Development of a Comprehensive Performance-Testing Protocol for Competitive Surfers


Purpose: Appropriate and valid testing protocols for evaluating the physical performances of surfing athletes are not well refined. The purpose of this project was to develop, refine, and evaluate a testing protocol for use with elite surfers, including measures of anthropometry, strength and power, and endurance. Methods: After pilot testing and consultation with athletes, coaches, and sport scientists, a specific suite of tests was developed. Forty-four competitive junior surfers (16.2 ± 1.3 y, 166.3 ± 7.3 cm, 57.9 ± 8.5 kg) participated in this study involving a within-day repeated-measures analysis, using an elite junior group of 22 international competitors (EJG), to establish reliability of the measures. To reflect validity of the testing measures, a comparison of performance results was then undertaken between the EJG and an age-matched competitive junior group of 22 nationally competitive surfers (CJG). Results: Percent typical error of measurement (%TEM) for primary variables gained from the assessments ranged from 1.1% to 3.0%, with intraclass correlation coefficients ranging from .96 to .99. One-way analysis of variance revealed that the EJG had lower skinfolds (P = .005, $d = 0.9$) than the CJG, despite no difference in stature ($P = .102$) or body mass ($P = .827$). The EJG were faster in 15-m sprint-paddle velocity ($P < .001$, $d = 1.3$) and had higher lower-body isometric peak force ($P = .04$, $d = 0.7$) and superior endurance-paddling velocity ($P = .008$, $d = 0.9$). Conclusions: The relatively low %TEM of these tests in this population allows for high sensitivity to detect change. The results of this study suggest that competitively superior junior surfers are leaner and possess superior strength, paddling power, and paddling endurance.

Keywords: paddle, strength, power, assessment, surfing

Surfing (wave riding) is a mass-participation sport worldwide, enjoyed by both sexes and a broad age demographic. Waves are being surfed on every continent, with 69 countries having a national federation membership in the International Surfing Association (ISA) and 30 to 35 of these federations contesting ISA World Junior Championships and World Surfing Games each year, as well as hundreds of elite athletes contesting the professional contests of the World Tour of the Association of Surfing Professionals.

Competitive surfing involves grouping 2 to 4 surfers in each 20- to 40-minute competitive heat, dependent on the format of the competition and surf conditions. Competitive success is determined by judging criteria applied to the act of wave riding only (the point the athlete moves from prone to standing on the breaking wave to the completion of the wave being ridden). The criteria examine the athlete’s ability to ride the best waves and perform controlled complex maneuvers. Generally, the athlete’s highest-scoring 2 waves in each heat are used to determine the heat outcome. In other words, success is judged by the ability to obtain and ride the best waves during a competition and ride them better than their competition. Like any tournament-style competition, the successful surfers from each round of competitive heats progress through the competition until quarterfinal, semifinal, and final rounds are completed and placing is determined.

Surfing competition takes places under a variety of conditions that have a large effect on activity patterns, such as duration of wave riding and time spent paddling. The type of wave break and changing conditions such as wind, swell, and tide conditions greatly influence the nature of the surfing activity. In a competition, wave-riding duration was found to be 3.8% of total time, with paddling accounting for 51.4% of time and no activity (ie, stationary sitting on board) representing 42.5% of total time (miscellaneous activities 2.2%). Although the mean paddling bout in a surfing competition was found to be ~30 seconds, the majority (~60%) of these paddling bouts were only 1 to 20 seconds (~25% <10 s, ~35% 10–20 s), highlighting the importance of shorter
bouts of intense paddling. As such, analysis of both competitive and recreational surfing suggests that surfing can be characterized as a sport requiring multiple short-duration intermittent paddle efforts.

