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Relationship between Maximum Aerobic Speed Performance and Distance Covered in Rugby Union Games

Original Investigation

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Preferred Running Head: Maximum Aerobic Speed in Rugby Union

Abstract

Researchers have shown a clear relationship between aerobic fitness and the distance covered in professional soccer, although no research has identified such a relationship in rugby union. Therefore, the aim of the study was to identify whether there was a relationship between maximal aerobic speed (MAS) and the distance covered in rugby union games. Fourteen professional rugby union players (age = 26 ± 8 years, height = 1.90 ± 0.12 m, mass = 107.1 ± 24.1 kg) participated in this investigation. Each player performed a MAS test on 3 separate occasions during the pre-season, to determine reliability and provide baseline data, and participated in six competitive games during the early stages of the season. Game data was collected using GPS technology. No significant difference ($p>0.05$) in total distance covered was observed between games. Relationships between players MAS and the average distance covered from six competitive games were explored using Pearson's correlation coefficients, with MAS performance showing a strong relationship with distance covered during match play ($r = 0.746$, $p < 0.001$). Significantly greater ($p=0.001$, Cohen's $d = 2.29$) distances were covered by backs (6544 ± 573 m) compared to the forwards (4872 ± 857 m) during a game. Similarly, backs recorded a significantly ($p=0.001$, Cohen's $d = 2.20$) higher MAS (4.9 ± 0.13 $m.s^{-1}$) compared to the forwards (4.2 ± 0.43 $m.s^{-1}$). Results of the study illustrate the importance of developing high levels of aerobic fitness in order to increase the distance that the athlete covers in the game.

Keywords: GPS technology; Aerobic Fitness; Match Analysis; Performance

INTRODUCTION

In order to deliver training programmes that elicit specific physiological adaptations for athletes, a deep understanding of the physiological demand of the sport must be known (11). An approach used by many teams in assessing the competition demands on athletes is time–motion analysis, identifying specific game tasks related to position. In rugby union the game play of forwards is generally comprised of close opposition contact, demanding high levels of strength and power in order to gain and retain ball possession, however physical requirements differ between positions, with front row forwards needing greater body mass, whilst the second row demands tall, athletic individuals for jump height during lineout's (10). Due to the repeated bout nature of such play high levels of aerobic fitness are advantageous to facilitate recovery between high intensity bouts. Similar to forwards, inside backs have high contact incidence with opposition requiring strength and power, however most physical attributes for backs emphasize speed and aerobic endurance, due to the defensive demand and support work, whilst also needing to control the game and evade the opposition (10).

Players have been found to cover distances of 5408-6190 m on average depending on the positional role, with backs generally covering the greater distances, consisting of sprinting, jumping and change of direction at various velocities (26). However, forwards perform high-intensity static exertion for longer periods 7:56 ± 1:56 minutes, performing 21 ± 12 scrums, each lasting 7.3 ± 1.1 seconds and performing more rucks (35 ± 8 vs. 11 ± 6), mauls (25 ± 8 vs. 4 ± 4) and tackles (14 ± 4 vs. 10 ± 4), contributing to 14% of total game time, compared to 1:18 ± 0:30 minutes of high-intensity static exertion by the backs (26). This is similar to the findings from Super 12 rugby (11) where forwards and backs spent 12% and 4% respectively of total game time completing high-intensity static exertions. The stop start nature of rugby union contains highly explosive sprints and high intensity running, thus recognising the importance for all players to obtain good acceleration and lower-limb explosive power, with mean sprint distances ranging between 11-20 m during games (11). Time-motion analysis found sprinting occurred on average 16 ± 15 and 23 ± 19 times for forwards and backs respectively, lasting on average 1.2 ± 0.2 seconds (26), with sprinting being found to contribute 10-15% of total game time (2). High intensity runs are performed 41 ± 16 and 59 ± 28 times by forwards and backs respectively lasting on average 1.3-1.5 seconds (26). Although the time spent performing high-intensity actions during a game can be brief and the distances sprinted can be relatively short, it must be recognised that multiple sprints are central to the game and for players to be competitive they must maintain these repeated bouts of high-intensity actions for extended periods (2).

