INFLUENCE OF STROKE RATE ON CORE STABILITY AND ROWING ERGOMETER PERFORMANCE

Y. Duchene[1], F. Simon[1], G. Ertel[1], H. Maciejewski[3], G. Gauchard[1,2], G. Mornieux[1,2]

[1]DevAH, Université de Lorraine, Nancy, France
[2]Faculty of Sport Sciences, Université de Lorraine, Nancy, France
[3]Fédération Française d'Aviron, Nogent-sur-Marne, France

The purpose of this study was to determine the effect of the stroke rate on rowing ergometer performance and more specifically on core stability. Twenty expert rowers performed 2 one-minute bouts at 20 and 34 strokes per minute, on a RowPerfect3 ergometer. The high stroke rate induced larger handle and trunk power production and delayed trunk extension during the drive phase. The analysis of co-activation ratios didn't help the understanding of the differences induced by the stroke rate manipulation, but higher abdominal muscles activation was reported, that should help stabilizing the trunk, while power, along with stroke rate, increased. These findings could help trainers to better adapt the stroke rate to the different purposes, i.e. power or technique, of the training.

KEY WORDS: rowing, stroke rate, EMG, muscles co-activation, trunk control

INTRODUCTION: In competition or training, stroke rate (SR) differs between rowers and sessions. For example, in the men's singles Olympics final in Tokyo 2020, mean rower SR ranged from 33.1 to 39.2 with an average of 37.4 strokes per minute (spm). During training sessions, coaches often vary the SR from 20 to 40 spm to induce different technical skills and physiological adaptations (Kleshnev, 2016). Monitoring training sessions can be performed by analyzing the mean power output at the handle, which has also been reported to be increased with higher SR (Buckeridge et al., 2016A).

Each rower has to produce a maximum power at the handles, which starts from the ability of rowers to develop force through their lower limbs, to efficiently transmit these forces via the trunk to the upper limbs (Hofmijster et al., 2007). The core stability is the ability of the trunk with respect to the pelvis to produce power and to transfer efficiently forces from lower limbs to the arms (Kibler, Press & Sciascia, 2006). Therefore, it might play a major role in performance (i.e. around 30% of handle power in Kleshnev 2000) but also in low back pain injuries (Alijanpour et al., 2021). With the increase of the SR, higher spine forces and larger L5/S1 range of motion (ROM) were noticed (Buckeridge et al., 2016B), underlining core stability's adaptations. Else, to target better training trunk angulations and to know when the SR impacts the kinematics, it seems necessary to analyze core stability through the drive phase. Moreover, trunk electromyographic (EMG) activity has been shown to be different along the drive phase with an early activation of the spinal muscle, followed by a co-activation phase between abdominals and spinal muscles, and then a late activation of abdominis and external oblique muscles (Pollock et al., 2009). The co-activation between the spinal muscles and the abdominals could lead to an increase of spine stiffness (Cholewicki et al., 1997) and therefore to a better force transfer from the lower limbs to the arms. Therefore, SR manipulation could influence trunk muscles co-activation together with trunk kinematics.

The purpose of this study was to determine the effect of the stroke rate on rowing ergometer performance and on core stability. We hypothesized that i) the power produced by the trunk would be larger at the high SR condition; ii) the core kinematics would vary through the drive phase inducing a larger ROM for the high SR condition; iii) the amount of co-activation would be larger for the high SR condition.

