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Specific test for water polo performance evaluation: A preliminary and profile study

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Abstract

Background: Water polo (WP) is a sport with great aerobic/ anaerobic physiological demands. There are few studies that have evaluated the physical demands during the WP game and its relationship with the physiological indices of aerobic fitness

Aim: Our aim was to determine the aerobic/ anaerobic profiles of the WP athletes through specific test.

Materials and Methods: WP male athletes participated in this study (24.5±5.6 years, 85.9±10.3 kg, 183.0±6.3 cm, n=23). The athletes performed an anaerobic WP test (TAnaWP) to determine the height (Alt- cm) of the 1st/ 15th/ 30th jumps, total time(s) of the jumps (TT30) and the fatigue index (FI). Blood lactate kinetics were determined immediately after (Lac0 min) and during the recovery period; Lac 1/ 3/ 5/ 8/ 12 min. They also performed an aerobic water polo test (TAerWP) to determine maximal oxygen consumption (VO_2max) a heart rate (HRmax), peak blood lactate (Lacp) and the second lactate threshold (LL2).

Results: The following results (in cm) were obtained in TAnaWP: Alt1st (44±6), Alt15th (32±7) and Alt30th (24±9); TT30 (56.9±9.5); FI (42.0±12.5%); (Lac0), (Lac1), (Lac3), (Lac5), (Lac8) and (Lac12) (5.2±1.7; 7.8±1.6; 9.0±2.0; 9.4±2.2; 9.2±2.7; 8.5±2.2 mmol/L, respectively). The mean maximal values for the aerobic test were: VO_2max=44.4±5.3 ml/kg/min, HRmax=174.3±9.1 bpm, Lacp=8.6±2.1 mmol/L. The values obtained at LL2 were: 157.5±13.5 bpm/ 90.5±8.2% HRmax).

Conclusion: The proposed tests may be a possibility to determining the physiological fitness of WP athletes.

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1. Introduction

Water polo (WP) training and practice include pool and synchronized swimming [1]. In addition, elite performance in WP requires rigorous training and practice to develop the appropriate sport-specific physiological, biomechanical, artistic, and strategic capabilities [1]. For example, game analysis demonstrates that several types of movements and swimming techniques occur in a match, however approximately 50% of them are registered in the horizontal position of the body [1, 2, 3].

The physical demands of WP through the technique of time and movement analysis demonstrate that WP is an intermittent game, with periods of 15 sec at a high intensity (sprints), with a predominance of anaerobic metabolism, interspersed with periods of 20 sec of recovery at low to moderate intensity, with a predominance of aerobic metabolism [2, 3].

During a WP game, there is a great demand on the lower limbs for the displacement and support of the athlete's body in the pool [1, 2, 3]. Thus, delimiting and evaluating physiological parameters that characterize this type of aquatic exercise by respecting the specificity of physical training can significantly affect evaluating physical and sports performance [2]. It should be noted that game analyzes have shown that WP is an intermittent sport consisting of intense bursts of activity of <15 sec in duration with intermediate intervals of lesser intensity with an average duration of <20 sec. The physiological measures obtained during the game indicate a cumulative effect of the repeated sequences of activities and suggest a high metabolic demand of the athletes [1].

Exercises performed in water offer different physiological conditions from those performed on land, such as the hydrostatic pressure exerted by the water, less use of muscle mass and the facilitation of venous return during and after exercise [4]. Thus, exhaustive exercise on a treadmill has a higher maximum heart rate and lactate peak after exertion than exhaustive exercise in water [5]. These data show the importance of elaborating specific tests in water for WP athletes to obtain indicators of the level of aerobic and anaerobic fitness.

The Wingate test is widely used to determine anaerobic fitness [3, 4, 5]. There are performance indices that the Wingate test can determine: (a) maximum power, the highest power developed during the test; (b) average power, average power evaluated during the 30 sec of the test; and (c) fatigue index, percentage drop between maximum and minimum power [6]. These indices correlate with the peak blood lactate concentration after a supramaximal exercise [6].