Repeated intermittent high-intensity activities and high contact frequency with the opposition contributes 15% of total game time and consists of sprinting, tackling and involvement in rucks, mauls and scrums, predominantly undertaken by the forwards, with low-intensity activities making up the remaining 85% of game time, consisting of standing still, walking and jogging, (10, 15). This demonstrates the need for an athlete to develop high levels of aerobic fitness for competition and is supported with heart rates reaching ≥86% of maximum (9).

Evidence suggests that aerobic fitness is a major physiological requirement of rugby union, with the intense passages of play involving repeated high-intensity activities occurring at critical times during games, with the ability or inability for players to perform these high-intensity activities being critical to the outcome of the game (12, 26). No research to date has focussed on the relationship between aerobic fitness and the amount of distance covered during a competitive rugby union game. However, similar research using soccer players has shown aerobic fitness to be related to distances covered during games (5, 16, 19, 20, 24). These increases in aerobic capacity have also been shown to increase match performance in soccer, including increases in distance covered (20%), number of sprints (100%) and involvements with the ball (24%) (15). Furthermore, data from various sports have shown a link between performance testing outcomes and success on the pitch (15, 22). Unlike many other sports, the static activities (rucks, mauls and scrums), make it difficult to determine the physical demands of the sport and therefore the requirements for high levels of aerobic fitness, especially for the forwards. Additionally the rules of the game are ever changing and modifications are being made to increase the speed of the game and increasing the time the ball is in play to increase the attractiveness of the sport, which is likely to increase the importance of aerobic fitness (4).

The aim of the study was to identify if there is a relationship between aerobic fitness and the distances covered in competitive rugby union games and to identify the differences in performances between forwards and backs. It was hypothesized that the relationship between MAS and distance covered would be similar to those previously identified in soccer performance (24). It was further hypothesized that greater MAS scores and distances covered would be observed in the backs compared to the forwards, based on previously reported match characteristics (7, 26).

METHODS

Experimental Design

Aerobic fitness was assessed using a 1200 m maximal effort time trial to determine each individual's MAS. GPS data was collected from six competitive games to permit assessment of any associations between the two by analysing the total distances covered by each individual player from each of the games.

Subjects

Fourteen, professional rugby union players (age 26 ± 6 years, height 1.90 ± 0.12 m, body mass 107.1 ± 24.1 kg), participated in this investigation. All players played for the same premiership rugby club, with participants made up of 8 backs and 6 forwards.

The study was approved by the University Ethics Committee, conformed to the principles of the World Medical Association's Declaration of Helsinki (1983) and all subjects provided informed consent before participation. All players were informed about the experimental procedures and were fully familiarised with the data collection procedures.

Procedures

The study consisted of participants initially undertaking two MAS tests one week apart to determine reliability. A further MAS test was performed at the end of pre-season to determine MAS scores to identify associations with GPS data from subsequent games. Total distance covered was collected using GPS units (StatSports Viper Rugby; StatSports, V2.0.4.9) during the first six competitive games and were used to determine associations with MAS data. Mean performances for total distance covered across the six competitive games was used for further analysis, as there were no significant differences ($p>0.05$) between games.

Maximal Aerobic Speed Testing (MAS)

After a standardized warm-up, each of the participant's MAS was determined by performing a 1200 m time trial on a grass field, wearing standard rugby boots. The 1200 m track distance was set using a measuring wheel, and marked out using line paint, ensuring the participants used the same track on every testing occasion. All participants were required to position themselves 0.5 m behind the start line and were instructed to complete the single effort maximally, with all scores electronically recorded (Brower, Speed Trap 2, Wireless Timing System, Draper, UT, USA.). Participant's MAS was calculated by dividing the total distance covered by the time taken to complete, which then resulted in each individual's 100% MAS for that mode of exercise (3). The MAS test has been used by researchers and strength and conditioning professionals and has been found to be a reliable and practical method for team sports in determining an athlete's aerobic capacity (3).

