REAL-TIME BIOFEEDBACK TO CONTROL TRUNK POWER PRODUCTION IN ERGOMETER ROWING

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The purpose of this study was to test a real-time feedback for ergometer rowing based on parameters describing a rower's technique, specifically the curve of the power produced by the trunk. The goal was to enhance the trunk engagement during the drive phase. Eleven rowers performed an ergometer rowing session at 20spm and maximum intensity, where their habitual technique was measured. Then, they performed six sessions of 3min with feedback exposure on trunk time to peak power and work ratio. On average, rowers were able to advance their trunk power production within the drive phase by 1.3%, but without significant effect on performance, despite a mean 43W increase in trunk power. Feedbacks of this kind could be used in training to address specific parameters of a rower's technique.

KEYWORDS: rowing, feedback, training, technique, performance

INTRODUCTION: The trunk plays an important role in rowing and it is fundamental in both power production and power transfer, with a major effect on performance (Kleshnev, 2016). In particular, when rowing with the 'Rosenberg' style, rowers execute a consecutive extension of the lower limbs followed by the trunk. Thus, the trunk acts first to transfer the power generated by the legs to the arms and then as a power generator itself. A study investigating rowers having 'Rosenberg' technical style on ergometer rowing (Simon et al., 2023) found that, among others, parameters describing the technical aspects of the trunk power production, were predictors of performance. In particular, time to peak relative to the drive phase (T2P%) and work ratio (WR) were among the strongest predictors, with earlier T2P% and higher WR predicting higher trunk power, suggesting that an early involvement of the trunk could be more performant. Thus, a biofeedback capable of guiding a rower towards a more performing technique would be of great help for training. Indeed, visual biofeedbacks in rowing have already been used with success. Systems like Peach (Peach Innovations, UK) are widely used to provide real-time feedback about strokes per minutes (spm). Sigrist et al. (2013) showed that different kinds of feedback were useful in learning to control the oar position. In addition, (Lintmeijer et al., 2019) showed that power output feedback helped rowers to comply with power output targets. Also, a biofeedback based on kinematics has been successfully used to correct the rower's technical errors such as early arm flexion during the rowing stroke (Gorman et al., 2021). The purpose of this study was to test the ability of a real-time biofeedback based on trunk power to change a rower's technique, and evaluate the effect of such change on performance. We hypothesized that using the real-time biofeedback would enable rowers to achieve earlier trunk power T2P%, while maintaining their habitual power output.

METHODS: Eleven rowers (22.2 ± 3.0 years old, 79.2 ± 8.4kg, 185 ±6 cm, 6:24 ± 0:10 2000m record on ergometer) volunteered to participate in the study. The ergometer (RP3®, Care RowPerfect BV, Hardenberg, The Netherlands) was equipped with BioRow (BioRow Tech, London, United Kingdom) force (handle and foot stretcher) and position (handle, shoulder and seat) sensors. Position sensors consisted of spring-loaded strings attached to the handle, to the sternum at shoulder level and to the seat. Data was acquired at 150Hz through an Arduino board and feedback was provided on a monitor using a code written in Matlab. The events of

catch and finish, defining the phases of the rowing cycle, were automatically detected based on the minima and maxima of the handle position, respectively.
Handle power was defined as handle force times handle velocity; arm power as arm velocity (i.e. handle velocity – shoulder velocity) times handle force, trunk power as handle force times trunk opening speed (i.e. shoulder velocity – seat velocity) and leg power as foot stretcher force times seat velocity (Kleshnev, 2000). T2P% was calculated as the percentage of the drive phase (defined as the interval from catch to finish) at which the peak of the trunk power curve occurred and T2Ps represents the time in seconds after catch of the peak trunk power. Duty cycle (DC) was defined as the ratio between drive phase and cycle duration times 100. WR was defined as the ratio between work produced by the trunk before the T2P% and the total work produced during the drive phase.

The protocol consisted of the following sessions, separated by two minutes rest periods:
1) *Warming session*. During this session, the rower was shown the real-time curve of the trunk power and was asked to try and see how to change the T2P%.
2) *A two minutes session at 20 spm, max intensity, with the rower's habitual technique*. Data collected in this session, was used to determine the rower's habitual T2P% and WR. These values were then used as target for the feedback sessions. Specifically, the rowers were asked to achieve a WR >= habitual WR and to target a T2P% = (habitual T2P% - 2SD) ± 1SD.
3) *Six sessions with biofeedback*. Each session consisted of two minutes at free intensity, followed by one minute at maximum intensity. Data for the subsequent analyses was collected during the high intensity minute.
In all of the sessions, the real-time spm were shown to the rowers, as it's customary for them to train with such an information. The instructions given to the rowers were to reduce the T2P% and maintain a WR equal or greater than the usual values, while rowing at maximum intensity.

