

CHAPTER 2

TWO RELIABLE PROTOCOLS FOR ASSESSING MAXIMAL-PADDLING PERFORMANCE IN SURFBOARD RIDERS



2.1 INTRODUCTION:

Surfboard riding (surfing) is an internationally recognised and highly-competitive professional sport. Advances in equipment and competition standards have resulted in the need for new coaching expertise and training techniques to help improve surfing performance and prevent injuries. Surfboard paddling takes up the largest proportion (~44-50%) of total surfing time with only 5-8% of total time spent wave riding (Meir, *et al.*, 1991; Mendez-Villanueva *et al.*, 2006). Wave riding cannot be performed without paddling; first to get from the shoreline to the wave break, and second to successfully catch a wave. However, during surfing competition, paddling has no influence on the judges' score. As a result, surfboard paddling has received little attention in scientific research.

Previous studies use tethered board paddling (Lowdon *et al.*, 1989), arm cranking (Lowdon *et al.*, 1989), swim-bench ergometers (Meir *et al.*, 1991), and modified kayak ergometers (Mendez-Villanueva *et al.*, 2005), to investigate peak aerobic power during surfboard paddling. Despite previous interest in the aerobic energy demands of surfboard riding, no previous study has assessed maximal-paddling performance in surfboard riders. As surfers are frequently required to paddle maximally for several seconds to catch waves or paddle out through wave sets, such performance is an important physical characteristic. Greater maximal-paddling ability would: i. Improve the surfer's chance of catching a wave, or ii. Allow the surfer to assume the ideal position in the surf for wave riding. Therefore, the assessment of maximal-paddling performance could be important for monitoring improvements in surfing performance, or examining physiological adaptations to training.

One way to evaluate maximal-intensity exercise is to measure external power output. This approach has been undertaken with other aquatic athletes, such as swimmers and surf lifesavers where measures during swim-bench front crawl (Swaine, 2000) and

knee-board paddling (Morton & Gustin, 1997) were reliable. However, it is not known if swim-bench ergometry can be used to assess maximal-paddling performance with similar reliability in surfers given their unique upper-body paddling technique (i.e., hyperextension of the trunk and lack of hip drive). Currently, swim-bench ergometers are the most sport-specific devices available for surfboard paddling.

The purpose of the present study was to examine the test-retest reliability of peak power output measured during maximal-intensity paddling on a swim-bench ergometer in competitive male surfers. A secondary purpose of the present study was to develop an equivalent field test to assess maximal-paddling performance in surfers that can be administered easily.

2.2 MATERIALS AND METHODS

Subjects

Eleven competitive male surfers (age 17 ± 1 yr, body mass 61.9 ± 3.1 kg, and stature 173 ± 2 cm) participated in the study. Each participant had been surfing for at least 4 yr and had qualified to compete in junior state titles in the last 12 mo. The study was approved by the Griffith University Human Research Ethics Committee and written informed consent was obtained from each participant as well as parental/guardian consent when surfers were under 18 yr.

Experimental design

Surfers underwent two days of laboratory testing and two days of field testing. Surfers practised with the testing equipment on a separate day before the laboratory testing commenced. The laboratory test consisted of 10 s of maximal-intensity paddling performed on a swim-bench ergometer. Peak power output (W) was recorded from the

digital display unit on the ergometer and used as the key performance indicator. Surfers completed six trials of the laboratory test over two days, completing three trials each day. The field test consisted of 10 s of maximal-intensity paddling performed on the surfers' personal surfboard in a 25-m swimming pool. Peak speed ($\text{m}\cdot\text{s}^{-1}$) was measured using a custom made speed probe (SP5000, Applied Motion Research, Gold Coast, AUS). Trial-to-trial reliability of peak speed was determined under two conditions: i. Arm paddling only (non-kicking), and ii. Simultaneous arm paddling and leg kicking (kicking). Field testing was conducted over two days with three trials of the non-kicking condition on one day and three trials of the kicking condition on another day. Testing was randomised to minimise order effect. The impact of leg kicking on paddling speed was determined by comparing peak speed of the two testing conditions.

