

# QUANTITATIVE ANALYSIS OF HEAD AND TRUNK POSTURE IN ROWERS DURING ERGOMETRY TRAINING

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## ABSTRACT

Rowers may develop adverse postural mechanics in an attempt to increase ergometry stroke output. To evaluate dynamic posture of the head and trunk, kinematic data were recorded from 2 elite (S1, male; S3, female) and 2 novice (S2, male; S4, female) rowers while they performed a 2500 m race on a Concept II ergometer. Ten consecutive strokes executed at the end of the race, at every 500m interval, and during the last 200 m, were analysed. The outcome variables were head and trunk posture related to the vertical line, relative head-trunk angle and maximal angular velocity (MAV) of the head's flexion/extension during the rowing cycle. All athletes revealed distinct dynamic postural patterns of the body segments. S1 exhibited a smooth and synchronized motion of the head and trunk. S3 demonstrated outstanding overall postural control. S2 and S4 showed excessive head movements and premature head and trunk reversals. S4 exhibited the highest MAV at the end of the drive phase. Repetitive head movements with high MAV and poor upper body postural control may result in microtrauma at cervical joints and vestibule-cochlear perturbations. Coaches may benefit from an in-depth understanding of these postural mechanisms to optimise the performance of their athletes.

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## INTRODUCTION

It has long been recognized that postural control is inextricably linked to movement. Skilled movement requires a high level of postural control. The maintenance of inappropriate posture during athletic training and competition, for example, may compromise effective technique in all sport disciplines.

Biomechanical measures of movement are being used increasingly to understand injury mechanisms and enhance performance (McGREGOR et al 2005). Athletes with poor postural mechanisms may suffer injury, particularly in rowing, which involves repetitive cyclic movements and high levels of force generation. Rowing injuries are attributed to poor rowing technique (McGREGOR et al 2005). Low back pain is a common problem in rowers (O'SULLIVAN et al, 2003; CALDWELL et al, 2003, McGREGOR et al, 2004).

Regardless of the level of experience and skill, rowers may adopt adverse postural mechanisms during ergometry training in an attempt to maximize stroke output. These mechanisms can compromise the effectiveness and safety of their technique. Physiological and biomechanical parameters of rowing ergometric have been extensively studied (MARTIN and BERNFIELD, 1980; NELSON and WIDULE, 1983; HAGERMAN, 1984; ZDANOWICZ et al., 1992; AFFELD et al., 1993; SECHER, 1993; STEINACHER, 1993; MULLER et al., 1994; HENRY et al., 1995; SMITH and SPINKS, 1995).

Many studies showed attention with postural mechanism in rowers. It happens because of two reasons: to reduce damages and improve efficiency. Muller et al. (1994) studied the function of the trunk musculature in elite rowers and concluded that the better the rowing performance was, the lower was the extension/flexion ratio, the coordination and the decrease in velocity during endurance testing. McGregor et al. (2002) studied trunk muscles and found that low back pain in rowers does not arise as a result of muscle weakness.

Appropriate stabilization of the spine and optimal segmental alignment are essential to support force generation and minimize

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the risk of injury during rowing (MAHLER et al., 1984). It is well established by physiology and anatomy that the axial segment of the body plays a crucial role in postural control. Although some studies have provided new insights into understanding the importance of trunk is largely supported by principles of embryology and anatomy (TANAKA and FARAH, 1997) and is widely applied in several proprioceptive neuromuscular facilitation patterns of movements (VOSS et al., 1968). Clinically, posture of the head, neck and shoulder has been analysed as a factor contributing to the onset and perpetuation of cervical pain dysfunction and syndromes (BRAUN and AMUNDSON, 1989; HAUNTEN et al., 1991).

For optimal physical conditioning of rowers, coaches and trainers should be aware that quantitative postural analysis can prove a valuable tool for the evaluation of motor skills in athletes. An in-depth understanding of dynamic postural mechanisms in all training modalities can highlight relevant aspects, thereby allowing performance optimisation of the athletes.

This study aimed to evaluate the dynamic posture of the head and trunk in rowers during ergometry training.

## METHODS

### Sample

It were selected four subjects. Two subjects were elite (S1, male; S3, female) and two novice (S2, male; S4, female) rowers. Subjects are described in Table 1.

Table 1 – Subject's characteristics.

