Journal of Sports Sciences, February 15th 2009; 27(4): 361–366

Routledge
Taylor & Francis Group

Does 2000-m rowing ergometer performance time correlate with final rankings at the World Junior Rowing Championship? A case study of 398 elite junior rowers

PAVLE MIKULIĆ[1], TOMISLAV SMOLJANOVIĆ[2], IVAN BOJANIĆ[2], JO HANNAFIN[3], & ŽELJKO PEDIŠIĆ[1]

[1]*Department of Sport, Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia,* [2]*Department of Orthopaedic Surgery, Clinical Hospital Centre, Zagreb, Croatia, and* [3]*Hospital for Special Surgery, Weill Medical College of Cornell University, New York, USA*

(Accepted 4 November 2008)

Abstract

In this study, we assessed the extent to which 2000-m rowing ergometer performance predicted final rankings at the World Junior Rowing Championship in a sample of 398 junior rowers competing in 13 events. The rowers' ergometer performance times were examined using a questionnaire, and in all 13 events they correlated ($P \leq 0.039$) with the final rankings at the Championship. The strongest correlations were observed for ergometer performance times in junior women's single sculls ($r = 0.92$; $P < 0.001$), followed by junior men's single sculls ($r = 0.80$; $P < 0.001$) and junior women's double sculls ($r = 0.79$; $P < 0.001$). The observed correlations were higher for smaller boats – singles, doubles, and pairs ($r = 0.64$–0.92; $P \leq 0.025$) – than for larger boats – quads, fours, and eights ($r = 0.31$–0.70; $P \leq 0.039$). Linear regression analyses were used to construct regression equations to predict final rankings based on 2000-m rowing ergometer performance times for each event. Although correlations in 10 of the 13 events were above $r = 0.5$, the large standard errors of the estimate impaired the prediction of rankings in all of the studied events. Using these equations, the most probable rowing ergometer performance times required for a particular ranking in a given rowing event might easily be calculated.

Keywords: *Boat categories, elite rowing, performance prediction, regression analysis*

Introduction

Rowing ergometers are designed to simulate on-water rowing and are widely considered to be valuable for rowing training, evaluation of a rower's sport-specific performance, and detection of changes in a performer's capability (Mäestu, Jürimäe, & Jürimäe, 2005). The time needed to cover a particular distance is likely to be the most relevant measure in the testing and evaluation of an athlete's capability. One of the most frequently used "all-out" ergometer tests to assess rowing-specific ability is performed over 2000-m (Hahn, Bourdon & Tanner, 2000; Mäestu et al., 2005), which corresponds to the distance used for Olympic rowing events.

Correlates for 2000-m rowing ergometer performance have been established in many studies and, to a lesser extent, correlates have also been established for on-water single-sculls rowing (for a review, see Mäestu et al., 2005). Such studies reveal differences among the strongest correlates and among regression equations used to predict rowing performance. These differences are probably attributable to variations in samples, including sex, competitive standard, and classification of rower.

Jürimäe and colleagues (Jürimäe, Mäestu, Jürimäe, & Pihl, 2000) compared ergometer rowing with on-water rowing and found that, while almost every anthropometric and body composition variable was correlated to 2000-m ergometer time, only lean muscle mass was correlated to 2000-m single-sculls time. The authors concluded that care should be taken when interpreting rowing ergometer results to predict on-water performance because "the influence exerted by anthropometric variables upon the result obtained on the rowing ergometer might be

Correspondence: P. Mikulić, Department of Sport, Faculty of Kinesiology, University of Zagreb, Horvaćanski zavoj 15, 10000 Zagreb, Croatia. E-mail: pavle.mikulic@kif.hr

ISSN 0264-0414 print/ISSN 1466-447X online
DOI: 10.1080/02640410802600950

too great''. McNeely (2004) examined the relationship between physiological variables measured on the ergometer and 2000-m on-water performance and found that while the Pearson correlations showed that certain physiological variables were related to 2000-m ergometer performance, there was no correlation between any of the measured variables and 2000-m on-water performance. In addition, no correlation was observed between 2000-m ergometer performance times and 2000-m on-water performance times.

