

Research article

Repeated Sprint Ability in Elite Water Polo Players and Swimmers and its Relationship to Aerobic and Anaerobic Performance

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Abstract

The purpose of this study was to determine indices of swimming repeated sprint ability (RSA) in 19 elite water polo players compared to 16 elite swimmers during a repeated sprint swimming test (RST), and to examine the relationships between these indices and aerobic and anaerobic performance capabilities in both groups. Indices of RSA were determined by the ideal sprint time (IS), the total sprint time (TS), and the performance decrement (PD) recorded during an 8 x 15-m swimming RST. Single long – (800-m) and short-(25-m) distance swim tests were used to determine indices of aerobic and anaerobic swimming capabilities, respectively. The water polo players exhibited lower RSA swimming indices, as well as lower scores in the single short and long swim distances, compared to the swimmers. Significant relationships were found between the 25-m swim results and the IS and the TS, but not the PD of both the swimmers and the water polo players. No significant relationships were found between the 800-m swim results and any of the RSA indices in either the swimmers or the water polo players. No significant relationships were found between the 25-m and the 800-m swim results in either the swimmers or the water polo players. The results indicate that swimmers possess better RSA as well as higher anaerobic and aerobic capabilities, as reflected by the single short- and long-distance swim tests, compared to water polo players. The results also indicate that, as for running and cycling, repeated sprint swim performance is strongly related to single sprint performance.

Key words: Intermittent activity, continuous effort, recovery, training.

Introduction

In contrast to the single, continuous efforts typically performed in individual sports, such as track and field or swimming, team sports are usually characterized by intense intermittent activity; that is, repeated short-duration, high-intensity efforts, interspersed with brief recovery periods. Therefore, team sport players are required to possess a high level of repeated sprint ability (RSA). The game of water polo is an example of a team sport that is intermittent in nature, requiring intense bursts of brief activity, each lasting between 7 to 14 seconds (Smith, 1998). These intense activities during a typical water polo game are interspersed by lower-intensity activities and by periods of recovery. As a consequence of these cumulative high-intensity periods, exercise intensity decreases in elite woman water polo players as the match progresses

(Tan et al., 2009), suggesting a fatigue effect during the late stages of the game. It is therefore important to understand factors that determine RSA in swimming to better inform strategies designed to improve this important fitness component.

Total swimming distance of male players during a water polo game ranges from 500-1000 m to 1500-1800 m (Smith, 1998). Despite this, players spend only 50% of game time in a horizontal body position; during the remaining time, they perform activities in a vertical body position, at moderate to high intensity, with and without contact with an opponent. Therefore, the velocity of horizontal displacement may not adequately reflect the intensity and the intermittent nature of the activities performed in the game, particularly for acceleration and deceleration movements in the vertical plane or in contact with opponents. It was also found that players' heart rate usually exceeds 80% of maximum at any stage of the game, suggesting that the intervening lower-intensity activities were of insufficient duration for complete recovery (Pinnington et al., 1990). The high proportion of moderate- and high-intensity activity, and the sustained elevated heart rates observed during a game, suggest that aerobic metabolism provides a large portion of the energy requirements of the game. In support of this, VO_2 max values are moderately high (58 to 61 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in national-level water polo players (Smith, 1998). These values are similar to those reported for players of other intermittent, contact team sports, such as basketball (McInnes et al., 1993), soccer (Meckel et al., 2009), and rugby (Nicholas, 1997), but lower than those reported for trained swimmers (63 to 69 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Fernandes and Vilas-Boas, 2012).

It has been suggested that a high level of aerobic fitness is a prerequisite for enhanced performance during repeated-sprint activities (Glaister, 2005; Spencer et al., 2005). However, the correlation between aerobic fitness (e.g., VO_2 max) and indices of RSA has been inconsistent. While some authors have reported significant correlations between the two (e.g., Aziz and Chia, 2000; Dawson et al., 1993), others have failed to do so (e.g., Castagna et al., 2007; Wadley and Le Rossignol, 1998). Further research is therefore required, especially with swimming as the exercise mode, as most repeated-sprint studies have employed running (Aziz and Chia, 2000; Meckel et al., 2009) or cycling (Bishop et al., 2004; Fitzsimons et al., 1993). To the best of our knowledge, only one study (Meckel et al., 2012) has investigated

indices of RSA in swimming. However, this study examined swimmers who are known to perform continuous single efforts and not repeated swim efforts.