Subject	Gender	Age	Experience (months)	Skill Category
S1	M	25	96	Olympic medal
S2	M	23	12	Novice
S3	F	25	24	Olympic finalist
S4	F	24	2	Novice

### Materials and Procedures

Rowers were evaluated during a single 2500 m race utilizing an instrumented Concept II model-C rowing ergometer. Kinematic

data acquisition and analysis in the sagittal plane involved a 2-D Motion Analysis System (Peak Performance), a CCD camera (Panasonic WV-BL600, 60Hz shutter speed) and reflective markers placed on the left side of the front of the head, occipital protuberance, shoulder and hip joint landmarks, as well as on the handle of the ergometer.

It was assumed that the position of the body segments in rowing in this study is 2-dimensional. It was analysed the trunk posture (TR) related to the vertical line, head posture (HE) related to the vertical line, relative angle between head and trunk (HE-TR) and maximal angular velocity (MAV) of the flexion/extension movement of the head, as shown in Figure 1.

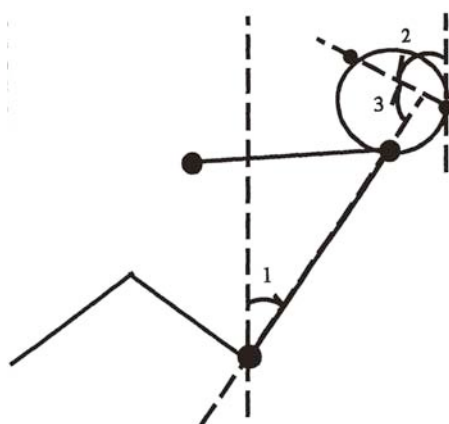


Figura 1 - Head and trunk angles. 1. Trunk angle related to the vertical line (TR); 2. Head angle related to the vertical line (HE); 3. Head angle related to the trunk (HE-TR). The arrows represent the positive direction of the movement.

The applied force was measured using a 1kN miniature load cell (ALD-MINI-UTC-M, InterTechnology), placed at the junction between the chain and the handle of the ergometer, which also provided the necessary data to derive the generated impulse (i.e., area under the force-time curve). A portable computer (486/33 MHz), a 12-bit 16-channel analogue-to-digital convertor (AT-M10-16F-5, National Instruments), and a virtual instrument generated with the LabView software (National Instruments) were used for kinetic data collection.

The horizontal handle displacement obtained from the reflexive marker on the handle of the ergometer was adopted as a reference for the length of stroke. Performance data regarding the time, stroke output, and stroke rate during the race were obtained from the Concept II Personal Computer Interface monitor. Feedback from the

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performance monitor of the ergometer was the only on-line information provided to the subjects.

For each athlete, data were collected at 6 pre-established intervals: the start of the race (interval 1), every 50 m (intervals 2 and 5) and during the last 200 m (interval 6) of the race. A self-selected stroke rate was allowed for intervals 1 and 6, and a target stroke rate of 24, 27, 30 and 34 strokes min<sup>-1</sup> were required for intervals 2 and 5 respectively. The stroke rate was maintained as constant as possible for 20 cycles in order to reach a steady-state within the interval according to the pre-established distances.

Data were corrected for the inherent noise by digital filtering to smooth the displacement data (moving average, 3 symmetrical neighbours technique). The stroke cycle with the impulse closest to the mean impulse within each interval was selected as the most representative stroke cycle of the interval. Analysis of the intervals 3 and 6 are presented in this paper. Interval 3 (27 strokes-1) was selected as it most closely represented a competitive stroke rate. A stroke rate of 27 using the Concept II ergometer is approximately equivalent to a stroke rate of 32 on-water. Interval 6 (self-selected stroke rate) and during normal on-water competition.

### Data Analysis

Results of novice and elite rowers were compared and the results were analysed through percentages.

## RESULTS

Each athlete exhibited a particular dynamic posture of the head and trunk during the stroke cycle. Figures 2 and 3 show the head and trunk posture as a function of the stroke cycle for subjects S1 and S4 respectively. The HE, TR and HE-TR angles along the stroke cycle are represented on the left Y axis; the negative values increasing as the trunk moves posteriorly. The handle displacement is represented on the right Y axis. Figure 2 reveals a smooth motion of the head and trunk (TR and HE-TR) and a slight variation of spatial head position (HE).

