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ABSTRACT

The purpose of the current study was to compare two water polo specific tests, the 14x25m swims (SWIM) and the 30-second crossbar jumps (30CJ) to a laboratory-based test of anaerobic power, the Wingate anaerobic power test (WAnT). Thirteen elite female water polo players (mean ± *SD*: age 22.0 ± 4.4 years, height 168.7 ± 7.9 cm, body mass 65.9 ± 6.1 kg, body fat 23.6 ± 3.5 %, maximum oxygen uptake 51.4 ± 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in the study. The SWIM involved 14 repeated 'all-out' sprints every 30 seconds. Swimming time was recorded and sprint velocity, mean velocity (Vmean) and gradient of the linear regression equation (GRADIENT) were calculated. The 30CJ involved repeated in-water water polo jumps and touching the goal crossbar with both hands. The number of touches in 30 seconds was recorded. Additionally, the subjects completed a 30 second Wingate anaerobic power test and mean power (Mp) and fatigue index (FI) were calculated. Kendall tau (τ) rank correlation was used to examine for correlation between ranks. Significance level was set at $P \leq 0.05$ No significant correlation was found between any of the measures of the WAnT and the two sport specific tests. It was suggested that WAnT may not be an appropriate evaluation tool for anaerobic power assessment of water polo players, stressing the importance of sport-specific tests.

KEYWORDS: leg power, performance monitoring, power tests, sport specific tests

INTRODUCTION

Evaluating an athlete's performance is an integral part of the training process in the attempts of the athlete, coach and sports scientist to improve it. Various laboratory-based methods have been developed to evaluate the physiological parameters of aerobic and anaerobic power. However, there is an increasing demand for sport-specific testing, as it is deemed to be more representative of the actual activities of the athlete, producing more comprehensive results and improve the training quality (15).

Water polo is a game which poses high physiological demands (26) on the players, due to the aquatic environment and the intermittent nature of the sport (14). The time-restricted offense results in repeated high-intensity swimming bouts (20). Additionally, water polo players frequently and repeatedly perform actions such as shooting, passing, blocking and scrimmaging (19, 20), which require excellent technical execution of the 'eggbeater kick' (cyclical movement of the legs) to generate upward forces (17, 24). Therefore, the ability to cope with these high anaerobic demands is vital for success in the game. Consequently, it is important for a coach to be able to assess and monitor players' performance in these aspects, in order to evaluate training interventions (23).

Two commonly used sport-specific tests of anaerobic power are the 14 x 25m water polo swims (SWIM) and the 30 seconds crossbar jumps (30CJ). SWIM was proposed by Rodríguez (21) and it involves repeated sprints from which swim specific anaerobic alactic capacity and a fatigue index are derived to indicate anaerobic power. 30CJ is a commonly used test involving repeated jumps from the players, attempting to evaluate lower limb anaerobic power (6). Both tests are administered in the field of play and allow for several players to be tested simultaneously. Additionally, their results are arguably more meaningful to coaches (28). The combination of these two tests should provide the coach an indication of the overall anaerobic fitness of the players.

An established measure of anaerobic power is the Wingate Anaerobic Test (WAnT; 7, 13) and despite some limitations (8), it is widely used for athletic populations (25, 27). WAnT presents additional appeals to the assessment of water polo players. Its non-weight bearing nature, the cyclical movement of the lower limbs and the lack of stretch-shortening action, resembles a typical situation of the water polo player in the water, i.e. weight supported by the water and intense eggbeater kick. It is of interest to obtain information on the relation of the sport-specific tests with this laboratory-based test, as it could potentially allow for a) standardization in testing, b) controlled comparisons, and c) compiling of profiling data.

Therefore, the aim of the study was to compare two sport specific tests, SWIM and 30CJ to WAnT. It was hypothesized that the a) fatigue index from SWIM and the fatigue index from WAnT, and b) 30CJ and mean power from WAnT, would be closely related.

METHODS

Approach to the problem

Thirteen elite female water polo players participated in this study. Subjects completed the WAnT, the SWIM and the 30CJ tests. Mean power and fatigue index were measured from the WAnT, mean velocity and the fatigue index (as the gradient of the linear regression equation) were calculated from SWIM and number of jumps was measured for 30CJ. The performances were ranked and correlations were examined between the above parameters.

