Factors That Affect Selection of Elite Women’s Sculling Crews

Trent W. Lawton, John B. Cronin, and Michael R. McGuigan

Purpose: There is no common theory on criteria to appropriately select crew rowers in pursuit of small performance gains. The purpose of this study was to establish whether anthropometry, rowing ergometry, or lower body strength were suitable criteria to identify differences between selected and nonselected sculling crews. Method: Twelve elite women performed a 2000-m ergometer time trial and a 5-repetition leg-press dynamometer test, were anthropometrically profiled, and participated in on-water national crew seat-racing trials. Log-transformed data were analyzed to compare percent (± SD) and standardized differences in group means (ES; ±90% confidence interval [CI]) between selected and nonselected oarswomen, with adjustments for body mass where appropriate. Results: Selected crew boats were 4.60% ± 0.02% faster and won by an average margin of 13.5 ± 0.7 s over 1500 m. There were no differences between crews on average in height, arm span, seated height, body mass, or 8-site skinfold sum (body fat). Difference in 2000-m ergometer times were also trivial (ES = 0.2, 90% CI = –0.6 to 1.1, P = .63); however, selected crews had moderately greater leg-press strength (ES = 1.1, 90% CI = 0.3–1.9, P = .03). Conclusion: Selected oarswomen with comparable anthropometry and 2000-m ergometer ability had greater lower body strength. Coaches of elite oarswomen might consider leg strength as part of crew-selection criteria, given acceptable on-water boatmanship and attainment of 2000-m ergometer benchmarks.

Keywords: anthropometry, 2000-m rowing ergometry, seat-racing trials, strength

Based on world-best times and depending on crew size, boat type, and weather conditions, an Olympic 2000-m rowing event lasts somewhere between 5:20 and 7:28 minutes on water. However, there is no common theory on criteria to appropriately select crew rowers in pursuit of small performance gains as little as 0.3% to improve final rankings at World Cup or Championship regattas.1,2 Sport-science selection strategies are common and typically involve some aspect of anthropometry. Olympic female heavyweight rowers were significantly taller (1.81 ± 0.05 m), heavier (76.6 ± 5.2 kg, P < .01), and of greater seated height (93.7 ± 3.1 cm) than nonrowers and, compared with their less successful competitors, had lower skinfold sum for 8 sites (82.1 ± 23.2 vs 99.8 ± 20.4 mm).3 Successful senior rowers were also on average significantly taller (+5.4 cm) and heavier (+11.1 kg)2 and had longer arm span and greater seated height than junior rowers.3 Height (r = –.81), body mass (r = –.85), and fat-free mass (r = –.91) are some of the simplest measures and strongest correlates of 2000-m rowing-ergometer performance.5 However, such differences within elite crew boats may be less likely, and as height is genetic and depends on maturation rate, it cannot be influenced by training.

In terms of possible physiological selection criteria, Hay6 reported that a 6-minute rowing-ergometer test was the strongest correlate of rank orders of 20 rowers based on rowing ability agreed on by 5 experts (Spearman rho = .89). Similarly, Kramer et al7 established the best 2 factors to reflect overall rowing ability (as determined by coach rank order) from a suite of descriptive, field, and laboratory tests as 2500-m ergometer speed (rho = –.86) and competitive experience (rho = –.91). In both cases, given knowledge of past performance in testing and competition, such strong interrelationships between factors indicated bias in expert judgments in the ranking of rowers.

Various protocols to assess individual physiological relationships between rowing ergometry and rowing ability have been used.7–11 Yet, ergometry assessments are only a rough guide of on-water crew-performance outcomes.10,12 Many “boat stoppers” are argued to have found their way onto crews when assigned on the basis of such data.9 Annual 2000-m ergometer-performance improvements are also likely to plateau on reaching champion elite status in A-final regattas (ie, ±0.3%).13 Given pacing strategies and errors of measurement associated with 2000-m ergometer assessment (eg, typical error as a coefficient of variation ~2.0%),14–16 establishing meaningful performance differences (eg, ±1.0%) between
highly trained rowers would be difficult and therefore problematic for crew-selection purposes.