As shown in Figure 3, S4 demonstrated an inconsistent head and trunk posture during the stroke cycle. An abrupt decrease in the HE-TR angles at the end of the drive phase and an increment in the HE (i.e., head flexion) occurred simultaneously. Figure 3

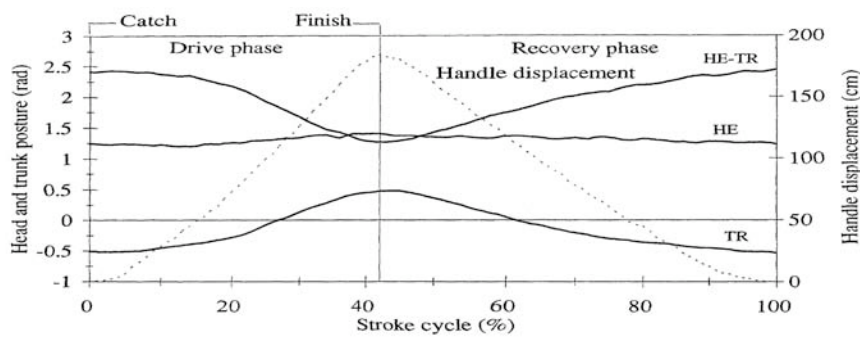


Figure 2 – Posture of head (HE) and trunk (TR) related to the vertical line, and the relative angle between the head and trunk (HE-TR), as a function of the stroke cycle of S1 (elite rower) for interval 3. The right Y-axis represents the horizontal handle displacement (dashed line).

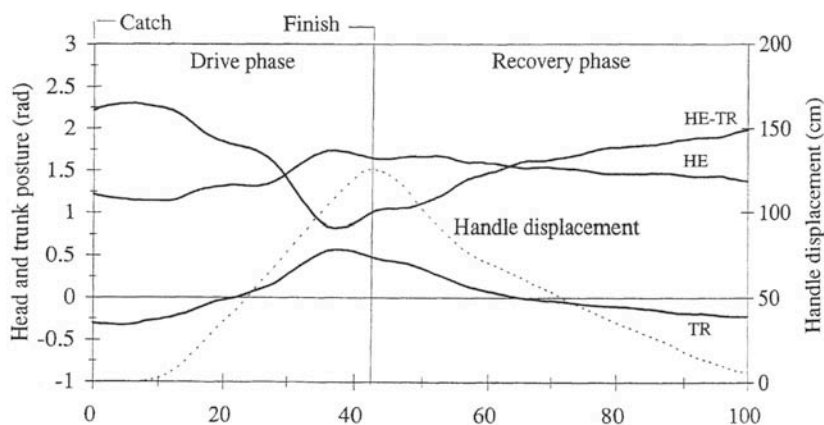


Figure 3 – Posture of head (HE) and trunk (TR) related to vertical line and the relative angle between head and trunk (HE-TR), as a function of the stroke cycle of S4 (novice rower) for interval 3. The right Y-axis represents the horizontal handle displacement (dashed line).

also shows that the head and trunk begin the opposite movement

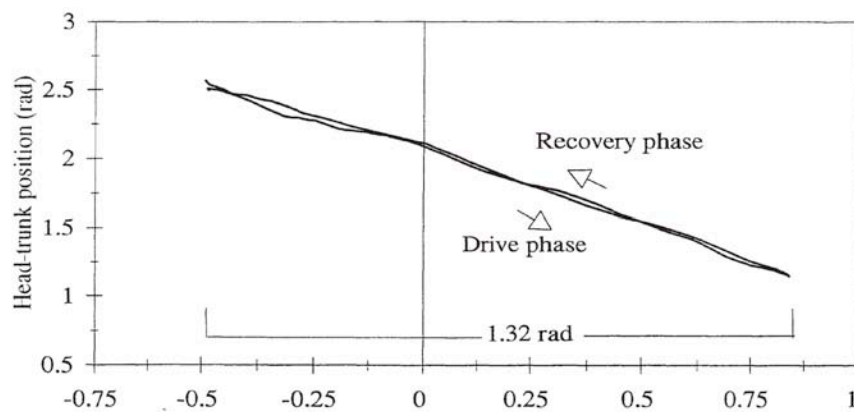


Figure 4 – Head-trunk position as a function of trunk posture along the stroke cycle of S3 (elite rower) for interval 3.

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before completion of the posterior displacement of the handle, indicating a premature head and trunk movement reversal and shortening of the stroke cycle (i.e., stroke length).