Although ergometer rowing differs from on-water rowing in terms of the skills required (Russell, Le Rossignol, & Sparrow, 1998), the biomechanical and metabolic demands of on-water rowing are similar (Lamb, 1989). As in sculling, trunk movement during ergometer rowing is straightforward, whereas rotation of the trunk that occurs in sweep rowing cannot be simulated on an ergometer. Because sweep rowers employ only one oar handle, as opposed to scullers, who must manipulate two oar handles, ergometer rowing is closer to sweep rowing. The importance of rowing technique is less evident for ergometer rowing than on-water rowing. Rowing is a complex task and comprises components such as balance, economy, and maintenance of boat-speed during the recovery phase, none of which can be measured on an ergometer (Mäestu et al., 2005). Furthermore, on-water performance also depends on external factors, including environmental conditions.

The extent to which rowing ergometer performance and on-water performance are related, as well as the accuracy of rowing ergometer 2000-m performance time as a predictor of 2000-m on-water performance, has not been thoroughly investigated. Hence, the aim of this study was to predict on-water rowing performance as measured using the final rankings achieved at the World Junior Rowing Championship. The predictions are based on 2000-m ergometer performance times in a sample of 398 male and female junior rowers competing in all 13 events at the 2007 World Junior Rowing Championship.

Methods

Participants

Five hundred and ninety-six rowers from 49 countries, 362 (61%) males (mean age 17.9 years, $s = 0.8$; body mass 83.2 kg, $s = 2.0$; stature 1.88 m, $s = 0.06$) and 234 (39%) females (mean age 17.6 years, $s = 0.7$; body mass 68.7 kg, $s = 6.7$; stature 1.77 m, $s = 0.06$), competing in 13 rowing events at the 2007 World Junior Rowing Championship, were invited to take part in the study. Three hundred and ninety-eight rowers from 45 countries completed and returned their questionnaires. The sample comprised 66% of all competitors, including 53% of the ''A'' finalists and 40% of the medalists; 231 (58%) rowers were male and 167 (42%) were female. Five participants (1%) were reserves. Coxswains were not included.

Study design

Questionnaires were distributed to team managers from each of the 49 nations attending the team managers' meeting under the auspices of FISA (Fédération Internationale des Sociétés d'Aviron), the world governing body for rowing, 3 days before the official start of the Championship. The aim of the study and the methods used to complete it were explained to the team managers, who relayed them, together with the questionnaires, to their rowers. In addition, the rowers were told where they could ask any questions about the study and where they could submit the questionnaires. To facilitate participation in the study, the questionnaire was available in 21 languages (Bulgarian, Chinese, Croatian, Czech, Dutch, English, Estonian, Finnish, French, German, Greek, Hebrew, Italian, Japanese, Norwegian, Portuguese, Russian, Serbian, Spanish, Swedish, and Turkish), translated from English by the national rowing team coaches and/or physicians. When the questionnaires were administered, interviews with non-English-speaking rowers were conducted by their team managers, team physicians or translators (Beijing Normal University students training to volunteer at the 2008 Olympic Games in Beijing).

The questionnaire included general and rowing-specific sections. The general section characterized the participating rowers by country, age, sex, stature, body mass, rowing experience, and previous rowing achievements. The rowing section was used to elicit information about the crew and the event in which each participating rower was competing at the Championship along with his or her best 2000-m rowing ergometer performance time achieved on a stationary Concept II rowing ergometer either during a training session or at an official competition during 2007. The study was approved by the local ethics committee and by the FISA Sports Medicine Commission.

