A Multistage Shuttle Swim Test to Assess Aerobic Fitness in Competitive Water Polo Players

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A 10m multistage shuttle swim test (MSST) was designed for the assessment of aerobic fitness of competitive water polo players. Test-retest reliability was determined using a sample of 22 female and 22 male trained water polo players. An intraclass correlation coefficient of 0.99 (p>0.05) was calculated between the two test scores. The technical error of measurement for the test was 2.3 shuttles or 5.0%. The validity of the test was determined using a sample of 13 female and 12 male water polo players. A validation correlation coefficient of 0.88 resulted between the number of shuttles completed during the MSST and VO₂max [litres/body surface area/ minute (l*BSA⁻¹.min⁻¹)] measured during an incremental tethered swim test to exhaustion. A stepwise multiple regression revealed that VO₂max (l*BSA⁻¹.min⁻¹) accounted for approximately 78% of the MSST variance. It was concluded that the 10m multistage shuttle swim test is a reliable and valid field test of aerobic fitness for use with trained water polo players.

Introduction

A water polo team consists of thirteen players, seven of which participate at any one time (six field players and one goalkeeper). The game requires all field players to be involved in both offence and defence and extends over four, seven minute quarters of actual playing time, often resulting in games lasting approximately 50 minutes, or in the case of extra time, for as long as 70 minutes. Although further investigation is required to confirm the energy demands imposed on water polo players during a game, research to date emphasises that a well developed aerobic energy system is an important requirement for elite water polo players (Goodwin & Cumming, 1966; Hohman & Frase, 1992; Lilley, 1982; Pinnington et al., 1988).

The direct measurement of cardiorespiratory fitness requires sophisticated equipment and trained personnel. Such tests are expensive, difficult to implement (especially when using a swimming protocol) and not practical for large groups of people (Ramsbottom et al., 1988). Field tests have been developed to assess aerobic fitness, whilst allowing a large group of subjects to be tested with relative ease and with minimal cost (Leger & Gadoury, 1989; Sproule et al., 1993), however these tests use running as the mode of exercise. To date there are few test batteries which have been developed specifically to assess the aerobic fitness of water polo players and the reliability and/or validity of these tests is unknown.
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(Australian Water Polo Incorporated, 1995; Petric, 1991). The purpose of this study was to develop a reliable and valid field test of aerobic fitness specifically for use with water polo players. The 20m multistage shuttle run test (Leger & Lambert, 1982; Leger et al., 1988) was used as a foundation for the development of the swimming shuttle test, based on its proven reliability and validity.

Methods

Pilot testing was conducted to determine the most appropriate shuttle distance for the Multistage Shuttle Swim Test (MSST). Distances of 8, 9 and 10m were trialled using 15 female and 11 male elite water polo players. Visual analysis of the results showed that a 10m distance provided the largest range of scores for the subjects. Increased distances were not assessed as a 10m distance seemed appropriate based on the spread of results and the time taken to complete each shuttle, relative to the MSRT.

The multistage shuttle swim test (MSST)

The subject swims a 10m distance within a progressively decreasing cued time frame. The timing is based on an audio cue where the interval between successive signals is reduced approximately every minute. The first level of the test requires a swimming velocity of 0.9 m·s⁻¹, which is increased by 0.05 m·s⁻¹ with each subsequent level. Lane ropes mark the boundaries of the test area to prevent the subjects from using the pool wall for assistance in turning. Subjects are required at the end of each shuttle to touch and immediately release the lane rope. They then remain stationary while awaiting the cue for the commencement of the next shuttle. The swimmer is given one warning if they fail to be within one arm stroke of the lane rope, prior to the audio cue for the next shuttle. The subject is removed from the test if they fail to be within one stroke of the lane rope on two consecutive occasions. The subject score is recorded as the last level and shuttle successfully completed.

The research project was divided into two parts:

Part 1: Assessment of the test-retest reliability of the MSST.

Part 2: Determination of the validity of the MSST as a field test of aerobic fitness.

