Occupational fitness standards for beach lifeguards. Phase 2: the development of an easily administered fitness test

T. Reilly¹, C. Iggleden¹, M. Gennser² and M. Tipton¹

Background No task-based fitness standard currently exists for beach lifeguards (BLGs).

Aim To formulate an easily administered fitness test for BLGs based on the physical demands identified in Phase 1 of the project (previous paper).

Methods A range of anthropometric and land- and water-based (swimming pool and flume) fitness assessments were administered to 25 male and female volunteer subjects (13 BLGs from the UK).

Results The mean (SD) VO₂max (l/min) were 3.04 (0.61) for towing a casualty, 2.08 (0.53) for board paddling with a casualty and 2.97 (0.67) for freestyle swimming. A significant correlation (r = −0.82, P < 0.001) was identified between distance paddled in the sea in 3.5 min (established in Phase 1) and pool 400-m front crawl swim time and between towing VO₂max and deltoid circumference/log₁₀ 400-m front crawl swim time (r = −0.83, P < 0.001).

Conclusions The regression identified allows the conclusion that if a BLG can swim 400-m front crawl in a pool in <7.5 min, he/she should be able to paddle 310 m in the sea in <3.5 min. Final recommendations for a fitness test for potential BLGs are presented.

Key words Fitness standards; lifeguarding; occupational fitness; rescue.

Introduction

In Phase 1 of this project [1] the most physically demanding generic critical tasks associated with beach lifeguarding were established and characterized. No specific, validated and easily administered tests exist that predict the performance of individuals on the critical tasks associated with beach lifeguarding, and the direct measurement of aerobic power involves considerable time, expense and technical expertise, and is impractical for large groups of people.

Jackson et al. [2] established a correlation of 0.898 between the distance covered during a 12-min front crawl swim and the endurance and peak aerobic power (VO₂max) results obtained from tethered, multi-stage swimming test time to exhaustion. Conley et al. [3] attempted to validate the 12-min swim test by direct comparison with oxygen consumption measured during tethered swimming and concluded that it had relatively low validity as a field test of peak aerobic power. Lavoie et al. [4] described a multi-stage swim test for competitive swimmers that correlates well (r = 0.877) with oxygen consumption up to maximal levels. However, its usefulness is limited for subjects with more variable swimming ability. Costill et al. [5] have reported that the best predictors of VO₂max for trained swimmers are lean body mass and stroke index (distance per stroke, r = 0.97). These predictors have not been tested with mixed-ability swimmers.

In this phase of the project, the objective was to establish if performance on the critical rescue tasks of paddling and casualty towing could be predicted for beach lifeguards (BLG) from a combination of pool-based tests and anthropometric measures, thereby establishing a minimum fitness standard.

Methods

Thirteen BLGs, 10 of whom had completed the previous phase of the project, and 12 other subjects, 8 of whom were lifeguards from Sweden, constituted the 25 volunteers for this phase. The protocol was approved by the Ethical Committees of both the Karolinska Institute and University of Portsmouth.

Height (cm), mass (kg), arm length (cm, acromion to mid dactylion), shoulder circumference (cm, greatest

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width mid-deltoid), chest circumference (cm, nipple height), percentage body fat (Durnin and Womersley [6]), surface area and body mass index [7] were measured with subjects wearing a swimming costume.

Subjects performed a multi-stage shuttle run to estimate VO_{2\text{max}} [8] and as many standardized push-ups as they could in 60 s.

Each subject was given the opportunity to familiarize himself/herself with the swimming flume (temperature 20°C). Throughout these tests subjects wore a nose clip and breathed through a mouthpiece (Spirotechnique, France) into respiratory tubing. The subjects wore their lifeguarding swimming costume. Each subject undertook three tests to VO_{2\text{max}}:

(i) Towing test: following 4 min of self-paced towing, the velocity of the flume was increased every 0.5–1 min by 0.05–0.1 m/s until volitional exhaustion. The subjects towed a 50-kg marine anthropometric manikin (designed to float in the water as an unconscious 50th percentile male) using a rescue tube secured around the chest of the manikin.