All subjects completed all three tests, with a minimum of 24 hours intervening. The WAnT was selected as the laboratory anaerobic power evaluation tool, because of the resemblance of the cycling activity to water polo eggbeater. SWIM was selected as a swimming test for anaerobic assessment of water polo players while the 30CJ as a test to evaluate anaerobic power of lower limbs.

Subjects

Thirteen elite female water polo players (mean ± *SD*: age 22.0 ± 4.4 years, height 168.7 ± 7.9 cm, body mass 65.9 ± 6.1 kg, body fat 23.6 ± 3.5 %, maximum oxygen uptake 51.4 ± 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$) who were all members of a National team for over two years at the time of the study, provided written informed consent. The study was approved by the Institutional Ethics Committee.

Procedures

For all the anthropometric measurements, standard International Society for the Advancement of Kinanthropometry (ISAK) procedures were followed. Height (Ht) was measured to the nearest 0.1 cm using a stadiometer (Holtain, Crymch, UK). Body mass (BM) was measured using a calibrated balance beam scale (Seca, Birmingham, UK) and was recorded to the nearest 0.1 kg. Body fat percentage (BF) was estimated from skinfold measurements (Harpenden, Sussex, UK) at bicep, tricep, subscapular and suprailiac sites (10) with measurements taken to the nearest 1 mm.

Swimming anaerobic power assessment involved a sport-specific test, developed by Rodríguez (21). In this test (SWIM), the players performed 14 repetitions of 25m swims every 30 seconds, swum at maximal velocity ('all-out' efforts) with the total duration of the test being 7 minutes. All sprint times were recorded to the nearest 0.1 second (Digi Sport Instruments, Irun, Spain) and velocity for each sprint was calculated. Mean velocity (Vmean) and the gradient of the linear regression equation (GRADIENT) were also calculated. The fastest 25m length (Vmax) indicated the swim specific anaerobic alactic capacity and GRADIENT was an indication of the players swim specific speed-endurance (21). The tests took place in a regulation size field of play (20x25m) and all the players swum together.

A 30-second crossbar jump test (30CJ) was performed, which is commonly used in water polo. For this test, the subjects started from the fundamental floating position with their heads and shoulders above the water and repeatedly jumped out of the water and touched the vertical bar of a regulation sized water polo goal, aiming to achieve as many jumps as possible in 30 seconds. In order to jump, the subjects vigorously treaded water with their hands (sculling) to position their body in an upright position. At the same time, they used high-intensity eggbeater kicks to push the body upwards. The eggbeater is a cyclical action of the legs with the two legs performing similar but alternative actions. The jumping movement was completed with a simultaneous powerful downwards kick, which lifted the body out of the water (17). The subjects touched the crossbar with both hands at the highest point of the jump. Finally, eggbeater was used again after the jump and decelerated the body returning in the water; the action was then repeated. Correct execution form was maintained throughout, while the subjects were continuously encouraged.

Anaerobic power was measured in the laboratory via the Wingate Anaerobic Test (WAnT). Initially, a 5-minute warm up was conducted at a workload of 100 W with a 5 second sprint at 3 minutes, followed by a 5-minute rest (29). The test required the subjects to cycle maximally on a calibrated ergometer (Monark 834E, Varberg, Sweden) for 30 seconds against a resistance of 7.5% body mass (7, 9, 29). Pedal revolutions were recorded every one second and mean power (Mp) and fatigue index (FI) were calculated (Cranlea, Birmingham, UK). Mp was calculated as the average power achieved over the 30 second period while FI as the percent power decrease. The subjects were seated and verbally encouraged throughout the test. The equipment was calibrated according to manufacturers' standardized procedures.

All tests took place with adequate rest between them, as suggested by the American College of Sports Medicine (3). Additionally, they were performed at the same time of the day to avoid variations due to circadian rhythms (5).

