The Water-Polo Intermittent Shuttle Test: A Match-Fitness Test for Water-Polo Players

Iñigo Mujika, Greg McFadden, Mark Hubbard, Kylie Royal, and Allan Hahn

**Purpose**: To develop and validate an intermittent match-fitness test for water-polo players. **Methods**: Eight male junior players performed the Water Polo Intermittent Shuttle Test (WIST) twice to assess test reliability. To assess test sensitivity and validity, 104 male and female players from different competition standards and playing positions were tested. Eighteen players performed the WIST 5 times throughout a season to track fitness changes. Twelve players performed the WIST 48 hours before 4 consecutive National League games, and coaches awarded individual match-fitness scores based on game performances to assess the relationship between match fitness and test results. Heart rate (HR) and blood lactate ($L_a^\text{blood}$) were measured during and after each test, respectively. **Results**: Test–retest performance values were $216 \pm 90$ vs $229 \pm 96$ m ($r = .98$, $P = .0001$, coefficient of variation [CV] = 5.4%), peak HR $190 \pm 8$ vs $192 \pm 10$ bpm ($r = .96$, $P = .0002$, CV = 1.2%), and $L_a^\text{blood}$ $7.0 \pm 1.8$ vs $6.4 \pm 1.6$ mmol/L ($r = .84$, $P = .0092$, CV = 8.8%). Significant differences were observed among different standards of play (range junior regional females $102 \pm 10$ m, senior international males $401 \pm 30$ m) and playing positions (field players $305 \pm 154$ m, center forwards $255 \pm 118$, goal keepers $203 \pm 135$ m). Test performance was lower in the early season ($344 \pm 118$ m) than the remainder of the season (range $459 \pm 138$ to $550 \pm 176$ m). WIST performance and match-fitness scores correlated for all field players ($r = .57$, $P = .054$) but more highly for field players other than center forwards ($r = .83$, $P = .0027$). **Conclusions**: The WIST is a reliable, sensitive, and valid match-fitness test for water-polo players. It could become a useful tool to assess the effects of different interventions on match fitness. **Key Words**: intermittent exercise, recovery, reliability, validity, performance

Water polo is a team sport characterized by a high-intensity, intermittent activity pattern. Players have been reported to perform around 100 high-intensity and sprint activities during water-polo match play, with durations ranging from 7 to 14 seconds. These bursts of intense activity are interspersed with lower intensity activities of similar or slightly longer duration. Insight into the cardiovascular and metabolic demands of the sport provided by simple physiological measurements such as heart

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rate and blood lactate also indicates that high demands are placed on both aerobic and anaerobic metabolic pathways during match play.\textsuperscript{5-9} In view of these observations, it seems clear that any performance test aiming to assess a player’s physiological capabilities should take into account the intermittent nature of the game and try to mimic the metabolic demands of its intense exercise/recovery activity pattern.

Intermittent performance tests have been developed and validated to assess match fitness in several land-based team sports such as soccer.\textsuperscript{10-14} Some of these tests have been used to assess the performance capabilities of players and referees\textsuperscript{11,13,15,16} and to evaluate the effects of various training\textsuperscript{13,15} and nutritional\textsuperscript{12,17,18} interventions on fitness and performance.

Recently, a multistage shuttle swim test became available to assess the aerobic fitness of water-polo players. Performance on this test was shown to correlate well with maximal oxygen uptake as determined during an incremental tethered swim test to exhaustion, thus providing a fair estimation of a player’s aerobic fitness.\textsuperscript{19} The test failed, however, to account for the intermittent activity pattern observed in match play, limiting its validity as a tool to assess match fitness of water-polo players. The aim of this study was to develop an intermittent match-fitness field test for water-polo players and assess its reliability, sensitivity, and validity. The new test, called the Water Polo Intermittent Shuttle Test (WIST), is based on the Yo-Yo Intermittent Recovery Test (level 1), which consists of repeated $2 \times 20$-m running bouts performed at progressively increasing speeds controlled by audio signals, interspersed with 10-second active recovery periods and performed until exhaustion.\textsuperscript{10,13} This test has been shown to be reliable, sensitive, and a valid measure of match fitness in soccer players\textsuperscript{13,16} and referees.\textsuperscript{15}