Statistical analyses

Statistica for Windows 7.0 software (Tulsa, Oklahoma, USA) was used to process and report the data. Before processing, the data were inspected visually and the Shapiro-Wilk test was used to test the assumption of normality. Descriptive statistics were calculated for each of the 13 events in which the participants competed at the Championship. The independent-samples *t*-test was used to compare 2000-m rowing ergometer performance times between scullers and sweep rowers. Pearson's correlation coefficient (r) was used to determine the association between 2000-m rowing ergometer performance time and final rankings at the Championship. Using linear regression analyses, regression equations for each event were established based on 2000-m rowing ergometer performance times. Coefficients of determination (R^2) and standard errors of the estimate (SEE) were also calculated.

Results

Five reserves who completed the questionnaire but did not compete at the Championship, together with 11 rowers with invalid 2000-m ergometer performance times, were eliminated from the analysis because they had not completed the 2000-m ergometer test in 2007 or their ergometer tests included rowing over 2500 m. The final number of participants included in the analysis was 382, of whom 222 (58%) were male and 160 (42%) were female.

Descriptive statistics and correlations

The reported rowing ergometer performance times and their correlations with final World Junior Rowing Championship rankings are displayed in Table I. Rowing ergometer performance times correlated ($P \leq 0.039$) with final rankings in each of the 13 events competed in. The observed correlations between rowing ergometer and on-water performance both for junior men and junior women were higher for smaller boats – singles, doubles, and pairs ($r = 0.64$–0.92; $P \leq 0.025$) – than for larger boats – quads, fours, and eights ($r = 0.31$–0.70; $P \leq 0.039$).

To provide a better understanding of the strength of the relationship between 2000-m rowing ergometer performance times and final on-water rankings, scatterplots with regression lines representing 2000-m ergometer performance times for competitors in the events in which the strongest correlations were observed are presented for the junior men's events (single sculls, eight, and coxless pair) and junior women's events (single sculls, double sculls, and coxless pair) in Figure 1 and Figure 2 respectively.

Table I. Descriptive statistics and Pearson correlation coefficients (r) for competitors' 2000-m rowing ergometer performance times.

Event	N	Mean $\pm$ s (time in seconds)	Correlation with final WJRC rankings	Probability of correlation
Single sculls (JM)	24	386 ± 14	0.80	<0.001
Double sculls (JM)	30	390 ± 14	0.64	<0.001
Quadruple sculls (JM)	60	386 ± 10	0.31	0.002
Coxless pair (JM)	24	395 ± 15	0.67	<0.001
Coxless four (JM)	33	388 ± 12	0.54	0.001
Coxed four (JM)	16	385 ± 10	0.54	0.030
Eight (JM)	35	378 ± 9	0.70	<0.001
Single sculls (JW)	13	449 ± 18	0.92	<0.001
Double sculls (JW)	39	448 ± 15	0.79	<0.001
Quadruple sculls (JW)	40	441 ± 13	0.33	0.039
Coxless pair (JW)	11	446 ± 14	0.69	0.025
Coxless four (JW)	27	440 ± 10	0.66	<0.001
Eight (JW)	30	443 ± 11	0.45	0.013

Note: WJRC = World Junior Rowing Championship; JM = junior men; JW = junior women.

Regression models

Using linear regression analysis, regression models for each of the 13 events were established (Table II). The most accurate predictions were obtained with the model used to predict rankings in junior women's single sculls ($R^2 = 0.85$, SEE = 2.0), followed by the model used to predict rankings in junior men's single sculls ($R^2 = 0.65$, SEE = 5.8).

Discussion

In this study, we examined the relationship between 2000-m rowing ergometer performance and 2000-m on-water performance in a large sample of junior rowers of both sexes. The 2000-m rowing ergometer performance times of competitors from all 13 events held during the 2007 World Rowing Junior Championship were correlated ($P \leq 0.039$) with their final rankings at the Championship. The strongest correlations (Table I) were observed for junior women's single sculls ($r = 0.92$; $P < 0.001$) followed by junior men's single sculls ($r = 0.80$; $P < 0.001$), junior women's double sculls ($r = 0.79$; $P < 0.001$), and junior men's eight ($r = 0.70$; $P < 0.001$). The stronger correlations for smaller boats than for larger boats can probably be explained by the fact that considerably higher speeds can be reached in larger boats, so rowers need to coordinate and synchronize their individual performances. These factors cannot be assessed on a rowing ergometer, where overall performance is based solely on an individual rower's performance.