The experimental protocol was approved by the Ethics Committee of the University of Western Australia and each subject signed a declaration of consent prior to the commencement of testing. For Part 1 of the study, the sample comprised 22 female and 22 male subjects, aged 15 years or over who were all current A grade water polo players. The mean age of the female and male subjects was 18.2±3.5 years and 16.3±1.1 years respectively. To establish the reproducibility of the MSST, each subject performed the test on three occasions following a standardised warm up, the first trial served as a familiarisation session. The two final tests were conducted in the subject’s normal training session, seven days apart. Each subject was asked to follow the same pre test protocol prior to each test. The pre test protocol required the subject to refrain from strenuous exercise on the day prior to testing and to avoid smoking, drinking alcohol, tea or coffee on the day of testing. The subject was also asked not to exercise in the three hours or eat in the two hours leading up to the test. No more than five subjects were tested at any one time and there was a minimum of one observer per three subjects participating. The same sub groups completed the MSST on each occasion, to counteract any socialisation effect (Weinberg & Gould, 1995).
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<table>
<thead>
<tr>
<th></th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Skinfold Sum* (8 sites - mm)</th>
<th>BSA** (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
<td>21.0</td>
<td>173.1</td>
<td>70.6</td>
<td>118.9</td>
<td>1.85</td>
</tr>
<tr>
<td>(n=13)</td>
<td>±3.8</td>
<td>±4.5</td>
<td>±8.9</td>
<td>±38.2</td>
<td>±0.10</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>16.3</td>
<td>180.7</td>
<td>73.9</td>
<td>76.7</td>
<td>1.94</td>
</tr>
<tr>
<td>(n=12)</td>
<td>±1.1</td>
<td>±5.3</td>
<td>±7.6</td>
<td>±20.9</td>
<td>±0.10</td>
</tr>
</tbody>
</table>

Table 1: Mean (±SD) physical characteristics of female and male subjects who completed part 2 of the project.

Twelve males and 13 females from Part 1 of the study volunteered as subjects for Part 2. The 12 male subjects were all members of the under 20 years Western Australian Institute of Sport (WAIS) water polo squad, the 13 female subjects comprised four A grade, six State level and three National level water polo players. Subject characteristics are documented in Table 1. This phase of the project required each subject to complete the MSST; a continuous, incremental tethered swim test to volitional exhaustion to determine \( \dot{V}O_2 \text{max} \); a timed 400m swim and a swimming sprint/ agility test. Each subject completed a 200m (slow freestyle swim) warm up, followed by five minutes of stretching prior to starting each test. Test order was randomly assigned and all tests were completed within three weeks to minimise any variance caused by a change in fitness status.

The sprint/agility test and the MSST were the only tests completed on the same day. The sprint/agility test was always performed first, with a 5 to 10 min recovery period given prior to the commencement of the MSST. The two remaining tests were performed on separate days. All four tests were completed at approximately the same time of day to account for any circadian variation (Winget et al., 1985).

For the MSST, tethered swim and 400m swim, heart rate was measured immediately post test using a Sports Tester (Polar Electro PE4000) heart rate monitor. Capillary blood was collected from a hyperaemic earlobe at one and three min post - exercise, for the determination of blood lactate concentration. All samples were stabilised, capped and stored on ice and analysed within one to two hours of collection, using an Analox LM3 Multi-Channel analyser which was calibrated across the operational range.

**Sprint/agility test**

Each subject completed three trials of a sprint/agility test (the best result was reported). The test was performed within the confines of the 10m boundaries of the MSST. Each subject was instructed to start the test with their head positioned on the lane rope (starting body posture was selected by the subject), then swim to and touch the opposite lane rope with their hand, turn around and swim back to the original lane rope as fast as possible. Two markers were placed at 3m and 7m from each lane rope, on either side of the pool. A Panasonic DP800H (VHS) camcorder was positioned and set to record each trial. The subject started the test on a visual cue stimulated by the pressing of a button, which provided an electrical pulse to illuminate a 10mm ultra bright LED positioned in the camcorder field of view.
The video tape was later analysed using a FORA VTG video timer. Time was recorded to the nearest 0.05 s, when the subject’s head broke the line on the monitor at 3m, 7m and again at the 7m mark following the turn. This test provided data on acceleration (0-3m), maximal swimming speed (3-7m) and agility (7-10-7m) for each subject (Draper & Lancaster, 1985).

