

THE EFFECT OF THE ERGOMETER DESIGN ON PELVIC TWIST AND LOWER-BACK FLEXION IN ELITE ROWERS

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Pelvic twist and lower-back flexion are considered as two important risk factors regarding lower-back injuries in rowers training frequently on ergometers. Mobile ergometers could be helpful because their design decreases the inertial loads that the rower has to overcome at the catch. Hence, the purpose of this study was to investigate pelvic twist and lower-back flexion with respect to the ergometer design. These two kinematic parameters were examined on ten elite rowers during one stationary and two mobile ergometer sessions performed at 20 strokes per minutes. The differences related to pelvic twist and lower-back flexion were very small. These findings suggested that further studies should be performed at higher paces and focused on the whole trunk motion and muscle activity to offer an overview of the influence of the ergometer design.

KEY WORDS: kinematics, rowing, injury.

INTRODUCTION: Rowing ergometers are widely used by elite rowers because they represent a good alternative when outdoor conditions are inappropriate for on-water rowing. However, in a recent cross-sectional study, Smoljanovic et al. (2015) reported that more than 50% of acute injuries occur during ergometer training with lower-back injuries representing the most frequent site of injury in elite rowers. In this context, pelvic twisting motion, i.e. axial rotation of the pelvis, was recently investigated because of its possible implication in the occurrence of lower-back injuries (Buckeridge et al., 2012, 2014). Interestingly, Buckeridge et al. (2012) showed high levels of pelvic twist with absolute values averaging 13.4° for the elite group. Moreover, Wilson et al. (2013) recently reported higher values of lumbar flexion, known as a major risk factor for lower-back injuries, when rowing on an ergometer in comparison with on on-water rowing.

However, these study were performed on the same type of ergometer, i.e. stationary ergometer, whereas several ergometer designs exist and are at the disposition of the rowers since the last two decades. These ergometers can be classified as stationary or mobile ergometers. The stationary ergometers with the seat sliding along the rail and the footrest fixed to the ergometer frame are most frequently used by rowers during their indoor training sessions. The mobile ergometers differ from the stationary ergometers by the sliding motion of the foot stretcher-flywheel complex or the ergometer frame. Greene et al (2013) showed that rowing on a stationary ergometer increases lower-limb joint loads because of the higher inertial masses that the rower needs to overcome at the catch.

An investigation of the pelvis twist and lower-back flexion could give more insights into the effect of the ergometer design regarding the rower's injury risk. More precisely, it would be interesting to see if the use of mobile ergometers helps to decrease the pelvic twisting motion and lower-back flexion. Thus, the purpose of this study was to compare the pelvic twist and lower-back flexion in elite rowers during rowing sessions performed on stationary and mobile ergometers.

METHODS: Ten elite male rowers were involved in the study (25.7 ± 4.2 years, 1.95 ± 0.04 m, 95.0 ± 4.7 kg). Three different ergometers were tested: the stationary Concept 2 Model C Indoor Rower (Concept2 Inc., Morrisville, VT USA) (C2F), the Concept 2 Model C

with slides fitted to the front and rear stands (C2S) and the RowPerfect (RP) with a free-floating stretcher mechanism (Care RowPerfect BV, 7772 JV Hardenberg, The Netherlands). Each trial lasted 60 seconds and the rowing intensity was fixed at 20 strokes per minute and controlled in real-time by the rowers using a visual display (Speed Coach®, Nielsen-Kellerman, Marcus Hook, PA USA). The C2F, C2S and RP ergometer conditions were presented on the same day for each participant. The order of presentation was balanced to reduce carry over effects.

Three-dimensional kinematics were recorded using a 9-camera motion analysis system (Motion Analysis Corporation, USA). Seven retroreflective markers were placed on the ergometer frame, footrest and handle. The marker placed on the handle was used to detect the catch and finish instants of the drive phase. The markers placed on the ergometer frame and footrest were used to define a frame embedded to the ergometer.

A static trial was recorded with six markers on pelvic landmarks: right and left iliac crests, anterosuperior iliac spines and posterosuperior iliac spines. The local coordinates of each marker was expressed in a local frame attached to the pelvis and defined following the recommendations of the International Society of Biomechanics (Wu et al., 2005). The two markers on the antero-superior iliac spines were removed for the rowing trials because of their inappropriate location regarding the rowing movement: important gaps in trajectories and mislocation due to large skin movement when the trunk is bending forward. A six degree-of-freedom optimisation procedure was implemented to find the position and rotation of the pelvis at each instant (Fohanno et al., 2013). The chosen Cardan sequence started with the angle of interest, i.e. pelvic axial rotation or twist. The lower-back flexion was calculated using three points: midpoint between both posterosupeior iliac spines, 3rd lumbar spinous process and 10th thoracic spinous process. These three points were expressed in a frame attached to the pelvis and the lower-back flexion angle was extracted using their coordinates in the sagittal plane of the pelvis frame.

Ten consecutive drive phases were selected in the middle of each trial for analysis. The average value of the pelvic twist over the entire drive phase and between the catch and the maximal handle force instant was computed. Additionally, the value at the maximal handle force instant and the range of pelvic twist were calculated. The force at the handle was measured using an one-dimensional force transducer (Model TLL-500, Transducer Techniques Inc., CA, USA, linearity 0.24 %, hysteresis 0.08 %) attached between the handle and the chain. The minimal (backward bending), maximal (forward bending) and range of lower-back flexion were also examined during the drive phase. The effect of the ergometer design was investigated using a one-way ANOVA for each parameter. A Fisher-LSD test was followed when appropriate.

