ARTICULAR EFFORTS QUANTIFICATION AT L4/L5 LEVEL FOR THE ROWER

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INTRODUCTION

Most rowers, either amateur or professional, complain sometime or another of pain in the spinal column (lumbago, low back pain). Furthermore, clinical and radiological investigations made it clear that out of 45 top Australian oarsmen, 68% suffered from Scheurmann's disease and 48% had undergone a degeneration of the spinal column (Dal Monte, 1989). Studies have been undertaken to detect the causes of these algias. Coquisart (1994) showed that rowers cannot protect their spinal cords through the use the Vasalva maneuver during their movements. Pumeyrol (1989) illustrated the overuse of the L5/S1 lumbosacral joint at the time of forward bending of the trunk during the start of propulsion by a test Schober L5. Borg (1994) thought that the bad carrying of the boat or the correction of equilibrium in sweep rowing were responsible for these algias. Thus, the causes for these algias are still not fully understood. In a different field of research, that of manual lifting tasks, the movement being similar to the rower's, spinal pain is often considered as a biomechanical problem. Contrary to psychophysical and physiological evaluations, biomechanical evaluations are distinguished by the quantitative nature of their information (Marras, & Ranqarajulu, 1987). This approach is based on the supposition that the onset of lower back pain is related to imbalance in the mechanical components of the back (Ladin, 1990). The direction of this work corresponds to this perspective. The purpose of this paper is to present the first results of the computation of the articular efforts at L4/L5 level, the joint of the spine where damage is most often observed (Leamon, 1994), on a male rower competing at French regional level, at 6 stroke rates.

METHODS

Estimation of articular efforts at L4/L5 level was carried out via a three-dimensional inverse dynamics analysis. A model of the studied part of the body was defined (Figure 1) and an experimental device was constructed.

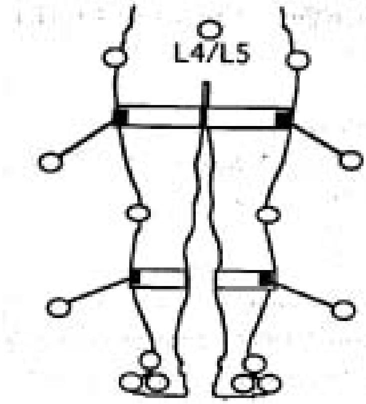


Figure 1. Position of rower's markers

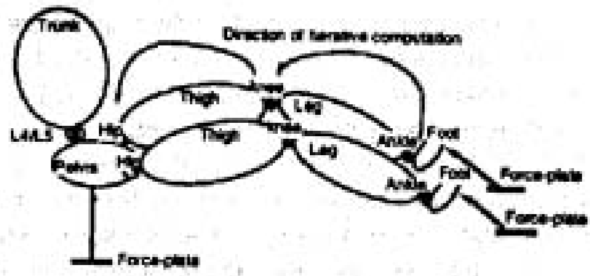


Figure 2. Iterative computation

Feet, legs, thighs and pelvis were considered as rigid bodies linked together by spherical articulations assumed to involve no friction. Feet, legs and thighs were compared to truncated cones (Hanavan, 1964) and the pelvis to a rotary ellipsoid. The anthropometric characteristics such as mass and the position of centres of gravity come from Dempster (1955). The experimental device was made up of a Model Concept II fully instrumented ergometer (Pudlo, 1996) and an opto-electronic system SAGA-3 (Cloup, 1989). The device allowed the measuring of effort (force and moment) at the contact points (hands, feet and bottom) of the rower-egometer system, and the measuring of the 3d-coordinates of the different markers (Pudlo, 1996).

A pre-treatment module allowed the computation of external efforts, the computation of application points in the global frame (Pudlo, 1996) and the correction of the position of the marker laid on the skin at L4/L5 joint level. The Euler parameters have been kept to define the orientation and the acceleration of the segments because they haven't any singularity.

The computation of the forces and the torques was based on the Newton-Euler principle. The quintic splines have been used to smooth the 3d coordinates coming from the optoelectronic system, to derive the position of the centers of gravity of body segments and to derive the Euler parameters. The computing code was iterative and was a new configuration of the Barbier code (1994). The computation of the forces and the torques at L4/L5 level was carried out in an iterative way, in computing successively articular efforts at ankle, knee and hip levels (Figure 2). The articular efforts were filtered with a fourth order Butterworth filter using cut off frequency equal to 6 Hz.