Figure 4 corroborates that HE-TR and TR are strongly dependent on each other for S3, while Figure 5 indicates that S4 achieved the highest hysteresis loop between HE-TR and TR.

Figures 4 and 5 show that S4 also exhibited a lower range of motion of the TR (0.90 versus 1.32 rad), while HE-TR remained

Table 2 – Range of motion of head and trunk related to the vertical line, head related to the trunk and maximal angular velocity of the head's flexion along the stroke cycle for all subjects at interval 3 and 6.

Subject	Interval (Stroke)	Range of motion (rad)				MAV (rad s <sup>-1</sup> ) *
		HE	TR	HE-TR	HE-TR	
S1	3 (8)	0.2	1.01	0.11	2.20	
	6 (6)	0.24	1.05	1.27	2.32	
S2	3 (2)	0.43	1.26	1.48	3.93	
	6 (3)	0.45	1.22	1.44	4.66	
S3	3 (1)	0.12	1.33	1.44	2.76	
	6 (5)	0.29	1.34	1.44	2.69	
S4	3 (7)	0.59	0.91	1.48	4.07	
	6 (3)	0.59	0.93	1.39	4.82	

The data presented refers to the stroke (number in brackets) with impulse closest to the mean impulse within the corresponding interval.

HE –head; TR – trunk; HE-TR – head related to trunk; MAV – maximal angular velocity. \* MAV –  $\dot{\Delta}_{max} - \dot{\Delta}_{min}/dt$ ,  $\dot{\Delta}_{max}$  refers to the maximum angle,  $\dot{\Delta}_{min}$  to the minimum angle, and dt to the interval of time.

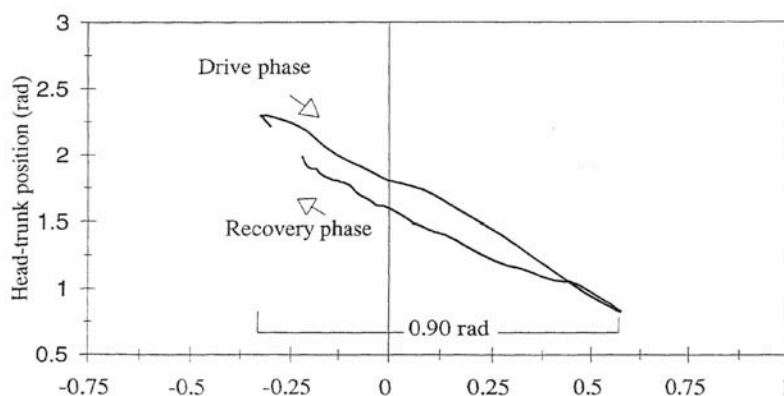


Figure 5 – Head-trunk position as a function of trunk posture along the stroke cycle of S4 (novice rower) for interval 3.

constant. Table 2 presents the range of motion of the head and trunk and the MAV of the flexion movement of the head of all subjects.

All athletes displayed a distinct range of motion of HE, TR and HE-TR during the stroke cycle. Low variation of range of motion was observed between intervals 3 and 6 for each subject, except the HE of S3. Although S3 demonstrated a significant increment in the range of motion of the head (0.17 rad), both range of motion values were lower than those achieved by S2 and S4. In interval 3, S3 demonstrated outstanding postural control of the head and trunk. All subjects achieved MAV of the head at the end of the drive phase. Both novice athletes reached a critical MAV of 4.658 and 4.815 rad s<sup>-1</sup>, for S2 and S4, respectively. Both subjects showed a large increase in MAV between intervals 3 and 6.

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## DISCUSSION

A good posture is indispensable to good athletic performance. Inadequate posture and movements, with more or less movement or force than the necessary, can lead to injuries and athletic handicapped. Bull and McGregor (2000) observed that biomechanical and especially kinesiological investigations into the mechanical efficiency of rowers are rare and there is a limited understanding of the movement of the trunk and body segments during rowing.