Similar testing procedures were used for the laboratory-, and field-testing protocols. A 5-min warm up was performed that comprised 3-min light-intensity continuous paddling, followed by a 30-s rest and three, 5-s maximal-intensity paddling efforts replicating the test start. Each 5-s effort was separated by a 30-s rest. The warm up was followed by a 10-min rest and three, 10-s maximal-intensity paddling trials; each trial separated by 10 min of rest. Testing was performed at, or as near as possible to, the same time of day, with the four testing days separated by 48 to 72 h. The same instructions were used for each trial with the surfers verbally encouraged to paddle as hard as they could for the whole trial. Surfers were not informed of the elapsed trial time. Verbal encouragement lasted 11-12 s before the command of “stop” was given, to prevent the surfer from slowing down prematurely.

Laboratory-testing equipment

The wind-braked swim-bench ergometer used in the present study (Figure 2.1) was a *classic* Vasa Swim Ergometer (Vasa, Inc., Essex Junction, VT, USA) that is similar to the biokinetic swim-bench ergometer previously described by Sharp *et al.* (1982). Biokinetic swim-bench ergometers are neither isotonic nor isokinetic as the force and speed of the arm pulling varies and is not constrained at a predetermined setting (Sharp *et al.*, 1982). Biokinetic swim-bench ergometers have been described as a semi-accommodating resistance device that can be preset to a regulation speed that provides constant acceleration in proportion to the force applied by the user (Sharp *et al.*, 1982).



Figure 2.1 Example of a surfboard rider during paddling on the swim-bench ergometer.

The swim-bench ergometer used in the present study consisted of hand paddles attached to two pull ropes induced rotation of the isokinetic-resistance device. The external power output of each separate arm pull is determined from two suitably mounted force transducers on each hand pulley that measure tensile forces, distance through which

these forces act, and the duration of the application of force. When force is applied to the hand paddles, the pull-rope pays out a velocity which ranges up to maximum, termed the maximum pull velocity (MPV). The resistance unit on the swim-bench ergometer provided seven MPV settings. Power output was calculated and continuously fed back to the surfer via a digital display unit. The display unit had no memory storage, so the duration of each trial was video recorded and played back to obtain 1-s power output values. The paddling ergometer was calibrated before testing using methods previously described (Sharp *et al.*, 1982).

Pilot testing previously performed in our laboratory determined the optimal MPV setting (of the seven settings), necessary to achieve peak power output. Pilot testing consisted of twenty recreational male surfers (age 21 ± 1 yr, body mass 76.1 ± 0.16 kg) undertaking six, 10-s maximal-intensity paddling trials, performed at three MPV settings (2, 4 and 7). Two trials were performed at each of the three MPV settings and testing was undertaken over two days, completing three trials each day, each separated by a 10-min rest. The body mass of the twenty surfers ranged between 58.5 and 86.0 kg. To determine the interaction between body mass, MPV setting and peak power output, the results were split according to body mass; < 70 kg ($n = 5$), $70-80$ kg ($n = 7$) and > 80 kg ($n = 8$). Results showed that the highest peak power output for all three body mass groups was achieved at the highest MPV setting (Figure 2.2). Consequently an MVP setting of 7 was used for all surfers in the present study. It is not known if a higher MPV setting would have resulted in further increases in peak power output, as a higher MPV setting was not available on the present ergometer.