Gallagher et al\(^\text{17}\) proposed that the practical significance of differences in 2000-m ergometer-performance gains associated with strength were noteworthy, equivalent to almost a boat length or 4 seconds on water. In particular, lower body strength appears to account for performance differences between individuals of varying rowing ability, with strong, possibly curvilinear, associations reported with 2000-m ergometer performance and simulated 6-minute on-water racing.\(^\text{7,18–23}\) In practical terms, relatively large differences in lower body strength may be required to account for comparatively small though important performance outcomes between elite rowers. However, the role of strength, particularly leg strength, in predicting crew performance and the selection of individual rowers is unknown.

Given the preceding information, the purpose of this study was to establish whether lower body strength, anthropometry, or rowing ergometry accounted for performance differences observed between selected and nonselected rowers contesting representation on national sculling crew boats. Current national crew-boat selection strategy in New Zealand is based on each rower’s ability to contribute to on-water boat speed, methodically determined by “seat racing.” Seat-racing trials involve head-to-head races between 2 crews, after which rowers are switched between boats. Seat-racing trials overcome most standard error of between 2 crews, after which rowers are switched between boats. Seat-racing trials overcome most standard error of terms. Therefore, once crew combinations have been trialed, objective factors thought to differentiate between faster and slower crews can be examined. To our knowledge, this is the first study to investigate factors influencing actual crew-selection outcomes.

**Methods**

**Study Design**

This study compared mean (± SD) differences in anthropometry, 2000-m ergometer time, and lower body strength between selected and nonselected crew scullers subsequent to national selection seat-racing trials. Twelve elite women performed a 2000-m ergometer time trial and a 5-repetition leg-press dynamometer test, were anthropometrically profiled, and participated in on-water national-crew seat-racing trials conducted at the commencement of a 4-month competition phase. Log-transformed data were analyzed to compare percent (± SD) and standardized differences in group means (ES; ±90% confidence interval [CI]) between selected and nonselected oarswomen, with adjustments for covariates as appropriate.

**Subjects**

Twelve elite women age 23.1 ± 3.8 years with an average rowing experience of 7.6 ± 3.5 years were retrospectively investigated in this study. All oarswomen were crew scullers (eg, double-scull) and had previously competed in A-finals in World-Cup and Championship regattas. Selected crews from the respective boat classes examined in this study went on to achieve bronze medals at world championships. The study protocol was approved by the AUT University ethics committee. Informed voluntary signed consent was obtained after rowers attended project information and familiarization seminars. Rowers who were cleared by medical staff for participation in regular training were allowed to test.

**Test Procedures**

Scullers aspiring for national selection participated in 2000-m time trials held at the various rowing centers of excellence and then attended the national championships regatta. Top-ranked national scullers (ie, premier finalists) were invited by national selectors to participate in seat-racing trials. After the announcement of crews, all scullers were anthropometrically measured and strength-tested. The entire selection and testing protocol was completed within 4 weeks.

**Assessments**

**2000-m Time Trial.** A stationary air-braked rowing ergometer (Model D, Concept 2 Inc, Morrisville, VT) with the drag factor setting of 110 was used for the 2000-m self-paced time trial. During testing, participants had access to the console information, which included the elapsed distance (m), test time (min, s), 500-m interval time/splits (min, s), and stroke rate expressed in strokes/min. This test was performed as part of national selections at various rowing centers of excellence.