However, the Wingate test is not specific for evaluating WP athletes. Still, the way it was designed could help to develop an anaerobic test that meets the biomechanical and metabolic demands of the modality [5]. Therefore, the upward movement (simulation of "vertical jump") in the water, which constitutes a fundamental technical skill of the WP [7], can be used in the conception of a specific test.

Additionally, the maximum oxygen consumption (VO_2max) and the second lactate threshold (LT2) are important physiological indices that reflect the power and the aerobic capacity, respectively [8]. VO_2max can be defined as the maximum capacity to capture, transport, and use oxygen during a maximal incremental exercise. This index is still widely used to predict aerobic performance [9]. The LT2 corresponds to the effort intensity from which the blood lactate concentration systematically increases. There are different methodologies and terminologies to identify LT2 [6, 7]. Among the main methodologies we have lactate, ventilatory, and glucose thresholds. These methodologies are based on fixed concentrations, where the LT2 occurs at a concentration of 4 mmol/L [10]. However, recently, there has been growing interest in using wearable sensors to provide high-resolution and precision data [8].

In other sports with intermittent characteristics, such as soccer, a high and significant correlation between aerobic fitness and physical demands (total and partial distance covered, number of sprints and number of involvements with the ball) during the matches was observed [11]. However, there are few studies that have evaluated the physical demands during the WP game and its relationship with the physiological indices of aerobic fitness [1, 8, 9]. For example, during a WP match, most of the total playing time (85.6±2.8%) is performed at swimming speeds well below LT2 or rest, evidencing the importance of aerobic fitness in WP [1, 2]. Thus, it is important to determine the aerobic fitness indices in a more specific way as one of the steps of the physical performance evaluation process capable of predicting the performance of WP players.

The aim of the present study was to determine the aerobic and anaerobic profiles of WP athletes through a specific test protocol. In general, the tests used are aimed at direct evaluation during tethered swimming (head-up crawl), cycle ergometry, treadmill running, free swimming (front crawl), tethered front crawl swimming or based on recovery measurements following free swimming [2]. Our purpose is that tests that simulate the modality's movements can guarantee the application of the specificity principle for training planning among WP athletes. This, in theory, could increase the sports performance of these athletes.

2. Materials and Methods

Twenty-three WP players aged 18 years or older were included in the study. Of the 23 athletes, 13 were part of the Brazilian national team who participated in the Pan American Games in Rio de Janeiro/ RJ, Brazil, in 2007. All other players were part of the water polo team of elite clubs in Brazil, mainly Pinheiros Sport Club which was one of the main clubs in Brazil in terms of world and Olympic level athletes.

Using a scale and a stadiometer, body mass and height of the athletes were evaluated before the start of the battery of tests. Initially, the athletes were submitted to the Anaerobic Water Polo Test (TAnaWP) and, only after 48 hours, to the Aerobic Water Polo Test (TAerWP). The anthropometric profile of the evaluated athletes was obtained by measuring age (24.5±5.6 years), body weight (85.9±10.3 kg) and body height (183±6.3 cm). The average speed of the sample of athletes in the sprint of 25-meter pool was 1.95±0.27 m/s.

Athletes were informed of the potential risks and benefits of the study and signed an informed consent form to take part in this study.

The tests were discussed, elaborated, and developed by sports scientists, coaches and physical trainers specialized in the modality. During the anaerobic test, swimmers stood upright in a pool where they couldn't stand (they held themselves in position using WP-specific leg movement).

Starting from this position, the athletes should make an acute effort to get as much of the trunk out of the water as possible, as if they were jumping 30 times in a row. Before the test, the athletes received a mark at the height of the xiphoid process (zero point of the height measured in the test) and from which four others were made every 4 cm lower. The test execution was filmed, and the athletes' performance was determined through the heights (cm) of the 1st (Alt1st), 15th (Alt15th) and 30th (Alt30th) jump measured through the body markings.

The total time of jumps (TT30) and the fatigue index (FI) was calculated as follows: FI= [(height of the biggest jump - height of the smallest jump)/ height of the biggest jump]x100.