Sprint paddling appears to be a key feature of competition to catch waves and gain a position advantage over one’s competitors during a heat, as well as to ensure fast entry speed into waves to optimize position on the wave face for the execution of maneuvers that will maximize the judges’ score. Indeed, adult competitive surfers are superior in sprint paddling to junior competitive surfers, highlighting this physical quality as an important development consideration. When you also consider the repeated bouts and extensive nature of surfing activity, endurance-paddling ability is also likely to be a highly relevant physical quality. As such, assessments of both sprint- and endurance-paddle ability in surfers are likely an important component of a comprehensive testing protocol for competitive surfers.

Surfboard paddling is considered a closed-kinetic-chain task, as the surfers “pull” their body over the water surface as opposed to pulling the water surface toward them. Previous examinations have used stationary paddle ergometry to determine sprint- and endurance-paddle performance, which was an open-kinetic-chain task, with conflicting results in discriminating between higher- and lower-performing surfers. It would seem more appropriate, and indeed more practical, to evaluate paddling ability with surfers in the water to provide greater context validity.

Surfing a wave requires a continual and relatively rapid production and arresting of force, particularly in the lower body, to execute the maneuvers required to maximize scores under the judging criteria. Despite this, there have been no studies involving surfers that have examined strength and power measures of the lower body, despite their likely importance to performance. As such, currently there is no established protocol for the assessment of strength and power from which to implement measures into a comprehensive protocol.

To advance the understanding of the physical capabilities of surfers, and to pursue further research into the responses and adaptations of these qualities with training, valid test measures must first be established. Therefore, the purpose of this study was to develop and evaluate a testing protocol with practical reliability and context validity, such that the testing protocols assess physical qualities that relate to performance in the sport, including measures of anthropometry, strength and power, and sprint and endurance qualities.

Methods

Subjects

Forty-four competitive junior surfers (16.2 ± 1.3 y, 166.3 ± 7.3 cm, 57.9 ± 8.5 kg) participated in this study, which involved 2 groups: an elite junior group of 22 international competitors (EJG) and an age-matched group of 22 domestic competitors (CJG). The EJG were both nationally and internationally competitive surfers at junior competitions (eg, World Junior Championships) and were included in national-team programs, while the CJG competed in national competitions (eg, state and national titles) but were not a part of the national program.

All subjects received a clear written and verbal explanation of the study and all risks and benefits, with written informed consent obtained by the subjects and their parent or guardian. The study procedures were approved by the human ethics committee at Edith Cowan University, and procedures conformed to the code of ethics of the World Medical Association (Declaration of Helsinki).

Design

After a development and refinement process, subjects were familiarized with the testing procedure and conducted practice trials. After this, a repeated-measures analysis was conducted within the same day with the subjects from the EJG to establish reliability of the measures. To assess the validity of the testing measures to discriminate athlete ability, a comparison of performance results was then performed between the EJG and the CJG.

Methodology

Anthropometry. Subjects were assessed for height, body mass, and the sum of 7 skin folds. The sum of 7 skin folds was determined after measurement of the triceps, subscapulae, biceps, supraspinale, abdominale, thigh, and calf skin folds using a Harpenden skinfold caliper (British Indicator, Hertfordshire, UK). A composite ratio of body mass divided by the sum of 7 skin folds was then determined to reflect the amount of mass that was made up of lean tissue, termed the lean-mass index, modified by original methods. All tests were conducted in accordance with the International Society for the Advancement of Kinanthropometry’s guidelines by a practitioner whose percent typical error of measurement (TEM) for skinfold measurements was 1.12% to 1.70%, and 0.10% for all other measures.