**Tethered swimming test**

A swimming ergometer as described by Costill (1966) was used for the tethered swimming test. Maximal oxygen consumption was assessed using an on-line gas analysis system consisting of an Applied Electrochemistry Oxygen Analyser (S-3A), Carbon Dioxide analyser (CD-3A) and a Morgan ventilometer. The analysers and ventilometer were calibrated prior to each test and their accuracy verified following each test.

**400m swimming test**

Each subject performed an individual 400m timed swim in a 50m swimming pool. The subject was instructed to complete the distance in the fastest possible time and was allowed to adopt their own pacing strategy. The stopwatch was started when the subject’s feet left the wall and stopped when their hand touched the wall at the completion of the 400m. Subjects were permitted to do tumble turns.

**Treatment and analysis of data**

Statistical significance was set at p<0.05 for all analysis. An intraclass correlation coefficient was calculated (test 1 v test 2 - post familiarisation trial) to determine the reliability of the MSST. A one way repeated measures analysis of variance (ANOVA) was used to determine if there was a significant difference between the first and second test scores. Technical error of measurement (TEM) (Knapp, 1992) for the MSST was also assessed. The TEM will allow people who administer the test to discriminate between a real change in individual performance, versus a change that may be associated with measurement error and expected biological variation.

For Part 2 of the study, Pearson Product-moment correlation coefficients were calculated to determine the degree of association between the MSST score, the tethered swim VO2max and the 400m swim time. A multiple regression was also performed, using the number of shuttles completed in the MSST as the dependent variable and VO2max, acceleration, maximal swimming speed, turning time and total time from the sprint/agility test as the independent variables.

**Results**

**Part 1: reliability**

For the pooled data (n = 44) the mean (±SD) number of shuttles completed on the first test was 46.2 (±14.2), and on the second test 47.1 (±14.4). Results from a repeated measures ANOVA showed no significant difference between the two trials (p>0.05). An intraclass correlation coefficient of 0.99 (p<0.05) was calculated between the two test results and the TEM was 2.3 shuttles or 5.0%.

The data was also analysed for any gender effect. For the 22 female subjects the mean (±SD) number of shuttles completed was 39.2 (±10.5) and 40.2 (±10.0) for the first and second MSST trials respectively. No significant difference (p>0.05) between the two trials was determined using a repeated measures ANOVA. An intraclass correlation coefficient of 0.98 (p<0.05) was established and a TEM of 1.8 shuttles, or 4.4% was calculated for female subjects performing the MSST.
<table>
<thead>
<tr>
<th>Sample Group</th>
<th>Number of Shuttles</th>
<th>MSST Peak HR (bpm)</th>
<th>MSST Peak Hla (mmol·l⁻¹)</th>
<th>VO₂max (1·BSA⁻¹·min⁻¹)</th>
<th>VO₂max (1·min⁻¹)</th>
<th>Tethered Swim VO₂max (ml·kg⁻¹·min⁻¹)</th>
<th>Peak HR (bpm)</th>
<th>Peak Hla (mmol·l⁻¹)</th>
<th>400m Swim Time (s)</th>
<th>Peak HR (bpm)</th>
<th>Peak Hla (mmol·l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n=25)</td>
<td>48.8 (±16.4)</td>
<td>178 (±8)</td>
<td>8.4 (±2.2)</td>
<td>1.95 (±0.27)</td>
<td>3.70 (±0.64)</td>
<td>51.3 (±7.0)</td>
<td>178 (±9)</td>
<td>8.4 (±2.3)</td>
<td>318.1 (±34.4)</td>
<td>173 (±10)</td>
<td>9.1 (±2.6)</td>
</tr>
<tr>
<td>Females (n=13)</td>
<td>40.9 (±11.7)</td>
<td>176 (±8)</td>
<td>8.9 (±2.5)</td>
<td>1.76 (±0.14)</td>
<td>3.25 (±0.34)</td>
<td>46.4 (±5.1)</td>
<td>178 (±5)</td>
<td>8.9 (±2.5)</td>
<td>333.4 (±32.4)</td>
<td>171 (±11)</td>
<td>9.7 (±3.3)</td>
</tr>
<tr>
<td>Males (n=12)</td>
<td>57.5 (±16.7)</td>
<td>181 (±8)</td>
<td>7.8 (±1.7)</td>
<td>2.15 (±0.21)</td>
<td>4.18 (±0.53)</td>
<td>56.6 (±4.5)</td>
<td>177 (±12)</td>
<td>8.1 (±1.5)</td>
<td>302.8 (±30.4)</td>
<td>174 (±9)</td>
<td>8.5 (±1.7)</td>
</tr>
</tbody>
</table>

Note: * = p<0.05; significantly different from MSST and tethered swim values. # = p<0.05; significantly different from MSST and tethered swim values.
+= p<0.05; significantly different from MSST and tethered swim values.