**Methods**

This investigation was conducted in 4 phases, including a test reliability phase and 3 phases to assess test sensitivity and validity: comparison among different standards of competition and playing positions, tracking seasonal fitness changes, and assessing the relationship between test performance and match performance. Various groups of players, whose physical characteristics are presented in Table 1, were involved in the different phases of the investigation. All participants were thoroughly informed of the experimental procedures, possible discomfort, and potential risks associated with the investigation before giving their written consent to take part. The testing procedures were approved by the Australian Institute of Sport’s ethics committee.

**The Water-Polo Intermittent Shuttle Test (WIST)**

The WIST consists of repeated $2 \times 7.5$-m swims out and back at progressively increasing speeds, also controlled by audio signals. Shuttle distance is delimited by 2 lane ropes 7.5 m apart and at least 2.0 m away from the pool walls to keep the players from pushing off at the start of each shuttle or after turning. Subjects are instructed to start swimming from a stationary position, with their head by the lane rope, “as they would in a match swim-off,” when they hear the initial audio signal. They are also instructed to adjust their swimming speed to reach the turning lane rope in time with a second signal, touch and immediately release the lane
rope, turn as quickly as possible, and swim back to get to the start/finish lane rope in time with a third audio signal. Players are free to swim with their head in or out of the water, but they need to take it out when approaching the turn and finish in order to hear the audio signals. At the end of each out-and-back shuttle, they are required to wait for the next shuttle in an unsupported stationary position, “ready for a new swim-off.” Active recovery time between shuttles is 10 seconds. Players are given a warning if they fail to be within 1 arm stroke of the start/finish lane rope when the third audio signal is heard, and they are eliminated from the test when they fail a second time. When a player is eliminated from the test, the final level that they started is recorded, and this is converted to total distance in meters, which is the test result. The test begins with 4 shuttles at 1.03 to 1.36 m/s, followed by 7 shuttles at 1.43 to 1.46 m/s. Thereafter, speed increases by 0.05 m/s every 8 shuttles until a player can no longer keep up with the required speed.

### Reliability of the WIST

Eight junior players from the 2003 Australian Capital Territory Academy of Sport Water Polo Program (Table 1) were involved in this phase of the study. Players performed the WIST on 3 occasions, 48 hours apart. The first test was used as a familiarization trial, whereas the second and third were used to assess the reliability of the WIST. Training sessions on the day before each trial were matched for duration and intensity, and players were instructed to refrain from any strenuous exercise on the day of the trials and to maintain a consistent diet for the duration of the intervention. All 3 tests were preceded by a standardized warm-up consisting of 10 minutes of dry-land stretching and dynamic articular mobility exercises; 4 × 100-m front-crawl swims with water-polo turns (no push off the wall) every 25 m, start every 110 seconds; and 4 × 25-m swims (12.5-m sprint, 12.5-m recovery), start every 50 s.

### Table 1 Physical Characteristics of the Subjects Participating in the Different Phases of the Investigation, Mean ± SD

