Introduction

The final time of a rowing crew during competition is determined by the average velocity of the boat and the distance to be covered. The average velocity of the boat depends mainly on the force applied to the blade, which is resultant of internal forces (muscular) and external ones (gravitational, inertial, resistance).

No study appears to compare torques developed by the main muscle groups during rowing with corresponding torques measured in static conditions.

The purpose of the study was to determine the strength potential utilisation during rowing on Concept II model C ergometer depending on stroke rate and class of rower.

Methods

The first stage consisted of measuring torques of the main muscle groups (elbow, shoulder, knee, hip and torso extensors, and flexors) in statics in 4 finalists of world championships (group I) and in 4 rowers representing national level (group II). Then the force applied to the ergometer grip was measured and main joints displacements were recorded during 10 maximal strokes on the Concept II ergometer at stroke rates 32 s/min, 36 s/min and 40 s/min. Raw data were smoothed using fourth-order Butterworth filter. Mass and inertia characteristics of the rowers were estimated by using regression equations (Zatsiorsky & Seluyanov, 1983).

In the second stage a biomechanical model of rower (Fig 1.) was built using the DADS (CADS Inc., USA) software package. The three-dimensional model consisted of 18 segments linked by 18 hinge joints representing left side of the body and had 12 degree of freedom. Then the inverse dynamics problem was solved. It was assumed that muscle torques measured in statics represent 100 % of strength capabilities. They were compared with muscle torques developed during rowing at the same joint angles.

Figure 1: Model of rower during propulsion
Results

Results (Fig. 2 and Fig. 3) show that hip extensors had the highest level of strength potential utilisation in group I (about 124%) and group II (113-119%) at the studied stroke rates. The next muscle groups with regard to strength potential utilisation were:

1) in group I: shoulder extensors (96 % increased to 104 %) and knee extensors (78 % increased to 86 %),
2) in group II: knee extensors (72 %) and shoulder extensors (60 %).

Torso extensors had similar value for both groups of rowers (49 %). Other muscle groups had small magnitude of utilisation except the hip flexors 60 % (group I) and 58 % (group II) at 40 s/min.

Strength potential utilisation was not estimated for knee and torso (36 s/min) flexors, and elbow extensors, because their muscle torque signs during rowing (at selected joint angles) were opposite to torque signs generated by these muscle groups. In this way antagonistic muscles activation, which execute eccentric work during recovery was shown.

Characteristic was almost twice bigger strength potential utilisation of shoulder extensors for the group I than for the group II, which could indicate a connection of this phenomenon with class of rowers.

![Figure 2: Utilisation of strength potential in group I for studied stroke rates](image)

sr-stroke rate [s/min], EF-elbow flexors, EE-elbow extensors, SF-shoulder flexors, SE-shoulder extensors, KF-knee flexors, KE-knee extensors, HF-hip flexors, HE-hip extensors, TF-torso flexors, TE-torso extensors

![Figure 3: Utilisation of strength potential in group II for studied stroke rates](image)

sr-stroke rate [s/min], EF-elbow flexors, EE-elbow extensors, SF-shoulder flexors, SE-shoulder extensors, KF-knee flexors, KE-knee extensors, HF-hip flexors, HE-hip extensors, TF-torso flexors, TE-torso extensors
Discussion

Magnitudes of torques of the main muscle groups in statics are lower compared to the results of Janiak et al. (1993) but these authors agree on that the strongest groups are: hip, torso and knee extensors.

Main muscle groups should be divided into 2 types with regard to their function in the rowing cycle:
1) responsible for propulsion: extensors of knee, hip, torso and shoulder, and elbow flexors,
2) responsible for recovery: flexors of knee, hip, torso and shoulder, and elbow extensors.

Muscle groups of type I are stronger and their magnitude of strength potential utilisation at selected joint angles is bigger because during propulsion they cope with external resistance on the grip (near maximal value), which doesn't happen during recovery.

High values of the strength potential utilisation suggest a predominantly dynamical character of exercises in rowing training, because they strengthen the dynamic muscle force (18 %) not the static one (9%) (Schröder, 1973). It could be assumed that for the subjects rowing was an automatic activity and they recruited the optimal amount of motor units in muscles generating this motion. In consequence it could be accepted that the amount of recruited motor units in the studied movement phases was similar in dynamic and static condition.

So values above 100 % of strength potential utilisation may suggest a need to reconsider if torques in statics really could be assumed as 100 % of strength capabilities.

Results of the study indicate that strengthening hip extensors as the group with the highest level of strength potential utilisation can significantly improve final results of rowing.

References


Acknowledgements

This study was supported by the State Committee for Scientific Research. Grant no. 4P05D 04119.