Lower-Body Strength and Power. With a lightweight wooden bar across the shoulders, subjects conducted 3 or 4 trials of a jump squat from a self-selected depth. Subjects then performed 2 trials of a maximal isometric midthigh pull, using a 130° knee angle and corresponding hip angle of 155° to 165°, as described in previous research. With the hip and knee angles determined using a handheld goniometer. If the trials differed by >250 N, a third trial was performed. The best trials as determined by maximum force (isometric midthigh pull) and maximum jump height were retained for analysis.
All movements were conducted with the subjects standing on a commercially available force plate sampling at 600 Hz (400 Series Performance force plate, Fitness Technology, Adelaide, Australia). The force plate was interfaced with computer software (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) that allowed for direct measurement of force–time characteristics (force plate), and data were then analyzed using the Ballistic Measurement System software (Fitness Technology, Adelaide, Australia). Force–time data recorded from the jumps were processed using the impulse-momentum method to determine velocity and displacement data. Peak force and jump height determined as the peak in displacement were used as the representative performance measures. Before all data collection procedures, the force plate was calibrated using a spectrum of known loads spanning the likely measurement range (20 and 200 kg) and then assessed against 3 criterion masses (of 40, 100, and 200 kg).

**Sprint and Endurance Paddling.** Sprint-paddle testing was conducted in an outdoor 25-m swimming pool. This allowed for easy outline of distances for the subjects and control of the potential effect of tides and currents. Subjects used their own surfboard for the testing (the one they use in competition) to provide context validity. All subjects wore surf boardshorts.

Before the paddling test and in addition to the general warm-up, subjects performed a progressive paddling warm-up consisting of 200 m of low-intensity paddling, followed by a specific sprint-paddling warm-up of 4 × 15-m sprint-paddling efforts at 60%, 70%, 80%, and 90% volitional effort at ~2-minute time intervals. After 2 minutes rest, the subjects then performed 2 maximal-effort sprint-paddling time trials (ie, 2 × 15 m) to determine maximum sprint-paddling performance. The sprint-paddle efforts were initiated from a stationary, prone position.

Using a purpose-built horizontal position transducer (I-REX, Southport, Australia) attached to the back of each subject’s shorts, kinematic data were obtained and stored for analysis on a personal computer. The position transducer recorded a time stamp for each 0.02 m of displacement, thereby allowing determination of sprint time from the start to 5 m, 10 m, and 15 m and by differentiation to determine peak sprint-paddle velocity, a procedure that has been validated previously with surfboard paddling in a pool.14

The timed endurance-paddle test was conducted over a 20-m up-and-back course in the same pool, using 2 pool-lane widths, so that continuous paddling to a total of 400 m could be accomplished. The paddling test was conducted with small buoy markers at both ends of the 20-m segment. As such, the subjects paddled 20 m and completed a turn at each end around the buoy until the 400 m was completed. The subjects paddled up to and around the buoy, completing a 180° turn while remaining prone on their surfboards. The time to complete the endurance-paddle test allowed for determination of subjects’ maximum aerobic speed, which was intended to reflect their endurance capabilities in the specific context of surfboard paddling.

**Statistical Analyses**

Reliability data were calculated by determining the intraclass correlation coefficient, TEM, and percentage TEM (as covariance, percent TEM). Comparisons of the difference between higher (EJG) and lower performers (CJG) was determined by ANOVA, with Cohen’s effect size (d) applied to determine the magnitude of any differences observed. For all means-based testing, minimum significance was considered to be achieved when P < .05, with a 90% confidence interval.

**Results**

Table 1 outlines the reliability of experimental measures used in this study. The EJG had lower total skin-fold values (P = .005, d = 0.9), despite no difference in height (P = .102, d = 0.5) or mass (P = .827, d = 0.1) (Figure 1), consequently resulting in a higher lean-mass index (P = .001, d = 1.1).

The EJG had a higher peak force (1802 ± 351 N) than the CJG (1531 ± 308 N) in the isometric midthigh pull (P = .041, d = 0.7). In regard to peak jump height, there were no clear differences observed between the EJG (0.40 ± 0.07 m) and the CJG (0.38 ± 0.09 m; P = .505, d = 0.3), or for the peak velocity (P = .521, d = 0.3), or for peak force (P = .787, d = 0.1) in the jump squat (Figure 2).