Arterialized blood samples were obtained from the earlobe previously prepared with a vasodilator ointment (Finalgon, Boehringer Ingelheim, Germany). The collection was performed in heparinized capillaries calibrated to 25 µl and then stored in properly labeled ffffffff ff a aaaaa aa aa'aa aa aaaaaa fluoride (NaF). Samples were obtained immediately after (Lac0) the 30th jump and at minutes 1 (Lac1), 3 (Lac3), 5 (Lac5), 8 (Lac8) and 12 (Lac12) of recovery at rest for the determination of blood lactate concentration (YSI 1500 Sport, Yellow Springs Instruments, USA).

During the aerobic test, the athletes were instructed to perform alternating and vertical chest kicks, maintaining the height of the water in the xiphoid process, with an initial weight of 2 kg, and 2 kg added every 3 min until exhaustion (the weight was ddddd dd eee rrrr eee"" ttttt tt tttttt tt n was assessed by the athlete's subjective perception of exertion and if the athlete was unable to maintain the height of the water in the xiphoid process line when jumping out of the water. However, the test was designed for a predicted duration of 12 min.

At the end of each stage of the test, the athletes performed a 30-sec rest interval to add weights to the ballast, collect arterialized blood to determine blood lactate concentrations, and measure pulmonary gas exchange (for this, the equipment mask- K4b2, Cosmed, Italy- was placed on the athlete's face). For these data collections, in the competition and training environment, the athlete moved to the edge of the pool, which was uncovered, and kept his head out of the water and rested both hands on the edge. The heart rate (HR) was measured continuously during the test by telemetry (T31, Polar, Finland). Maximum oxygen consumption (VO_2max) and maximum heart rate (HRmax) were determined as the highest value of these variables reached during the stage in which the athlete entered exhaustion. The maximum load (Cmax) of the ballast was considered the weight corresponding to the last complete stage of the test. Peak blood lactate concentration (Lacp) was considered as the blood lactate value obtained in the last stage of the incremental test, even if incomplete. The weight of the ballast and the heart rate corresponding to the LT2 was determined through linear interpolation for the blood lactate concentration of 4 mmol/L. The percentage of maximum heart rate (%HRmax) and maximum load (%Cmax) at LT2 were calculated.

2. 1. Statistical analysis

We performed a descriptive statistical analysis to analyze the data, presenting the aerobic and anaerobic fitness indices as mean±standard deviation. In addition, a eeeeeeeet t-test was performed to determine whether there was a statistically significant difference ($P<0.05$) between the first and second half of the TAnaWP. Our main aim regarding the statistical analysis was to present a profile study of the elite water polo players in Brazil.

3. Results

The average time to perform the 30 jumps (TT30) was 56.9±9.5 sec, and there was a statistically significant difference (P<0.05) between the time to perform the 1st (26.9±4.4 sec) and the 2nd half of the protocol (30±5.7 sec). Alt1st, Alt15th and Alt30th were 44±6, 32±7 and 24±9 cm, respectively. The IF presented by the group was 42.0±12.5%, ranging from 16.7% to 85.7%.

Figure 1 shows the behavior of blood lactate (mmol/L) immediately after and during the recovery period of the anaerobic water polo test (TAnaWP). The lactate concentrations in the recovery time were: (Lac0 min), (Lac1 min), (Lac3 min), (Lac5 min), (Lac8 min) and (Lac12 min) (5.2±1.7; 7.8±1.6; 9.0±2.0; 9.4±2.2; 9.2±2.7; 8.5±2.2 mmol/L, respectively). The highest blood lactate value (9.4±2.2 mmol/L) reached its average around the 5th min of recovery, and a drop in its concentration was observed afterward.