Interpretation of observed correlations for larger boats should consider two points in particular. First, in large boats the final result depends on the performance of a group of athletes. This collective performance is likely to increase the variability of results. For example, in an eight, underperformance

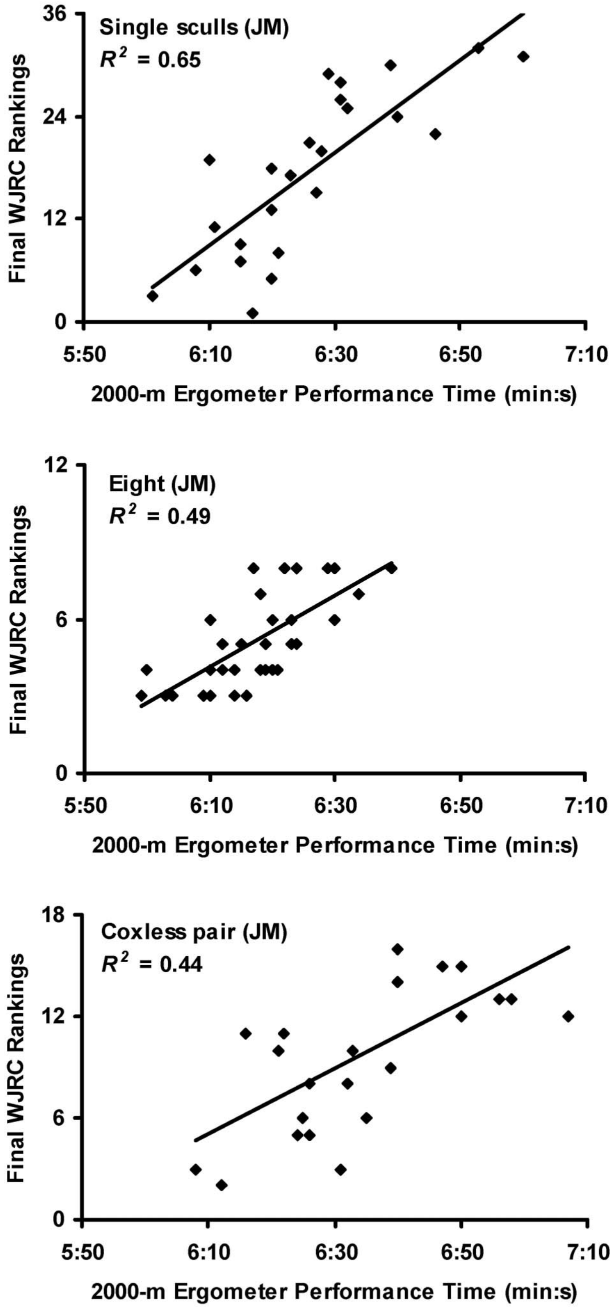

Figure 1. Scatterplots with regression lines for three junior men's (JM) events in which the strongest correlations between 2000-m rowing ergometer performance times and final rankings at the World Junior Rowing Championships (WJRC) were observed.

by only one of the crew is sufficient to lose the race for a crew whose other members possess the physical characteristics to win. Second, the variability of results, which directly affects the correlation coefficient (*r*), is reduced in larger boats because of the lower number of entries (and, consequently, the lower number of final rankings) and also to the wide spread of ability at each ranking. This could be considered a statistical artifact. Hence, technical background influences apparent relationships.