**Table 1  Reliability (90% Confidence Intervals) of Measures on the Tests in Elite Junior Competitive Surfers**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Intraclass correlation</th>
<th>Typical error of measurement (TEM)</th>
<th>%TEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jump squat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>height (m)</td>
<td>.98 (.94–.99)</td>
<td>0.01 m (0.01–0.02)</td>
<td>2.67% (2.00–4.30)</td>
</tr>
<tr>
<td>peak force (N)</td>
<td>.97 (.91–.99)</td>
<td>37.3 N (27.3–58.8)</td>
<td>2.99% (2.20–4.80)</td>
</tr>
<tr>
<td>Isometric midthigh-pull peak force (N)</td>
<td>.99 (.97–.99)</td>
<td>42.5 N (32.9–60.1)</td>
<td>2.25% (1.80–3.20)</td>
</tr>
<tr>
<td>15-m sprint paddle (s)</td>
<td>.97 (.93–.99)</td>
<td>0.11 s (0.09–0.16)</td>
<td>1.13% (0.90–1.60)</td>
</tr>
</tbody>
</table>
EJG produced superior sprint-paddle times to 5 (\(P = .000, d = 1.4\)), 10 (\(P = .000, d = 1.3\)), and 15 m (\(P = .000, d = 1.2\)) and a higher sprint-paddle velocity (\(P = .000, d = 1.3\)), which was achieved in the 5- to 14-m interval. The EJG also had a lower endurance-paddle time (\(P = .008, d = 0.9\)) and consequently a higher endurance-paddling velocity (\(P = .000, d = 0.9\); Table 2).

**Discussion**

To advance sport science’s knowledge of the physical capabilities of competitive surfers, and to advance further research into the responses and adaptations of these qualities, valid test measures must first be established for use with this population. The first purpose of this study was to develop and evaluate a testing protocol that demonstrated practical reliability such that practitioners can be confident that small training-induced changes can be detected by the tests and not attributed to biological and measurement noise. The second purpose was to evaluate the protocol for its ability to discriminate between competitive levels, thereby reflecting the validity of the measurements.

The relatively low TEM values for the variables obtained in this study demonstrate considerable practical use for coaches and sport scientists; a high TEM makes interpreting small changes in performance difficult, because unless the change measured is larger than the TEM, the practitioner cannot be confident that the change is due to training or detraining or simply due to measurement and biological noise associated with the testing protocol. Previously, favorable reliability has been found with a 10-second paddling time trial with surfers,\(^{14}\) and we previously found high reliability using the jump-squat and isometric-midthigh-pull protocols in other sports.\(^{9,10}\) However, this is the first study to comprehensively evaluate the repeatability of measures usable in an entire suite of tests to evaluate the physical qualities of surfers. The low TEM observed across the entire protocol indicates that comparably small magnitudes of change can be detected in the test scores, likely providing a sensitive protocol for practitioners working with surfing athletes.

Although the EJG and the CJG did not differ in terms of height or mass, the EJG had lower total sum of