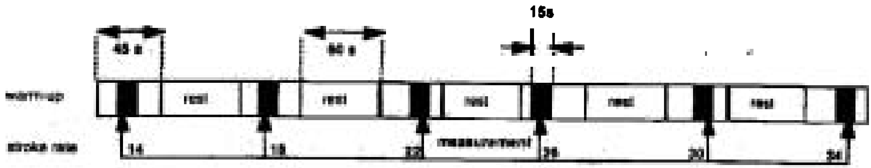


Figure 3. Description of the measurement recordings

A healthy rower volunteered for this study. He was 24 years old, 1.87 meters tall, weighed 85 kg, and was familiar with the experimental device. Figure 1 shows where the markers were placed on the rower. The experiment consisted of 6 measurements with respective order rates equal to 14, 18, 22, 26, 30 and 34. The measurement time was 15 s. Figure 3 describes this protocol in detail. Finally, the calibration of the cameras was carried through so that the Y-axis that belongs to the laboratory reference has the same direction as the movement of the rower (Figure 4). The error of parallelism was equal to 0.55 degrees.

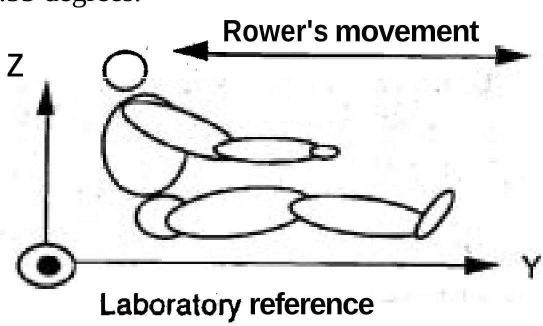
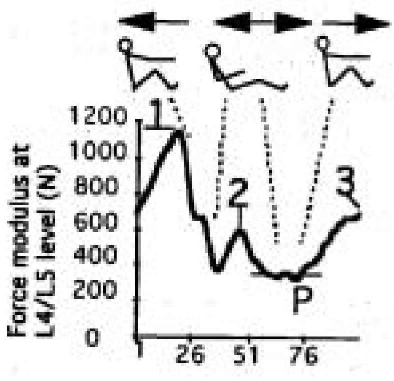


Figure 4. Laboratory reference and the rower's movement

RESULTS

The shapes of the curves of forces and torques for the 6 studied stroke rates were identical; therefore, only these of the average rate at L4/L5 level which correspond to the 34 order rate are illustrated. The average articular efforts (force and torque) have been computed for 8 cycles and extended to represent 100% of the cycle. The forces and torques modulus were computed and are presented in Figures 5 and 6. Table 1 presents the morphological characteristic values retained for the force (points 1, 2 and 3 in Figure 5) and torque (points 1, 2, 3 and 4 in Figure 6) for the 6 stroke rates.

Figure 5 shows that, for this rower: the maximum modulus of the articular force at L4/L5 level is reached when the lower limbs are pushed (Figure 5, reference point 1), decreases to a minimum when the trunk is vertical and increases again toward the end of propulsion (Figure 5, reference point 2), flattens out during the recovery phase with an amplitude equal to the mass of the body above the L4/L5 joint (Figure 5, reference point P), and increases when the back is bending (Figure 5, reference point 3). Figure 6 shows 3 peaks for the torque at L4/L5 level. The first corresponds to the resistance of the back at the extension of the lower limbs (Figure 6, reference point 1); the second to the action of the back and the upper limbs (Figure 6, reference point 2); and the third to the recovery of the back (Figure 6, reference point 3). Finally, Table 1 shows that the force and torque increase according to the stroke rate in the main.



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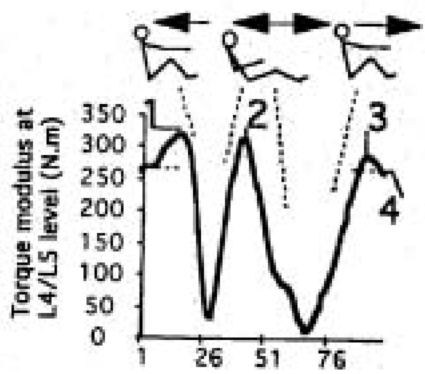

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Figure 5. Force modulus at L4/L5 level. **Figure 6.** Torque modulus at L4/L5 level.