METHODS: 20 healthy and voluntary high-level rowers part of the Elite, U23 and University categories of the French rowing federation were recruited (14 men and 6 women, 20.2 ± 2.1 years old; 1.82 ± 0.05m; 76.1 ± 4.4kg). After a free warm-up of 10 minutes, each rower performed 2 one-minute bouts at 20 and 34 spm. The rationale for these spm values was that the training sessions considered low and high stroke rate, with kinematic adaptations (McGregor et al., 2004). Two trials at their self-chosen optimal SR were performed to normalized EMG signals. The instructions were to row at maximum intensity for each SR. The mobile rowing ergometer (RP3®, Care RowPerfect BV, Hardenberg, The Netherlands) was also equipped with BioRow Catch Training System (BioRow Tech, London, United Kingdom) registering force data, at the handle and at the foot stretcher, and positions of the seat, trunk and handle. All these parameters were measured at 25Hz. In addition, trunk kinematics were measured using an inertial measurement unit (iSen, STT Systems, Spain) placed in the back between the two scapulas (trunk), recording the 3D spatial positions at 100Hz. A positive angle represented an extension with respect to trunk verticality. Surface electromyography recordings of core muscles, sampled at 2000 Hz and synchronized with the IMU, were obtained from the rectus abdominis, the external oblique and the erector spinae of the right and left sides (Trigno™, Delsys, Natick, MA, USA).

All data were analyzed over 12 consecutive drive phases. The catch and finish were defined by the handle position with respect to the stretcher (i.e. minimum and maximum values, respectively). The position data from the seat, trunk and handle were derived to obtain the speeds. The mean power produced for each stroke was computed using the following calculation method (Kleshnev, 2000):

Power at the handle (Phandle, W) = handle force * handle speed.

Power of the trunk (Ptrunk, W) = handle force * (trunk speed - seat speed).

The trunk ROM in the sagittal plane was calculated with its maximal and minimal value during the drive phase. A 25ms electromechanical delay was considered for the EMG analysis. RMS normalized values for each muscle signal during the whole drive phase were calculated and then left and right values were averaged. The Directed Co-Contraction Ratio (DCCR) and the Co-Contraction Index (CCI) were computed through the drive phase as follows:

If agonist mean EMG > antagonist mean EMG: $DCCR = 1 - \frac{EMG\ antagonists}{EMG\ agonists}$

Else : $DCCR = \frac{EMG\ agonists}{EMG\ antagonists} - 1$

$$CCI = \frac{Lower\ EMG}{Higher\ EMG} * (Lower\ EMG + Higher\ EMG)$$

DCCR represents the balance between agonists and antagonists' activations while CCI represents the amount of co-activation.

All power, kinematic and EMG RMS variables were averaged for each participant. Repeated-measures ANOVAs and post-hoc (Fisher's LSD) test were performed with Statistica® software to quantify the effect of rate on the measured variables. Differences in trunk power, kinetics, muscles activations and co-activations through the drive phase between the two stroke rates were examined using one-dimensional statistical parametric mapping (SPM) using Random Field Theory (Pataky et al., 2013). The level of significance was set at 0.05.

RESULTS: The SR for the two conditions were 20.7 ± 0.5 spm and 34 ± 0.9 spm. Power and trunk kinematics results are presented in Table 1. Moreover, RMS values for the rectus abdominis, the external oblique and the erector spinae were not significantly different between the two SR conditions.

Table 1: Performance and trunk kinematic parameters at the two stroke rates

Variable	20spm	34spm
Phandle mean (W)	619 ± 130	702 ± 139*
Ptrunk mean (W)	226 ± 64	254 ± 61*
Trunk ROM (°)	75.1 ± 7.6	75.3 ± 5.3

*Significant difference from 20spm (p<0.05)

Trunk power was significantly different from 27% to 54% and from 86% to 92% of the drive phase, with larger values for the 34spm condition (Figure 1A). Trunk kinematics was significantly different from 51% to 82% of the drive phase, with the trunk being more extended for the 20spm condition (Figure 1B).

