinting movement and distance that was encountered during the test including a static stretching session in which the athletes had the freedom to stretch any muscles they needed. Following the warm-up, each athlete participated in the RSA test that consisted of 10, 30-meter sprints. All sprint times were recorded via stopwatch by the one trained researcher to minimize tester error. Percent heart rate was recorded to assess maximal efforts throughout the RSA test. For the RSA test, once the first 30-meter sprint was completed, the athlete rested and then began the next sprint 30 seconds after their previous sprint started. Therefore, the actual rest time between each sprint varied based on the sprint time of each athlete. After deceleration, the work-to-rest ratio was approximately 1:4 (~ 6 seconds of work, 24 seconds of rest). Upon completion of the RSA test, athletes participated in an active cool-down for five minutes to allow their heart rate to safely return to resting levels followed by a five-minute static stretch.

Fatigue Index (FI) was calculated upon completion of the study to assess rate of fatigue as a percent. To calculate rate of fatigue for each athlete, the following equation was used: [(Fasted Sprint - Slowest Sprint) / Fastest Sprint] × 100.

Statistical Analysis

Descriptive statistics using mean and standard deviation were calculated for all physical characteristics (e.g., age, height, and weight) and performance (e.g., VO_{2max}, average sprint time, percent heart rate maximum, and fatigue index). Differences between males and females were analyzed using an independent samples t-test.

A single, three-time point (1st, 5th, and 10th sprint) repeated measures analysis of variance (ANOVA) was utilized to assess any differences in percent of maximal heart rate that athletes exerted. Post hoc analyses were conducted using paired samples t-test and the Benjamini and Hochberg False Discovery Rate correction for multiple comparisons (3). Males and females percent maximal heart rate was not significantly different; therefore, gender was excluded from the ANOVA model.

Lastly, multiple correlation analyses were utilized to assess if any relationships exists between VO_{2max}, age, average RSA sprint times, and rate of fatigue. Gender was excluded from all correlation models due to the small number of participants in each group (n = 10). All statistics were analyzed using IBM SPSS 21.0 (Version 21.0, IBM Inc, Armonk, NY). The criterion for statistical significance was set a priori at $P < 0.05$.

RESULTS

Males weighed significantly more, were taller, older, faster and had greater aerobic capacities than female athletes ($P \leq 0.046$, Table 1).

Table 1. Physical characteristics and performance outcomes for male and female soccer athletes

	Males (n = 10)	Females (n = 10)
Age (years)	20.5 ± 0.7*	19.7 ± 0.9
Height (cm)	178.2 ± 6.8*	167.6 ± 6.3
Weight (kg)	74.8 ± 5.3*	62.5 ± 5.2
VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	66.3 ± 5.1*	51.7 ± 5.9
Average Sprint Time (sec)	4.7 ± 0.2*	5.4 ± 0.3
Heart Rate Maximum (BPM)	189.7 ± 6.8	188.5 ± 5.0
Fatigue Index (%)	6.5 ± 1.4	5.3 ± 1.9

Data are means ± SD; * Significantly different than female soccer athletes ($P \leq 0.046$)

The correlation analysis that tested the relationship between VO_{2max} and RSA revealed there were significant ($P < 0.001$, Table 2) negative correlations between VO_{2max} and all 10 repeated sprint times. After averaging all ten RSA sprint times, there was a significant negative relationship between VO_{2max} and average sprint time ($r = -.767$, $P < 0.001$).

Table 2. Pearson's Product Correlations between VO_{2max} and each sprint time for all participants.

RSA Test	Pearson's (<i>r</i>)	<i>P</i> -value
Sprint 1	-0.730	< 0.001
Sprint 2	-0.768	< 0.001
Sprint 3	-0.762	< 0.001
Sprint 4	-0.803	< 0.001
Sprint 5	-0.690	< 0.001
Sprint 6	-0.722	< 0.001
Sprint 7	-0.715	< 0.001
Sprint 8	-0.740	< 0.001
Sprint 9	-0.735	< 0.001
Sprint 10	-0.761	< 0.001

Strong, significant negative correlations existed between VO_{2max} and every sprint time.

There was no significant relationship between VO_{2max} and athlete's rate of fatigue calculated using a fatigue index ($r = .333$, $P = 0.15$).