(ii) Paddle test: following 4 min of self-paced paddling, the velocity of the flume was increased every 0.5–2 min by 0–0.2 m/s until volitional exhaustion. Subjects paddled prone with the manikin on the rescue board (Figure 1).

(iii) Front crawl test: subjects swam in the flume using front crawl. Following 4 min of self-paced swimming, the velocity of the flume was increased every 0.5–2 min by 0.1–0.2 m/s until volitional exhaustion.

Oxygen consumption was recorded breath-by-breath using a Metamax 3B analyser (Cortex Biophysik, Germany). Effort was monitored by blood lactate sampling measured from a fingertip blood sample 3 min after cessation of all maximum efforts in the flume and pool (ProTest meter, Arkray Inc., Japan).

Following a warm-up period, the following timed tests were performed in a 25-m swimming pool:

(i) Four-hundred-metre front crawl: the number of strokes taken during the 2nd, 8th and 15th laps was recorded.

(ii) Three-hundred-metre breast-stroke.

(iii) Two-hundred-metre one-armed breast-stroke: subjects swam 200-m breast-stroke at maximal effort while holding onto a swimming float with one arm. They were permitted to alternate arms. The test was designed to replicate swim towing with a casualty.

A minimum of 30 min elapsed between consecutive tests. Maximum effort was monitored by blood lactate sampling.

Having established that the necessary assumptions had been met, data were analysed using Student’s t-test, Wilcoxon’s signed-rank test and Pearson’s product moment correlation coefficient with Minitab® 13. Variables with the greatest degree of association were investigated further using linear regression analysis. P < 0.05 unless stated otherwise.

Results

The physical characteristics of the subjects are presented in Table 1.

The results obtained from the swimming flume are presented in Table 2. The oxygen consumption recorded during towing and swimming did not differ significantly; both were higher than those seen during paddling. The mean blood lactate levels (SD) recorded following towing and swimming were 8.5 mmol/l (1.8) and 7.1 mmol/l (2.8), respectively; both were higher than the levels seen following paddling (arm-only exercise), 6.9 mmol/l (2.3).

The results obtained in the pool are presented in Table 3. Data are presented, and were analysed, for all of the subjects and separately for the UK BLG only. The most significant correlations obtained between the variables measured in the present study are shown in Table 4.

None of the land-based tests of strength or fitness predicted performance of BLG on their critical tasks.

On the basis of the correlation between distance paddled in 3.5 min in the sea and the time taken to swim 400 m in the pool, a regression equation was identified (r = 0.72, P < 0.001, n = 13 BLG) in which the distance paddled to a casualty in 210 s equalled:

\[ \text{Distance paddled in 210s} = 850 - (1.2 \times 400 \text{ m front crawl time in seconds}) \]

From this a BLG should be able to paddle 310 m in the sea in <3.5 min provided he/she can swim 400-m front crawl in a pool in <7.5 min. Ninety-one per cent of the present subjects achieved this time.
Maximum aerobic capacity during towing was most closely associated with VO_{2max} during swimming, swimming performance and anthropometric measures (see footnote b in Table 4). As the measurement of both swimming VO_{2max} and lean body mass require specialist methods, the relationship between deltoid (shoulder) circumference, swimming performance and towing VO_{2max} was explored further. It was determined that tow VO_{2max} (l/min) and [deltoid circumference (cm)/log_{10} 400-m swim time (s)] had an r value of 0.83. The regression equation being:

\[ \text{Tow VO}_{2}\text{max (l/min)} = -1.97 + 0.106 \times \frac{\text{deltoid circumference (cm)}}{\log_{10} \text{400 m swim time (s)}}. \]

The relationship is primarily determined by deltoid circumference; deltoid circumference (cm) and tow VO_{2max} (l/min) (BLG only) correlated with an r value of 0.76.

