

DOES A MODIFIED FOOT-STRETCHER IMPROVE 500-M ON-WATER AND ERGOMETER ROWING PERFORMANCE TIME AND COMFORT?

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Foot-stretcher force contributes to rowing performance. A New Zealand designed modified rowing foot-stretcher has a rigid clog shoe with heel and toe wedges to allow contact of the whole surface of the foot to the foot-plate throughout the entire rowing stroke. This study examined the effect of modified and standard foot-stretchers for eight competitive rowers during on-water double scull and static Concept2 ergometer 500-m rowing. Race time and comfort were recorded. Comfort measures indicated that the modified foot-stretcher was preferred both on-water and ergometer. Performance time measures indicated a potential performance enhancement with the modified foot-stretcher on-water (2.0%), however due to large confidence intervals, the results were unclear. This modified foot-stretcher assisted athletes rowing comfort and showed potential for performance enhancement.

KEY WORDS: mechanics, feet, Visual-Analogy Scale (VAS), performance.

INTRODUCTION: Competitive rowing may be seen as an optimization problem where the overarching goal is to maintain the highest average velocity over a 2000-m course (Pettersson, Nordmark, & Eriksson, 2014). At the elite level, variations in race performance of 0.3% between rowers can make the difference between final medal-awarding positions (Smith & Hopkins, 2012). Optimization requires consideration of multiple factors including, but not exclusive to, minimisation of energy loss, application of propulsive force and decreasing the drag for each stroke (Baudouin & Hawkins, 2004). An optimal performance is one, which depends on a well-tuned biological system (the rower) and mechanical system (rowing shell) working as one entire system in order to advance the rowing shell over a set distance (Pettersson et al., 2014).

From a dynamic systems perspective, when one factor is adjusted or influenced (e.g. shortening of the oars, or rower fatigue), there are changes to other areas of the entire rower-boat system, and subsequently performance (Davids, Glazier, Araujo, & Bartlett, 2003). A dynamic system approach examines inter-linking relationships, rather than looking at changes in performance in isolation to other contributing factors. The mechanical nature of the rowing boat means that rowers are physically connected to the boat at their feet, buttocks and hands. High boat velocities are achieved by producing large, symmetrical foot forces, which are efficiently delivered through the human kinetic chain to the foot-stretcher and the handle/oars (Buckeridge, Bull, & McGregor, 2015; Hofmijster, Van Soest, & De Koning, 2008). Substandard technique occurs through imprecise sequencing of body segment motion, which negatively affects the forces applied to the foot-stretcher, and impacts the efficiency of transfer to the handle/oars, thus reducing mean boat velocity (Soper & Hume, 2004).

Traditional foot-stretchers (Fig 1) are designed for rowers to approach the catch (start of rowing stroke) with a raised heel, and then push the heel down quickly for a stable connection to the foot-plate base. A potentially more efficient design would allow a solid connection with the whole foot to the foot-plate similar to the whole-foot contact between the foot and floor when performing a barbell squat or a leg-press movement. The mechanical structure of the rowing boat constrains where the rower can position themselves during performances. Although there are some adjustments that can be made to suit individual differences, the construction of the boat and rigging in effect determines the biomechanical position of the rower.

A modified foot-stretcher (Fig 2) design prototype was designed in New Zealand and approved for use in competition by FISA (World Rowing Federation). The modified foot-stretcher design has a rigid clog shoe with heel and toe wedges to allow contact of the whole surface of the foot

to the foot-plate throughout the stroke duration to potentially allow better heel connection. Rowing New Zealand's men's single sculls five-time World Champion and 2012 Olympic Gold Medallist has been training with the modified foot-stretcher and reported anecdotal evidence that it may be beneficial for on-water performance and ergometer training. However, a scientific study had not been completed to examine the effects of the modified foot-stretcher. Therefore, this study examined the effects on performance time and rower comfort of the modified foot-stretcher compared with the current standard foot-stretcher for eight competitive rowers during on-water double scull and static Concept2 ergometer rowing.



Figure 1 – Traditional foot-stretcher (raised heel at catch).



Figure 2 – Modified foot-stretcher (wedge at toes and heel).

METHODS: Eight experienced high-school male rowers (mean 16.8 ± 0.6 years old), with two to four years rowing experience, performed four 500-m time-trials on-water in double sculls (on-water boat) and on a Concept2 rowing ergometer (on land). Testing involved the rower aiming to travel the 500-m distance in the shortest time (m:ss.0) possible. An M-T-M-T or T-M-T-M order (T= traditional foot-stretcher and M=modified foot-stretcher) was used, with a period of active recovery between each test so that the rowers could swap over the foot-stretchers. The rowers had adequate familiarity with the foot-stretcher set-up prior to the study as per the recommendations of Taylor & Fletcher (2012). A 210 mm Visual Analogy Scale (VAS) (0-mm= not comfortable at all; 210-mm=most comfortable imaginable) was used by the rowers to report their perceptions of the foot-stretcher comfort after each trial (Mills, Blanch, & Vicenzino, 2010; Salles & Gyi, 2013). Meaningful changes were set to a standardised effect size (ES) of 0.2. Paired trial times for T and M foot-stretcher conditions were averaged and difference scores were calculated using mean differences (MDiff), standardized effect sizes, and magnitude-based inferences using confidence intervals (CI) of the ES with limits set at 95% to determine significance and practical importance (Hopkins, 2007).