Some authors studied kinematic parameters aiming to improve the rower performance. McGregor (2000) related the spinal motion with rowing technique, making possible to discriminate good and bad rowers. Caldweel et al. (2003) studied the changes in lumbar flexion due to level of erector spinae muscle activity during rowing. Authors studied 16 young adult school rowers and detected that rowers attain relatively higher levels of lumbar flexion during the rowing stroke, and these levels are increased during the course of the rowing trial. They also found evidence of muscle fatigue in erector spinae muscles, which may be responsible for the increased levels of lumbar flexion observed. McGregor et al (2004) measure spinal and pelvic motion and force generated at the handle during rowing ergometer exercises in 10 male collegiate rowers. Results showed that rowing kinematics and force profiles change at higher rowing intensities.

The rower kinematic parameters are also studied to understand



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and prevent injuries. Bull and O'Sullivan et al (2003) used complex statistical techniques to prove that rowing technique is associated with low back pain. Holt et al. (2003) developed a system to measure spinal and pelvic motion and force generated at the handle during rowing on an exercise rowing ergometer. Testing it in 13 oarsmen, authors detected an increase in the amount of spinal motion, which can be related to back pain. McGregor et al (2005) quantified the spinal kinematics of elite rowers at different incremental work intensities and also noted changes in lumbopelvic and spinal kinematics at increasing work levels. Authors concluded that this changes could be related to the development of low-back pain.

In this study, S1 (i.e., the Olympic medal rower) demonstrated a synchronized and smooth motion of the head and trunk. The movement of the head was led by the trunk, producing slight oscillation in the HE curve. These organized movements between segments provide the subject with proper muscular support of the axial axis for the appendicular movements. As the head in the segment located at the cranial edge of an open-type muscular chain (TANAKA and FARAH, 1997), this muscular support aims to control the angular velocity of the head during the stroke cycle. In S4, these characteristics were not observed. The range of motion of the head for S4 denoted that this segment was moving in its own pattern rather than being led by the trunk. This poor control of posture may be caused not only excessive head movements (0,59 rad) but also MAV (4.815 rad s<sup>-1</sup>) and an inconsistent posture of the trunk and head during the stroke cycle (FIGURE 3).

The inadequate dorsal muscular support, that could be either the cause or consequence of poor postural control, may also compromise the stability of the scapular girdle that is necessary for movement of the upper limbs. This stabilization is crucial to the safety of the technique, considering that the force applied to the handle may reach up to 100 percent of the subject's total body weight and that the upper trunk is the most involved segment during ergometry training. All athletes exhibited better postural control in interval 3 than in interval 6, possibly due to the effects of fatigue. S3 exhibited outstanding motor skills in terms of postural control. Although a higher range of motion of the trunk (1.34 rad) was necessary to reach an appropriate stroke length, S3 (i.e., Olympic finalist rower) maintained postural control of the head.

But the quantitative analysis of head and trunk posture goes beyond explaining how posture control can influence the athletic

performance. For example, rowers can experience microtrauma at cervical spine joints due to repetitive pathokinesiobiological effects at high angular velocity of the head. This may also lead to perturbations at the vestibule-cochlear system. Functional blood supply alteration at the supra-segmental levels may occur due to anatomical spatial correlation between the cervical skeleton and vertebral-basilar arterial system (TANAKA et al., 1991).

As the ergometry technique simulates on-water rowing (LAMB, 1989), further biomechanical studies are necessary to provide coaches and athletes with valuable feedback to promote an effective and safe training program. Coaches and trainers may also benefit from an in-depth understanding of these findings, thereby allowing them to optimise physical conditioning of the athletes.

Measures of spinal motion of rowers can discriminate good and bad rowing styles (BULL and McGregor, 2000). This study looked at the main movements of head and trunk in the sagittal plane during ergometry training. The authors, found, however, that protraction and retraction of the shoulder and head may be associated with the anterior and posterior position of the trunk at the catch and at the end of the drive phase. Additional research should aim to quantify these movements and evaluate their importance to the achievement of an effective and safe rowing technique while using different training modalities.

## CONCLUSIONS

Research can aid in the advancement of rowing skills through the evaluation of the biomechanical principles that govern rowing technique. Quantitative analysis of the head and trunk posture conducted in athletes during the 2500 m ergometry race revealed 3 main aspects. First, characteristic dynamic postural control mechanisms of the head and trunk by the elite subjects. Second, premature head and trunk reversals by novice rowers, and last, critically high levels of MAV (4.815 rad s<sup>-1</sup>) of the head at the end of the drive phase by the less experienced athletes. A better understanding of postural mechanisms involved in ergometry rowing could provide the basis for effective and safe indoor training regimes, and the optimisation of athletic performance.

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