### Table 1. Physical characteristics of UK and Swedish subjects

<table>
<thead>
<tr>
<th>Subjects in Sweden (BLGs and SWE) (n = 25)</th>
<th>Just BLGs in Sweden (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td><strong>Body fat (%)</strong></td>
</tr>
<tr>
<td>Mean</td>
<td>26.5</td>
</tr>
<tr>
<td>SD</td>
<td>6.4</td>
</tr>
<tr>
<td>5th%</td>
<td>19.0</td>
</tr>
<tr>
<td>95th%</td>
<td>38.8</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td><strong>Mass (kg)</strong></td>
</tr>
<tr>
<td>Mean</td>
<td>177.9</td>
</tr>
<tr>
<td>SD</td>
<td>7.5</td>
</tr>
<tr>
<td>5th%</td>
<td>164.9</td>
</tr>
<tr>
<td>95th%</td>
<td>189.8</td>
</tr>
<tr>
<td><strong>Arm length (cm)</strong></td>
<td><strong>Chest circumference (cm)</strong></td>
</tr>
<tr>
<td>Mean</td>
<td>81.0</td>
</tr>
<tr>
<td>SD</td>
<td>4.9</td>
</tr>
<tr>
<td>5th%</td>
<td>75.1</td>
</tr>
<tr>
<td>95th%</td>
<td>89.9</td>
</tr>
</tbody>
</table>

BLG, beach lifeguard (UK); SWE, Swedish lifeguard.

### Table 2. Oxygen consumption at a self-selected pace and VO_{2max} during paddling, towing and swimming in the flume

<table>
<thead>
<tr>
<th></th>
<th>Paddle</th>
<th>Tow</th>
<th>Swim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-selected</td>
<td>VO_{2max} (n = 25)</td>
<td>VO_{2max} (n = 25)</td>
<td>VO_{2max} (n = 25)</td>
</tr>
<tr>
<td>Mean l/min</td>
<td>1.26</td>
<td>2.08</td>
<td>2.13</td>
</tr>
<tr>
<td>Mean ml/kg/min</td>
<td>16.24</td>
<td>26.9</td>
<td>27.7</td>
</tr>
<tr>
<td>SD l/min</td>
<td>0.41</td>
<td>0.53</td>
<td>0.49</td>
</tr>
<tr>
<td>SD ml/kg/min</td>
<td>4.15</td>
<td>5.12</td>
<td>5.15</td>
</tr>
<tr>
<td>5th% l/min</td>
<td>0.75</td>
<td>1.26</td>
<td>1.48</td>
</tr>
<tr>
<td>5th% ml/kg/min</td>
<td>10.4</td>
<td>18.9</td>
<td>20.8</td>
</tr>
<tr>
<td>95th% l/min</td>
<td>2.06</td>
<td>2.81</td>
<td>2.85</td>
</tr>
<tr>
<td>95th% ml/kg/min</td>
<td>22.6</td>
<td>34.1</td>
<td>37.5</td>
</tr>
<tr>
<td>VO_{2} at self selected pace as % of VO_{2max}</td>
<td>62%</td>
<td>70%</td>
<td>68%</td>
</tr>
<tr>
<td>5th%</td>
<td>45%</td>
<td>62%</td>
<td>48%</td>
</tr>
<tr>
<td>95th%</td>
<td>87%</td>
<td>85%</td>
<td>87%</td>
</tr>
</tbody>
</table>

The percentages of VO_{2max} that subjects chose to self-pace at are also shown.
In the flume, a 0.1 m/s increment in towing velocity required an increase of 0.35 l/min in oxygen consumption. The average towing velocity of subjects at self-selected pace was 0.4 m/s, and this required them to work at 70% of their VO2max (see Table 2). In fit, trained but non-elite athletes this is as high a percentage as is recommended to work to avoid excessive anaerobic metabolism and fatigue [9–12].

The requirement to return a casualty to the beach within 10 min [1] leaves a maximum of 6.5 min to return them to the shore. The maximum distance a BLG would need to cross-chest tow an unconscious casualty is 100 m, as at this point other lifeguards would have come to assist in rescue boats. To cover 100 m in 6 min (assuming 30 s for securing the casualty) requires a towing speed of 0.28 m/s. From the relationship between tow speed and tow oxygen consumption, an average tow speed of 0.28 m/s requires an oxygen consumption of 1.7 l/min. This should not represent 70% of towing VO2max, which must therefore be 2.43 l/min. This towing VO2max corresponds to a deltoid circumference/log10 400-m swim time of 41. Eighty-nine per cent of the subjects tested achieved this standard.