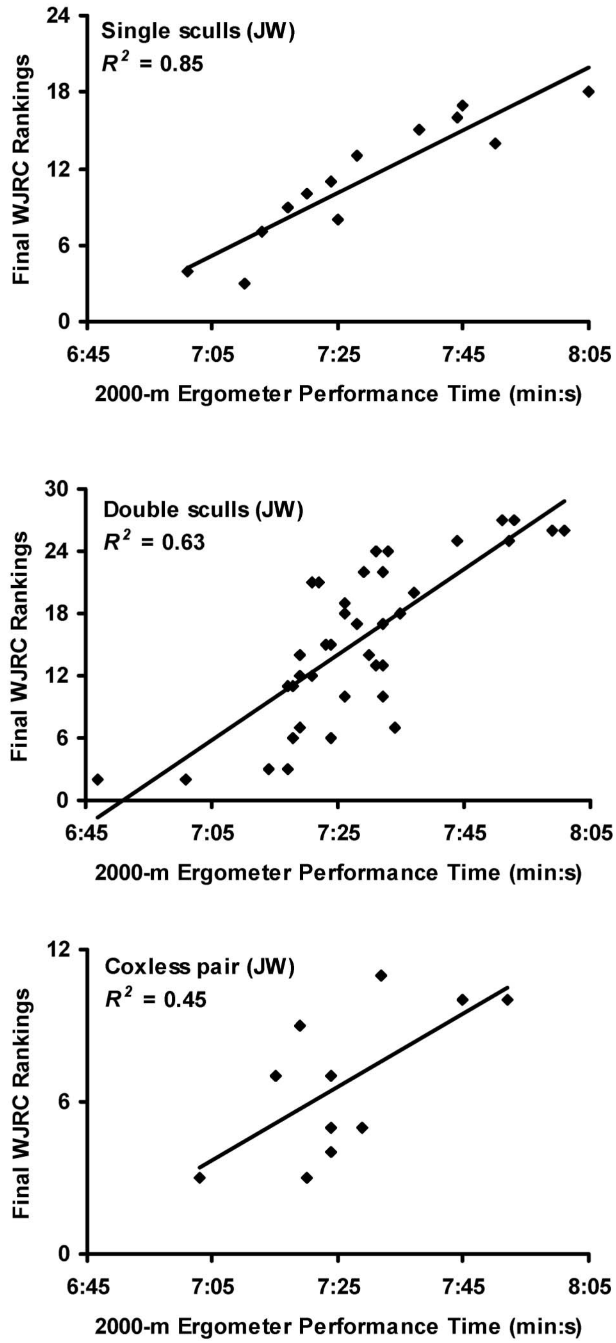

Figure 2. Scatterplots with regression lines for three junior women's (JW) events in which the strongest correlations between 2000-m rowing ergometer performance times and final rankings at the World Junior Rowing Championships (WJRC) were observed.

When the observed correlation coefficients between rowing ergometer performance times and on-water performance are compared according to sex, similar correlation coefficients are observed for each boat category (for example, junior men's single sculls vs. junior women's single sculls). Junior women's events produced slightly higher correlation coefficients in all boat categories except in eights. Indeed, the ergometer times for the junior men's eight had a notably higher correlation coefficient with

Table II. Regression analysis summary: predicting the final rankings at the World Rowing Junior Championships based on 2000-m rowing-ergometer performance time.

Event	Regression equation	R^2	SEE
Single sculls (JM)	FR = −191.9 + 0.54 × (ergometer time)	0.65	5.9
Double sculls (JM)	FR = −99.7 + 0.29 × (ergometer time)	0.41	5.0
Quadruple sculls (JM)	FR = −52.0 + 0.17 × (ergometer time)	0.10	5.4
Coxless pair (JM)	FR = −66.8 + 0.19 × (ergometer time)	0.44	3.3
Coxless four (JM)	FR = −56.5 + 0.17 × (ergometer time)	0.29	3.1
Coxed four (JM)	FR = −56.6 + 0.16 × (ergometer time)	0.30	2.6
Eight (JM)	FR = −46.9 + 0.14 × (ergometer time)	0.49	1.3
Single sculls (JW)	FR = −98.3 + 0.24 × (ergometer time)	0.85	2.0
Double sculls (JW)	FR = −167.7 + 0.41 × (ergometer time)	0.63	4.7
Quadruple sculls (JW)	FR = −30.6 + 0.09 × (ergometer time)	0.11	3.2
Coxless pair (JW)	FR = −58.0 + 0.15 × (ergometer time)	0.45	2.3
Coxless four (JW)	FR = −74.1 + 0.18 × (ergometer time)	0.43	2.1
Eight (JW)	FR = −34.3 + 0.09 × (ergometer time)	0.20	2.0