Statistical analyses

The subjects' results for each test and all variables were converted to rank scores, with a rank score of 1 representing the best score. Tied ranks were scored according to Zar (30) (sum of rank scores for same results / number of same results). Kendall's tau correlation analysis was used to examine for relationships between the variables, as this particular statistical test is appropriate for smaller sample sizes (30). 95% confidence interval (95%CI) was also calculated. Significance level was set at $p \leq 0.05$. All statistical analyses were conducted using SPSSv14.0.

RESULTS

Descriptive statistics of the test results for all variables can be found in Table 1.

TABLE 1 ABOUT HERE

No correlation was found between any of the laboratory anaerobic power test variables and the sport-specific anaerobic power variables. Additionally, no correlation was found between any of the anaerobic power variables of the two sport-specific tests. Finally, when individual performances were examined all individuals achieved different rankings at the different variables.

DISCUSSION

The aim of the study was to compare the Wingate Anaerobic Test with two water polo specific tests of anaerobic power; the 14x25m and the 30-seconds crossbar jumps. The results indicate that none of the parameters of the above tests correlate well with the WAnT parameters.

Elite players that were proficient in the execution of the tasks required and able to withstand extreme athletic conditions, were selected in the current study, The selection of the sample along with the high difficulty level of the tests, was aimed to improve reliability (28) and minimize individual variability. However, that impacted on the sample size, with thirteen subjects being a small sample for the comparisons made (2). Therefore, caution should be exercised in the interpretation of the results, as they are applicable to elite athletes and should not be generalized.

There is no published data for females to compare the Vmean and Vmax obtained from SWIM in the current study. Elite male Spanish water polo players (21) have achieved Vmean of 1.83 $m \cdot s^{-1}$ Vmax of 1.93 $m \cdot s^{-1}$. It is suggested that the Vmean and Vmax of the present study is somewhat low. This could partially explain the very low GRADIENT obtained from SWIM, which indicated a very small velocity decrease.

Fatigue index is representative of the ability of an individual to resist fatigue; a higher fatigue index percentage indicates inability to maintain power. The subject's fatigue index in the present study is higher than Arslan's (4), who used female subjects involved in regular exercise (48.3±7.1 and 35.6±11.4 W, respectively), indicating inability to maintain power throughout the test's duration. Technical execution of water polo skills decreases with fatigue (22), therefore higher maintenance of power is important. Nevertheless, fatigue index is affected by more explosive individuals reaching a higher peak power and subsequently often having a steeper decrease. Platanou and Geladas (20) have shown that different positional roles perform different movements, specific to the role (20). Therefore, future studies should consider a larger sample that would investigate potential positional role differences.

GRADIENT and FI were deemed to measure similar qualities, namely the gradual anaerobic power loss of the athletes. However, the comparison of these two variables showed no correlation, not supporting our hypothesis. Indeed, as explained above, the GRADIENT was very low while the FI very high. The SWIM's duration of 7 minutes and larger muscle groups involvement in swimming suggest a need for higher aerobic contribution compared to 18.6% for the WAnT (8). Additionally, SWIM comprised 14x25m swims, with swimming lasting an average of 17.8 seconds every 30 seconds while the WAnT protocol was a single, continuous exercise. The fatigue index for the two tests (GRADIENT and FI) may have been more closely related if a multi-bout, discontinuous WAnT protocol was utilized. Our findings concur with findings by Hoffman et al (12) who compared WAnT to basketball-specific tests and found no correlation between the fatigue indices. These results strongly imply that the WAnT is not a good indicator of anaerobic performance decreases in intermittent-nature sports, thus doubting its use as an evaluation tool for such sports.

In order to examine for any potential effects of anthropometric characteristics on the results, a Pearson's correlation between the 30CJ scores, height and body mass was conducted. Due to the nature of the test ('fixed' distance to cover), it was postulated that taller or lighter individuals may be able to reach the crossbar easier. However, no significant relationship was found for 30CJ and anthropometric characteristics.

With regards to Mp, the athletes in the present study had higher Mp compared to the study by Cooper et al (9), who used female game athletes of very similar anthropometric characteristics. When corrected for body mass, the subjects in the present study also performed better than in Cooper's (9) study (27.7±1.8 and 26.7±3 W·kg-0.67, respectively). This could be perceived as a somewhat surprising result, given that the other game players benefit from impact with the ground that water polo players do not. However, water polo players use the eggbeater kick for ~47.0% of the overall game time (19) at an intensity of ~89% of peak heart rate (20). It is suggested that despite the lack of fixed resistance, the prolonged use of eggbeater at that intensity is accountable for the higher Mp.