<table>
<thead>
<tr>
<th>Phase</th>
<th>n</th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>8</td>
<td>17.0 ± 1.1</td>
<td>178.8 ± 6.9</td>
<td>73.3 ± 7.8</td>
</tr>
<tr>
<td>Group comparison</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>junior regional females</td>
<td>9</td>
<td>16.0 ± 1.5</td>
<td>165.3 ± 9.0</td>
<td>65.8 ± 11.3</td>
</tr>
<tr>
<td>junior regional males</td>
<td>10</td>
<td>16.4 ± 1.3</td>
<td>181.2 ± 8.3</td>
<td>71.2 ± 9.3</td>
</tr>
<tr>
<td>junior state males I</td>
<td>6</td>
<td>16.2 ± 1.5</td>
<td>181.5 ± 8.2</td>
<td>69.2 ± 6.0</td>
</tr>
<tr>
<td>junior state males II</td>
<td>8</td>
<td>17.0 ± 1.1</td>
<td>178.8 ± 6.9</td>
<td>73.3 ± 7.8</td>
</tr>
<tr>
<td>junior elite males</td>
<td>18</td>
<td>17.6 ± 0.5</td>
<td>187.4 ± 6.1</td>
<td>85.6 ± 6.2</td>
</tr>
<tr>
<td>senior national males</td>
<td>12</td>
<td>24.5 ± 4.3</td>
<td>181.8 ± 3.3</td>
<td>81.9 ± 9.0</td>
</tr>
<tr>
<td>senior elite females</td>
<td>22</td>
<td>23.4 ± 2.9</td>
<td>174.1 ± 5.1</td>
<td>68.8 ± 7.8</td>
</tr>
<tr>
<td>senior elite males</td>
<td>19</td>
<td>22.7 ± 3.4</td>
<td>189.0 ± 6.5</td>
<td>88.8 ± 8.3</td>
</tr>
<tr>
<td>Seasonal changes</td>
<td>18</td>
<td>17.1 ± 0.5</td>
<td>183.4 ± 6.4</td>
<td>79.1 ± 9.4</td>
</tr>
<tr>
<td>Performance relationship</td>
<td>12</td>
<td>16.9 ± 0.5</td>
<td>183.0 ± 5.6</td>
<td>78.6 ± 8.3</td>
</tr>
</tbody>
</table>
All trials were conducted at the Australian Institute of Sport’s indoor 50-m pool, at the same time of the day (8 pm) and under similar environmental conditions: water temperature 26.9 to 27.1 °C (Digi-Thermo, IMO Controls International, Seven Hills, NSW, Australia), ambient temperature 21.4 to 23.5 °C, and relative humidity 49.9% to 63.2% (Kestrel 4000 Pocket Weather Tracker, Nielsen Kellerman, Boothwyn, Pa, USA). Players were instructed and encouraged to provide a maximal effort on each occasion by the same investigator. Four subjects swimming in parallel were tested at a time, and the same subgroups were maintained in each testing session.

**WIST Results for Different Standards of Competition and Playing Positions**

A total of 104 players participating in different standards of competition were tested in this phase of the investigation. These included novice schoolgirls and schoolboys from Queensland Country, Australia, defined in this study as junior regional females (n = 9) and junior regional males (n = 10); junior players from the Spanish club Larraina (junior state males I, n = 6); junior players from the Australian Capital Territory Academy of Sport Water Polo Program 2003 (junior state males II, n = 8); the scholarship holders from the Australian Institute of Sport Water Polo Program 2003 (junior elite males, n = 18); senior players from the Spanish first-division team Larraina 2003–2004 (senior national males, n = 12); members of the Australian National female squad 2004 (senior elite females, n = 22); and members of the Australian National male squad 2003 (senior elite males, n = 19). Physical characteristics of the different groups of players are reported in Table 1. To assess possible differences between playing positions, data from all these groups were pooled, and comparisons were made between field players (n = 70) other than center forwards (n = 16) and goalkeepers (n = 18).

Because of limited access to the different players involved, no familiarization trials could be carried out in this phase of the investigation, but all groups received identical verbal explanations before being tested with the WIST, performed an identical standardized warm-up (described previously), and were tested and received verbal encouragements to provide a maximal effort by the same investigator. Junior state males I and senior national males were tested in an indoor 25-m pool, and senior elite females, in an outdoor 50-m pool. All other groups were tested at the Australian Institute of Sport’s indoor 50-m pool. Within each squad, players were randomly distributed and tested in groups of 3 to 5 athletes.