RESULTS: The double sculls on-water 500-m trial times improved by 2.2 s (2.0%) on average with the modified foot-stretcher (Table 1). The effect size of performance time for the traditional to modified foot-stretchers was -0.9 (95% CI = -2.4 to 0.5), supporting a moderate performance improvement with the sample using the modified foot-stretcher on-water. However, the confidence interval was slightly too large to make a clear inference for the wider rowing community. Similarly, the effect of the modified foot-stretcher on the ergometer was unclear due to the large confidence interval. Rowers preferred the modified foot-stretcher to the traditional foot-stretcher, supported by an extremely large effect size for the on-water comfort rating (ES = 10.5, 95% CI = 9.1 to 11.9) and a moderate effect size for the ergometer comfort rating (ES = 1.0, 95% CI = 0.6 to 1.4).

Table 1. Descriptive and effect size statistics for 500-m trial time and VAS comfort ratings for foot-stretcher types.

Boat/ Erg	Variable	Traditional foot-stretcher		Modified foot-stretcher		Traditional to Modified			Outcome
		Mean	±SD	Mean	±SD	MDiff	ES	ES 95% CI	
M2x	Time	1:52.2	0:02.4	1:50.0	0:02.3	-2.2 s	-0.9	-2.4 to 0.5	Unclear; need more data
Erg _{static}	Time	1:34.0	0:04.3	1:33.5	0:03.5	-0.5 s	-0.1	-0.5 to 0.3	Unclear; need more data
M2x	VAS	12.6	0.5	18.3	0.2	5.7	10.5	9.1 to 11.9	Clear, extremely large
Erg _{static}	VAS	11.0	5.6	16.6	3.5	5.5	1.0	0.6 to 1.4	Clear, moderate

Time data reported in *mm:ss.0* where mm = minutes, ss = seconds, 0 = tenths of a second; VAS is a unit-less rating system on a scale of 0-21 (least comfortable to most comfortable). MDiff = mean difference of time reported in seconds and VAS reported on a unit-less rating system on a scale of 0-21; ES = effect size, a unit-less number showing the standardized effect; CI = confidence interval of the effect size.

DISCUSSION: On-water performance times were faster and VAS comfort ratings highest in the sample when using the modified foot-stretcher. However there were no significant improvements in performance times with the modified foot stretcher, even though VAS comfort ratings were moderate to extremely large. VAS scores for both foot-stretchers showed large beneficial effects and overall comfort by the performers. The lack of significant performance time findings is likely due to the small sample size of rowers. The modified foot-stretcher seemed to make less of a pronounced effect on the ergometer in both performance time and comfort. Why the on-water performance times improved in the sample, while the ergometer times did not, is unknown. On-water rowing is a flexible system, with high degrees of freedom. The boat, oars and rower can move in adaptable ways due to the interacting nature of these factors. A systems approach that looked at optimisation between these factors in order to maximise performance (Pettersson et al., 2014) showed some possible reasons for differences between on-water and ergometer performance. On-water, if a rower is in a dorsiflexed position for a long period of time during the drive phase, could contribute to changes in boat balance and oar placement. In practice, there is a performance consequence to this position (the boat may go off balance) that there is not on the ergometer. A small change in one part of the system, i.e. the feet, may have contributed to other changes in the entire system and consequently produced a faster performance.

While there were still performance differences in favour of the modified foot-stretcher on the ergometer (0.5 s), these did not have the same effect size differences as the on-water performances. This difference could be in part due to the different performance environments with on-water compared to the ergometer. The ergometer system could be a more rigid system in terms of how the rower is able to move. The modified foot-stretcher has in some part made this system more fixed, by reducing the degrees of freedom exploited by the rower at the catch. This change in the foot-stretcher could correspondingly help shape the way the rower moves and encourage them to apply forces differently at the catch than use of the traditional foot-stretcher allows. For instance, the traditional foot-stretcher on the ergometer allows the rower to be in a dorsiflexed position for a long period of time, which as understood in other sports, decreases performance (Lapole, Ahmaidi, Gaillien, & Lepretre, 2013).

The modified foot-stretcher design appeared to enhance 500-m performance in our men's double sculls by a moderate amount (an average reduction in trial time of 2.2 s), which is ~2% change in performance time. The difference observed in our study is far greater than the 0.3% smallest worthwhile difference reported in rowing literature (Smith & Hopkins, 2012), so the

modified foot-stretcher is effective for enhancing performance of the on-water participants in this study. However more data are needed to make a clear inference for the wider rowing community. The modified foot-stretcher made a trivial/unimportant difference in ergometer time in our observations. Overall, rowers preferred the modified foot-stretcher design given the higher comfort ratings, which supports the notion that the traditional foot-stretcher design is not optimal. Further research should focus on more participants, the mechanism behind the potential performance enhancement, which is more likely to be noticed on-water, and repeated studies with various sculling boats, rowing classes, skill levels, and gender to determine its applicability in the wider rowing community. Given the potential for performance enhancement on-water, and the comfort ratings being good, it is recommended that rowers try the modified foot-stretcher.

CONCLUSION: Comfort measures indicated that the modified foot-stretcher was preferred both on-water and ergometer. Performance time measures indicated a potential performance enhancement with the modified foot-stretcher on-water (a reduced time of 2.2 s, 2.0% improvement), however due to large confidence intervals, the results were unclear. The influence of the modified foot-stretcher on ergometer performance was unclear. The development of the new foot-stretcher assisted athletes improve rowing comfort and showed potential for performance enhancement.

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