ORIGINAL ARTICLE

An analysis of the pacing strategy adopted by elite competitors in 2000 m rowing

S W Garland

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Objectives: To determine the pacing strategies adopted by elite rowers in championship 2000 m races.
Methods: Split times were obtained for each boat in every heavyweight race of the Olympic Games in 2000 and World Championships in 2001 and 2002, and the top 170 competitors in the British Indoor Rowing Championships in 2001 and 2002. Data were only included in subsequent analysis if there was good evidence that the athlete or crew completed the race in the fastest possible time. The remaining data were grouped to determine if there were different strategies adopted for on-water versus ergometer trials, ''winners'' versus ''losers'', and men versus women.
Results: Of the 1612 on-water race profiles considered, 948 fitted the inclusion criteria. There were no differences in pacing profile between winners and losers, and men and women, although on-water and ergometry trials showed a competitively meaningful significant difference over the first 500 m sector. The average profile showed that rowers performed the first 500 m of the race faster than subsequent sectors—that is, at a speed of 103.3% of the average speed for the whole race, with subsequent sectors rowed at 99.0%, 98.3%, and 99.7% of average speed for on-water rowing, and 101.5%, 99.8%, 99.0%, and 99.7% for ergometry.
Conclusions: These data indicate that all athletes or crews adopted a similar fast start strategy regardless of finishing position or sex, although the exact pace profile was dependent on rowing mode. This strategy should be considered by participants in 2000 m rowing competitions.

Correspondence to: Dr Garland, English Institute of Sport, Baltic Business Centre, Saltmeadows Road, Gateshead, Tyne & Wear NE8 3DA, UK; stephen.garland@eis2win.co.uk

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The sport of rowing has received little scientific research on the effect of different pacing strategies on performance. This is perhaps surprising given the popular belief that pacing strategies have major effects on performance in most sports, and although there may be little physiological difference between elite competitors, athletes may win or lose depending on their pacing strategy.[1 2]

In competitive rowing, it is tactically and psychologically advantageous to gain placement at the front of the race by increasing effort at the start. This will allow the rowers, who look backwards down the course, to be able to monitor the position of other boats and react to any sudden advances from other competitors, and also allows them to avoid the wake of other boats. In some sports, there is some evidence that a fast start is the optimal strategy[1 3–5] whereas in other sports a slow start may be beneficial.[6] There is also evidence that variations in pace may be detrimental to performance.[1 2 7] There has been only one previous investigation of pacing strategies in rowing [8] and no investigations of other sports with races of similar duration to rowing (6–8 minutes).

The purpose of this study was to determine the pacing strategies adopted by elite rowers in championship 2000 m races.

METHODS

Subjects

Split times every 500 m were obtained for each boat in every heavyweight race of the Olympics in 2000 and World Championships in 2001 and 2002 (a total of 1612 boats). In addition, data from the best 170 2000 m indoor rowing ergometer (model C; Concept II Morrisville, Vermont, USA) time trials performed at the 2001 and 2002 British Indoor Rowing Championships were analysed.

Separately for on-water and ergometer rowing modes, the competitors were sorted into the following groups for comparison: (*a*) men versus women; (*b*) ''winners'' (placing in the top half of the field) versus ''losers'' (placing in the bottom half of the field).

Data analysis

Races were only included in subsequent analysis if there was good evidence that the athlete or crew completed the race in the fastest possible time. For example, boats trailing in last place or a long way ahead of the other competitors may have deliberately slowed toward the end of the race to conserve energy for subsequent rounds of the competition. These boats were excluded from the analysis.

To allow comparison of race profiles over the whole range of race finishing times, it was necessary to normalise the data. This was achieved by calculation, for each individual profile, of the average velocity for each 500 m sector, and expression of this velocity relative to the average velocity for the whole race.

Table 1 Descriptive data from the three championship regattas

Regatta	Number of races: Men	Women	Total in regatta
Sydney 2000	298 (185)	169 (74)	467 (259)
Lucerne 2001	380 (250)	198 (129)	578 (379)
Seville 2002	366 (226)	201 (84)	567 (310)
Total in class	1044 (661)	568 (287)	1612 (948)

The data are the total number of profiles considered with number that fitted the inclusion criteria in parentheses. The mean (SD) time to complete the race for boats that fitted the inclusion criteria was 381.0 (8.2) seconds for men and 417.2 (8.9) seconds for women.