Table 2: Mean (±SD) results for trained water polo players who completed the multistage shuttle swim test, tethered swim test and 400m swim test in Part 2.

<table>
<thead>
<tr>
<th>Acceleration Time (s)</th>
<th>Max Swim Speed Time (s)</th>
<th>Turning Time (s)</th>
<th>Total Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males (n=12)</td>
<td>2.38 (±0.24)</td>
<td>2.59 (±0.19)</td>
<td>3.64 (±0.41)</td>
</tr>
<tr>
<td>Females (n=13)</td>
<td>2.53 (±0.20)</td>
<td>2.71 (±0.13)</td>
<td>3.93 (±0.29)</td>
</tr>
<tr>
<td>Males (n=12)</td>
<td>2.20 (±0.15)</td>
<td>2.45 (±0.15)</td>
<td>3.32 (±0.26)</td>
</tr>
</tbody>
</table>

Table 3: Mean (±SD) acceleration time (0-3m), maximal swimming speed time (3.7m), turning time (7-10-7m) and total time for trained water polo players recorded in the sprint/agility test.
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<table>
<thead>
<tr>
<th></th>
<th>MSST VO₂max (1+BSA⁻¹min⁻¹)</th>
<th>MSST VO₂max (ml·kg⁻¹·min⁻¹)</th>
<th>MSST 400m Swim Time</th>
<th>400m Swim Time</th>
<th>400m Swim Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>0.883</td>
<td>0.826</td>
<td>0.825</td>
<td>0.931</td>
<td>0.767</td>
</tr>
<tr>
<td>(n=25)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>0.774</td>
<td>0.508</td>
<td>0.854</td>
<td>0.925</td>
<td>0.575</td>
</tr>
<tr>
<td>(n=13)</td>
<td>(p=0.002)</td>
<td>(p=0.076)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.051)</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>0.924</td>
<td>0.900</td>
<td>0.733</td>
<td>0.938</td>
<td>0.856</td>
</tr>
<tr>
<td>(n=12)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
<td>(p=0.000)</td>
</tr>
</tbody>
</table>

Table 4: Pearson product-moment correlations (with reported significance) between the multistage shuttle swim test (number of shuttles), VO₂max and the 400m swim test.

For the 22 male subjects the mean (±SD) number of shuttles completed was 53.2 ±14.2 and 54.0 ±15.0 for the first and second tests respectively. Repeated measures ANOVA results showed no significant difference between the two trials (p>0.05). An intraclass correlation coefficient of 0.98 (p<0.05) was calculated between the two test results and the TEM for male subjects was 2.8 shuttles or 5.2%.

**Part 2: Validity**
The MSST, tethered swim and the 400m test results are presented in Table 2. The pooled results showed that peak heart rate measured after both the MSST and tethered swim was significantly higher than that measured after the 400m swim (p<0.05). There was no significant difference between the peak blood lactate results, measured following the MSST, tethered swim and the 400m swim. The sprint/agility test results are reported in Table 3 and the correlation results between the MSST, tethered swim and the 400m swim are summarised in Table 4.

A stepwise multiple regression determined that for the pooled data VO₂max (ml·kg⁻¹·min⁻¹) accounted for approximately 78% (p<0.05) of the total MSST variance. For the female subjects two other variables, VO₂max (ml·kg⁻¹·min⁻¹) and total sprint/agility test time, together accounted for approximately 83% (p<0.05) of the variance of the MSST. For the male group VO₂max (ml·BSA⁻¹·min⁻¹) alone accounted for approximately 85% (p<0.05) of the MSST variance.

