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CHAPTER 5

A new submaximal rowing test to predict 2000 meter rowing ergometer performance

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ABSTRACT

The purpose of this study was to assess predictive value of a new Submaximal Rowing Test (SmRT) on 2000 m ergometer rowing time-trial performance in competitive rowers. In addition, the reliability of the SmRT was investigated. Twenty-four competitive male rowers participated in this study. After determining individual HR_{max} , all rowers performed a SmRT followed by a 2000 m rowing ergometer time-trial. In addition, the SmRT was performed 4 times (2 days in between) in order to determine the reliability. The SmRT consists of two six-minute stages of rowing at 70 and 80% HR_{max} , followed by a three-minute stage at 90% HR_{max} . Power was captured during the three stages and 60 seconds of heart rate recovery (HRR_{60s}) was measured directly after the third stage. Results showed that predictive value of power during the SmRT on 2000 m rowing time also increased with stages. $CV_{TEE\%}$ is 2.4%, 1.9% and 1.3%. Pearson correlations (CI) are -0.73 (-0.88 - -0.45), -0.80 (-0.94 - -0.67) and -0.93 (-0.97 - -0.84). 2000 m rowing time and HRR_{60s} showed no relationship. Reliability of power during the SmRT improved with the increasing intensity of the stages. The Coefficient of Variation ($CV_{TEM\%}$) was 9.2%, 5.6% and 6.0%. Intra-class Correlation Coefficients (ICC) and Confidence Intervals (CI) were 0.91 (0.78 - 0.97), 0.92 (0.81 - 0.97) and 0.90 (0.79-0.96). The $CV_{TEM\%}$ and ICC of HRR_{60s} was 8.1% and 0.93 (0.82 - 0.98). In conclusion, the data of this study shows that the SmRT is a reliable test that is able to accurately predict 2000 rowing time on an ergometer. The SmRT is a practical and valuable submaximal test for rowers which can potentially assist with monitoring, fine-tuning and optimizing training prescription in rowers.

Keywords: Athletic performance; submaximal testing; SmRT; reliability; LSCT

INTRODUCTION

Competitive rowers perform intensive rowing ergometer tests in order to measure the effects of their highly demanding training regime on performance. Testing and monitoring performance (i.e. training status) is important to optimize training prescription. As the absolute training intensity is similar for all rowers within the same team, it is challenging to individualize training prescription. Therefore, some rowers may under-train and some may over-train. To improve rowing performance, training intensity and recovery should be well-balanced as imbalance can result in stagnation or a decreased performance caused by non-functional overreaching or even overtraining syndrome [24,25]. In an attempt to optimize performance, it is important to monitor athletes continuously by means of a non-invasive, practical and reliable test that can predict performance accurately.

Previously, several maximal ergometer tests have been used to assess rowing performance. The most commonly used test to assess rowing performance is the 2000 m time-trial [21], which is usually performed on an indoor rowing ergometer, such as the Concept2® ergometer. Although the 2000 m time-trial is known to be reliable and widely used to assess training status of rowers [30], anecdotal evidence from rowers confirms that this test has an extremely high level of exertion. Therefore, this test is not suitable to be performed on a regular basis. Other tests that are valid to measure rowing performance include peak power [4] and power at maximal oxygen uptake (VO_{2max}) [26] during incremental maximal performance tests and peak power output during a Wingate test [28]. However, all of these performance tests require maximal exertion of the rowers, which tends to interfere with normal training and racing habits [16].

In a recent review, it is concluded that lactate power at $4 \text{ mmol}\cdot\text{L}^{-1}$ during a maximal incremental exercise test have adequate validity for assessing moderate differences in training status of a rower [30]. Although lactate power is a valid method, the reliability of determining blood lactate concentration by ear or finger sampling is associated with a high measurement error [32]. Moreover, it is an impractical measure because of the invasiveness of blood sampling and because it is measured during a maximal performance test. Therefore, lactate power cannot be considered optimal for frequent measurements of training status.