Therefore, the aims of the present study were to determine indices of swimming RSA, as well as the best single long- (800m, as an index of aerobic performance) and short- (25m, as an index of anaerobic performance) distance swimming results in national-team level water polo players, and to compare them to national-team swimmers. In addition, we examined the relationships between RSA indices and the water polo players' and swimmers' best single long- and short-distance results. We hypothesized that, due to the nature of the sport, swimmers would demonstrate faster times in the single short- and long-distance swims. However, water polo players would demonstrate lower performance decrement (PD) in the repeated sprint test (RST) compared to the swimmers. We also hypothesized that swimming RST indices would correlate with both short- and long-distance swim results (as indicators of anaerobic and aerobic capacity respectively).

Methods

Participants

Nineteen water polo players (age 20.9 ± 3.4 y, height 1.81 ± 0.06 m, body mass $77.8 \pm$ kg) and 16 swimmers (age 18.6 ± 2.2 y, height 1.81 ± 0.07 m, body mass 76.6 ± 6.1 kg), specializing in 100- to 400-m swim distances, all members of the Israeli national team, participated in this study. Participants had several years of training and competitive experience at a national and international level. Training experience of the water polo players and swimmers was similar (average 6.0 years each). However, as swimming competitions start in our country at earlier age, the swimmers had a 2.5 years greater experience in national and international level competitions than the water polo players. Testing sessions were performed upon completion of the preparatory training period, prior to the beginning of the competitive season. During this period an average of 10 swimming sessions were performed by the swimmers every week, covering distances of about 40–50 km-week⁻¹. Out of that, about 50% was devoted to long-distance aerobic-type training, 25% to interval training and 15% to sprint training. The swimmers also spend some time practicing special technical drills (about 10% of total distance) in the water. The water polo players trained 8 times per week, covering about 30–40 km-week⁻¹. Out of that, about 25% was devoted to long-distance aerobic-type training, 20% to interval training and 15% to sprint training. The players also spend some time playing games (about 25% of total distance) and practicing special tactical drills (about 15% of total distance) in the water. Both groups also had three sessions of strength training every week. The participants, and parents for participants under the age of 18, were informed of the experimental procedures and signed an informed consent form. All procedures were conducted in accordance with the standards of the Institutional Ethics Committee.

Procedures

The participants performed three tests with a 3–4 day break between each test. The first test consisted of a 25-m swim, the second consisted of an 800-m swim, and the third consisted of the swimming repeated sprint test (RST) protocol. All three tests were performed in the afternoon, using two different indoor swimming pools: the 800-m test was performed in a 50-m Olympic-size pool and the RST and the 25-m test in a 25-m X 15-m pool. The water temperature was 26°C and the air temperature was 26–28°C during all tests. In order to prevent the effects of fatigue on the study results, swimmers were instructed to avoid intense activity for 24 h before each test. Prior to each test, the swimmers performed a standard warm-up that included an 800-m swim and 4 x 15-m sprints, and then rested 15 min before starting the test. An electronic timing system (Omega RS 21, Vill, Switzerland), with an accuracy measurement of 1/1000 s, was used for recording time during each swim. The front crawl swimming style was used in all tests.

Repeated sprint test

All participants completed 8 repetitions of a 15-m all-out sprint (8 x 15m), each separated by a 30-s rest interval. This protocol was chosen to match typical activity pattern during water polo games (Smith, 1998), and was previously used for RST studies among swimmers (Meckel et al., 2012). The participants started each sprint in the water with a two-legged push from the wall. The participants were instructed to start swimming immediately after their feet disengaged from the wall, and to avoid diving under the water, as usually occurs when jumping off starting blocks. This procedure was practiced by the participants prior to testing. In addition, participants were informed that if these criteria will not be fulfilled test will be terminated and they will be required to restart the test again. Nevertheless, all participants fulfilled these criteria and none had to restart the test. During the rest periods between sprints the participants swam back slowly to the starting point, at an intensity corresponding to about 50% of their maximal speed. This speed was familiar to the participants, as they routinely used it for recovery during interval training sessions. This speed is also considered to be the slowest speed possible with the use of a proper swimming technique (Toubekis et al., 2008). After returning to the starting point, the participants took the starting position for the next sprint.