**Discussion**
**Reliability of the multistage shuttle swim test**
The test-retest results indicate that the MSST is a reliable test for use with both female and male populations (r = 0.98 and r = 0.98 respectively). The reliability of the MSST score is similar to that reported for the multistage shuttle run test (MSRT) (r = 0.95) (Leger et al., 1988). A MSST TEM score of 2.3 shuttles (5.0%), 1.8 shuttles (4.4%) and 2.8 shuttles (5.2%) was reported for the pooled, female and male results respectively. There are no reports in the literature of TEM scores for the MSRT, however unpublished data collected by the Australian Laboratory Standards Assistance Scheme (1994) reported a TEM score for two state sports
institutes. The average TEM reported was 1.8 shuttles (3.2%), a similar result to that found for the MSST.

**Validation of the multistage shuttle swim test as a measure of aerobic fitness**
The validity of a field test can be determined by concurrently measuring field test performance and a criterion measure, and by statistically assessing the relationship between the test scores. The direct assessment of VO$_2$max is the criterion measure of aerobic power, a parameter strongly associated with aerobic fitness. To validate the MSST, 25 subjects performed the MSST and a graded tethered swim with direct measurement of oxygen consumption. The MSST score was then correlated with VO$_2$max.

Heart rate and blood lactate was measured following the MSST, VO$_2$max test and the 400m swim (Table 2). For the pooled group the mean peak heart rate reported for the MSST and VO$_2$max test were not significantly different but were both significantly higher than for the 400m swim (p<0.05). The difference seen in mean peak heart rate may be explained by the incremental nature of the MSST and VO$_2$max test, compared to the self pacing strategy which was adopted for the 400m swim. Self pacing may have resulted in a less than maximal effort, particularly towards the latter stages of the swim and subsequently lower heart rates. No significant difference was identified between the peak blood lactate results following each test, suggesting that the contribution from the anaerobic (lactic) energy system was similar between the three tests.

Maximal oxygen consumption was reported in units of l·min$^{-1}$, ml·kg$^{-1}$·min$^{-1}$ and l·BSA$^{-1}$·min$^{-1}$. Generally, for weight supported exercise (such as swimming) VO$_2$max is expressed as an absolute value (l·min$^{-1}$), although reports of VO$_2$max relative to body mass (ml·kg$^{-1}$·min$^{-1}$) are also common. Chatard et al. (1990) indicated that swimming resistance is influenced by body surface area. Resistance to movement whilst changing direction during the MSST would also be largely influenced by the body surface area of the subject. Hence VO$_2$max was also reported relative to body surface area (l·BSA$^{-1}$·min$^{-1}$).

Mean VO$_2$max for male water polo players in this study (4.18 l·min$^{-1}$ and 56.6 ml·kg$^{-1}$·min$^{-1}$), was comparable to that reported for trained male swimmers during tethered swimming by Magel and Faulkner (1967) (4.27 l·min$^{-1}$ and 54.7 ml·kg$^{-1}$·min$^{-1}$); although somewhat lower than the mean VO$_2$max reported by Pinnington et al. (1988) for elite male water polo players (4.90 l·min$^{-1}$ and 61.0 ml·kg$^{-1}$·min$^{-1}$). Pinnington et al. (1988) used state senior level players as subjects, compared to state under 20 level subjects, hence a slightly higher VO$_2$max would be expected. There are no reports of maximal oxygen consumption measured in trained female water polo players, other than those presented in the current study (Table 2).

The correlation coefficients determined between the MSST and VO$_2$max (Table 4) were similar to those reported for the MSRT versus VO$_2$max (r = 0.87 and r = 0.84) (Leger & Gadoury, 1989 and Ramsbottom et al., 1988). The strong correlations calculated in the current study indicate that the MSST is a valid field test of aerobic fitness for trained water polo players.