**Tracking Seasonal Fitness Changes With the WIST**

Eighteen junior elite players, all scholarship holders at the Australian Institute of Sport in 2004 (Table 1), took part in this phase of the investigation. Players performed the WIST 5 times throughout the 2004 season, always immediately after the previously described standardized warm-up: February, within 1 week of entering the program; April, at the end of the 2004 Australian National League season, 2 months into the program; June, after 2 months of intensive training with a focus on aerobic fitness and muscular hypertrophy; October, immediately after 2 weeks of reduced training; and November, after a match-specific training phase in preparation for the 2004 Sydney Metropolitan Competition. Players were randomly distributed and tested in parallel in groups of 3 to 5 athletes.
Relationship Between WIST Performance and Match Performance

Twelve junior elite players, all field players and scholarship holders at the Australian Institute of Sport 2004 (Table 1), participated in this phase of the investigation. Two days before the first of a 4-match series representing the last matches of the 2004 Australian National League season, players performed the WIST. Players were randomly distributed and tested in 3 groups of 4 athletes. Testing took place between 5:00 and 5:45 pm at the Australian Institute of Sport’s indoor 50-m pool, after a standardized warm-up (previously described). No physiological measures were obtained during or after the test.

At the end of the National League season, the 2 team coaches were asked to provide a single list ranking the players from 1 to 12, based on subjective estimates of current water-polo fitness obtained from the 4-match series. When making these rank-order lists, the coaches were unaware of what they would be used for, and they had no access to the WIST results attained by the players 2 days before the series. Players were awarded match-fitness scores in reverse order, ranging from 12 points to 1 point, so that the player at the top of the rank-order list received a score of 12 points and the player at the bottom of the list received only 1 point. These scores were used to assess the correlation between the WIST results and current match fitness.

Heart Rate

Heart rate (HR) was continuously monitored throughout most of the testing sessions (Polar S610 Heart Rate Monitor, Polar Electro, Kempele, Finland). The transmitter was secured around each athlete’s chest with 7.5-cm-wide waterproof adhesive tape (Sleek, Smith & Nephew Medical Fabrics Ltd, Brierfield, England).

Blood Lactate

Immediately after completing the WIST in most testing sessions, each player exited the pool and a 5-µl capillary blood sample was taken from his or her earlobe, which was analyzed for lactate concentration (La\textsubscript{blood}) (Lactate Pro, Arkray Factory Inc, Shiga, Japan).

Statistical Analysis

All statistical analyses were performed with StatView SE and SuperANOVA (Abacus Concepts Inc, Berkeley, Calif). Reported values are means and SDs unless otherwise stated. Correlations between variables were calculated from linear regression. Typical error of measurement and 95% confidence limits were calculated for reliability measures. The coefficient of variation, calculated as the SD of repeated measures divided by the mean and multiplied by 100, was used as a measure of test reliability. Differences between groups were assessed using a 2-factor analysis of variance, with standard of competition and playing position as the 2 factors. When appropriate, Scheffé’s post hoc procedure was used to identify the differences. A multiple paired $t$ test with Bonferroni correction was used to determine significant differences among repeated trials, using the initial trial as the reference value. The level of statistical significance was set at $P < .05$. 
Results

Reliability of the WIST

Mean ± SD values for reliability trials 1 and 2 were as follows (Figure 1): WIST performance 216 ± 90 versus 229 ± 96 m; typical error of measurement (TEM) 13 m; peak HR 190 ± 8 versus 192 ± 10 bpm; TEM 2 bpm; $\text{La}_{\text{blood}}$ 7.0 ± 1.8 versus 6.4 ± 1.6 mmol/L; and TEM 0.7 mmol/L.