**National Selection Trials (Crew Seat Racing).** Seat-racing trials involved head-to-head races over 1500 m between 2 crew boats fitted with standardized rigger spans and oar gearing and, in this study, involved selection of national sculling crew boats (eg, double-scull). Based on 2000-m time-trials rank orders (eg, fastest vs slowest rowers), the starting combinations for the initial crew-boat trials were announced by national selectors. An initial 1500-m trial was held and finishing order (rank) established, with the margin between race times (expressed as a percentage) assigned to the winning crew (eg, margin win of 0.8% assigned to crew A). Using no predetermined order, selectors announced which 2 scullers were to switch seats between crew boats, and after approximately 20 minutes, a subsequent 1500-m trial was held. Finish margins were again determined and compared with trial 1, with the winning seat race assigned to the rower in the now-faster crew (eg, rower A retrieved 0.5% of the 0.8% margin between crews and was therefore ranked higher than rower B). Switching between boats was continued until all scullers were ranked by changes in boat margins (thus boat speed). Previously assessed trials were on occasion repeated, and although rowers were able to observe differences...
in boat lengths (as crews crossed the finish line), they were not made aware of final margins or individual rankings.

No more than 8 trials were performed on a particular day (ie, 4 trials in each morning and afternoon session). Weather conditions (air temperature and wind speed) were monitored throughout trials, and seat racing was suspended or discontinued when weather conditions became inclement (eg, head or tail wind >1.5 m/s). On establishment of rankings, the fastest-ranked crew-scullers were raced against the slower-ranked crew. If necessary, further trials or switches between seats were made, if in the opinion of selectors performance margins were negligible (eg, <the average % margins won) or boatmanship was poor, until a favored crew combination was announced by selectors.

**Anthropometry.** Standing height, seated height, and arm span were assessed using wall-mounted stadiometers, with body mass measured using calibrated electronic scales (Tanita HD-316, Tanita Corp, Tokyo, Japan). Skinfolds were measured using a Slim Guide caliper (Creative Health Products, Plymouth, MI) at 8 sites: biceps, triceps, subscapularis, supraspinale, iliac crest, abdominal, midthigh, and calf. All anthropometrical measures were performed per International Society for the Advancement of Kinanthropometry guidelines. 24

**Leg-Press Dynamometry.** A dynamic-strength-training dynamometer (DYNO, Concept 2 Inc, Morrisville, VT) was used to measure average concentric work (ie, force × distance) produced during 5 repetitions of leg-press exercise. The dynamometer provided resistance by flywheel inertia combined with air-braking fans to create drag comparable in design to a Concept 2c rowing ergometer. The drag factor was set with 2 air dampeners opened. A repetition was commenced every 2 seconds (or equivalent to a rating of about 30 repetitions/min) to ensure that tests were performed within a target completion time (approximately 10 s). Three trials were performed, with at least 3 minutes between attempts, and the best score recorded as the test result. All rowers had previously used the dynamometer and were familiar with the leg-press technique. Previous test–retest reliability of the dynamometer 5-repetition leg-press strength test in our laboratory was CV = 2.5%, ICC ≥ .99.

**Statistical Analysis**

Individual scores were tabulated and represented as mean ± SD for selected and nonselected sculling crews (groups). A one-way ANOVA was used to establish differences between groups, with respective P values and 90% CIs reported. 25 Mean, percent mean, and standardized differences in 2000-m ergometer and 5-repetition leg-press data, adjusted for by body mass as a covariate, were calculated using a spreadsheet. 26 Differences in body mass were adjusted for by standing height as a covariate. Adjustments were performed by fitting a simple linear model to the relationship between the change scores and anthropometrical covariate in each group. The linearity and homoscedasticity of data were examined by visual inspection of bipolar plots with least-squares regression analysis, and the distribution and normality of data were assessed using histograms, probability plots, and Shapiro–Wilk test on SPSS (version 17). All data were log-transformed before analysis to reduce nonuniformity of error. Magnitudes of standardized effects (ES) were calculated by dividing the appropriate between-rows standard deviation and using a modified Cohen scale defined as <0.2 = trivial, 0.2–0.59 = small, 0.6–1.19 = moderate, 1.2–1.99 = large, and ≥2.0 = very large. 27 Differences were deemed significant where P ≤ .05, but given a small participant sample, it was unclear if the confidence intervals for ES overlapped the thresholds for smallest positive and negative effects (ie, 0.2 × SD).