Discussion

Our findings suggest that the performance of critical rescue tasks of paddling and casualty towing can be predicted from a combination of pool-based tests and anthropometric measures.

Swimming VO2max was strongly associated with both paddling ($r = 0.84$) and towing VO2max, but is difficult to measure. Attempts have been made to develop simple, indirect tests and indices that predict swimming aerobic power and performance, including simulated swimming [13], a multi-stage swim test [4], measurement of energy expenditure [5], a 12-min swim test [2,3], upper body anaerobic power [14] and arm stroke index [15]. Costill et al. [5] reported that the best predictors of VO2max for trained swimmers are lean body mass and stroke index (distance per stroke). In the present study, with mixed-ability swimmers, the stroke index did not correlate with swimming, paddling or towing VO2max.

It was not possible to identify a land-based, indirect assessment of running VO2max (shuttle run) that would
predict swimming, towing or paddling VO$_{2_{\text{max}}}$ - This is in contrast to the findings of Magel and Faulkner [16] who found that the VO$_{2_{\text{max}}}$ recorded in tethered swimming and treadmill running were highly correlated. It is noted that these authors tested highly trained college swimmers, and others have reported that VO$_{2_{\text{max}}}$ can be anything from 75 to 100% of running VO$_{2_{\text{max}}}$ depending on the skill level of the swimmers [17,18].

Upper body anaerobic power has been reported to predict swimming performance in swimming events up to 400 m [14]. The correlations obtained in the present study between towing VO$_{2_{\text{max}}}$ and both upper body anthropometric measures (e.g. deltoid circumference) and push-ups support the conclusion that upper body strength is an important characteristic for rescue swimming. It would therefore be beneficial to encourage potential recruits to develop their upper body strength and endurance.

At first sight, the lack of a relationship between the pool (swim time) and flume (oxygen consumption during swimming) performance appears surprising. Past research indicates that flume swimming, free swimming and tethered swimming elicit a similar VO$_{2_{\text{max}}}$ [19]. However, higher values have been reported during free swimming [16] and Costill et al. [5] note little relationship between VO$_{2_{\text{max}}}$ and 400-yard front crawl performance: despite almost identical oxygen consumptions, recreational swimmers swim significantly slower than competitive swimmers due to large differences in swimming efficiency. Differences in body attitude and hydrodynamics between flume, free and tethered swimming make a direct comparison between these forms of exercise in terms of work efficiency difficult [16].

On the basis of the results of this and the previous study [1] the following task-related tests are recommended:

(i) Pool swim of 400 m in <7.5 min—to predict paddling performance.
(ii) Pool swim of 200 m in <3.5 min—to predict sea swimming performance.
(iii) Twenty-five-metre underwater swim immediately followed by 25-m surface swim; complete in <50 s—to assess confidence under the water and swimming efficiency.
(iv) Lift 41 kg torso manikin with both arms and move backwards 10 m (appropriate training in manual handling to be provided prior to lift).

Additional tests to be used for guidance and preparation only:

(i) Candidate’s deltoid circumference (cm) to be measured and divided by the log$_{10}$ of his/her 400-m front crawl swim time (s). Resulting number to exceed 41.
(ii) Two-hundred-metre beach run as fast as possible; complete in <40 s.
(iii) Push-ups: males to achieve 37, females 15 in 1 min, resting permitted within the minute.
(iv) A 2.4-km run to achieve ‘good’ or above according to published norms [males aged 20 years ‘good’ = 3.55 l/min (52 ml/kg/min); females aged 20 years ‘good’ = 2.3 l/min (43 ml/kg/min)] [20]. Potential male recruits should train so that they can run 2.4 km in 10 min 15 s and no slower than 11 min 44 s. Potential female recruits should train so that they can run 2.4 km in 11 min 56 s and no slower than 14 min 24 s.

The tests should not be used in isolation, as success in one test does not guarantee adequate physical fitness for beach lifeguarding. The tests are related to fitness required to undertake a task, not the level of skill.

Acknowledgements

Thanks to David Salt for help with the statistics. The project was funded by the Royal National Lifeboat Institution.

Conflicts of interest

None declared.

References