In the current study, the design of a promising submaximal cycle test, the Lamberts and Lambert Sub-maximal Cycling Test (LSCT) [15,20], is translated to a Submaximal Rowing ergometer Test (SmRT). Within the LSCT multiple variables are collected such as mean power output, cadence and ratings of perceived exertion, while 60 seconds heart rate recovery (HRR_{60s}) is also captured after the final stage at the end to the test. Lamberts et al. showed that mean power output during the third stage of the LSCT (cycling at 90% of HR_{max}) is the strongest predictor of peak power output ($r = 0.94$), VO_{2max} ($r = 0.91$) and 40 km time-trial performance ($r = -0.92$) [20]. Even stronger relationships between the LSCT and peak power output ($r = 0.98$), VO_{2max} ($r = 0.96$) and 40 km time-trial performance ($r = -0.98$) are found when multivariate analyses are used [15]. In addition, the LSCT changes with a change in training status and is able to reflect a state of non-functional overreaching [18,19]. Based on these positive results and as the data within a rowing ergometer test can be collected similarly as within a cycle ergometer test, the design of the LSCT was translated to the rowing ergometer.

The aim of the current study was to assess the predictive value of the SmRT on 2000 m ergometer rowing time in competitive rowers. In addition, the reliability of the SmRT was determined.

METHODS

Experimental Approach to the Problem

A group of rowers performed an incremental rowing test during the first laboratory visit. The rowers were familiarized to the SmRT on at least 3 occasions. All rowers performed an SmRT followed by a 2000 m rowing time-trial with one to three days in between to determine predictive value of the SmRT. A sub-group of rowers performed the SmRT 4 times with 2 days in between in order to determine reliability of the SmRT.

Subjects

Twenty-four competitive male rowers were recruited to participate in the study. All rowers had experience in competitive rowing of 4 ± 3 years (ranging from 2 to 11 years). The rowers trained 10 - 12 hours per week on average, including 2 - 3 hours of strength training, divided over 2 sessions. In addition to outdoor training, the rowers were accustomed to training on an indoor rowing ergometer

(Concept2®). The coach agreed to planning the tests during a low-intense training period. Nine rowers were classified as “light weight class rowers” and fifteen as “open class rowers”. A rower classified as lightweight may not weigh more than 72.5kg on the racing day according to the rules of racing by FISA [8]. Within open class rowing, there are no weight restrictions. Before participation, a sport physician medically cleared all rowers according to the Lausanne recommendations [2] and all rowers signed an informed consent. This study was approved by the local ethics and research committee. The study has been conducted in line with the requirements of the Declaration of Helsinki.

Procedures

The incremental rowing test started with a three minute warm-up at a power output of a 150 W for light weight class rowers and 175 W for open class rowers. Subsequently, rowers were asked to increase their power output by 25 W every minute. When the rowers were not able to elicit the predetermined power output, they were asked to perform a 30 s all-out sprint [22]. The rowers were verbally encouraged during the test and feedback about power, time, distance and stroke rate was displayed on the screen of the rowing ergometer during the whole test. Heart rate during the test was recorded continuously using a Garmin sport watch (Garmin ForeRunner 310XT®, Hampshire, UK) and calculated as 1s averages. HR_{max} was determined as the highest heart rate recorded during the test. In addition, gas exchange was measured using an automated breath-by-breath analyzer (Cortex Metalyzer 3b, Leipzig, Germany). $\dot{V}O_{2max}$ was defined as the highest 30 second $\dot{V}O_2$ interval observed during the test.

All tests were performed on a Concept2® rowing ergometer (Model D, Morrisville, USA) equipped with a PM4 computer (Concept2®, USA) in similar environmental conditions ($14.6 \pm 3.5^\circ\text{C}$ and $49 \pm 8\%$ relative humidity). Rowers refrained from strenuous exercise and consuming alcohol 24 hours before each test and the rowers did not consume caffeine 4 hours before all tests. During the tests, the drag factor of the ergometer was set at $120 \cdot 10^6 \text{ kg}\cdot\text{m}^{-1}$ for light weight class rowers and $130 \cdot 10^6 \text{ kg}\cdot\text{m}^{-1}$ for open class rowers. These drag factors were in line with drag factors of the rower's regular ergometer training.