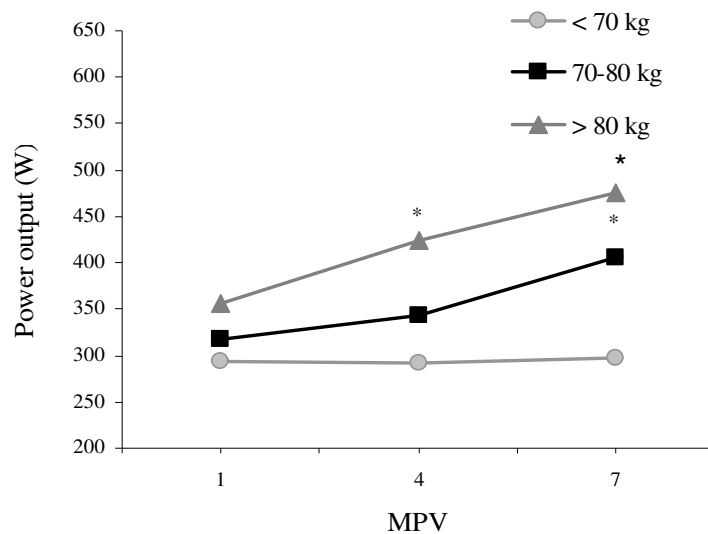


Figure 2.2 The group mean values of peak power output determined during three 10-s maximal-intensity paddling tests performed at three resistances (1, 4, 7) in twenty recreational male surfers grouped according to body mass. *Different from peak power output in the same group at the other two resistances.

Field-testing equipment

A speed probe was used to determine peak speed of the surfer during the 10-s field tests. The speed probe determined speed by measuring displacement via a 10-cm circumference, machined wheel. A non-stretch line (tether) was wrapped around the wheel and then attached to the surfer’s waist (the wheel was wide enough that the line did not wrap onto itself). The surfer entered the pool with the tether attached, and lay on their board with their feet just off the pool wall to prevent a push off. The test began when the chief investigator gave the command of, “On your marks, go!” As the surfer progressed, the pull on the line forced the wheel to spin. The faster the wheel spins, the greater the displacement or distance paddled. The distance that the tether travels, and the time in which it travels, is measured by an infrared light that passes over ten drill holes (1 cm apart) situated around the circumference of the wheel. As the wheel spins,

the infrared light measures the number of holes passed (distance) and the time between each hole (time). The analogue output from the wheel is then converted into a digital signal recorded onto a personal computer using custom designed software that calculates speed from distance and time (Sports Studio 2005, Applied Motion Research, Gold Coast, AUS). Figure 2.3 displays an example of the field-testing set up.

The speed achieved by one surfer performing a 10-s maximal-intensity paddling trial (field) is displayed in Figure 2.4. The wave-like motion of the speed curve is because of the alternate arm paddling of the surfer and therefore the small oscillation in speed with each stroke. Speed is greatest at the end of each paddle and least just before the hand re-enters the water, similar to that of swimming. Speed values were averaged into 1-s intervals with peak speed taken as the highest 1-s value achieved over the 10-s period of the trial.



Figure 2.3 Example of a surfboard rider during a 10-s maximal-paddling test performed in a 25-m swimming pool paddling on a surfboard.

The output results for one individual surfer completing a 10-s maximal-paddling trial performed in the swimming pool is displayed in Figure 2.4. The wave like motion of the velocity curve is due to the alternate arm paddling of the surfer and therefore the small oscillation in velocity with each stroke. Velocity is greatest at the end of each paddle and least just before the hand re-enters the water, similar to that of swimming. Velocity values were averaged into 1-s intervals with peak velocity taken as the highest 1-s value achieved over the 10-s period of the trial

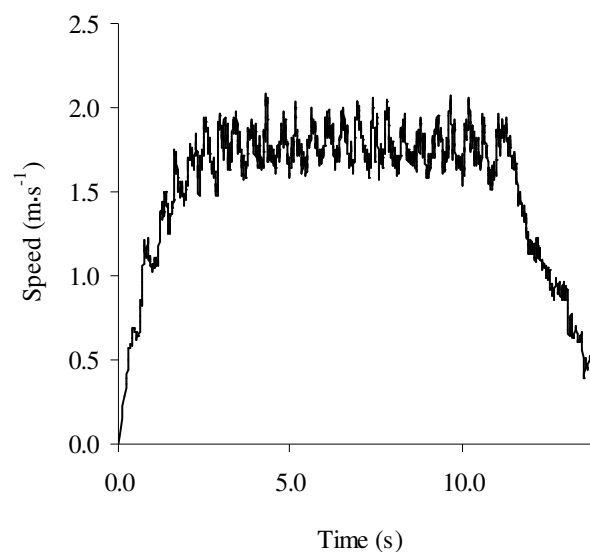


Figure 2.4 The speed of one competitive male surfer during a 10-s maximal-intensity paddling test performed on a surfboard in a 25-m swimming pool.