Table 2 Descriptive data from the British Indoor Rowing Championships of 2001 and 2002

	Number of races		
Championships	**Men**	**Women**	**Total**
2001	46	50	96
2002	36	38	74
Total in class	82	88	170

All races fitted the inclusion criteria. The mean (SD) time to complete the race for boats that fitted the inclusion criteria was 361.8 (1.8) seconds for men and 428.8 (3.3) seconds for women.

Statistical analysis

Analysis of variance with repeated measures was applied to the subgroups identified above to determine any differences between groups (sex × sector, winner × sector, mode × sector). If a main effect was observed, one way analysis of variance was used to determine which sectors showed significant differences. The level set for significance was $p<0.05$.

RESULTS

Of the 1612 on-water race profiles considered, 948 fitted the inclusion criteria. Tables 1 and 2 show the number of races considered and included in subsequent profile analysis, together with the average race performance.

No significant differences were seen when winners were compared with losers and men with women for either on-water (fig 1) or ergometer (fig 2) rowing ($p>0.05$ for all cases). However, a significant difference was observed when modes of exercise were compared (fig 3), with this difference apparent across the first three sectors of the race.

Every group showed a race profile that significantly differed from even pace—that is, significant differences were observed when sectors within groups were compared. Table 3 and fig 3 show the average race pace profiles. The first 500 m of the race was rowed 5.1 seconds and 1.7 seconds faster than subsequent sectors for on-water and ergometry respectively—a difference likely to be competitively meaningful. Differences were also observed when other sectors were compared, and the magnitude of these differences was always less than 1.3 seconds. These differences were statistically significant, although are unlikely to be of competitive significance.

DISCUSSION

This study is one of only two that have examined pacing strategies in 2000 m rowing, with no investigations of other sports in which races last 6–8 minutes. This investigation confirms and builds on the briefer study by Secher *et al*,[8] who performed similar averaging for all male finalists at the 1974 Olympic Games. Our study is an important development from that of Secher *et al*,[8] and has included men and women from all races in three world class regattas along with indoor rowing ergometry data, and has included a filtering process to include only those races in which the athletes made a good effort. Elite competitive rowers have been shown to adopt a similar race pace profile regardless of finishing position or sex, for a given mode of rowing, with the first 500 m being rowed at a practically and statistically significant faster pace than subsequent sections (figs 1–3).

The performance averaging method adopted in this study is similar to that used by Wilberg and Pratt[9] and Foster *et al*,[1,7] who determined race profiles for track cyclists[1,7,9] and speed skaters.[1,7] Wilberg and Pratt[9] found a difference in race profile between winners and losers and concluded that cyclists lost races because of accelerating too rapidly at the start of the race. Our study does not show such a difference between winners and losers. The discrepancy between these two studies is almost certainly due to our consideration of only those races in which there was evidence that the competitors made a good attempt to complete the course in the shortest possible time. The evidence used to exclude these races was usually an appreciable slowing of the boat over the final 500 m, and resulted in the exclusion of 41% of all regatta races. In most cases, this slowing was probably due to

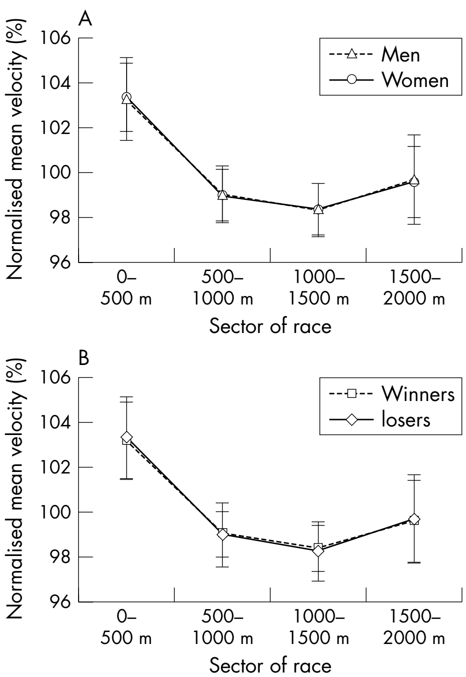

Figure 1 On-water race pace profiles comparing (A) men (n = 661) and women (n = 287), and (B) winners (n = 500) and losers (n = 448).