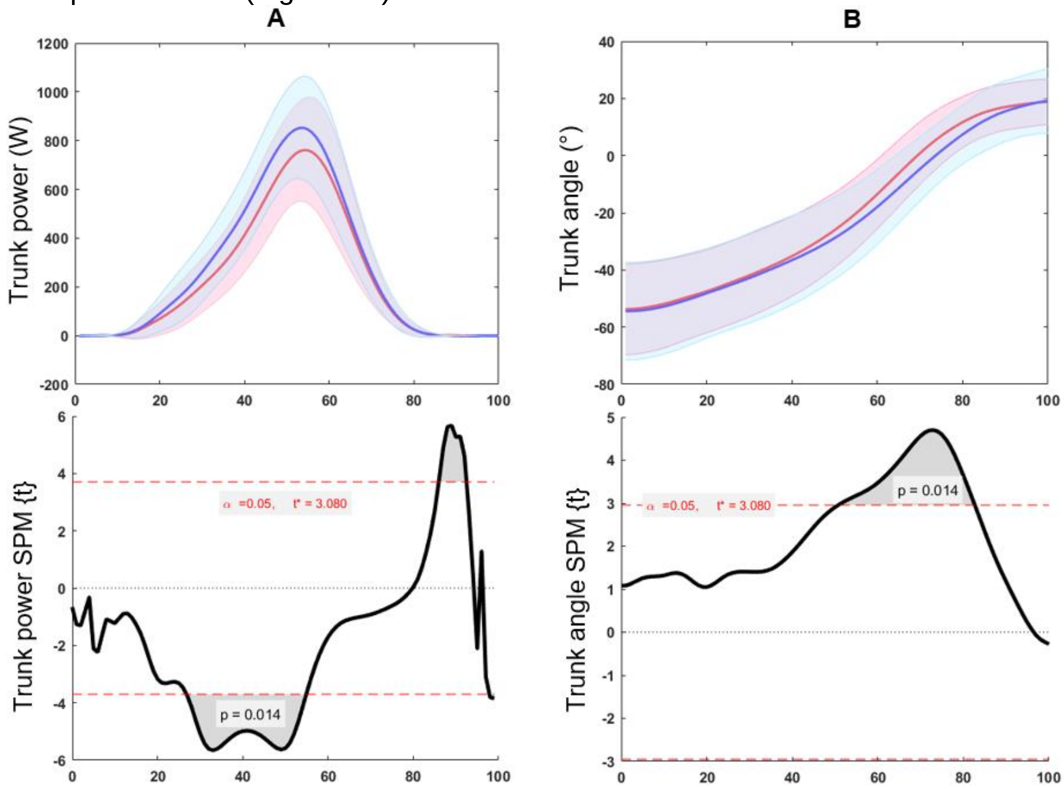

Figure 1. A) Trunk power and B) trunk kinematics through the drive phase, with their respective SPM analysis below. The 20spm condition is represented in red and the 34spm condition is in blue. Grey shaded areas represent the significant differences between the two conditions. Red dotted lines depict the threshold for significance.

The SR variation didn't impact significantly DCCR nor CCI. The rectus abdominis and the external oblique activations were higher at the latest part of the drive phase (from 60% and 62% respectively, to 92% and 100%) for the 34spm condition. The erector spinae activation wasn't significantly different between the two conditions for the complete drive phase.

DISCUSSION: The mean power produced by the rowers at the high SR was higher at the handle level, as seen previously in the litterature (Hofmijster et al., 2007), as well as for the trunk. Indeed, the increase of SR speeded up the handle and segments' speeds to then enhance power (Kleshnev, 1996). Interestingly, the trunk ROM were not larger for the high SR whereas Li et al. (2020) found that the thoracic ROM was increased between a 18spm and a 32spm condition (e.g. by 3.9° in average for the trunk). Moreover, the average trunk ROM in their study, whatever the condition, was around 40°, while ours rather reached 75°. The main difference between our setups was the instructions given to the rowers, as these authors asked for a long training session intensity whereas rowers were asked for a maximal intensity in the