Match Day Data Collection

Players were asked to wear individual GPS units, encased within a protected harness, positioned between the shoulder blades. Devices were switched on 5 minutes before the game and turned off immediately after the game. Data sets were then downloaded, where further analysis was carried out via the system software provided by the manufacturer (StatSports Viper Rugby; StatSports, V2.0.4.9). Each pod contains four processors, a state of the art GPS module (10 Hz), a 3-D accelerometer (100 Hz), a 3-D gyroscope, a 3-D digital compass, a long range radio and a heart rate receiver. The main metric of focus during the study was the total distance covered by each player, during the first six competitive matches.

Statistical Analyses

Intraclass correlation coefficients (ICC) were performed to assess reliability of the first two MAS tests. Shapiro Wilk's test of normality was performed to determine if data was normally distributed. Differences in total distances covered, during the first six competitive games was compared via a repeated measures analysis of variance (ANOVA). Additionally, independent t-tests were performed to determine if there were significant differences between MAS and distances covered in games between the backs and forwards, with effect sizes determined using the Cohen's *d* method, and interpreted based on the recommendations of Rhea (25) who defined <0.35, 0.35-0.8, 0.8-1.5 and >1.5 as trivial, small, moderate and large respectively. Relationships between MAS performance and the average total distance covered by each player during the six competitive games were determined using Pearson's correlations. Statistical analyses were performed using SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA), with post-hoc statistical power calculated using G*Power (version 3.1.9.2; University of Dusseldorf, Dusseldorf, Germany) (14). An Apriori alpha level set $p \leq 0.05$.

RESULTS

Analysis of the Shapiro-Wilk's test of normality revealed that data was normally distributed ($p \geq 0.05$), for both the distances covered during competitive rugby union games and MAS. Intraclass correlation coefficients showed a high level of reliability for MAS ($r \geq 0.899$, $p < 0.001$). Repeated measures ANOVA showed no significant differences ($p > 0.05$, power 0.98) in total distance covered between games (5811.5 ± 1142 m; 90% CI = 5309.5–6313.5 m), with squad average distances ranging from 5751 ± 1166 m to 5872 ± 1118 m across games. Therefore, average distance covered across the games was used for correlation analysis.

Pearson's correlation showed a strong significant relationship ($r=0.746$, $p < 0.001$) between distance covered during match play and MAS, with a coefficient of determination of $r^2=0.557$ (Figure 1).

****Insert Figure 1 here****

When comparing between positional groups, backs (6544 ± 573 m, 90% CI = 6187.8-6900.2 m) covered a significantly greater distance ($p=0.001$, power = 0.99, Cohens d = 2.29) during games, than the forwards (4872 ± 857 m, 90% CI = 4339.2-5405.8 m) (Figure 2). Similarly, backs (4.9 ± 0.13 $m.s^{-1}$, 90% CI = 4.82-4.98 $m.s^{-1}$) demonstrated a significantly greater MAS ($p=0.001$, power = 0.98, Cohens d = 2.20) in comparison to forwards (4.2 ± 0.43 $m.s^{-1}$, 90% CI = 3.93-4.47 $m.s^{-1}$) (Figure 3).

****Insert Figure 2 here****

****Insert Figure 3 here****

DISCUSSION

A strong relationship was observed between MAS and distance covered during a game, which is similar to the findings, reported in elite level soccer players (18, 24) and in line with the hypothesis. Additionally, backs covered a significantly ($p=0.001$) greater distance during the game (6544 ± 573 m), whilst also recording higher MAS scores (4.9 ± 0.13 $m.s^{-1}$), when compared to the distances covered (4872 ± 857 m) and the MAS (4.2 ± 0.43 $m.s^{-1}$) of the forwards, with both differences demonstrating large effect sizes, in line with the hypotheses.

No significant differences were observed between the total distances covered across the six games, in line with previous findings in rugby league (17). Overall, the study found a strong relationship between performance in the MAS test and distance covered during competitive rugby union games, which may play an important role in the success a team has during a season due to the ability to perform a greater volume of work during the game, as previously reported in soccer (15). Furthermore the strong correlation ($r = 0.746$, $p < 0.001$) between distance covered during match play and performance in the MAS test is similar to that reported by Krustrup et al. (18) in elite male soccer players ($r = 0.71$, $p < 0.05$). In addition, Apor (1), found that the best four teams ranked in the Hungarian top football division was the same as the rank among their average VO_{2max}, further demonstrating the relationship between aerobic fitness and performance, while demonstrating that increases in aerobic fitness not only increased the total distance covered, but also increased the number of sprints (100%), involvements with the ball (24%) and improved running economy (6.7%). It must be considered that whilst improving the aerobic performance other physiological characteristics may be negatively affected, however, Helgurud et al. (15) found that during a period of endurance training no changes were observed in one-repetition maximum (1RM) back squat, 1RM bench press, vertical jump height or running velocity, albeit in elite level soccer players.