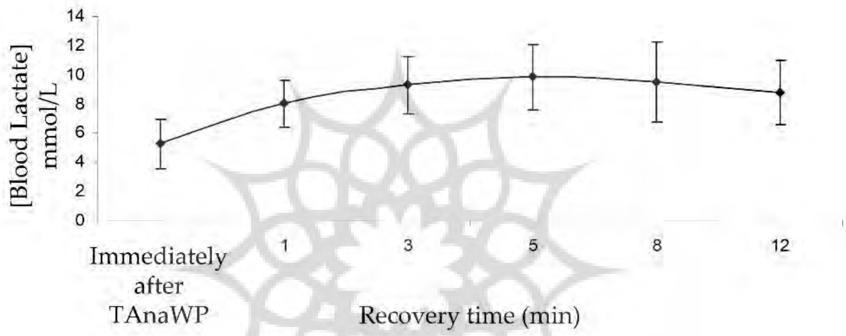

Figure 1. Blood lactate behavior immediately after and during the recovery period (min) of the anaerobic water polo test (TAnaWP)

Regarding the sub-maximal parameters, the LL2 occurred at a HR of 157.5±13.5 bpm (90.5 ± 8.2% HRmax), ballast weight of 8.9±2.5 kg (69.2±14.4% Cmax). The maximum values reached during the test were: HRmax 174.3±9.1 bpm, Cmax 12.9±2.3 kg, [Lacp] 8.6±2.1 mmol/L and VO_2max 44.4±5.3 ml/kg/min. The average exhaustion time (min) in the aerobic test, for the total sample, was 11.2±1.8 (max-min, 12.60-9.98). The behavior of HR throughout the test (start/end of stage) was as follows: stage 1 (109.0±23.3/ 125.3±19.2); stage 2 (136.8±10.5/ 151.5±10.7); stage 3 (160.9±6.6/ 166.1±4.8); and stage 4 (175.0±10.4/ 173.0±10.2).

4. Discussion

The aim of the present study was to determine the aerobic and anaerobic profile of WP athletes through specific test protocols. Our purpose is that tests simulating the movements of the modality can guarantee the application of the principle of specificity for planning the training of water polo athletes. This, in theory, could increase the sports performance of these athletes.

It is noteworthy that alternating upright legwork is largely responsible for the increased metabolic demand during a WP match. Although many know this characteristic, we found in the literature that no references have validated adequate and specific methodologies to measure this ability. There are, however, several studies that evaluated the metabolic demand through activities that simulate the game and specific tests [12] after each period of the WP game [13], swimming tests [3, 14] or even in an arm cycle ergometer [12]. However, it is necessary to evaluate and simulate specific interventions of strength training and physical conditioning, mainly high-intensity intermittent resistance and anaerobic fitness [13].

In the present study, we suggest the use of two distinct but complementary protocols to measure the aerobic and anaerobic capacity of the legwork in the vertical position of WP players. The peak blood lactate concentration after a 1-minute supramaximal exercise is often used as a metabolic indicator of the ability to use anaerobic metabolism [15], which is in line with the time it took athletes to perform the 30 jumps (56.9±9.5 s). In addition, the last 15 jumps were significantly slower than the first 15 jumps, demonstrating muscle fatigue in the lower limbs during the test.

No specific field test was found in the literature to determine the anaerobic fitness of WP players, which makes a comparison with our results difficult. However, after maximum effort tests of 30 s of freestyle swimming [16] or 30 s of maximum effort in an isokinetic arm ergometer in swimmers [17], lactate peaks of 6.5 mmol/L and 7.78±1.92 mmol/L, respectively, were found. These values are lower than the lactate peak found in our study (9.4±2.2 mmol/L), probably because the upper limbs were evaluated (less muscle mass) and in a shorter period in these exercises.

Values like those of our study were obtained by Weinstein et al. (1998) after the Wingate test on lower limbs in sedentary to very active individuals (9.7 mmol/L) [18]. In this study, the authors found a lactate peak in the 3rd min of recovery, without a drop until the 9th min, different from the findings of our study. Perhaps this can be explained by the different levels of physical fitness among the samples evaluated.