![Figure 1](image-url) — Test–retest reliability of the (A) Water Polo Intermittent Shuttle Test performance, (B) peak heart rate, and (C) posttest blood lactate concentration. Dashed line is the identity line ($x = y$).
WIST Results in Different Standards of Competition

Figure 2 shows that the best WIST performance was achieved by senior elite males (401 ± 30 m), followed by junior elite males (379 ± 33 m), senior national males (324 ± 42 m), senior elite females (260 ± 22 m), junior state males II (204 ± 33 m), junior state males I (185 ± 17 m), junior regional males (137 ± 23 m), and junior regional females (102 ± 10 m). Significant differences were observed among groups (Figure 2). Peak HR was not significantly different among groups (Table 2). Junior elite males had significantly higher post-WIST $\text{La}_{\text{blood}}$ than all other groups except senior national males and junior state males II, and the latter also had higher values than senior elite females and junior regional females (Table 2).

WIST Results in Different Playing Positions

Field players covered the most distance in the WIST (305 ± 154 m), followed by center forwards (255 ± 118 m) and goalkeepers (203 ± 135 m), with the difference between field players and goalkeepers reaching statistical significance ($P = .0276$). No significant differences among positions were observed in peak HR (field players 184 ± 10, center forwards 179 ± 8, and goalkeepers 183 ± 7 bpm) or $\text{La}_{\text{blood}}$ (field players 6.4 ± 2.4, center forwards 6.4 ± 2.4, and goalkeepers 5.4 ± 2.3 mmol/L).

![Figure 2](image_url) — Water Polo Intermittent Shuttle Test performance in different standards of competition, mean ± SE. *Denotes a significant difference between groups.
Tracking Seasonal Fitness Changes With the WIST

Figure 3 shows changes in WIST performance throughout the season. Mean ± SD test results were as follows: February, 344 ± 118 m (n = 16); April, 472 ± 133 m (n = 15); June, 459 ± 138 m (n = 14); October, 464 ± 115 m (n = 12); and November,

Table 2  Peak Heart Rate During and Blood Lactate Concentration Immediately After the Water Polo Intermittent Shuttle Test, Mean ± SD

<table>
<thead>
<tr>
<th>Standard of competition</th>
<th>n</th>
<th>Peak heart rate (bpm)</th>
<th>Blood lactate (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior regional females</td>
<td>9</td>
<td></td>
<td>4.6 ± 1.2*†</td>
</tr>
<tr>
<td>Junior regional males</td>
<td>10</td>
<td>184 ± 7</td>
<td>5.6 ± 1.5*</td>
</tr>
<tr>
<td>Junior state males I</td>
<td>6</td>
<td>185 ± 5</td>
<td>4.7 ± 0.8*</td>
</tr>
<tr>
<td>Junior state males II</td>
<td>8</td>
<td>192 ± 8</td>
<td>8.5 ± 2.3</td>
</tr>
<tr>
<td>Junior elite males</td>
<td>18</td>
<td>187 ± 7</td>
<td>8.7 ± 2.4</td>
</tr>
<tr>
<td>Senior national males</td>
<td>12</td>
<td>182 ± 14</td>
<td>6.4 ± 2.7</td>
</tr>
<tr>
<td>Senior elite females</td>
<td>22</td>
<td>180 ± 6</td>
<td>5.3 ± 2.1*†</td>
</tr>
<tr>
<td>Senior elite males</td>
<td>19</td>
<td>179 ± 11</td>
<td>5.6 ± 1.3*</td>
</tr>
</tbody>
</table>

*Denotes a significant difference compared with junior elite males.
†Denotes a significant difference compared with junior state males II.

Figure 3 — Water Polo Intermittent Shuttle Test performance at different times of the season, mean ± SE. *Denotes a significant difference between testing occasions.
550 ± 176 m (n = 13). Significant differences were observed among testing occasions (Figure 3). Peak HR was significantly lower in February (175 ± 12 bpm) than June (183 ± 8 bpm, \( P = .0108 \)) and October (188 ± 10, \( P = .007 \)) but not November (187 ± 11 bpm). Blood lactate concentration values measured in February (6.2 ± 2.8 mmol/L) were not significantly different from those recorded in June (4.6 ± 1.0 mmol/L), October (5.5 ± 1.3 mmol/L), and November (5.4 ± 1.1 mmol/L). No HR or La\(_\text{blood} \) data were collected in April.