**Results**

Selected crew boats were 4.6% ± 0.02% faster and won by an average margin of 13.5 ± 0.7 s over the final 1500-m seat race. Table 1 shows that no significant differences in height, arm span, seated height, body mass, or 8-site skinfold sum were observed between selected and nonselected rowers (all P > .05). The mean 2000-m ergometer time was 412.2 ± 7.6 seconds, and 5-repetition leg-press strength was 648 ± 65 J. Mean differences in 2000-m ergometer times between selected and nonselected scullers were trivial and unclear (ES = 0.2, 90%CI = –0.6 to 1.1, P = .63). In contrast, significant and clearly greater leg strength was found in selected scullers (ES = 1.1, 90%CI = 0.3–1.9, P = .03), as shown in Table 2.

**Table 1 Anthropometrical Characteristics and Differences Between Selected and Nonselected Crew Scullers (N = 12), Mean ± SD**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Selected (n = 6)</th>
<th>Nonselected (n = 6)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>178.9 ± 5.1</td>
<td>177.1 ± 2.2</td>
<td>.36</td>
</tr>
<tr>
<td>Arm span (cm)</td>
<td>182.7 ± 10.0</td>
<td>179.5 ± 3.1</td>
<td>.39</td>
</tr>
<tr>
<td>Seated height (cm)</td>
<td>92.2 ± 3.3</td>
<td>92.8 ± 2.9</td>
<td>.71</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>73.5 ± 3.8</td>
<td>73.8 ± 4.2</td>
<td>.88</td>
</tr>
<tr>
<td>8-site skinfold sum (mm)</td>
<td>82.0 ± 7.6</td>
<td>85.0 ± 15.8</td>
<td>.38</td>
</tr>
</tbody>
</table>
While there is general agreement that a number of physiological, psychological, and technical factors are important in order to perform, the extent to which each factor contributes in the assignment of rowers to crews is seldom quantified. Individual technique and crew boatmanship are difficult if not intangible factors to replicate off water. Nonetheless, specific criteria to select a replacement, to set goals to monitor progress, or to assess the possible impact of any crew change involving individual rowers are desirable off water. In the current study, we examined whether anthropometry, 2000-m ergometry, or leg-strength factors were such suitable criteria. Our main finding was that height, arm span, seated height, body mass, 8-site skinfold sum, and 2000-m rowing-ergometer data did not differ between successful and unsuccessful elite crews. However, all other factors remaining equal, selected oarswomen who were faster in sculling crews had greater lower body strength.

In a practical sense, oarswomen differed in height and body-fat sum as individuals. These relatively small variations did not amount to any meaningful difference in the assignment of oarswomen to crews (Table 1). Similarly, selected crews who went on to become successful at international regattas (ie, bronze medalists at World Rowing Championships) were only marginally shorter (−2.0 cm) and lighter in body mass (−3.0 kg) but were otherwise comparable in seated height and body-fat sum to data reported of champion rowers at Olympic Games (2000). Based on these data, we conclude that moderate differences (standardized effect size ~0.8) of about 18 mm of body fat (or around 1–2 kg) would be more likely to influence selection outcomes. In addition, although our oarswomen were relatively homogeneous in height and body fat, future research might investigate whether the distribution of lean body mass differed in segments critical to the development of rowing power (ie, anterior thigh, posterior chain complex, and erector spinae muscle groups of the legs and trunk) by use of ultrasound or magnetic resonance imaging. The greater gains in height and body size and muscle hypertrophy.3,4,29–31