The Wingate test is widely used in the evaluation of the anaerobic potency of lower and upper limbs [5, 16]. The fatigue index value found in the TAnaWP is close to the fatigue index values found in Wingate tests for lower limbs for weightlifters (45.0±8.0%), gymnasts (47.0±3.5%) and wrestling athletes (43.0±5.2%) [19].

In our study, in the TAerWP we obtained HRmax values of 174±9 bpm, VO_2max of 44.4±5.3 ml/kg/min and [Lacp] of 8.6 ± 2.1 mmol/L. For the assessment of aerobic fitness, specific tests of lower limbs in water for WP players were also not found in the literature. However, there are studies with incremental tests of displacement in water (deep-water running) [20], such as those by Town and Bradley (1991) [21] and Butts et al. (1991) [22], that found VO_2max-values in deep-water running of 49.0 and 46.8 ml/kg/min, respectively. Regarding HR, studies by Frangolias and Rhodes (1995) [23] and Svedenhag and Seger (1992) [24] exploring deep-water running measured an HR of 175 and 172 bpm, respectively.

The proposed test did not reach the HRmax predicted by age. It is known that HRmax presents lower values in water due to less stimulation of the sympathetic system due to hydrostatic pressure and baroreflex activation, which determines the facilitation of the venous return, with an increase in systolic volume and cardiac output (with a consequent decrease in heart rate) and, to the thermodynamic factor, determining the facilitation of the body's heat exchange with the external environment [25, 26]. However, the athletes stopped the test due to exhaustion and the peak lactate concentration was 8.2±2.1 mmol/L.

In relation to VO_2max, there seem to be some factors that explain the decrease of this variable in water. Because water has a higher density than air, resistance to movement increases and a higher percentage of anaerobic metabolism must be used to travel in water compared to the terrestrial environment. In addition, the lower perfusion pressure in the legs can result in a decrease in muscle blood flow, which can lead to a decrease in VO_2max during exercise compared to running on land [26]. Although maximal HR and VO_2max are lower in water compared to treadmill and cycle ergometers, lactate concentration at maximal exertion appears to be no different between aquatic and terrestrial environments [27].

Although the determination of LT2 by the criterion of a fixed concentration of 4 mmol/L is criticized for its variability, this methodology is widely used in scientific research and practical sports training activities [10]. The results of our study showed that LT2 occurred at an HR of 157.5±13.5 bpm (90.5±8.2% HRmax) and for a load of 8.9±2.5 kg (69.2±14.4% Cmax). We could not compare the results obtained in TAerWP with the results of the specific literature for WP since we proposed two new tests for this modality. However, studies that used incremental test protocols with other exercise modalities to determine the physiological indices of aerobic performance found results like ours in relation to the relative intensities where the LT2 occurred [28, 29, 30].

5. Conclusion

In summary, the WP's complexity, variation, and intermittent nature make the assessment and interpretation of physiological responses related to training and competition technically difficult. Still, the TAnaWP and the TAerWP proved to be adequate not only for evaluating athletes of high-performance WP, but they were also helpful in prescribing an effective individual training program. We can also consider that the indices obtained for anaerobic fitness are compatible with those found in the Wingate test (gold standard) in other studies and that the aerobic leg test reached criteria for determining VO_2max and LT2, the values found being compatible with those of other studies, performing water exercises.

6. Limitations

We consider that the main limitation of this study is that we did not assess the reproducibility of our data. However, we assess Brazil's sporting elite. In addition, the idealized tests used modality-specific skills. This probably decreases the familiarization effect, which would theoretically make our findings more reproducible.

Another limitation, due to the lack of opportunity to spend time with the athletes, due to competitions and trips to competitions and because in Brazil WP athletes cannot "live on sport" and need to exercise other professions, is that we cannot apply, due to the lack of ideal logistics, the traditional tests for assessing power and aerobic and anaerobic capacity to assess possible correlations with the specific tests. However, our goal was to evaluate in a specific situation and with high ecological validity and in the swimming pool and training field. But these are not fatal limitations and do not make our findings unviable since the tests were designed and applied by sports science and physical training professionals who also had extensive experience working with athletes from the world's elite sports.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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