present study. Moreover, larger ROM might increase force production (Buckeridge et al., 2016B).Therefore, the high intensity might cancel the stroke rate effect on the trunk ROM to produce a maximum of force.
Despite the absence of difference in the trunk ROM, we observed an delayed extension of the trunk at the high SR. This delay occurs right after the significantly higher power production of the trunk while ES muscles didn't present a larger activation. This indicates that the trunk power produced might mainly be the consequence of the lower limb kinetics instead of the trunk biomechanics. Therefore, it is possible that the trunk might act more like a force transferer than a force producer when the SR rises.
As trunk power production and trunk kinematics were different between our conditions, we would have expected that the amount of co-activation would be increased to stiffnen the spine (Cholewicki et al., 1997) and transfer more efficiently forces. The co-activation strategy didn't vary with SR change, unlike trunk power and kinematics variations. However, we noticed an increase of abdominal muscles activation in the latest part of the drive phase. This behaviour indicated a higher eccentric action to probably control and stabilize the trunk when its extension is delayed and to prepare the recovery phase. Training at maximal intensity at 20 spm is likely to induce lower power than higher SR conditions, and different trunk kinematics. Therefore, we would rather advice to train at high SR to get closer to the competition condition. However, if coaches want to train specific technical aspects, as for instance earlier trunk extension, the 20spm condition might help to modify trunk kinematics.

CONCLUSION: The higher stroke rate induced larger handle and trunk power production and delayed trunk extension during the drive phase. The analysis of co-activation ratios didn't help the understanding the differences induced by the tasks, but we noticed a higher abdominal muscles activation that should help stabilizing the trunk with the power increase. Further work is needed to better understand force transfer mechanisms through the trunk during rowing tasks.

REFERENCES:

Alijanpour, E., Abbasi, A., Needham, R. A., & Naemi, R. (2021). Spine and pelvis coordination variability in rowers with and without chronic low back pain during rowing. *Journal of Biomechanics,* 120, 110356.
Buckeridge, E. M., Weinert-Aplin, R. A., Bull, A. M. J., & McGregor, A. H. (2016A). Influence of foot-stretcher height on rowing technique and performance. *Sports Biomechanics*, 15(4), 513-526.
Buckeridge, E. M., Bull, A. M. J., & McGregor, A. H. (2016B). Incremental training intensities increases loads on the lower back of elite female rowers. *Journal of Sports Sciences*, 34(4), 369-378.
Cholewicki, J., Panjabi, M. M., & Khachatryan, A. (1997). Stabilizing function of trunk flexor-extensor muscles around a neutral spine posture. *Spine*, 22(19), 2207-2212.
Hofmijster, M. J., Landman, E. H. J., Smith, R. M., & Van Soest, A. J. K. (2007). Effect of stroke rate on the distribution of net mechanical power in rowing. *Journal of Sports Sciences*, 25(4), 403-411.
Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine*, 36(3), 189-198.
Kleshnev, V. (1996). The effects of stroke rate on biomechanical parameters and efficiency of rowing. *ISBS-Conference Proceedings Archive*, 1.
Kleshnev, V. (2000). Power in rowing. *XVIII Symposium of ISBS, Proceedings*, Hong-Kong, pp. 96-99.
Kleshnev, V. (2016). The biomechanics of rowing. The Crowood Press.
Li, Y., Koldenhoven, R. M., Jiwan, N. C., Zhan, J., & Liu, T. (2020). Trunk and shoulder kinematics of rowing displayed by Olympic athletes. *Sports Biomechanics*, 1-13.
McGregor, A. H., Bull, A. M. J., & Byng-Maddick, R. (2004). A comparison of rowing technique at different stroke rates: a description of sequencing, force production and kinematics. *International Journal of Sports Medicine*, 25(6), 465-470.
Pataky, T. C., Robinson, M. A., & Vanrenterghem, J. (2013). Vector field statistical analysis of kinematic and force trajectories. *Journal of Biomechanics*, 46(14), 2394-2401.
Pollock, C. L., Jenkyn, T. R., Jones, I. C., Ivanova, T. D., & Garland, S. J. (2009). Electromyography and kinematics of the trunk during rowing in elite female rowers. *Medicine and Science in Sports and Exercise*, 41(3), 628-636.