Submaximal Rowing Test (SmRT)

The SmRT protocol was based on the LSCT in which cyclists were asked to cycle at 60%, 80% and 90% of individual HR_{max} [20]. After pilot tests and based on feedback from the rowers, the initial stage of the SmRT was changed from 60% to 70% of HR_{max} , because it was too difficult for the rowers to keep their heart rate stable at 60%. The total duration of the SmRT was 17 minutes, during which the rowers were asked to row 6 minutes at 70% and 6 minutes at 80% of HR_{max} , followed by 3 minutes at 90% of HR_{max} and 2 minutes of rest (Figure 1). Rowers were asked to row at a heart rate within 2 beats of the predetermined target heart rate. Within the rest stage, rowers sat up straight and did not speak for 2 minutes, in order to capture HRR_{60s} accurately. Ratings of Perceived Exertion (RPE) [3] were asked 30 seconds before the end of each stage (5:30, 11:30 and 14:30 min:s, respectively). Rowers received continuous feedback on heart rate and elapsed time on the screen of the ergometer. However, they did not receive any feedback on power output during the whole test.

Mean power, stroke rate and the difference between the predetermined target heart rate and actual heart rate during all three stages of the SmRT were calculated and used for further analysis. Due to the slow half-life of heart rate [1,20], the first minute of every stage was excluded from analyses. Hence, performance parameters over the last 5 minutes of stage 1 and 2 (1:00 - 6:00 min:s and 7:00 - 12:00 min:s) and the last 2 minutes of stage 3 (13:00 - 15:00 min:s) were analyzed (Figure 1) [20]. Although 2 minutes of HRR_{60s} data were captured within the SmRT, HRR_{60s} was only calculated over the initial 60 s of the recovery period because HRR_{60s} measurements have been shown to be more reliable and associated with lower day-to-day variations than HRR_{120s} measurements [17]. HRR was calculated as the difference between mean heart rate in the last 15 s of stage 3 (14:45 - 15:00 min:s) and mean heart rate in the last 15 s during the first minute of rest (15:45 - 16:00 min:s) [7,20].

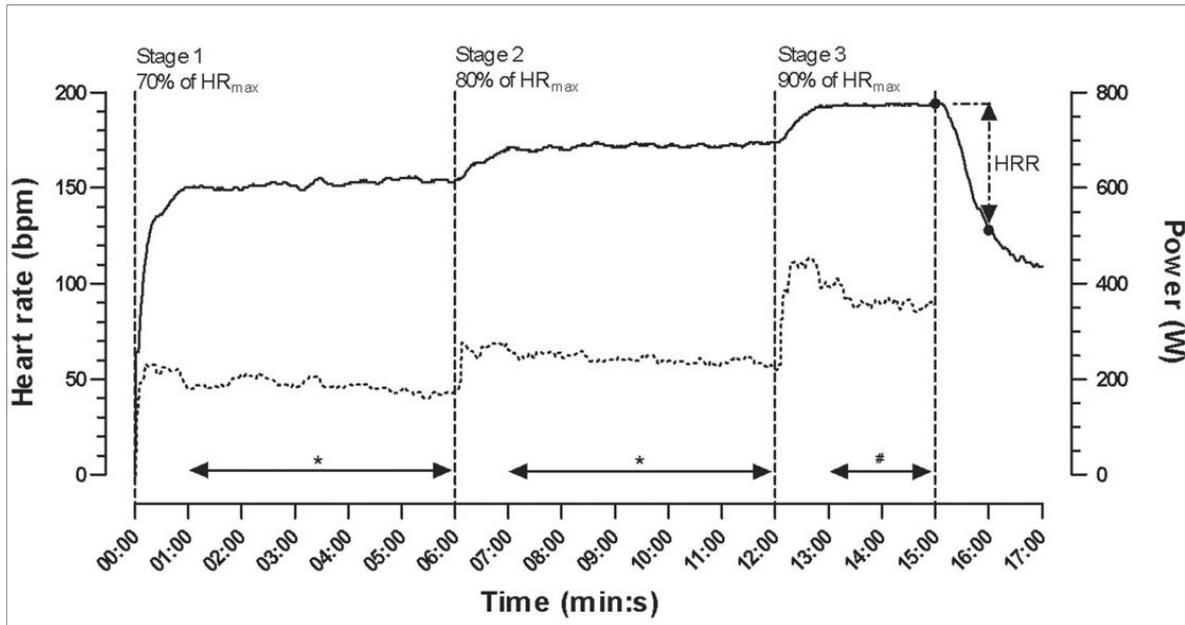


Figure 1. A rower's heart rate and power profile response to a Submaximal Rowing Test (SmRT).