There was main effect of condition for percent of maximum heart rate ($P = 0.001$). Athlete's percent of maximum heart rate increased from the 1st (73%) to the 5th (87%) sprint and then increased again after the 10th sprint (93.5%). Independent samples t-test revealed that athletes, regardless of gender, contributed a similar percent of their maximum effort (assessed via heart rate) throughout the RSA test ($P \geq 0.127$ for all). There were no other main effects ($P = 0.750$).

There was a significant positive relationship between VO_{2max} and age of the athletes, ($r = .451$, $P = .046$).

DISCUSSION

Contrary to the hypothesis, the negative correlations found suggest that VO_{2max} or aerobic capacity does play a significant role in repeated sprint performance in that more aerobically fit athletes are faster than their less aerobically fit peers. These results coincide with previous research that suggests VO_{2max} is related to improved RSA test performance (20). Tomlin and Wenger (20), postulated, and the current results support, that athletes with greater aerobic capacity may have superior power recovery and can perform well during repeated high intensity work. Additionally, the current results are contrary to previous research suggesting aerobic fitness does not significantly influence sprint performance during an RSA test of less than 40 meters because the anaerobic energy needed to complete a five second sprint is less likely to be influenced by oxygen uptake (1, 7). While the energy demands of a single sprint may not be influenced by aerobic fitness, it appears that faster repeated sprint times and perhaps RSA may actually be associated with greater levels of aerobic fitness, even if the sprint distance is less than 40 meters.

In addition to VO_{2max} and RSA times, rate of fatigue is an important factor to assess when examining a soccer athlete's conditioning level or anaerobic capacity. In the current study, athletes fatigued at a rate of 5.7%. While anaerobic capacity was not measured via a Wingate test, the small percentage in which athletes fatigued suggests the athletes were well trained anaerobically. The low rate of fatigue in addition to the aerobic capacity results highlight the importance for strength and conditioning coaches to emphasize training both aerobic fitness and anaerobic capacity. Research strongly suggests the use of 1:1 or 2:1 work-to-rest ratios to maximize training for the improvement of both of aerobic and anaerobic pathways (11, 18, 19).

Furthermore, these results and recommendations can be applied to elite level soccer athletes. A VO_{2max} of $60 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ or greater has been used as a physiological indicator for researchers to establish a minimum fitness level for men's professional soccer athletes (17). On average, male athletes in the current study had an averaged VO_{2max} of $66.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, which is well above the aforementioned minimum for professional or elite status.

Moreover, these results also suggests that younger college athletes should begin training and conditioning aimed to improve their VO_{2max} . There was a positive relationship between the athlete's age and VO_{2max} suggesting that older college athletes in the study had a greater VO_{2max} and a plausible explanation for the relationship may be due to the fact the older athletes have trained more and with greater intensities throughout their college career. Although training age (i.e., number of years training) was not reported in the current study, it could be advantageous for younger soccer athletes to focus their training on methods to improve aerobic (VO_{2max}) and anaerobic capacity to potentially perform better on an RSA test.

While the results reveal a strong negative relationship between VO_{2max} and RSA sprint performance, it is not without limitations. Anaerobic capacity and rate of fatigue were not measured using a validated anaerobic capacity test such as the Wingate test or a running anaerobic sprint test (22). Using a validated running anaerobic capacity test would provide

useful information regarding peak and minimum power outputs. Using peak and minimum outputs may provide a better calculation of rate of fatigue and anaerobic capacity as opposed to using fastest and slowest sprint times. Understanding power outputs and power recovery, in addition to VO_{2max} , may allow for better strength and conditioning programming to improve rate of fatigue and RSA performance (20). Another limitation could be that factors other than VO_{2max} could be associated with RSA performance (i.e., nutrition, sleep, and recovery) and were not assessed in the current study. Although there are other physiological factors to consider when testing athletes RSA, the purpose of the study was to assess if VO_{2max} was associated with RSA performance when sprint distances of less than 40 meters were employed. Shorter sprint distances with ~25 seconds of recovery are believed to not be influenced by aerobic metabolism's assistance with PCr repletion (9) and the current results suggest otherwise.

Division I soccer athletes that are more aerobically fit (i.e., greater VO_{2max}) appear to be faster on average and during every sprint than their less aerobically fit peers when participating in a 30-meter repeated sprint test. Training to enhance a soccer athlete's aerobic fitness is highly recommended.

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