Heart rate was recorded immediately upon the completion of each sprint using a Polar heart rate monitor (Polar Accurex Plus, Polar Electro, Woodbury, NY). Blood lactate was taken from a fingertip two minutes after the completion of the RST using a portable lactate analyzer (Accusport, Boehringer Manneheim, Germany). Rating of perceived exertion (RPE) was determined using the modified 1–10 (1 being the easiest and 10 the hardest) Borg scale (Borg, 1982) immediately upon completion of the RST. Standard calibrated scales and stadiometers were used to determine height and body mass.

The three measures of the RST were the ideal 15-m swim time (IS), the total swim time (TS) of the 8 sprints, and the performance decrement (PD) during the test. Ideal sprint time was calculated as the fastest 15-m swim time

Table 1. Physiological responses and RPE following the repeated sprint test (RST), and swimming times of the study participants. Data are means (\pm SD).

	Swimmers (n=19)	Water polo players (n=16)
Post RST Heart rate (beats·min ⁻¹)	175 (9)	178 (9)
Post RST Blood Lactate (mmol·L ⁻¹)	8.0 (2.9)	8.8 (2.2)
Post RST RPE (1 - 10)	7.4 (1.2)	6.8 (4.0)
25-m swim time (s)	11.65 (.31)*	12.26 (.30)
800-m swim time (min)	9.43 (1.20) *	11.43 (1.10)

* p < 0.01

multiplied by 8. Total sprint time was calculated as the sum of all sprint times. PD was used as an indication of fatigue and was calculated as [(TS / IS) X 100] – 100 (Fitzsimons et al., 1993). The test-retest reliability of running RST was found to be 0.942 for total running time and 0.75 for PD (Bishop et al., 2001; Stewart and Hopkins, 2000).

Single short and long swim trials

The 25-m and the 800-m swim trials were performed according to official competition rules in order to determine the best performance time for these distances. While the 800-m trial started by jumping off starting blocks into the water, the 25-m trial started in the water with a two-legged push away from the wall. Similar to the RST procedure, in the 25-m trial the participants were instructed to start swimming immediately after their feet disengaged from the wall, and to avoid diving under the water. In order to simulate competitive-like conditions, the swimming trials were performed with groups of 4-5 participants according to the participants' personal records and current fitness level.

Statistical analyses

ANOVA was used to compare performance and physiological data between water polo players and swimmers. Pearson linear correlation analysis was used to evaluate the relationships between each of the RST indices (IS, TS, and PD) and the 25-m or the 800-m swimming times. Data are presented as mean \pm SD. Significance level was set at p < 0.05.

Results

The participants' physiological responses (heart rate and blood lactate concentration), RPE, and 25-m and 800-m swim times are presented in Table 1. Results for the 25-m swim and the 800-m swim were significantly faster in the swimmers compared to the water polo players. Performance indices of the swimming RST of the water polo players and swimmers are presented in Figure 1. IS and

TS were significantly faster and PD significantly lower among the swimmers compared to the water polo players.

We found significant correlation between the IS and TS in the RST and the times in the 25-m swimming trial among both water polo players and swimmers. There was no significant correlation between the PD in the RST and time in the 25-m swim trial (see Table 2). The relationships between the RST performance indices and the times in the 800-m swimming trial were not significant (Table 2). No correlation was found between the 25-m and 800-m swim results.

Discussion

The main findings of the present study were that, consistent with our first hypothesis, water polo players achieved lower scores in the single short- and long-swim distances compared to the swimmers. However, in contrast to our second hypothesis, water polo players exhibited poorer RSA compared to the swimmers (Figure 1). In addition, significant relationships were found between the 25-m swim results and the IS and the TS, but not the PD of both groups. No significant relationships were found between the 800-m swim results and any of the RSA indices in both groups.