Data analysis

Means (\pm SD) values were calculated for physical characteristics, peak power output, and peak speed. ANOVA with repeated-measures for Day and Trial was used compared peak power output across all six laboratory tests. A second ANOVA with repeated measures for Condition and Trial was used to compare peak speed during the non-kicking and kicking field tests. When differences were detected, pairwise comparisons

with Bonferroni adjustments were performed to determine their source. The effect size of the difference was calculated as the standardised mean difference between the two groups i.e., (mean of kicking – mean of non-kicking)/standard deviation of kicking.

Trial-to-trial reliability was determined from intraclass correlation coefficients for all six trials of laboratory testing and all three trials of field testing in each condition. The coefficients for Trial 1 and Trial 2 performed on Day 1 both for laboratory testing and field testing were determined to investigate trial-to-trial reliability. Day-to-day reliability for laboratory testing was determined by calculating coefficients for peak power output measured for Trial 1 on Day 1 of testing and Trial 1 on Day 2 of testing. Statistical significance was set at $P < 0.05$. Intraclass correlation coefficients are highly sensitive to heterogeneity of the sample (Hopkins, 2000), therefore the change in mean and typical error were also determined to assess the reliability of the two testing methods. The change in mean and typical error were also expressed as a percentage of their respective means using log-transformed data. Typical error and change in mean values were chosen to characterise reliability because of the reasons outlined by Hopkins (2000, p. 15) in which he concluded that ‘observed values and confidence limits of the typical error and change in mean are necessary and sufficient to characterise the reliability of a measure’.

2.3 RESULTS:

Reliability of lab testing

There were no differences in peak power output among all six trials performed during laboratory testing ($F = 1.063$, $p = 0.364$), as illustrated in Figure 2.5. Table 2.1 presents the intraclass correlation coefficients, change in mean and typical error for peak power output calculated for Trial 1 and Trial 2 (trial-to-trial) as well as Trial 1 and Trial 4 (day-to-day) of laboratory testing. The intraclass correlation coefficient of all six trials was not notably different to the coefficient calculated for peak power output determined during Trial 1 and Trial 2 only. Similarly, the intraclass correlation coefficient associated with Trial 1 and Trial 4 was greater than 0.90. The group mean value for the change in mean and typical error were all less than 6%.

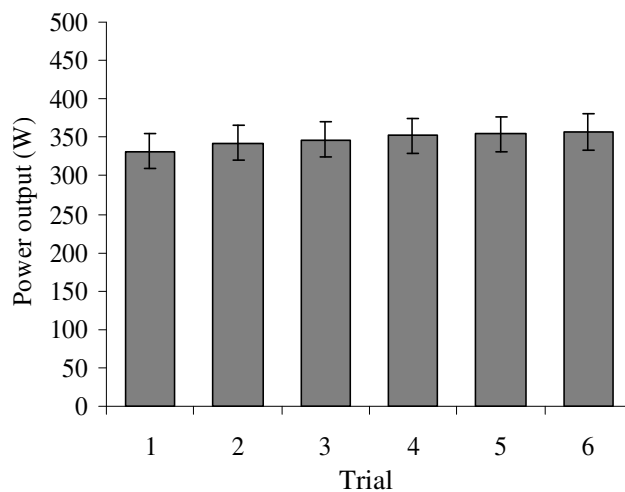


Figure 2.5 The group mean (\pm SD) values of peak power output determined during six 10-s maximal-intensity paddling tests performed on a swim-bench ergometer in eleven competitive male surfers. Six trials were performed over two days; three trials per day.

Table 2.1 Measures of reliability determined for peak power output obtained during maximal-intensity paddling ergometry in eleven competitive male surfers.