* = 5 minute period over which the mean SmRT performance parameters were analysed.
 # = 2 minute period over which the mean SmRT performance parameters were analysed.
 HRR = Heart Rate Recovery

2000 m rowing time-trial

Results of the 2000 m rowing time-trial were also used for selection purposes of the Dutch Rowing Association (KNRB). Therefore, the rowers were highly motivated to perform as well as possible. During the 2000 m time-trial, the rowers were verbally encouraged by their coach. A self-selected warm up was performed prior to the start of the 2000 m time-trial. Rowers received continuous feedback about power, time, distance and stroke rate on the screen of the ergometer. 2000 m rowing time (i.e. performance) was determined by time needed (min:s) to complete the time-trial.

Statistical analysis

All outcome variables were shown to be normally distributed by a Shapiro-Wilk's test ($p < 0.05$) and visual inspection of histograms, normal Q-Q plots and box plots.

Descriptive statistics for all variables were represented as mean \pm standard deviation (SD). Differences in the relationships between light weight class rowers and open class rowers were analysed by slope and Y-axis intercepts analysis

(GraphPad Prism version 6.03 for Windows, GraphPad Software, San Diego, California, USA). No significant differences in slopes and Y-axis intercepts between light weight class and open class rowers were found. Therefore, the analyses were performed for the group as a whole.

The predictive value of the SmRT was assessed by establishing the relationships between mean power output during the three stages of the SmRT, HRR_{60s} and 2000 m rowing time ($n=22$). The strength of these relationships were analysed with Pearson correlations, Typical Error of the Estimate (TEE) and TEE expressed as coefficient of variance ($CV_{TEE\%}$). In addition, 95% confidence intervals (95% CI) were calculated.

Reliability was determined over the sub-set of rowers ($n = 12$) who performed the SmRT on four occasions interspaced with 2 days. The repeatability of the SmRT (power output, RPE and stroke rate during the three stages and HRR_{60s}) was assessed by calculating intra-class correlation coefficients (ICC), Typical Errors of Measurements (TEM) and the TEM expressed as a coefficient of variation ($CV_{TEM\%}$).

The thresholds for interpretation of the magnitude of ICC were: very small (<0.1) low (0.1-0.3), moderate (0.3-0.5), high (0.5-0.7), very high (0.7-0.9), and nearly perfect (>0.9) [12]. $CV_{TEM\%}$ and $CV_{TEE\%}$ were doubled in order to interpret the magnitude of differences between tests as being very small ($<0.3\%$), small (0.3-0.9%), moderate (0.9-1.6%), large (1.6-2.5%), very large (2.5-4.0%) and extremely large ($>4.0\%$) [12,31]. All measures of validity and reliability were calculated using spreadsheets downloaded from <http://sportsci.org> [11].

RESULTS

Of the 24 rowers who participated, all test results of one rower were excluded for analysis because he was diagnosed with pneumonia a month before the tests and we could not determine with certainty that he was fully recovered. Of the 23 rowers who were included for analysis (see Table 1 for descriptive characteristics), 22 rowers were included in the predictive value study. This was because one rower did not complete the 2000 m rowing time-trial, because he was not feeling well that day.

A subset of twelve rowers was included in the reliability study, of which one rower could not complete the second SmRT due to transportation problems.