The single short- and long-swim performance times were significantly slower among the water polo players compared to the swimmers. A few possible reasons may have collaborated to explain these findings. First, it has been reported that water polo players are less economical and have greater inter-individual variation in swimming economy during head-down linear front-crawl swimming, as performed in the present study, compared to competitive swimmers (Cazorla and Montpetit, 1988; Montpetit et al., 1983). At velocities ranging from 1.1 to 1.5 m/s, elite male water polo players were found to have approximately 6 to 20% greater oxygen consumption than competitive swimmers (Cazorla and Montpetit, 1988). Such differences may be a function of stroke technique and/or the physical characteristics of the participants which effect hydrodynamic drag or propulsion (Smith et

Table 2. Relationship between RST indices and 25-m swim time (upper panel), and between RST indices and 800-m swim time (lower panel) among elite water polo players and swimmers.

		Swimmers (n=19)	Water polo players (n=16)
25-m Swim	Ideal swim time	.58 *	.66 *
	Total swim time	.73 *	.59 *
	Performance decrement	.19	-.03
800-m Swim	Ideal swim time	.10	.06
	Total swim time	.38	.33
	Performance decrement	.42	.29

* p < 0.05

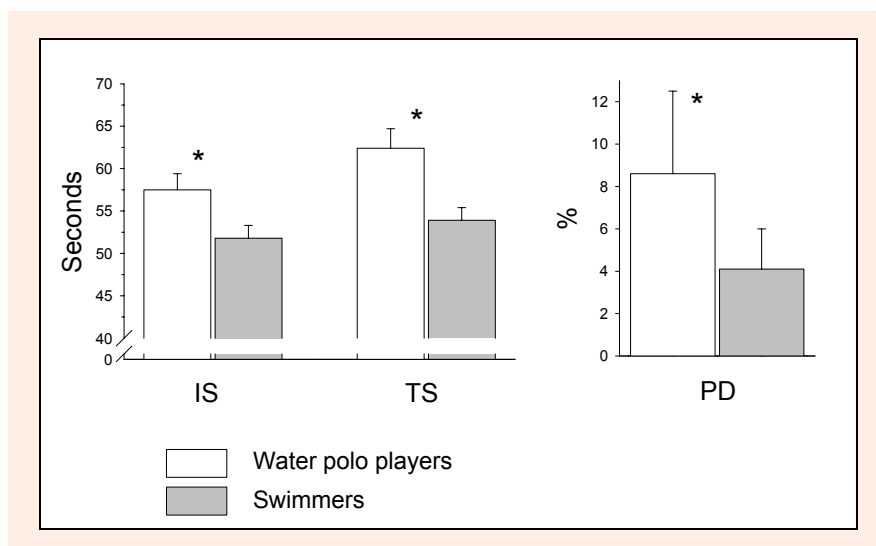


Figure 1. Repeated sprint test indices among elite water polo players and elite swimmers. IS = Ideal Sprint Time; TS = Total Sprint Time; PD = Performance Decrement

al., 1988; Toussaint and Hollander, 1994). In addition, the better performance of swimmers over water polo players in the continuous single short 25-m and long 800-m swim distances (Table 2) may reflect greater training experience and specific training adaptation. Swimmers tend to train more extensively, and to perform single efforts, while water polo players usually engage in intermittent activity during practice sessions and competitions. Although split times in the long-swim distances were not monitored in the present study, it may be assumed that, given their experience and practice differences, the swimmers execute better swim tactics than the players, adapting a better pacing strategy to maximize performance.

Despite the intermittent nature of water polo and the repeated intense activities performed in training and games, RSA was significantly lower among the water polo players compared to the swimmers. This was noted in all performance indices – IS, TS and PD (Figure 1). These findings may indicate that the superior head-down front-crawl swimming skill previously noted for swimmers compared to water polo players (Cazorla and Montpetit, 1988) may also influence repeated swimming sprints performance. It may also suggest that the overall better swimming performance and economy of swimmers has a greater influence on RSA than training mode, per se. The superiority of the swimmers over the players in RSA may also reflect the differences in training load between the two groups suggesting that the swimmers were better trained and this masked possible effect of specialized training. In addition, it should be noted that the single 25-m swim, the IS and the TS in the present study, rely largely on energy supply from the same source (e.g., PCr and Glycolysis). Therefore, although the water polo players are more accustomed to intermittent type of activity, the swimmers seems to possess better swimming skills allowing them to travel faster in the water in both single swimming events as well as in repeated sprints. Consistent with these observations, the significantly higher PD, despite slower swimming times, as well as the non-significant higher blood lactate and heart rate values of the water polo players compared to the swimmers in the

present swimming RST, may reflect the lower swimming economy, swimming skills and fitness of the water polo players compared to the swimmers. The higher PD of the water polo players compared to the swimmers may also be the result of the lower aerobic fitness (as reflected by the 800-m swim times) of the players and their inability to recover sufficiently between the sprints. Given the poorer IS, TS and PD of the water polo players, together with the intermittent nature of the game, the results of the present study may stress the need to improve RSA among water polo players.