	ICC		Change in mean	Typical error
All 6 trials	0.992			
Trial 1 – Trial 2	0.995	Mean (W)	10.9 W	6.9 W
		Confidence limits (W)	4.4 – 17.5 W	4.8 – 12.1 W
		Mean (%)	3.8%	2.6%
		Confidence limits (%)	1.3 – 6.5%	1.8 – 4.6%
Trial 1 – Trial 4	0.983	Mean (W)	20.2 W	14.9 W
		Confidence limits (W)	6.0 – 34.5 W	10.4 – 26.2 W
		Mean (%)	5.7%	3.7%
		Confidence limits (%)	2.1 – 9.5%	2.6 – 6.4%

Six 10-s paddling trials were performed over two days; three trials each day. Trial-to-trial reliability (All 6 trials, Trial 1 – Trial 2) and day-to-day reliability (Trial 1 – Trial 4) was assessed. 95% confidence limits were calculated. % values were derived from log-transformed data.

Reliability of field testing

There were no differences in peak speed among the three trials for kicking ($F = 0.154$, $p = 0.858$) and across the three trials for non-kicking ($F = 0.204$, $p = 0.661$). The intraclass correlation coefficient for peak speed measured during all three trials for kicking was > 0.90 that was similar to the intraclass correlation coefficient calculated for the three non-kicking trials (Table 2.2). There was no substantial change in the coefficient when only speed values from Trial 1 and Trial 2 were included in the calculation for both the kicking and non-kicking conditions. The change in mean and typical error were all less than 1% for peak speed from Trial 1 to Trial 2 for each condition.

Table 2.2 Measures of reliability determined for peak speed obtained during maximal-intensity paddling performed by eleven competitive male surfers in a swimming pool.

ICC			Change in mean	Typical error
Non-kicking trials				
All 3 trials	0.993			
Trial 1 –	0.985	Mean (W)	< 0.00 m·s ⁻¹	0.01 m·s ⁻¹
Trial 2		Confidence limits (W)	-0.01 – 0.02 m·s ⁻¹	0.01 – 0.03 m·s ⁻¹
		Mean (%)	0.2%	0.8%
		Confidence limits (%)	-0.6 – 1.0%	0.6 – 1.5%
Kicking trials				
All 3 trials	0.996			
Trial 1 –	0.995	Mean (W)	< 0.00 m·s ⁻¹	0.02 m·s ⁻¹
Trial 2		Confidence limits (W)	-0.01 – 0.02 m·s ⁻¹	0.01 – 0.03 m·s ⁻¹
		Mean (%)	-0.2%	0.8%
		Confidence limits (%)	-0.9 – 0.6%	0.6 – 1.5%

Three 10-s paddling only trials (non-kicking) were performed on one day and three 10-s paddling and kicking trials (kicking) were performed on a separate day. 95% confidence limits were calculated. % values were derived from log-transformed data.

Impact of leg kicking on surfboard-paddling speed

We found no interaction between Trial (1, 2, and 3) and Condition (kicking and non-kicking) ($F = 0.957$, $p = 0.821$). There was no main effect for Trial ($F = 1.092$, $p = 0.355$) but there was an effect for Condition ($F = 21.731$, $p < 0.001$), such that the mean peak speed for the kicking condition ($1.89 \pm 0.04 \text{ m}\cdot\text{s}^{-1}$) was greater than ($p < 0.001$, effect size = 4.00) the mean peak speed for the non-kicking condition ($1.73 \pm 0.03 \text{ m}\cdot\text{s}^{-1}$), see Figure 2.6.

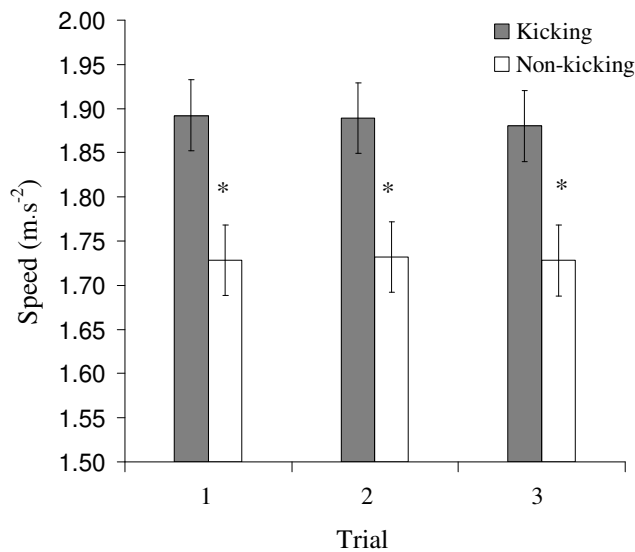


Figure 2.6 The group mean (\pm SD) values of peak speed determined during six 10-s maximal-intensity paddling tests performed in a 25-m swimming pool in eleven competitive male surfers. Three paddling trials were performed whilst arm paddling only (non-kicking) and three with simultaneous arm paddling and leg kicking (kicking). * Different from kicking, ($p < 0.001$).