Stroke rate	F(1) N	F(2) N	F(3) N	C(1) N.m	C(2) N.m	C(3) N.m	C(4) N.m
14.67	576.24	409.00	462.85	156.07	196.93	156.49	151.96
18.30	682.70	437.71	498.23	181.79	223.20	178.55	176.13
21.98	795.81	472.42	541.95	212.83	252.41	193.51	191.76
25.25	962.74	470.70	610.89	264.67	279.85	230.15	223.85
29.46	1052.30	529.56	665.44	292.53	294.57	266.58	228.55
32.67	1136.75	584.51	685.57	316.40	311.32	285.19	259.63

Table 1. Characteristic values of forces and torques modulus at L4/L5 level.

Figure 7 presents the articular torques at L4/L5 in laboratory reference (pelvis action on the body part above L4/L5 joint). The Cy and Cz torques represent an average 6% of the Cx torque. Their maximum value is reached at the extension of the lower limbs and is respectively 25 N.m and 65 N.m. The asymetric action of the lower limbs and upper limbs leads to a low rotation of the trunk which explains these positive values.

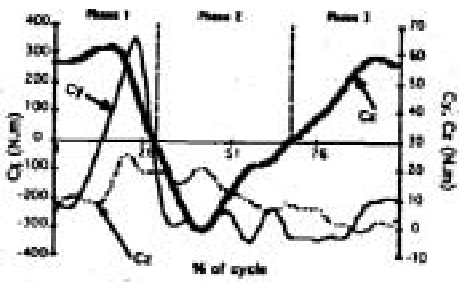

Figure 7. Cx, Cy, and Cz at L4/L5 level.

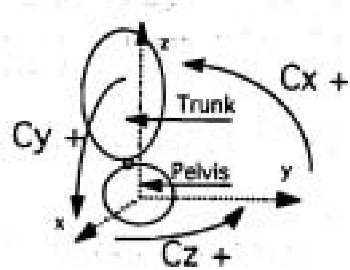

Figure 8. Positive direction of Cx, Cy and Cz.

Furthermore, the Cx torque analysis shows 3 phases with an approximate amplitude equal to 300 Nm In the first phase, Cx is positive at the start of propulsion as long as the trunk does not become vertical again. Therefore, the posterior muscular action seems preponderate. The action of the trunk is motor. In phase 2, Cx becomes negative as long as the trunk does not become vertical during the return movement. So, the anterior muscular action seems preponderate. The back continues to bend until the end of the propulsion. The action of the back is resistant. Next, the back starts its recovery. There is an inversion of motor action. In phase 3, Cx is positive until the end of the recovery. So, the posterior muscular action seems preponderate. There is an inversion of resistant action of the back. Figure 9 presents the articular forces at L4/L5 level in the laboratory reference (pelvis action on the body part above L4/L5 joint). The Fx force is almost equal to zero during the entire cycle. The maximum of Fy force is 1010 N. It is reached at the vertical position of the trunk. In spite of a high rate of 32.67, this force peak remains far from the maximum limit of 3400 N in the 1981 Manual Material Handling Guide. Finally, the Fz force is approximately equal to the body weight above L4/L5 joint (464 N) and the minimum is equal to 256 N when the trunk reaches the vertical axis during the recovery phase.

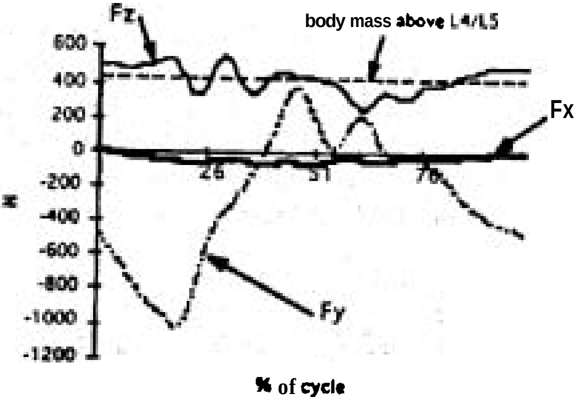

Figure 9. Fx, Fy, and Fz at L4/L5 level

CONCLUSIONS

This paper has presented the methodology used to compute the articular efforts at L4/L5 level. The adopted model has been presented, the experimental device has been constructed, and an iterative implementation of inverse dynamics has allowed the computation of articular efforts at L4/L5 level. Some experiments have been carried out. They have allowed the quantification of the articular efforts in the laboratory reference as well as their modulus for 6 stroke rates.

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