Although rowing ergometry can discriminate between rowers of competitive ability,6,7,9 a 2000-m time trial was not a significant discriminator in the assignment of elite oarswomen to crews in the current study. It may be that the technique used to maximize ergometer results does not relate to, or is in contrast to, on-water rowing techniques. For example, counterproductive habits on water, such as rushing into the catch, pulling the oar handle to the neck, or excessive body swing at the finish, have little negative and perhaps greater beneficial performance outcomes in rowing ergometry. In addition, rowing ergometry uses a very stable base of support and has little requirement for balance, consideration or reaction to crewmates and weather conditions, or skill with the oar.10,11 Hill suggested that the dynamics of stroke force and synchronicity were equally if not more important in the performance of larger crews. That is, the only real way to rank rowers is based on their ability to contribute to a crew’s performance in terms of actual boat speed. Therefore, at best, the prediction of on-water performance based on rowing-ergometry data appears constrained to the setting of competitive benchmarks for standards of performance attained by oarswomen in preparation for international competition. It may be, however, that ergometer tests that are explicit measures of aerobic power or condition provide more useful data to differentiate candidates vying for crew selection8,10,11

Gallagher et al17 postulated that the greater gains observed in the rate of 2000-m rowing-ergometry improvement from strength development may amount to gaining almost 1 boat length on water. If this were the case, the oarswomen assigned to the selected crews in our study should have attained faster 2000-m ergometer times on average. In fact, 2000-m times did not differ between crews, as overall, our sample of oarswomen were relatively homogeneous (412.2 ± 7.6 s, coefficient of variation = 1.8%). More to the case, elite oarswomen assigned to faster crews had moderately greater lower body strength (ie, +11.8%, 90%CI = 3.1–21.3%, P = .03). That is, among oarswomen of comparable ergometer ability, it was the attainment of greater leg strength that accounted for a 13.5 + 0.7-s difference in 1500-m on-water performance between selected (686.5 ± 77.4 J) and nonselected (647.5 ± 64.7 J) crews. Given the greater heterogeneity in our sample (648 ± 65 J, CV = 10%), lower body strength emerged as the only useful datum on which to predict the on-water 1500-m performance outcome (win/loss) between crews.

While differences in lower-body strength were clear, due to the small sample size of this investigation, the

### Table 2 2000-m Ergometer and 5-Repetition Leg Press Adjusted for Body Mass (N = 12), Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>Selected (n = 6)</th>
<th>Nonselected (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-m ergometer time trial (s)</td>
<td>413.2 ± 6.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>411.2 ± 8.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5-repetition leg-press dynamometry (J)</td>
<td>686.5 ± 77.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>608.5 ± 52.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>The probability that selected scullers were 0.5% slower was not significant and unclear (90%CI = −1.3% to 2.3%, P = .63).<sup>b</sup>The probability that selected scullers were clearly 11.8% stronger was significant (90%CI = 3.1–21.3%, P = .03).
reader must remain cognizant of type II error in the determination of differences in other data (ie, a “true” difference was not detected). There may also be differences in upper body strength unaccounted for in the current study that affect performance or individuals who have varying rowing styles that reflect the strength requirements of particular boats (eg, 8s) or seat positions (eg, bow or stroke seats). We therefore conclude that techniques to assess strength concurrent to on-water rowing endurance and technique should be considered in the selection and preparation of elite oarswomen for sculling crews.

Practical Applications

In the absence of crew seat-racing trials and where homogeneity of 2000-m ergometer scores is evident (eg, CV <2.0% or <8 s), lower body strength differences (ES >0.8 or 10%) may provide meaningful insight for the objective refinement of crew selections or preparations. On attestation of on-water boatmanship, coaches might consider techniques to emphasize the leg drive and increase lower body strength in preparation for competition or selection trials. Finally, they might consider benchmarks for aspiring national representatives that incorporate lower body strength alongside anthropometric and 2000-m ergometer time-trial criteria.

Acknowledgments

No funding from the National Institutes of Health, Welcome Trust, Howard Hughes Medical Institute, or others was received for this work. The authors thank Mr Alan Cotter, high performance manager of Rowing New Zealand, for facilitating the implementation of this study. The results of the current study do not constitute endorsement of the product by the authors or the journal. The authors have no conflicts of interest that are directly relevant to the content of this original investigation.

References