Some differences in correlations were evident between genders. For the male subjects the absolute VO$_2$max provided a stronger correlation with the MSST than did the score of VO$_2$max in ml·kg$^{-1}$·min$^{-1}$; a result expected due to the weight supported nature of the activity. For the female subjects VO$_2$max relative to body
mass correlated higher with MSST than the absolute measure of $\dot{V}O_2_{\text{max}}$. For the female subjects, body mass and skinfold sum ranged 31.4kg and 124.5mm respectively. In comparison, male subject size was more uniform with mass and skinfold total ranging 25.0kg and 66.9mm respectively. The weaker relationship between absolute measures of aerobic power to MSST performance in females than in males, may relate to the greater variation in body size and composition in the female group. Female subjects who had a large body mass and attained a high $\dot{V}O_2_{\text{max}}$ (l•min$^{-1}$) in the tethered swimming test, may have been unable to utilise their physiological potential to perform well in the MSST due to a large proportion of their body composition being ineffective mass. When female body mass and body surface area was taken into consideration and relative measures of $\dot{V}O_2_{\text{max}}$ were assessed, the strength of the correlation to MSST performance was increased. For the pooled data the highest correlation result ($r = 0.88$) was calculated between the MSST and $\dot{V}O_2_{\text{max}}$ (l•BSA$^{-1}$•min$^{-1}$). Because swimming resistance is largely determined by body surface area (Chatard et al., 1990) and given the activities involved in the MSST (ie. swimming and turning), as well as the large variation in body size and composition of the subjects, the expression of $\dot{V}O_2_{\text{max}}$ with reference to body surface area may be the best method of comparison for the pooled group.

The validity of the $\dot{V}O_2_{\text{max}}$ measure relative to BSA was further supported when a stepwise multiple regression was performed. For the pooled data, $\dot{V}O_2_{\text{max}}$ (l•BSA$^{-1}$•min$^{-1}$) accounted for approximately 78% ($p<0.05$) of the total MSST variance. When only male results were entered into a stepwise multiple regression, the amount of MSST variance $\dot{V}O_2_{\text{max}}$ (l•BSA$^{-1}$•min$^{-1}$) accounted for was slightly greater (~85%, $p<0.05$). Stepwise multiple regression analysis of the female results revealed that two different variables accounted for the majority of MSST variance. Both $\dot{V}O_2_{\text{max}}$ (ml•kg$^{-1}$•min$^{-1}$) and total time taken for the sprint/agility test accounted for approximately 83 % of the total MSST variance.

Towards the latter stages of the MSST, aerobic power may not be the limiting factor for female subject’s in maintaining the required pace. Variables involved in the total time to complete the sprint/agility test also affect the final result. These variables may include a combination of turning ability, speed and anaerobic power. Efficient turning and acceleration would depend on both technique and strength.

No previous MSRT research has attempted to explain the test variance not accounted for by aerobic power. The sprint/agility test results in the current project were used to determine whether the subjects swimming speed, acceleration and turning ability would have a significant impact on their MSST score. This was apparent for the female subjects and should be taken into consideration when interpreting results of the MSST.

Currently a 400m swim is used by Australian Water Polo Incorporated (1995) to determine the aerobic fitness of elite water polo players. For pooled data the correlations between the 400m swim time and $\dot{V}O_2_{\text{max}}$ were significant, but were lower than the significant correlations reported between the MSST and $\dot{V}O_2_{\text{max}}$ (Table 4). The results indicate that for trained water polo players the MSST is a better field test of aerobic fitness than the 400m swim, as it demonstrates greater criterion and logical validity for water polo and permits large groups of players to be tested at one time. Therefore the MSST would be an appropriate replacement for the 400m swim.
Conclusion
Aerobic fitness has been identified by previous researchers as an integral requirement of competitive water polo players (Hohmann & Frase, 1992; Lilley, 1982; Pinnington et al., 1988). The primary purpose of this study was to develop a reliable and valid field test of aerobic fitness for water polo players.

The test-retest results demonstrate that the MSST is a reliable test. The correlations reported between the MSST score and $VO_2\text{max}$ indicate that the MSST is also a valid method for testing aerobic fitness in trained water polo players. The strength of the MSST as a test of aerobic fitness has been demonstrated via its validity and reliability, however it should be remembered that the sample was limited to elite water polo players. The MSST may not be a valid or reliable test for inexperienced water polo players as skill may affect MSST score more so than $VO_2\text{max}$. For elite level water polo players, test specificity is an important consideration and the intent of this study was to trial a test specifically for use with this population. Further research is suggested to determine whether the MSST is suitable for lesser-trained players.

On the basis of the results and within the limitations of this study, it may be concluded that the MSST can provide the trained water polo player and coach with a simple and inexpensive, yet valid and reliable tool for monitoring aerobic fitness.

References
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