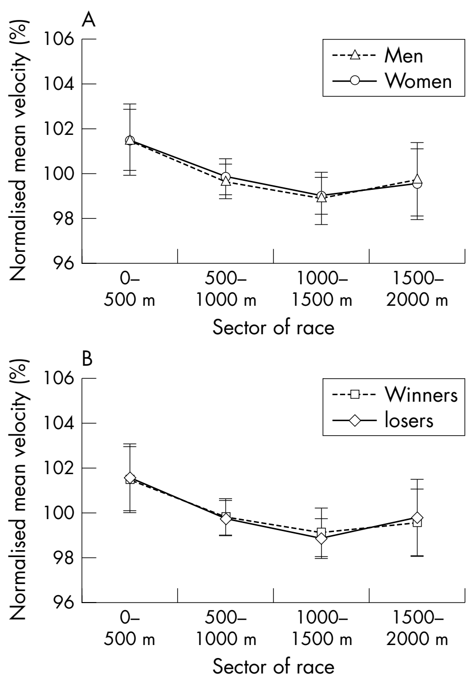

Figure 2 Ergometer race pace profiles comparing (A) men (n = 82) and women (n = 88), and (B) winners (n = 85) and losers (n = 85).

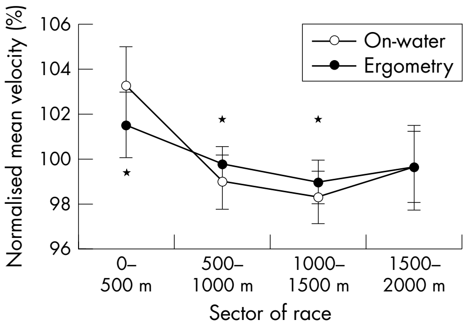

Figure 3 Race pace profiles comparing on-water (n = 948) and ergometry (n = 170) trials. *Significant differences between the two groups ($p<0.05$).

the crew overestimating their ability and setting off at a pace that was too fast for their ability, or a deliberate tactical decision to slow down to conserve energy for further rounds of the competition. It was impossible to distinguish which of these two possibilities was the reason for the late slowing of pace. In either case, the result was for the first 500 m to appear to be extremely fast in comparison with other sectors, and in comparison with the athletes who were not excluded. The same observation was made by Wilberg and Pratt[9] for their losing competitors. Exclusion of races in which the cyclist deliberately slowed toward the end of a race may have resulted in Wilberg and Pratt[9] interpreting their data differently, and proposing a different conclusion. Their comparison may perhaps be better expressed as a comparison between athletes who showed evidence that they completed the race in their shortest possible time compared with athletes who did not show such evidence. Such a comparison is not as valuable as the other comparisons made in the present study.

In addition to showing no difference between winners and losers, this study also shows no difference in pacing strategy between men and women despite possible differences in the physiological characteristics of these athletes that may affect the distribution of energy expenditure during a race.

However, a difference in pacing strategy was observed between on-water and ergometer rowing, although both showed a fast start strategy. The first 500 m of the race was rowed on average 5.1 seconds and 1.7 seconds faster than the second 500 m, for on-water and ergometer rowing respectively. This pattern for ergometry time trials is perhaps surprising, as there is no tactical or psychological advantage in setting off fast on an indoor rowing ergometer in the same way that there is for on-water rowing. It is possible that these athletes become accustomed to setting off fast on the water, and this strategy transfers to ergometer time trials. However, another possibility is that setting off fast is the physiologically optimal strategy to adopt, and this strategy is naturally adopted by elite competitors.

Table 3 Average race profiles for the two modes of rowing

	Pace (%)	
	On-water	Ergometry
0–500 m	103.3 (1.8)	101.5 (1.5)
500–1000 m	99.0 (1.2)	99.8 (0.8)
1000–1500 m	98.3 (1.2)	99.0 (1.0)
1500–2000 m	99.7 (1.9)	99.7 (1.6)

Pace is expressed as mean (SD) percentage velocity for the race as a whole.

Evidence from sprint running, sprint cycling, and speed skating,[5] two minute kayaking,[3] 1500 m speed skating,[1] and 1000 m, 2000 m, and 4000 m cycling[1 4 7] suggests that, for the shortest duration races (less than 120 seconds), the best strategy is all out at the start, with a decline in power output (and therefore pace) towards the end of the race.[3 5] As the race gets longer (between 120 seconds and 290 seconds), the strategy should tend to a short powerful (but submaximal) start, followed by more even pacing.[1 4 7] This transition in profile continues so that for races of long duration, a slow start with an increase in pace towards the end of the race—that is, ''negative splitting''—should be adopted, as shown by Mattern *et al*[6] for 20 km cycling (lasting about 33 minutes).