There were significant correlations between the 25-m swim time and the TS or the IS (Table 2). These findings are in line with other RST studies that have investigated the relationships between RSA and anaerobic capabilities (Dawson et al., 1993; Mendez-Villanueva et al., 2007; 2008; Wadley and Le Rossignol, 1998). This may emphasize the important contribution of anaerobic metabolism to these exercise types in both water polo players and swimmers. These relationships, however, depend on specific performance variables, such as length and number of intervals, rest time, mode of exercise and the type of aerobic/anaerobic measure. For example, in a previous study (Meckel et al., 2012) we failed to find significant relationships between swimming RST (8 X 15-m) performance indices (IS, TS and PD) and 100-m swim time. This may be related to the fact that the 55-60 s 100-m swim relies largely on the glycolysis energy system, while the 11-12 s 25-m swim relies mostly on the ATP-CP phosphagen system for energy supply. Moreover, it has been documented that in a competitive event such as the 400-m run, with a performance time similar to the 100-m swim time (~50 seconds), the aerobic system contributes up to 40% of the total energy requirements (Duffield et al., 2005).

We did not find significant relationships between RSA and 800-m swim time (as an index of aerobic capacity) in either the swimmers or the water polo players (Table 2). Although the re-synthesis of phosphocreatine (PCr) and the recovery of sprint performance were found to be controlled by the rate of oxidative metabolism

within the muscle (Bogdanis et al., 1996; Tomlin and Wenger, 2001), the non-significant correlation between the 800-m swim time and any of the RST indices in the present study is in line with our previous swimming RSA study (Meckel et al., in press), as well as with other previous running and cycling RSA studies (e.g., Aziz and Chia, 2000; Meckel et al., 2009; Wadley and Le Rossignol, 1998), which reported non-significant to low correlations ($0.42 < r < 0.56$) between aerobic fitness and RSA. The low correlations between the two may be linked to the concept that PCr recovery appears to be mainly dependent upon peripheral muscle factors such as mitochondrial function (Bassett and Howley, 2000), while the major variable limiting VO_2 max is central cardiovascular factors, such as cardiac output to supply blood to the activating muscle. It has also been suggested that the ability to buffer H^+ may be a more important determinant of repeated sprint performance than VO_2 max (Bishop et al., 2004), and that the restoration of power output during repeated sprints may be influenced by the distribution of muscle fibers, the level of the lactate threshold, and the duration of the recovery period between sprints (Tomlin and Wenger, 2001).

Conclusion

The present study reports lower RSA and lower aerobic and anaerobic capabilities in elite water polo players compared to elite swimmers. Further studies to evaluate these capabilities, however, should use testing protocols that simulate the participant's sport-specific movement patterns. A 25-m swim trial significantly correlates with IS and TS, emphasizing the important contribution of anaerobic metabolism for these exercise types in both water polo players and swimmers. Consequently, 25-m swim results can be used to assess swimmers and water polo players' RSA. The lack of correlations between the 800-m swim results and the RSA or 25-m swim results demonstrates the great discrepancy in exercise-dependent energy sources between the long distance swim and the other two testing procedures.

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Key points

- Elite water polo players demonstrated lower repeated sprint ability (RSA), aerobic and anaerobic capabilities compared to elite swimmers.
- A 25-m swim trial correlated significantly with ideal sprint time and total sprint time, emphasizing the important contribution of anaerobic metabolism for these exercise types in both water polo players and swimmers.
- 800-m swim results did not correlate with RSA or 25-m swim results, demonstrating a discrepancy in exercise-dependent energy sources between the long distance swim and the other two testing procedures.

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