A high VO_{2max} has also been reported to be related to increased repetitions of high-intensity efforts and is positively related to distances covered, involvements with the ball and number of sprints in soccer (15), with its importance in rugby also being recognised (26). Backs are reported to posses higher a VO_{2max} (57.5 ± 2.7 ml.kg.min^{-1}), in comparison to forwards (53.8 ± 3.5 ml.kg.min^{-1}) (27), in line with our findings for MAS performance. A similar study using the multi-stage shuttle run as a VO_{2max} predictor also found backs to obtain a higher aerobic fitness than forwards with inside backs achieving the VO_{2max} highest predicted value (62.5 ± 16.9 ml.kg.min^{-1}), in comparison to the hookers who obtained the highest score among the forwards (58.7 ± 16.9 ml.kg.min^{-1}) (23). Although these findings are unable to be directly compared to that of the current study in relation to the subject's MAS scores, it does show a consistent trend for backs demonstrating a greater maximal aerobic fitness in comparison to forwards.

In the present study backs covered a greater total distance (6544 ± 573 m) compared to the forwards (4872 ± 857 m), which is in line with the previous research (8, 26). Roberts et al. (26) reported a slightly lower distance for backs (6217 m), but a greater distance for forwards (5581 m). However, not all participants completed the full 80 minutes, with some participants only playing 40 minutes of the game, leading to potentially inappropriate comparisons between positions (26). Low GPS sampling rates (1-5 Hz) and use of methods of computerised notational analysis (5, 7, 8, 15, 26) also make direct comparison between studies difficult, as 10 Hz GPS devices, as used in the current study, have been found to be more accurate and reliable (6). It has also been found that 1 Hz GPS devices increase in measurement error as the velocity of movement increases (21), whilst computerised notational analysis over-estimates the distances covered when compared to GPS technology, although it was suggested that computerised notational analysis in experienced hands were as accurate as GPS technology (13). While this study did not use direct gas analysis to determine maximal aerobic performance of the participant's, MAS has been reported to be a reliable and practical mode of assessing maximal aerobic performance for team sports (3).

This study found a strong relationship between performance in the MAS test and distance covered ($r \geq 0.746$, $p < 0.001$), accepting the original hypothesis. It must be acknowledged, however, that a strong correlation does not imply cause and effect; for example backs may cover a greater distance because of a superior MAS or this could be due to the fact that forwards have a different role within the game, where there are a greater number of high-intensity static exertions which are not detected by GPS. Forwards in rugby are involved in a greater number of static exertions than backs (89 ± 21 vs. 24 ± 10), for longer mean durations (5.2 ± 0.8 s vs. 3.6 ± 0.8 s), with the difference a result of the forwards involvement in 21 ± 12 scrums, as well as performing more rucks (35 ± 8 vs. 11 ± 6), mauls (25 ± 8 vs. 4 ± 4) and tackles (14 ± 4 vs. 10 ± 4) than backs (26), which may hold some explanation to why backs cover greater distances during games than forwards. It is therefore suggested that future research should determine if a greater aerobic fitness not only shares a relationship with distance covered but also with performance measures related to other facets of the game, including the number and time spent performing high-intensity static exertions, which will allow for a more descriptive view on the effect aerobic fitness has on the modern game.

Practical Applications

Enhancing MAS through appropriate conditioning may increase the total distance covered by professional rugby union players during competitive matches, thereby increasing work rates in the athletes. Strength and conditioning coaches should ensure that players maximise their aerobic capacity during pre-season, which may result in improvements in the distances covered during competitive matches. Aerobic fitness should be improved as part of a periodized training program, ensuring other physical qualities, such as strength and power, are not neglected. Strength and conditioning coaches should consider incorporating conditioning ≥100% of MAS for short durations (15-30 s) with equal respite, as this has been found to be one of the most beneficial ways to increase aerobic performance (9). Alternatively, small sided games, performed at 90-95% for 4 x 4 min, has elicited increases in both maximal aerobic performance and match performance (16).