Table 1. Rowers' characteristics (mean \pm standard deviations)

	NR rowers	R rowers	All rowers
	n = 11	n = 12	n = 23*
Age (years)	23 \pm 1	20 \pm 1	22 \pm 2
Height (cm)	190 \pm 7	190 \pm 7	191 \pm 7
Body mass (kg)	83 \pm 3	80 \pm 8	82 \pm 8
HR _{max} (b \cdot min ⁻¹)	195 \pm 10	193 \pm 6	194 \pm 8
VO _{2max} (L \cdot min ⁻¹)	5.1 \pm 0.3	5.4 \pm 0.4	5.3 \pm 0.4
VO _{2max} (mL \cdot kg ⁻¹ \cdot min ⁻¹)	61.6 \pm 5.1	67.8 \pm 4.5	64.9 \pm 5.5

NR rowers = Rowers who did not participate in the reliability study; R rowers = rowers who participated in the reliability study. * = one of these rowers did not complete the 2000m test.

Predictive value of the SmRT on 2000 m rowing times

Relationships between mean power output during all measures within the SmRT and 2000 m rowing time are shown in figure 2^{A-D} (n = 22). The association between parameters of the SmRT and 2000 m performance increased with stages (intensity) during the SmRT and CV_{TEE%} decreased with stages. The highest correlation and lowest CV_{TEE%} was shown by power output during stage 3 (r = -0.93; CI: -0.97 - -0.84 and 1.3%; CI: 1.0 - 1.9%). This indicates that rowers who had a higher mean power output associated with 90% HR_{max} were able to complete the 2000 m rowing time-trial faster.

No significant relationship was found between HRR measured within the SmRT and 2000 m rowing time.

Table 2 shows mean physiological and subjective responses to the SmRT before the 2000 m rowing test. The mean 2000 m rowing time was 6:29 \pm 0:14 min:s and ranged from 6:11 to 6:52 min:s. The average power output over the 2000 m time-trials was 382 \pm 39 W, ranging from 331 W to 440 W. Power during stage 1, 2 and 3 during the SmRT was 43 \pm 6%, 54 \pm 4% and 75 \pm 5% of average 2000 m time-trial power.