**Relationship Between WIST Performance and Match Performance**

For the 12 field players, a correlation coefficient of .57 (\( P = .054 \)) was observed between the WIST performance and the match-fitness scores (Figure 4A). When field players other than the 2 center forwards were considered (n = 10, Figure 4B), the correlation coefficient increased to .83 (\( P = .0027 \)).

**Figure 4** — Relationship between Water Polo Intermittent Shuttle Test performance and match-fitness score in (A) all field players or (B) field players other than the 2 center forwards.
Discussion

The main findings of this investigation were that the WIST (1) proved to be a reliable intermittent field test for water polo, (2) appeared to be a valid match-fitness test in that the response of some physiological indices was similar to that observed during water-polo match play and test performance correlated with actual match performance, and (3) showed a high sensitivity to detect performance differences among players based on playing level and position and to track seasonal fitness changes.

There have been some earlier attempts to develop field-based intermittent fitness tests specific to water polo. An intermittent field test consisting of 14 repetitions of 25 m maximal “head-out” front-crawl swims on 30-second cycles was developed by Rodríguez. Performance and $La_{\text{blood}}$ response to the test were described for players of the Spanish National team. Test reliability, sensitivity, and validity were not reported, however. More recently, Rechichi et al. designed a multistage shuttle swim test for the assessment of aerobic fitness. Although this test was shown to be reliable and to provide a fair estimation of a player’s aerobic power, it failed to mimic the game’s intermittent activity pattern. The results of the present investigation suggest the WIST to be both reliable and valid as an index of water-polo match fitness, but we recommend familiarizing players with the test before implementing it. The 5.4% coefficient of variation of the test was very similar to that of 4.9% reported for the Yo-Yo Intermittent Recovery Test, on which the WIST is based. In addition, the 13-m difference between WIST test–retest scores equated to 6%, or less than 1 out-and-back shuttle, which is also very similar to the 5% difference reported by Rechichi and colleagues for their multistage shuttle swim test.

In terms of validity, the WIST elicited HR and $La_{\text{blood}}$ values similar to those reported during water-polo match play. For instance, mean HR during the WIST among the senior elite males (Australian National squad 2003) in this investigation was $158 \pm 11$ bpm (results not shown), which is in perfect agreement with the mean match-play values of 158 bpm reported for players of the Greek Premier National Division during games with a 2-goal difference. Values were slightly lower (154 bpm) during less competitive games with a difference greater than 2 goals. Similar mean values of 156 and 157 bpm have been reported for Greek National Division and National Team players during games lasting 4 × 7 min and 4 × 9 min, respectively. Peak HR of the senior elite males performing the WIST (179 bpm) was close to that of Greek players (181 bpm) of similar competition standard. Both mean and peak HR values observed during the WIST also coincided with the earlier match-play values described for male Australian players by Pinnington and colleagues. Similar agreements were observed between HR values of our senior elite females (Australian National squad 2004) and those reported for British and Dutch National League female players.

Mean $La_{\text{blood}}$ at the end of the WIST was similar in the study groups to values available in the literature. Indeed, our junior and senior male groups’ mean $La_{\text{blood}}$ ranged between 4.7 and 8.7 mmol/L, with individual values ranging from 2.7 to 12.7 mmol/L. This compares closely with the range of match-play values of 3.4 to 4.4 mmol/L of Greek players, although values are slightly lower than those of 5.1 to 9.5 mmol/L (individual range 4.9 to 12.0 mmol/L) reported for Spanish players during actual competition, suggesting a somewhat lower glycolytic activity during the WIST than during competitive match play. In the case of the females, mean values of...
4.6 to 5.3 mmol/L (individual range 2.0 to 10.1 mmol/L) were observed in this study. These values closely match those of 3.5 to 4.6 mmol/L observed in British players during match play, as well as those of Dutch players (4.9 to 5.8 mmol/L, individual range 1.5 to 9.8 mmol/L) of the same level. These observations on HR and La\textit{blood} indicate that the physiological demands of the WIST are similar to those of water-polo match play, providing evidence of the physiological validity of the test.