RESULTS: Table 1 shows that pelvic twist-related parameters were low for all ergometers conditions. Indeed, the largest average value, reported for the ranges of motion, was 3.5°. No statistical difference was observed for the absolute mean, the absolute mean from catch to maximal handle force and the absolute value at the maximal handle force ($p = 0.61$, $p = 0.76$ and $p = 0.40$ respectively). However, the range of pelvic twist was reported to be significantly higher for C2F condition ($p = 0.02$).

Table 1
Parameters related to pelvic twist during each ergometer condition

Pelvic twist (°)	C2F	C2S	RP
Absolute mean	2.2 ± 1.2	2.1 ± 1.2	2.0 ± 0.9
Absolue mean from catch to maximal handle force	2.4 ± 1.4	2.1 ± 1.3	2.2 ± 1.1
Absolute value at maximal handle force	2.5 ± 1.6	2.3 ± 1.2	2.2 ± 1.5
Range of motion	3.5 ± 1.7	2.8 ± 1.3*	2.5 ± 0.8*

* denotes a significant difference with the C2F condition

On one hand, the results related to the investigation of the lower-back flexion showed lower maximal flexion of the lower-back, i.e. forward bending, for the C2F in comparison with both mobile ergometers ($p = 0.01$) (Table 2). On the other hand, the minimal flexion of the lower-back, i.e. backward bending, was reported to be more important for the C2F condition in comparison with the RP condition ($p = 0.02$). Finally, the results highlighted no significant difference between ergometers for the lower-back range of flexion ($p = 0.11$).

Table 2
Parameters related to lower-back flexion during each ergometer condition

Lower-back flexion (°)	C2F	C2S	RP
Maximal	15.3 ± 4.0	16.2 ± 4.0*	16.5 ± 3.9*
Minimal	0.9 ± 4.2	1.7 ± 3.4	3.2 ± 3.4**
Range of motion	14.3 ± 2.8	14.5 ± 2.2	13.3 ± 2.2

* denotes a significant difference with the C2F condition

denotes a significant difference with the C2S condition

DISCUSSION: The objective of this study was to assess the influence of the ergometer design on parameters related to the pelvic twist and lower-back flexion. Results showed that the obtained values were generally low for the pelvic twist. On one hand, these findings contradict the results of Buckeridge et al. (2012) where absolute pelvic twist was on average 14.5° for the elite group when rowing on a stationary ergometer. On the other hand, Buckeridge et al. (2014) re-examined the pelvic twist in similar conditions and reported a mean absolute pelvic twist of 2.5°, which is similar to level reported in the present study. This difference could be accounted from the method used to define the pelvic twist. The method used by Buckeridge et al. (2012, 2014) and validated by Bull and McGregor (2000) calculated the angle between a first vector formed by the anterosuperior iliac spines and posterosuperior iliac spines and a second vector formed by the two fifth metatarsal landmarks. Therefore, the orientation of the feet vector influences the calculation of the pelvic twist while, in the present study, the calculation was made using only markers placed on the pelvis (Wu et al., 2005).

From a biomechanical and an epidemiologic point of view, the pelvic twist and the lower-back flexion have a clear influence on the lower-back injury risk (Marras, 2000; Reid and McNair, 2000, Smith et al., 2015). This point is particularly true when external forces acting on the body reach high levels such as at the catch and maximal handle force instants in rowing. Although the range of pelvic twist was significantly higher on the stationary ergometer, the low values reported in this study indicated that elite rowers were able to maintain their pelvis position in a relatively fixed position around 0° (i.e. medio-lateral axis of the pelvis perpendicular to the longitudinal axis of the ergometer) during the drive phase although they had to overcome more inertial force on the stationary ergometer. In other words, the use of a stationary or mobile ergometers did not impair the pelvic twist of elite rowers which is known to be related to lower-back injuries. Concerning the lower-back flexion, results showed that the ergometer design had a significant impact on both maximal and minimal lower-back flexion. Rowers bended their lower-back more forward and less backward when rowing on a mobile ergometer. This feature explains the similar range of lower-back flexion. Although no statistical difference was reported, it is important to note that the results tends to show that rowers the range of motion was lower on the RP ergometer.

Hence, it is hard to say if one ergometer design should be favoured over another one to prevent lower-back injury from the results of the present study. Although rowers train mostly at low pace, the investigation of the same parameters at higher stroke rates would be interesting to see if the difference in the range of pelvic twist and lower-back flexion would be more important with the pace increase. Additionally, spinal motion and trunk muscles activity have been widely investigated in elite rowers to better understand the mechanisms related to lower-back injuries (Bull and McGregor, 2000; Mc Gregor et al., 2005). Hence, it would be

interesting for further studies to focus on the whole trunk motion and muscle activity to better understand the influence of the ergometer design regarding the rower's injury risk.

CONCLUSION: Kinematic parameters related to the pelvic twist and the lower-back flexion were investigated in elite rowers when rowing on stationary and mobile ergometers at a low pace. The results showed that the pelvic twist was generally low for the all ergometer conditions. Moreover, the difference in lower-back flexion between ergometer conditions were small suggesting that further studies should be realised at higher stroke rates and focused on the whole trunk motion and muscle activity are necessary to provide useful information to coaches and rowers regarding the risk of lower-back injury.

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