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Figure Legends:

Figure 1 Relationship between total distance covered and MAS

Figure 2 Comparison of distance covered in competitive matches between groups

Figure 3 Comparison of maximal aerobic speed between groups

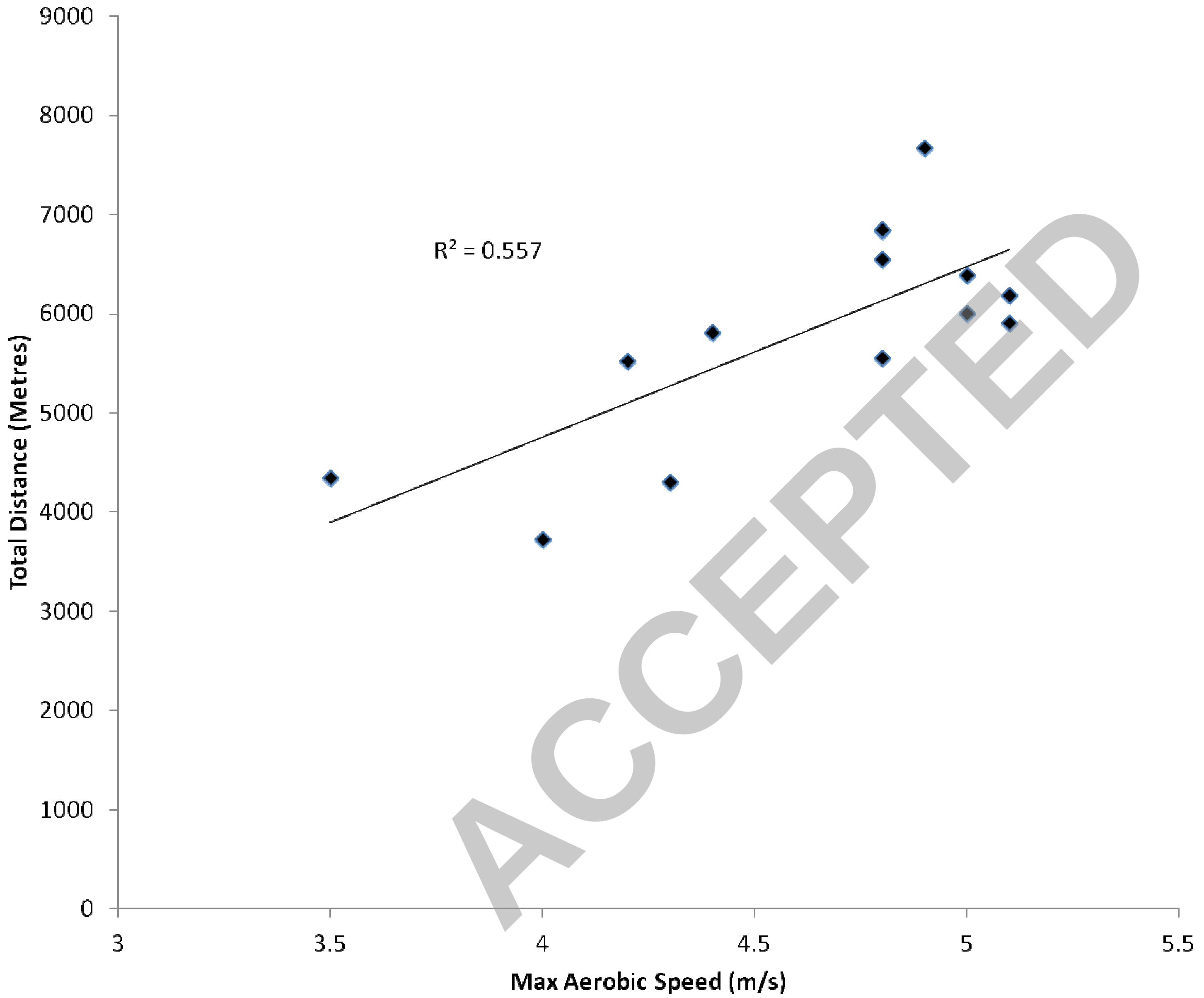

Figure 1: Relationship between total distance covered and MAS

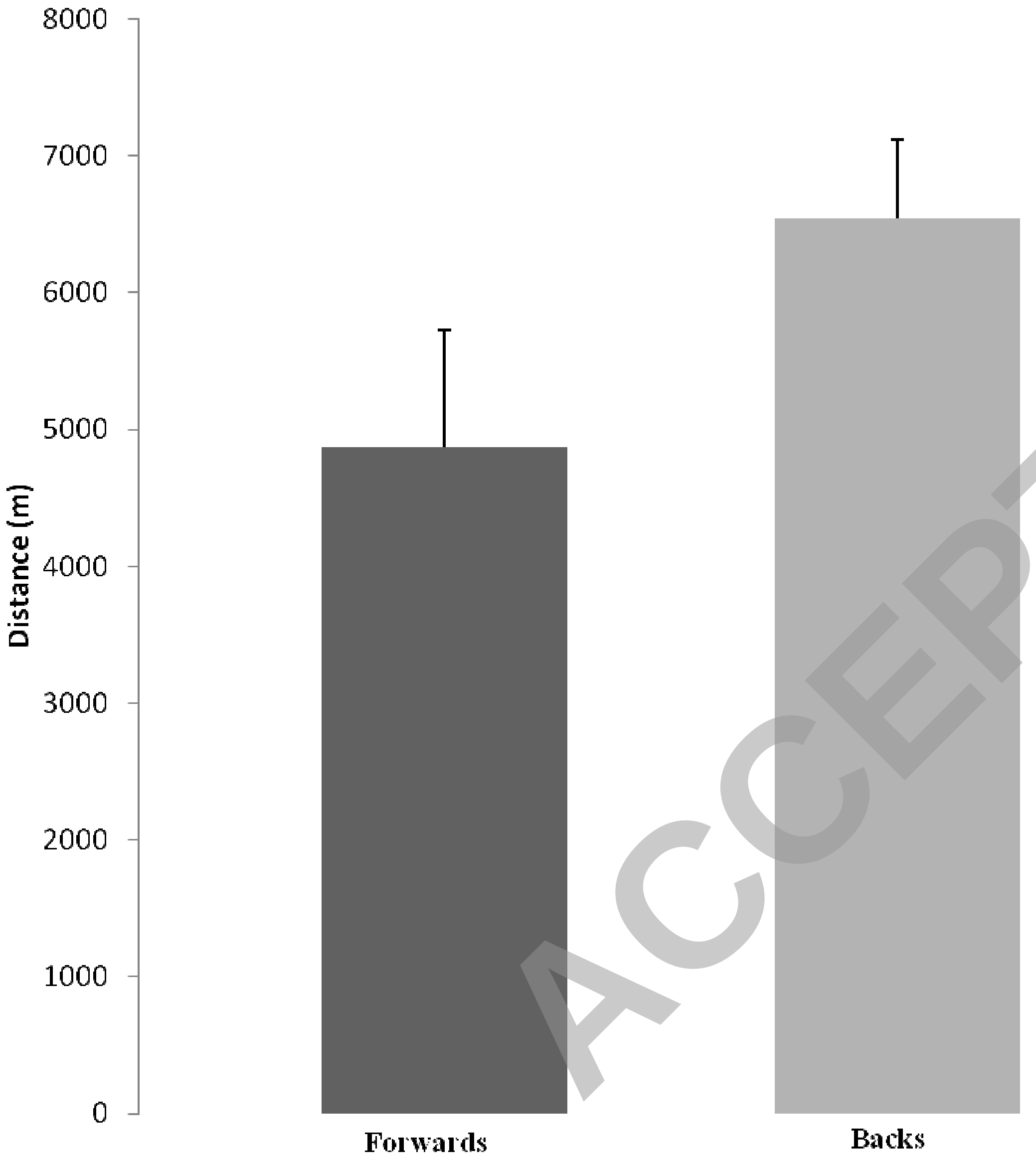

Figure 2: Comparison of distance covered in competitive matches between groups (p=0.001)