More important, performance on the WIST was closely related with performance during actual match play. This was the first time that a water-polo-specific field test was validated by relating its results to players’ performance in competition, quantified by means of match-fitness scores based on their coaches’ expert judgment. Match performance for the validation of the Yo-Yo Intermittent Recovery Test was described as the total distance of high-intensity running (>15 km/h) during soccer match play. This variable has been suggested to be a good descriptor of physical performance during soccer competition. Unfortunately, no such marker of successful performance has been described for water polo. Nevertheless, fitness scores based on rank-order lists provided by expert coaches’ observations during competition, such as that used in the present investigation, have been successfully used in the past. Steininger and Wodick reported a high correlation ($r = .90$) between a squash-specific field test and fitness scores derived from a rank-order list based on an independent, partly subjective estimate of fitness. Similarly, highly significant relationships were observed between expert judgments of competition performance and mean basal nocturnal excretion of norepinephrine ($r^2 = .84$) and dopamine ($r^2 = .86$) as indices of preparedness for competition in cross-country skiers. In the present study, the relationship between WIST performance and match-fitness score was greatly improved when center forwards were removed from the computation. This suggests that the test design, which requires an explosive start, fast swimming, and turning ability is not as well suited for center forwards as for other field players. Indeed, in modern water polo, a successful center forward is mainly required to wrestle with the defenders to either attain a goal-scoring position or force the defender to commit an exclusion foul resulting in temporary removal from the game.

Differences among standards of play and playing positions were reflected in the WIST results, indicating the sensitivity of the test. The range of test-performance values precisely matched the expected values, with the junior regional females attaining the lowest scores and the senior elite males the highest. Peak HR did not differ among groups, whereas La\textit{blood} was highest in the only groups that were not tested in a training-camp situation (junior state males II, junior elite males, and senior national males). This observation suggests that training camps, often characterized by 2 to 3 training sessions per day, might have led to glycogen depletion. Differences were also observed in the pooled WIST performance of field players, center forwards, and goalkeepers, in keeping with the specific requirements of their respective playing positions.

Another interesting feature of the WIST is that it also showed its sensitivity in detecting changes in the fitness levels of the players throughout the season. On average, a 37% improvement in test performance (6.8 times the test’s coefficient of variation) was observed from February (early season) to April (end of the National League, 2 months into the training program). After maintaining similar levels during most of the season, a further 16% improvement was observed in the final November
testing session, concurrent with the most match-specific phase of training and the
team’s best level of play, according to the coaching staff. Moreover, individual
variations were observed in the WIST performance that reflected the individual
circumstances of the players, such as periods of exceptional commitment to the
program or injury-related detraining. These observations emphasize the sensitivity
of the WIST to detect real changes in match fitness.

Although the WIST shows promise as an index of match fitness, shortcomings
in the study design need to be addressed. Limitations of the present investigation
were the small number of players included in the reliability study and restricted
access to elite and highly trained players, which precluded further insight into the
physiological response to the test. Future investigations should address these weak-
nesses and focus on a more objective validation of the test. This will require the
identification of measurable indices of match performance and their comparison
with test results.

Practical Applications and Conclusion

In summary, the results of this investigation indicated that the Water Polo Intermit-
tent Shuttle Test is a reliable, sensitive, and valid match-fitness test for water-polo
players. The test appears to place physiological demands on the players similar to
those reported during actual match play, and it assesses a player’s ability to perform
repeated high-intensity efforts interspersed with brief periods of active recovery.
Although test results could be interpreted on both a between- and within-athlete
basis, it is recommended that between-athletes comparisons be made within a
given playing position. In other words, test performance of center forwards or
goalkeepers should not be compared with that of other field players. The WIST
could become a useful tool for coaches and sport scientists to assess the effects of
different interventions on water-polo match fitness.

Acknowledgments

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