Note: FR = final rankings; SEE = standard error of the estimate of rank; JM = junior men; JW = junior women.

the final rankings than for the junior women's eight ($r = 0.70$ vs. $r = 0.45$).

Linear regression analyses were used to predict final rankings at the 2007 World Junior Rowing Championship (Table II). The most accurate predictions were for final rankings in junior women's single sculls ($R^2 = 0.85$, SEE = 2.0) followed by junior men's single sculls ($R^2 = 0.65$, SEE = 5.9). Although the correlations in 10 of 13 events were above $r = 0.5$, the large standard errors of the estimate impaired the ability of regression equations to predict rankings accurately in any of the studied events. The regression equations obtained in the present study could also be used to determine how fast a junior rower needs to perform on a 2000-m rowing ergometer time-trial to achieve a high ranking at the World Junior Rowing Championship. Using these equations, we calculated the most probable 2000-m ergometer performance times for the first-place finishers: 357 s for junior men's single sculls and 414 s for junior women's single sculls. These results yield close estimates of the winners' probable 2000-m ergometer performance times, as they are 10 s (3%) and 20 s (5%) slower than the world record 2000-m rowing ergometer performance times for junior men and junior women, respectively. The most probable 2000-m ergometer performance times for competitors in other boat categories could be calculated accordingly using the obtained regression equations.

For both male and female junior rowers, the best 2000-m ergometer performers (Table I) are likely to be selected for larger boats. In junior men's events, the best ergometer performers are likely to be selected for eights (mean $\pm$ *s*: 378 $\pm$ 9 s), coxed fours (385 $\pm$ 10 s), and quadruple sculls (386 $\pm$ 10), while in junior women's events, the best ergometer performers are likely to be chosen for coxless fours (440 $\pm$ 10 s), quadruple sculls (441 $\pm$ 13 s), and eights (443 $\pm$ 11 s). This observation might be attributable to the better on-water stability of larger than smaller boats. Therefore, they are less likely than smaller boats to be affected by a lack of balance-related technical skills. With a more stable boat, the emphasis is placed not on balance-related technical proficiency, but instead on rowers' physical fitness, which a rowing ergometer is designed to measure. There were no differences between 2000-m ergometer performance times of scullers and sweep rowers competing at the 2007 Championship, either for male (*t*-test: $P = 0.947$) or female (*t*-test: $P = 0.299$) junior rowers.

Mäestu et al. (2005) stated that the 2000-m rowing ergometer performance test is more suitable for rowers who compete in large boats, such as quads, fours, and/or eights, in ensuring a similar performance time. When rowers' performance in small boats is measured, a 2500-m ergometer distance appears to provide a more accurate reflection of the metabolic effort involved in on-water rowing for singles, doubles, and pairs. Mean 2000-m ergometer performance time in the present study was 387 s for male junior rowers and 445 s for female junior rowers. This 13% difference in ergometer performance times is consistent with sex-based differences in world record times on the rowing ergometer for 2000 m. Ergometer performance time for the female junior rower is 12% longer than that of her male counterpart; furthermore, ergometer performance time for the female open category rower is 13% longer than that of her male counterpart. Secher (2000) and Ingham and colleagues (Ingham, Whyte, Jones, & Nevill, 2002) observed that for on-water rowing, rowing times for women are about 10–11% longer than for men. This gap in athletic performance between females and males is also observed in other sports, although it appears to be decreasing as the numbers of female competitors increase (Wilmore & Costill, 1999).