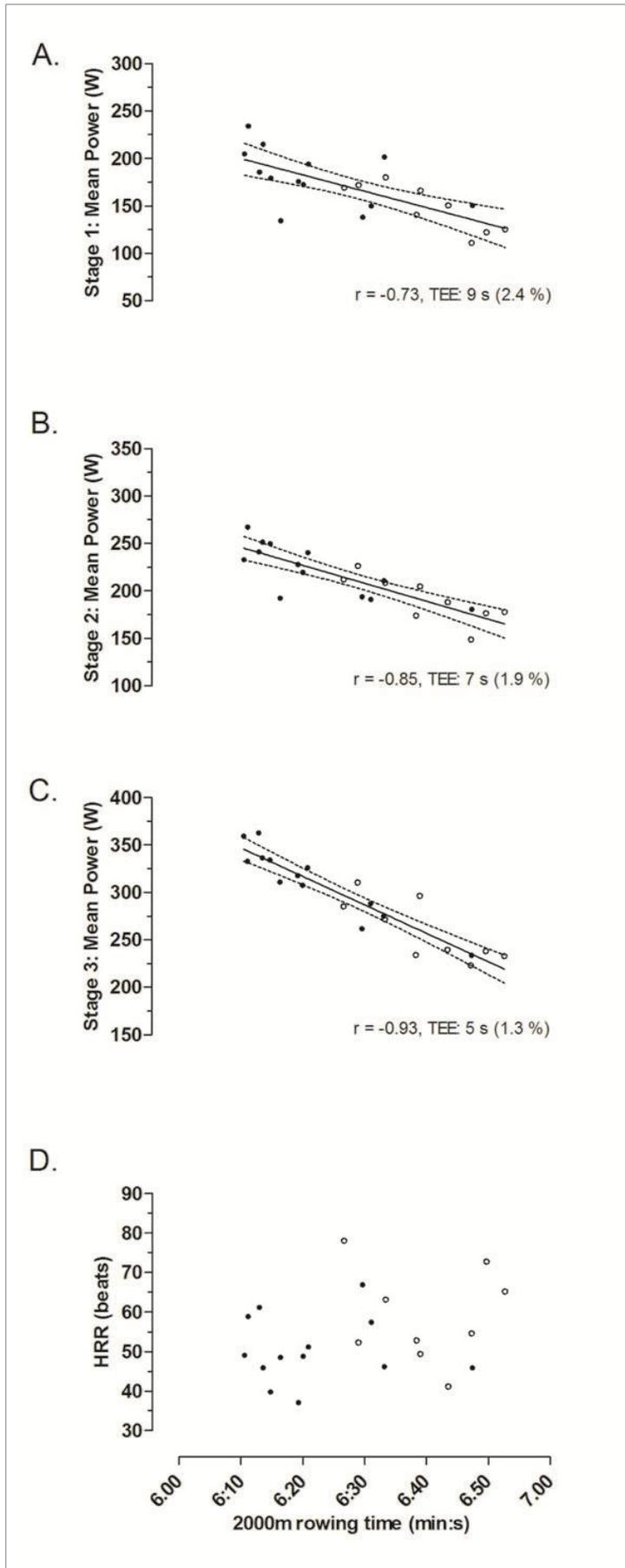


Figure 2. Relationships between mean power output during stage 1 (A), stage 2 (B), stage 3 (C) and Heart Rate Recovery (HRR) (D) of the SmRT and 2000 m rowing performance (time). Open class rowers (OC) are represented by closed circles (●). Light weight class rowers (LW) are represented by the open circles (○). Dotted lines represent 95% confidence intervals.

Table 2. Mean physiological and subjective responses to the last SmRT before the 2000 m rowing test

n = 22	
Stage 1	
Power (W)	167 ± 32
Stroke rate (strokes · min ⁻¹)	18 ± 1
RPE (units)	9 ± 2
HR difference (beats)	-1 ± 1
Stage 2	
Power (W)	209 ± 30
Stroke rate (strokes · min ⁻¹)	20 ± 2
RPE (units)	13 ± 1
HR difference (beats)	-1 ± 1
Stage 3	
Power (W)	290 ± 44
Stroke rate (strokes · min ⁻¹)	24 ± 3
RPE (units)	16 ± 1
HR difference (beats)	-1 ± 1
HRR _{60s} (beats)	54 ± 11

RPE = Rating of Perceived Exertion; HR difference = the difference between required HR and actual HR; HRR_{60s} = 60 seconds of heart rate recovery

Reliability of SmRT parameters

SmRT parameters of the four measurement occasions are shown in Table 3. All rowers adhered well to the predetermined HR during all three steps of the test. This was shown by the difference of only 1 bpm on average between predetermined HR and actual HR during the SmRT (Table 3). In addition to the SmRT parameters, ICC, TEM and CV_{TEM%} of power, stroke rate, RPE and HRR are shown in Table 2. Power in all three stages of the SmRT showed “nearly perfect” ICC's (0.91, 0.92 and 0.90, respectively). CV_{TEM%} was doubled for interpretation of the magnitude, as proposed by Smith & Hopkins [31], which classified CV_{TEM%} of power in stage 1, 2 and 3 (18.4%, 11.2% and 15.4%, respectively) as “extremely large”. CV_{TEM%} of power in stage 3 between the first and second test is 6.6%, between the second and third test 5.4% and between the third and fourth test 6.0%.