Elite competitive 2000 m rowing races take 330–460 seconds to complete. This duration falls between the two extremes of the range of pacing strategy studies previously published (and presented above). We observed that a fast start was the strategy adopted by elite rowers (figs 1–3, table 3), similar to that observed previously for races lasting 120–290 seconds.[1 4] The problem with a powerful start in longer duration time trials such as these is that the higher the initial power output, the higher the initial metabolic acidosis.[10] This may inhibit anaerobic glycolysis and muscle contraction, resulting in a decrease in maximal power output late in the race and the deterioration of the ability to produce an effective technique.[1 11 12]

The data presented in this paper do not fully express the magnitude of the increased effort and increased physiological load at the start of the race, because only times and speeds are recorded, rather than power output—a superior index of physiological load. The first 500 m section was the fastest despite the inclusion of the initial acceleration from a stationary start. It requires a much higher average power output to complete the first 500 m in 100 seconds, for example, than it does to complete the second 500 m in 100 seconds. However, these hypothetical data would appear to show an even paced profile if presented as in figs 1–3. Steinacker[13] has provided data, which have been plotted in fig 4, indicating that power outputs to accelerate the boat from standing to race pace are as high as 700 W compared with 350–500 W later on in the race. These additional considerations make the adoption of a fast start strategy even more remarkable.

These results also have a practical application, providing guidelines for competitors to follow. For example, an athlete may have a target of 400 seconds for a 2000 m ergometry time trial, which is an average velocity of 5 m/s. To achieve this, the athlete should row the first 500 m at 101.5% of the average velocity (the average pace shown for the elite athletes in this study; table 3)—that is, at 5.08 m/s, to complete the first 500 m in 1 minute 38.5 seconds. Subsequent sectors should be rowed at 99.8%, 99.0%, and 99.7% of average

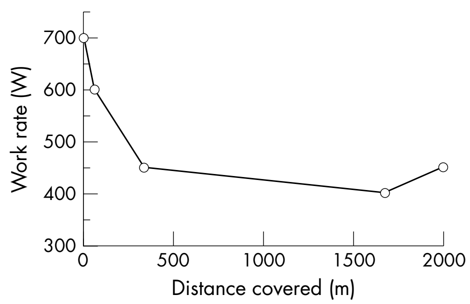

Figure 4 Work rate profile (rather than race velocity profile as presented in figs 1–3) for 2000 m on-water rowing, which emphasises the powerful first phase of the race. Data have been reconstructed from Steinacker.[13]

velocity—that is, 4.99 m/s, 4.95 m/s, and 4.99 m/s, resulting in splits of 1 minute 40.2 seconds, 1 minute 41.0 seconds, and 1 minute 40.3 seconds, and a total time of 400 seconds.

It should be noted that this study has only shown the self selected pacing strategy used by rowers, but has not necessarily shown the physiologically optimal pacing strategy, nor provided physiological evidence as to why the first 500 m sector is rowed faster than the other sectors. Although there are notable tactical and psychological reasons for starting fast, at least for on-water rowing, it is less easy to identify physiological reasons why this is the adopted strategy. Possible mechanisms for enhancing performance by starting quickly include an accelerated increase in blood flow,[14] ventilation,[15] and/or oxygen uptake[16] which may attenuate fatiguing mechanisms later in the race. These were not investigated in this study, and further, laboratory, work is required in this area.

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Conflict of interests: none declared

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ELECTRONIC PAGES

Online case reports

The following electronic only articles are published in conjunction with this issue of *BJSM*

Harlequin syndrome in two athletes

K E Fallon, J J May

Two cases are reported of harlequin syndrome, a disorder of the sympathetic nervous system in which sweating and flushing of the skin in response to exercise is diminished. This condition is most likely to be first noticed in sporting situations.

(*Br J Sports Med* 2005;**39**:e1) http://bjsm.bmjjournals.com/cgi/content/full/39/1/e1

Weight loss pressure on a 5 year old wrestler

R A Sansone, R Sawyer

The case is reported of a 5 year old boy who was pressured to lose weight in order to wrestle at a lower weight class. Although a minority of athletes engage in unhealthy weight management practices, this is an unusual case because of the age of the athlete and the influential role of a parent.

(*Br J Sports Med* 2005;**39**:e2) http://bjsm.bmjjournals.com/cgi/content/full/39/1/e2

Rhabdomyolysis in 119 students after repetitive exercise

A C-M Lin, C-M Lin, T-L Wang, *et al*

Exercise induced rhabdomyolysis is well known, but has rarely been reported in high school students. This is the report of 119 cases in high school students who exercised vigorously (120 push ups in five minutes) in cold weather. Most of them developed muscle pain and dark urine within two to four days of the exercise.

(*Br J Sports Med* 2005;**39**:e3) http://bjsm.bmjjournals.com/cgi/content/full/39/1/e3