2.4 DISCUSSION

The present study found that peak power output measured during maximal-intensity surfboard paddling on a swim-bench ergometer is reliable in competitive male surfers. Peak power output determined for the group of eleven male surfers did not change across six, 10-s maximal-intensity paddling trials and there was no change in the intraclass correlation coefficient when calculated for the first two trials ($r = 0.995$) compared with the value calculated for all six trials ($r = 0.992$). Furthermore, we established that peak power output could be determined reliably ($r = 0.983$) on separate days. We conclude that there is good trial-to-trial and day-to-day reliability in peak

power output for surfboard paddling determined during swim-bench ergometry in competitive male surfboard riders.

Maximal-paddling performance has not been assessed in surfers of any standard (Mendez-Villanueva & Bishop, 2005). Maximal-intensity surfboard paddling might be a major determinant of a surfer's ability to catch a wave and assume the ideal position for wave riding. The present study demonstrates that peak power output achieved on the swim-bench ergometer (mean of six trials = 348 ± 23 W) is similar to peak power output observed in competitive swimmers (304 ± 22 W) (Swaine, 2000) and surf lifesavers (326 ± 29 W) (Morton & Gastin, 1997), measured during 30-s all-out front-crawl swimming and 60-s all-out knee-board paddling (surf lifesavers) on similar swim-bench ergometers. Upper-body peak power output of competitive swimmers and surf lifesavers is probably among the highest of any sportsman given the nature and energy demands of their sports. Therefore, the similar peak power output values observed in the present study for competitive surfers suggests that surfing also requires high upper-body power output.

The ability to reliably measure peak power output for paddling will enable coaches and exercise scientists to: i. Estimate maximal-intensity exercise capability, ii. Monitor changes in peak power output as a result of training, iii. Establish a goal for a rehabilitation program, iv. Use test results as a motivational tool, and v. Establish normative values for varying standards of surfing ability. In addition, a reliability study that provides anticipated change in mean values or typical error confidence limits for the measurement of peak power output during paddling allows coaches to identify physiologically meaningful changes.

The day-to-day reliability reported for peak power output on the swim-bench ergometer in the present study are comparable to values reported in studies that have investigated repeated sprints during leg cycling on a cycle ergometer (typical error values ranging

between 3.1-7.3%), as summarised in a meta-analytical review on the reliability of power in physical performance tests (Hopkins *et al.*, 2001). To the best of our knowledge, only one study has investigated the trial-to-trial reliability of front-crawl paddling on a swim-bench ergometer in which two tests were performed and a change in mean value was reported as 6.9% (Swaine, 2000). No previous study has reported day-to-day reliability of a swim-bench ergometer.

An increase in peak power output of 53% has been reported for surf lifesavers after 10 wk of high-intensity surfboard training (Morton & Gastin, 1997). The present study suggests that smaller changes in peak power output observed in competitive surfers after an intervention (e.g., training) could be considered “worthwhile” (as defined by Hopkins, 2004) given the typical error value of 3.7% reported here for day-to-day reliability during laboratory testing. For example, an increase in peak power output of 1.9% (i.e., half the typical error), or about 6 W, could be considered to be “reasonably confident of a worthwhile change” (Hopkins, 2004). However, surfers should improve by about 7.4% (i.e., double the typical error), or about 20 W, from an initial peak power of 300 W. Nevertheless, this error value was derived from a small group of competitive male surfers. Thus, no firm conclusions can be made about worthwhile changes in peak power output when monitoring individual surfers.