Table 3. Mean physiological and subjective responses to the SmRT

N = 12	LSCT				Mean	ICC (CI)	TEM (CI)	CV _{TEM%} (CI)
	1	2*	3	4				
Stage 1								
Power (W)	151 ± 39	154 ± 40	166 ± 42	154 ± 31	156 ± 13	0.91 (0.78–0.97)	12.9 (10.3–18.1)	9.2 (7.3–13.1)
Stroke rate (·min ⁻¹)	18 ± 1	18 ± 1	18 ± 2	18 ± 1	18 ± 1	0.48 (0.15–0.78)	1.1 (0.8–1.5)	6.3 (4.4–10.9)
RPE (units)	9 ± 2	10 ± 1	10 ± 1	10 ± 1	10 ± 1	0.57 (0.26–0.83)	0.9 (0.7–1.3)	10.4 (8.2–14.9)
HR difference (beats)	-1 ± 2	-1 ± 1	-1 ± 2	-1 ± 1	-1 ± 2			
Stage 2								
Power (W)	191 ± 36	194 ± 38	203 ± 39	195 ± 27	195 ± 34	0.92 (0.81–0.97)	10.9 (8.5–15.2)	5.6 (4.4–8.0)
Stroke rate (·min ⁻¹)	19 ± 1	19 ± 1	20 ± 2	19 ± 1	19 ± 2	0.61 (0.30–0.85)	1.0 (0.8–1.5)	5.2 (4.1–7.3)
RPE (units)	13 ± 1	13 ± 2	13 ± 1	12 ± 2	13 ± 1	0.57 (0.24–0.83)	1.0 (0.8–1.5)	9.1 (7.1–12.9)
HR difference (beats)	-1 ± 1	0 ± 1	-1 ± 1	0 ± 1	-1 ± 1			
Stage 3								
Power (W)	263 ± 39	260 ± 47	271 ± 48	265 ± 38	265 ± 42	0.90 (0.79–0.96)	15.4 (12.6–20.4)	6.0 (4.9–8.0)
Stroke rate (·min ⁻¹)	23 ± 2	23 ± 3	24 ± 3	23 ± 2	23 ± 3	0.73 (0.46–0.90)	1.4 (1.1–2.0)	6.4 (5.0–9.1)
RPE (units)	16 ± 2	16 ± 2	16 ± 2	15 ± 1	16 ± 1	0.56 (0.23–0.82)	1.1 (0.8–1.5)	7.6 (5.9–10.8)
HR difference (beats)	-1 ± 1	0 ± 1	-1 ± 1	-1 ± 1	-1 ± 1			
HRR _{60s} (beats)	56 ± 18	53 ± 12	55 ± 10	53 ± 11	54 ± 13	0.93 (0.82–0.98)	4.0 (3.2–5.7)	8.1 (6.3–11.6)

RPE = Rating of Perceived Exertion; HR difference = the difference between required HR and actual HR; HRR_{60s} = 60 seconds of heart rate recovery; *N=11; 95% confidence intervals (CI) at Intra-class Correlation Coefficient (ICC), Typical Error of the Measurement (TEM) and TEM expressed as coefficient of variation (CV_{TEM%})

The ICC of stroke rate increased with intensity of the stages. During stage 3, the ICC of stroke rate was classified as “very high”. However, doubled $CV_{TEM\%}$ of stroke rate during all stages was “extremely large” (12.6%, 10.4% and 12.8%, respectively).

ICC of RPE during all three stages of the SmRT were classified as “high”, while doubled $CV_{TEM\%}$ of RPE during all stages was “extremely high” (20.8%, 18.2%, and 15.2%, respectively).

ICC of HRR_{60s} was “nearly perfect”, but $CV_{TEM\%}$ was “extremely high” (16.2%).

DISCUSSION

The aim of the current study was to determine if the LSCT [20], a submaximal cycle test which is able to predict and monitor cycling performance, could be translated to a submaximal rowing test (SmRT). An important finding of the study was that the design of the LSCT could be well translated to the SmRT. All rowers were able to row close to their predetermined submaximal heart rates (± 1 beat) during the three different stages of the SmRT. Although the intensity of the first stage of the SmRT was slightly higher (70% of HR_{max}) compared to the LSCT (60% of HR_{max}) [20], the mean rating of perceived exertion during the three stages were 9, 13 and 16, respectively. These ratings are similar to the three stages within the LSCT (8, 12 and 16, respectively) [20].

The main finding of the study was that the SmRT was able to accurately predict 2000 m rowing time when performed on an indoor rowing ergometer. Significant inverse relationships were found between 2000 m rowing time mean power during all three stages of the SmRT ($r = -0.73, -0.85$ and -0.93 , respectively). The strongest relationship between 2000 m rowing time and mean power during the third stage of the SmRT ($r = -0.93$) was associated with a typical error of the estimate of 5 seconds or 1.3% (see also Figure 2). These findings are in line with the finding by Lamberts et al. [20] who reported relationships between a 40 km time trial time (40km TT) and the second and third stage of the LSCT of $r = -0.84$ and $r = -0.92$, respectively. However, the associated typical error of the estimate for 40km TT time from stage 2 (3.1%) and stage 3 (2.2%) are slightly higher. This can likely be explained by the distance and duration of the performance tests as more

variation will be associated with longer tests. The increase in predictive value with exercise intensity within the SmRT, is in line with the findings of Lamberts et al. [20].