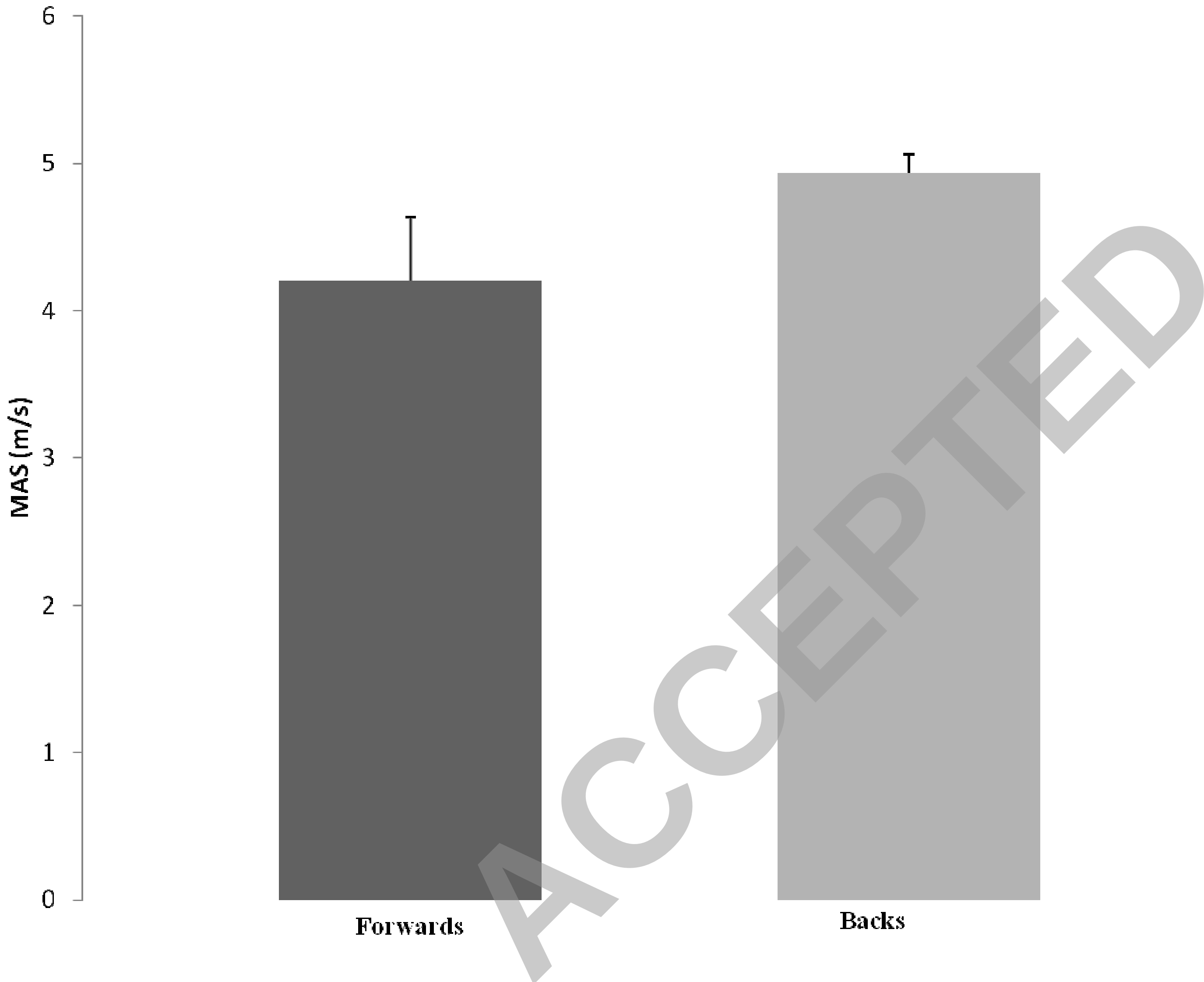

Figure 3: Comparison of maximal aerobic speed between groups (p=0.001)