It is unclear how upper-body peak power output measured on a swim-bench ergometer translates or relates to the actual speed of movement of the surfer through the water. A paddling test that can easily and quickly be performed in any swimming pool might be a useful tool for sport scientists or surfing coaches who might not have access to swim-bench ergometry. This is the first study to assess surfboard-paddling performance in the water. Peak speed for surfboard paddling in flat-water (swimming pool) was highly reliable in competitive male surfboard riders. The mean peak speed determined for the group of eleven male surfers did not change across three, 25-m maximal-intensity paddling trials under two conditions (non-kicking and kicking).

The present study determined the peak speed of surfboard paddling in the water under two conditions: i. Simultaneous paddling and kicking (kicking), and ii. Paddling only (non-kicking). Whereas measures from both were reliable, peak speed was greater when kicking than paddling only. There are three situations in surfing where a surfer will kick their legs while paddling to: i. Secure a wave, ii. Move away from the impact zone of a wave set (where the waves are crashing or dumping), and iii. Arrive in the take-off zone in competition to receive priority for the next wave. In contrast, a surfer will not kick when paddling from the shoreline to the wave-catching position, (typically at the back of the braking waves), or when moving into the best position to wait for a wave as they do not require high speeds and kicking could increase their fatigue.

Kicking while paddling was $0.16 \text{ m}\cdot\text{s}^{-1}$ faster than non-kicking. For a 5-10 s burst necessary for catching a wave, this is an increase in distance of between 0.8 to 1.6 m. Therefore, a surfer competing for the best take-off position will move 0.8 to 1.6 m further when kicking for 5-10 s. An increase in distance from 0.8 to 1.6 m could be the difference between reaching a wave before another surfer or not. The first surfer to stand up on the wave during competition gets priority for that wave. Therefore, we suggest that kicking while paddling could improve a surfer's chance of getting into the ideal position for catching a wave compared to paddling only.

The present study demonstrates that peak speed of surfboard paddling with no kicking is 92% of the speed of simultaneous arm paddling and kicking in competitive male surfers. This highlights the importance of upper- and lower-body contributions to peak power output in surfing. Further, the percent difference in performance between non-kicking and kicking might be more useful than absolute speeds to compare results between surfers. Comparing absolute values of speed between surfers is difficult because the combined effects of volume and dimensions of the surfboard and the stature and body mass of the surfer greatly influence the resultant speed of the overall system.

The dimensions and volume of the surfboard in relation to the surfer's stature and body mass need to be controlled to make accurate comparisons between the two testing methods or among individual surfers for field testing. This is unlike laboratory-testing results that can accurately and easily be compared between individuals by, for example, expressing peak power output values relative to body mass ($\text{W}\cdot\text{kg}^{-1}$). Nevertheless, trial-to-trial reliability of measures from the laboratory test can be compared with the trial-to-trial reliability of those from the field test via change in mean values, typical error scores, and typical error confidence limits for both tests, expressed as a percentage of the mean. Field-test measures had a smaller change in mean, typical error, and confidence limits than those from laboratory testing. The smaller typical error scores and change in mean values for field testing suggests that this test has greater sensitivity to assess smaller or physiologically meaningful changes in maximal-paddling performance than its laboratory equivalent.

Concluding Remarks

The ability of a surfer to accelerate quickly from a stationary position and achieve high-paddling speeds could be related to their ability to catch bigger waves, faster waves, or waves that are hard to paddle onto (waves breaking slowly, strong winds, or waves with less energy). We can only hypothesize about the relationship between peak power output and paddling speed with the ability to catch a wave. However, the development of a reliable laboratory and field test for the assessment of peak power output for paddling in surfboard riders has provided new tools and methods to undertake further research in this area. Such research should include the: i. Characterisation of maximal-intensity exercise capabilities and economy of surfboard paddling in surfers of different standard, ii. Characterisation of the kinematics of surfboard paddling both in the laboratory and in the field, and iii. Determination of the influence of body position, stroke rate, underwater-paddling technique, and board dimensions on muscle

recruitment patterns of board paddling. Such research could help investigate surfers' upper-body injuries that are attributable to board paddling, or help identify the influence of maximal-intensity exercise and/or paddling economy on performance. Finally, the dimensions and volume of the surfboard in relation to surfers' stature and body mass should always be considered or controlled when undertaking field-based research in this area.