Table 2  Mean (± SD) Sprint- and Endurance-Paddle Results Comparing an Elite Junior Group (n = 22) and an Age-Matched Group of Competitive Junior Surfers (n = 22)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Elite junior group</th>
<th>Competitive junior group</th>
<th>(P)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint-paddle time (s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 m</td>
<td>3.96 ± 0.30</td>
<td>4.35 ± 0.25</td>
<td>.000</td>
<td>1.4</td>
</tr>
<tr>
<td>10 m</td>
<td>7.08 ± 0.49</td>
<td>7.69 ± 0.44</td>
<td>.000</td>
<td>1.3</td>
</tr>
<tr>
<td>15 m</td>
<td>10.23 ± 0.68</td>
<td>11.04 ± 0.63</td>
<td>.000</td>
<td>1.2</td>
</tr>
<tr>
<td>Peak velocity (m/s)</td>
<td>1.66 ± 0.11</td>
<td>1.53 ± 0.09</td>
<td>.000</td>
<td>1.3</td>
</tr>
<tr>
<td>400-m endurance-paddle time (s)</td>
<td>324 ± 25</td>
<td>360 ± 18</td>
<td>.008</td>
<td>0.9</td>
</tr>
<tr>
<td>Endurance velocity (m/s)</td>
<td>1.17 ± 0.08</td>
<td>1.11 ± 0.05</td>
<td>.006</td>
<td>0.9</td>
</tr>
</tbody>
</table>
It has been shown to be a relevant quality to assess in surfboarders, it stands to reason that sprint-paddling ability interspersed with some inactive periods (sitting on the paddling ability). Considering that competitive heats the CJG, further highlighting the importance of sprint-velocity (d = 1.3) between the higher-performing EJG and the CJG, further highlighting the importance of sprint-paddling ability. A 10-second sprint-paddle assessment has previously been demonstrated to be a reliable method to evaluate paddling ability in surfers, and sprint-paddling ability has been shown to be a relevant quality to assess in competitive surfers. The results of this study demonstrate the relatively large difference in peak sprint-paddling velocity (d = 1.3) between the higher-performing EJG and the CJG, further highlighting the importance of sprint-paddling ability. The ability of laboratory-based endurance-paddling ergometer assessments to discriminate between higher- and lower-performing surfers has not been well established, with some studies suggesting that superior aerobic qualities can be determined with paddling ergometers, while other studies have not been able to detect maximal aerobic differences between groups. The current research is novel in that the endurance-paddling time trial was performed in the water, in a closed-kinetic-chain environment, and clearly delineated capacity between higher and lower performers (Table 2). Based on the current findings, if practitioners are examining paddling endurance in surfers, a paddling time trial may be most effective to achieve context validity. Furthermore, the time trial can be used for decision making on training needs, as the velocity achieved in the sprint paddle can be directly compared with that of the endurance-paddle time trial (a ratio of sprint-paddle to endurance-paddle velocity), to assert the relative performance of each quality (and thereby set training priorities). Further research and analysis should include a cross-sectional analysis of the sprint- and endurance-paddling velocities of a range of competitors at varying levels, to assist with creating guidelines that may help practitioners determine training-emphasis needs for sprint-paddling and endurance-paddling ability.

There are several limitations to this current data set that require future research focus. Due to the exhausting nature of the 400-m endurance-paddle time trial, we were unable to obtain reliability data from this population for the endurance assessment. Despite the large differences observed between groups (Table 2), this current limitation prevents us from calculating reliability statistics that allow for a determination of the smallest worthwhile change.

In addition, although the low TEM, and indeed the large differences observed between performance groups, suggests that the tests involved in this protocol will be sensitive to detect training-induced changes, this was not assessed specifically in this study. To evaluate this, future research should assess the ability of the testing protocol to detect potential training and detraining effects in the endurance qualities of surfers.

**Practical Applications**

Appropriate and valid testing protocols evaluating the physical performances of surfing athletes have not been well refined. This project developed and evaluated a comprehensive sport-science testing protocol for use with surfers, including measures of anthropometry, lower-body strength and power, and sprint and endurance ability. The outcomes from this study resulted in the creation of a national sport-science testing protocol for competitive surfers that can be adopted wholly, or in part, or expanded on by other training programs and for use with future research.

Higher-performing competitive junior surfers are leaner and stronger and have superior sprint- and endurance-paddling ability than lower-performing competitive surfers. As such, practitioners can emphasize developing these capabilities and use assessments of anthropometry, strength and power, and sprint- and endurance-paddling ability to evaluate the physical qualities of competitive surfers.

**Acknowledgments**

This research project was conducted through the Hurley Surf Science Research Project scheme and was funded by an Edith Cowan University Early Career Research Grant.
The authors would like to thank Martin Dunn, national coaching director with Surfing Australia, and Ben Falvey, head surf coach with Palm Beach Currumbin High School, for their involvement in this research project.

References