Cosgrove et al. [6] showed that correlations between submaximal rowing economy during submaximal testing and 2000 m time-trial increases with exercise intensity. The relatively strong correlation between mean power during the SmRT and 2000 m rowing time can likely be explained by the design of the SmRT. As the rowers row at a similar relative intensity (different absolute intensities) instead of rowing at fixed absolute intensities (different relative intensities), better relationships with rowing performance parameters can be expected. In addition, as the exercise intensity of the third stage of the SmRT was close to the exercise intensity of the 2000 m rowing time trial, this might explain that the strongest relationship was found between these two variables.

In contrast to Lamberts et al. [20], who found a weak relationship between HRR and 40km TT performance ($r = -0.55$), we did not find a relationship between HRR and 2000 m rowing time. The absence of this relationship and therefore poor predictive power of HRR can likely be explained by the duration of the rowing test and the relatively homogenous group of competitive rowers that was tested. Although, HRR has shown to be a valuable tool to monitor changes in training status in untrained to elite athletes [7] and is able to predict fitness and health status in the general population [5], the relationship between HRR seems and training status seems become weaker within homogenous groups [7,9,20]. This can likely be explained by genetic polymorphisms in the acetylcholine receptor M2 (CHRM2), which also influences the rate of HRR [9].

Another factor that might have contributed to the absence of a relationship between HRR and 2000 m rowing time is that in contrast to Lamberts et al. [20], a much shorter time-trial test was used with relatively small time differences between the rowers. Although HRR did not seem to be a good predictor of 2000 m rowing time, it still potentially can be an important monitoring tool to detect changes in training status of rowers. As HRR within the SmRT varied by about 4 bpm or 8.1%, changes in HRR of ≥ 5 beats should be interpreted as meaningful. This variation in HRR was slightly higher than within the LSCT (2 beats). An explanation may be that our rowers first detached their feet and only then were able to sit up straight. However, with keeping this in mind, the variation in HRR (ICC; 0.93) was arguably very low. This can be explained because factors

which influence HRR, such as the mode of exercise [10], the workload intensity [13,23] and duration [14,29], were all standardised and well controlled within of the SmRT.

Another finding of the study was that the SmRT is a relatively reliable test. Good ICC's were found for mean power output, which ranged from 0.90 to 0.92. Slightly weaker ICC's were found for stroke rate (ICC range: 0.48-0.73) and RPE (ICC range: 0.56-0.57) during the three stages. These reliability scores were similar to those found within the LSCT (ICC range: 0.91-0.99) [20]. Although the $CV_{TEM\%}$ of power during the third stage of the SmRT was higher than the 1% yardstick for variation in competitive on-water rowing performance [30], the magnitude of the ICC for the third stage was classified as 'nearly perfect' [12]. However, the data of each test should always be interpreted within its own capacities.

A limitation of the present study was that only well-trained competitive rowers were tested. Therefore we cannot conclude with certainty that the SmRT will also be able to accurately predict rowing times in less trained subjects. In addition, the current study does not show if the SmRT is able to reflect changes in training status and can be used as a practical monitoring tool. The SmRT's were completed under well controlled circumstances and the 2000 m rowing time-trial was completed in real competition conditions. However, this real competition was indoor and not in an on-water rowing competition. Therefore, 2000 m on-water rowing times are likely to vary more and measures of predictive value will probably be less precise.

In conclusion, this current study showed that the design of the LSCT could be well translated to a submaximal rowing test (SmRT). The SmRT is a relatively reliable test (ICC; 0.90-0.92) which is able to accurately predict 2000 m rowing time in competitive rowers (within 5 seconds).

Practical applications

The SmRT is a relatively reliable rowing test which is able to accurately predict 2000 m rowing time. As it is a relatively short and submaximal test, it potentially can be used as standardized warm-up on a weekly basis. The SmRT shows potential to be a sport specific and practical tool to predict and monitor changes in training status of rowers. Future research needs to confirm if the SmRT,

in addition to accurately predicting rowing performance, is also able to reflect changes in rowing performance.

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