In this study, we examined the season's best 2000-m ergometer performance times achieved on a stationary Concept II rowing ergometer, the type of ergometer most commonly used for testing. It is generally assumed that a more specific approach to testing rowers' capabilities is provided by dynamic ergometers (i.e. Concept II ergometer on slides or RowPerfect ergometer) that are more "on-water specific". Some recent studies (Colloud, Bahuaud, Doriot, Champely, & Chèze, 2006; Elliott, Lyttle, & Birkett, 2002) on the use of dynamic ergometers have found that they provide a closer match between the inertial forces and force–time curves recorded with those in a boat. Another benefit of dynamic ergometers is their ability to be combined and set up as a "sliding team boat", so that the total effort of the crew can be evaluated even more precisely.

In conclusion, in 10 of 13 events the correlation coefficients between 2000-m rowing ergometer performance time and 2000-m on-water performance in elite junior rowers was above $r = 0.5$. This suggests a strong association between the two types of rowing, as well as the ability of 2000-m rowing ergometer performance time to predict on-water rowing performance. However, the large standard errors of the estimate impair the ability of regression equations to predict rankings accurately in any of the studied events.

The practical applications of the present study include the possibility for rowing coaches and rowing athletes to put 2000-m rowing ergometer performance times into a broader perspective and to interpret these performance times within the context of the World Junior Rowing Championship rankings. Specifically, the regression equations obtained in the present study could be used to determine how fast a junior rower needs to perform on a 2000-m rowing ergometer time-trial to predict specific rankings at the World Junior Rowing Championship. Using these equations, the most probable rowing ergometer performance times required for a particular ranking in a given rowing event might easily be calculated.

References

Colloud, F., Bahuaud, P., Doriot, N., Champely, S., & Chèze, L. (2006). Fixed versus free-floating stretcher mechanism in rowing ergometers: Mechanical aspects. *Journal of Sports Sciences*, *24*, 479–493.

Elliott, B., Lyttle, A., & Birkett, O. (2002). The RowPerfect ergometer: A training aid for on-water single scull rowing. *Sports Biomechanics*, *1*, 123–134.

Hahn, A., Bourdon, P., & Tanner, R. (2000). Protocols for the physiological assessment of rowers. In C. J. Gore (Ed.), *Physiological tests for elite athletes* (pp. 311–326). Champaign, IL: Human Kinetics.

Ingham, S. A., Whyte, G. P., Jones, K., & Nevill, A. M. (2002). Determinants of 2000 m rowing ergometer performance in elite rowers. *European Journal of Applied Physiology*, *88*, 243–246.

Jürimäe, J., Mäestu, J., Jürimäe, T., &. Pihl, E. (2000). Prediction of rowing performance on single sculls from metabolic and anthropometric variables. *Journal of Human Movement Studies*, *38*, 123–136.

Lamb, D. H. (1989). A kinematic comparison of ergometer and on-water rowing. *American Journal of Sports Medicine*, *17*, 367–373.

Mäestu, J., Jürimäe, J., & Jürimäe, T. (2005). Monitoring of performance and training in rowing. *Sports Medicine*, *35*, 597–617.

McNeely, E. (2004). Rowing ergometer physiological and performance tests do not predict on water performance. *Journal of Strength and Conditioning Research*, *18* (4), e14.

Russell, A. P., Le Rossignol, P. F., & Sparrow, W. A. (1998). Prediction of elite schoolboy 2000 m rowing ergometer performance from metabolic, anthropometric and strength variables. *Journal of Sports Sciences*, *16*, 749–754.

Secher, N. H. (2000). Rowing. In R. J. Shephard & P. O. Åstrand (Eds.), *Endurance in sport* (pp. 836–843). Oxford: Blackwell Science.

Wilmore, J. H., & Costill, D. L. (1999). Sex differences in sport and exercise. In J. H. Wilmore & D. L. Costill (Eds.), *Physiology of sport and exercise* (pp. 570–606). Champaign, IL: Human Kinetics.