The feedback screen consisted of several elements related to the drive phase of the stroke (Figures 1 and 2):

- The average trunk power curve measured during the 20spm session with habitual technique. We included this to provide to the rower a visual representation of the shape and magnitude of the habitual curve.
- The new T2P% target with ±1SD boundaries.
- The curve of the trunk power during the last cycle:
    - If the last T2P% occurred later in the drive phase than the target, the curve was displayed red.
    - If it occurred earlier, the curve was yellow.
    - If it was within the target, the curve was green.
- We also provided feedback about the WR of the last cycle, by changing the colour of the area under the ascending part of the curve:
    - If the current WR was < the usual WR, the area was painted red
    - Otherwise, the area was green

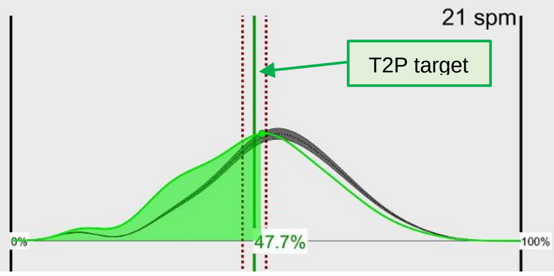

Figure 1- Feedback when both T2P% and WR met the target

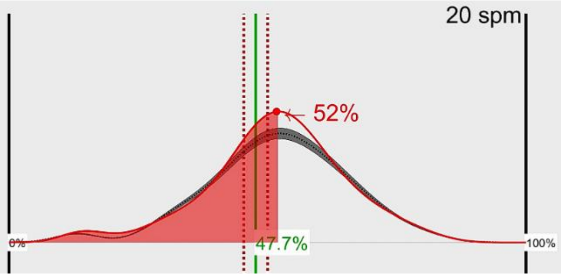

Figure 1- Feedback when neither the T2P% nor the WR met the target

T-tests for dependant variables were used to determine the success of the feedback, i.e. the differences between habitual technique values of T2P% and WR and their values during the last feedback session (alpha <0.05). Same T-tests were performed to evaluate the biofeedback effect on the power measured at the handle as well as the powers produced by each body segment (i.e. legs, trunk and arms).

RESULTS: The width of the T2P% target was 2.7± 1.5 %. On average, rowers were able to locate their trunk power T2P% within the target 42% of the cycles in their last feedback session. Over all subjects, statistical analysis showed a significant effect of the biofeedback on T2P%, with the last session of feedback showing that rowers advanced T2P% by 1.3% ($p<0.001$) of the dive phase (Table 1). No significant effect was measured with respect to the changes of the other parameter targeted by the feedback, namely the WR. Likewise, there were no significant changes in the parameters measuring the performance, i.e. the power transferred to the handle and the power produced by the rower's segments, despite a 43W increase in the trunk power production. There was also no significant effect on the change in T2Ps s and DC.

Table 1: Average values at 20 spm and changes induced by the feedback.

	20spm habitual	Changes in final feedback session
T2P trunk (%drive)	58.7 ± 3.2	**-1.3 ± 0.9 ***
WR trunk	0.61 ± 0.03	-0.01 ± 0.03
Power handle (W)	897.0 ± 141.7	+23.5 ± 48.2
Power arms (W)	168.4 ± 27.5	-6.6 ± 20.8
Power trunk (W)	340.4 ± 53.4	+43.1 ± 143.3
Power legs (W)	422.2 ± 81.6	+25.9 ± 91.1
T2P trunk (s)	0.53 ± 0.04	-0.03 ± 0.04
Duty cycle (%cycle)	31.12 ± 1.25	0.27 ± 1.58

* Significant differences induced by the biofeedback ($p<0.05$)

DISCUSSION: The proposed biofeedback was able to change the technique of the rowers without reducing the performance. On average, rowers achieved their trunk power T2P% 1.3% earlier within the drive phase. There was also a non-significant reduction of the T2Ps and a non-significant increase of the duty cycle. Suggesting that the strategy to generate an earlier peak of trunk power within the drive phase involved both a small absolute earlier trunk action and a small increase in the duty cycle. The differences in WR and powers were not significant, indicating that the changes in technique did not have a negative effect on performance. This is an improvement with respect to a previous similar study, where the rowers received oral instruction to engage their trunk earlier, without feedback, and resulted in decreased trunk and handle power production (Ertel et al., 2022).

Preliminary tests showed that some rowers had difficulties anticipating their trunk power T2P% too much. Thus, we chose a T2P% target centered at -2SD from the habitual value so that rowers would have a target within their reach. This resulted in targets with different width among the subjects (ranging from 1.4% to 5.9%), with more consistent rowers having narrower targets. However, we found that subjects with a narrower target didn't have more difficulty in executing successful strokes. On the contrary, they adapted faster and more consistently to the new requirements. The success of this kind of feedback, based on complex technical modification seems to be dependent on the technical level of the subject. Indeed, two out of 11 rowers could not advance significantly their trunk power T2P%. Rowers with a lower technical level might thus need more sessions to succeed consistently. All these measurements happened in a single day, so while the rowers were mostly able to adapt to the task, it remains difficult to anticipate what the long-term effects of the induced changes on performance and metabolic cost would be. However, the ability to achieve an earlier time to peak trunk power is likely to suggest that long-term effects could help to increase significantly trunk power output. Indeed, a 1SD change in T2P% has been found to correlate with a 3.17%

increase in mean trunk power (Simon et al., 2023), and hereby contribute positively to handle power output, i.e. performance. This study showed that a feedback of this kind can help change aspects of a rower's technique, even when it's targeting more complex parameters than kinematics or power output, as already presented within the literature.

CONCLUSION: The ability to target specific parameters of a rower's technique with a real-time feedback can be very useful to trainers and athletes. By decomposing the rower's power production into the different segments, it is possible to fine-tune the technique to the parameters that have been identified as important for performance (Simon et al., 2023). In this study, we succeeded in moving the trunk power T2P% earlier within the drive phase without affecting other technical parameters. In the future, such biofeedback could also try to address and correct precisely technical faults specific to individual athletes, e.g. the presence of negative power at the arms or trunk right after catch.

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