Subsequently, no correlation was found between the 30CJ and Mp, rejecting the respective hypothesis. This is a somewhat surprising result, because of the cyclical lower limb action, non-weight bearing and lack of any stretch-shortening cycle activity between the water polo eggbeater and cycling. Nonetheless, the two movements also present some significant differences. The contribution of the arms pushing at the beginning of the jump, the lack of a fixed resistance to push against in the water and the resulting inability of power transfer between biarticular muscles (17, 24), inevitably provide substantial mechanical differences between the two movements. In addition, the eggbeater action is technically a very skillful action (24) while cycling less so. These differences indicate that WAnT can not be used as a laboratory measure of the anaerobic ability of water polo players to perform eggbeater.

It has been previously suggested that field-based tests are frequently used by coaches (11). The results of the current study support this notion and, more specifically, that of sport-specific tests use. The value of sport-specific tests (rather than field tests), at least for water polo, was demonstrated by two studies by Platanou (17, 18), where the single ‘in-water’ vertical water polo jump was examined. The jump was found to be a reliable measure of the ability of the water polo players to elevate their body vertically out of the water (18). However, when compared to a dryland vertical jump (a commonly used field-based test; 11), a poor correlation was found (17). This discrepancy could be to a large extend explained by Sanders (24) who suggested that skillful execution of the eggbeater movement is more important than powerful movement alone (24); therefore, highlighting the need for sport-specific testing.

Overall, the parameters obtained from WAnT do not correlate well with the water polo-specific tests of anaerobic power. The results suggest that WAnT can not be used as an evaluation tool of the sport-specific parameters examined. Therefore, at present, the sport-specific tests need to be used for assessment of anaerobic abilities of the players.

PRACTICAL APPLICATIONS

It is imperative for coaches to be able to monitor and evaluate the training process accurately and reliably. The use of field and sport-specific tests has been suggested with caution (1) in order for the tests not to provide erroneous information to the coaches and athletes but with valid and reliable information on which they base subsequent decisions. However, sport-specific tests are chosen as they are better suited to the demands of the sport and provide the coach and athlete with useful results (15, 28).

The current study investigated two water polo specific tests, frequently used to assess player's performance. The multi-dimensional nature of water polo, suggests that a number of tests should be used to provide the coach with an overall evaluation of their players and the various skills required to be successful. Although currently water polo coaches use a number of tests to assess their players abilities, only few have been validated (14, 19). The development of a battery of tests that will take into account the complex nature of water polo is necessary to ensure accurate and reliable information to the coach.

A stronger link between laboratory and field practice must also be formed (1). Additional physiological measures, together with further assessments of reliability, will be useful in minimizing the inevitable variability that comes with a test conducted in the non-standardized environment of the practice field. A situation in which a sport-specific battery of tests can be conducted with the acquisition of relevant physiological data, which will provide quality information to support more specific and measurable improvements in performance (16), is ideal for the coach and the athlete.

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Tables

Table 1. Results for all tests variables with associated 95% confidence interval. Data are presented in mean ± *SD*.

	Mp (W)	**FI (%)**	**Vmax ($m \cdot s^{-1}$)**	**Vmean ($m \cdot s^{-1}$)**	**GRADIENT**	**30CJ (jumps)**
	459.2 ± 45.3	48.3 ± 7.1	1.51 ± 0.07	1.41 ± 0.07	-0.0061 ± 0.0072	21.8 ± 2.5
95% CI	438.5 – 479.8	45.1 – 51.6	1.48 – 1.55	1.37 – 1.43	-0.0089 – -0.0016	20.7 – 23.0

Mp, Mean Power; FI, Fatigue Index; Vmax, maximum velocity; Vmean, mean velocity; GRADIENT, gradient of the linear regression equation for velocity; 30CJ, 30 seconds crossbar jumps. 95% CI, 95% confidence intervals.