INTRODUCTION

Rowing is a technically and physically demanding activity that requires a coordinated and powerful sequence of actions utilizing most of the muscle groups in the body. Rowing simulators can be found in most gyms, but many people who use them have little or no instruction in technique. Non-experts are often not aware of faulty technique, which can lead consequently into injuries. A novel approach for training incorporates real-time feedback providing quantitative information about rowing mechanics, kinematics and kinetic parameters [1]. The purpose of the study was to develop and evaluate a system that measures all kinematic and kinetic parameters, calculates internal forces and joint moments, and provides real-time feedback about these parameters.

METHODS

Developed measurement setup consists of two computers for data acquisition, an optical system Optotrak Certus with two sets of line infrared cameras and 14 active markers, a video camera and an instrumented rowing simulator Concept2: a load cell (A) mounted between the chain and the handle, a six-axis sensor JR3 (B) mounted under the foot stretcher, an incremental encoder (C) mounted on the axle of a flywheel, a wire incremental encoder (D) mounted on the reverse side of the simulator seat track and beneath the seat (Fig.1).

From the measured data parameters of stroke were determined: the maximum pull force $f_{p,\text{max}}$ (max absolute value of the handle pull force), the max feet reaction force $f_{r,\text{max}}$ (max absolute value of the measured force vector on the foot stretcher), the force ratio $r_f$ (ratio between $f_{p,\text{max}}$ and $f_{r,\text{max}}$), the time delay $\Delta t$ (difference between the time instant when $f_{p,\text{max}}$ and $f_{r,\text{max}}$ occur), the stroke length $l$ (difference between the max and min length of the chain pull) and the ratio of the stroke phases $r_s$ (ratio between the duration of the drive and the recovery phase of the stroke). Joint loads for ankle, knee, hip, LS and shoulder joints were calculated according to the Newton-Euler inverse dynamics approach which is based on the recursive calculation procedure [2]. The rowing maneuver was considered as a planar problem with the assumption of body symmetry regarding the sagittal plane.

For the evaluation of the proposed methodology, ten volunteers (male, Caucasian) participated in the study: five top-level rowers (members of the National Team) and five non-experts (newly introduced to a rowing simulator). The test lasted for two minutes and consisted of three types of activity (the first minute of aerobic type activity at a rate of 20 str/min, followed by 30 seconds of aerobic threshold activity at 26 str/min and 30 seconds of anaerobic activity at 34 str/min). Each participant produced a rowing speed according to his abilities. Before performing the test, the participants warmed up properly.

RESULTS AND DISCUSSION

The results are presented in Table 1. The stroke length $l$ was kept constant by the experts in each stroke rate, while non-experts had shorter $l$ and
increased it with increasing stroke rate. The experts demonstrated a fast drive and a slow recovery, the ratio $r_s$ lowers with increasing stroke rate. The non-experts achieved a lower ratio of around 1:1, which did not change significantly with increasing stroke rate. The results show that $f_{p,\text{max}}$ and $f_{r,\text{max}}$ of the experts did not change significantly with increasing stroke rate. The forces of the non-experts were significantly lower (the most obvious difference occurred at a rate of 20 str/min, an increase in peak forces was noticed with increasing stroke rate).

Figure 2 presents the calculated joint torques for one non-expert subject (left) and one expert subject (right). The repeatable joint loads pattern for the expert at all stroke rates, and the variable pattern of joint loads for the non-expert, demonstrating the lack of technique, can be seen. Large loadings on the LS joint confirm frequent lower back pain and injuries.

CONCLUSIONS

A measurement environment for detailed on-line biomechanical analysis of rowing was developed. Data processing algorithms provide output data online in real time and allow instantaneous stroke analysis, enabling the coach and the athlete to obtain immediate feedback to their experimentation with rowing technique. The results of the evaluation experiment show noticeable distinctions of the measured parameters between the expert and non-expert rowers. It was demonstrated that the experts use a similar and consistent technique at all stroke rates, while the technique of non-experts varies.

REFERENCES


Table 1: Results of averaged rowing biomechanical parameters of the evaluation experiment.

<table>
<thead>
<tr>
<th>Stroke rate</th>
<th>20</th>
<th>26</th>
<th>34</th>
<th>20</th>
<th>26</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l$ (m)</td>
<td>1.59±0.05</td>
<td>1.61±0.07</td>
<td>1.57±0.07</td>
<td>0.98±0.16</td>
<td>1.09±0.12</td>
<td>1.16±0.19</td>
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<tr>
<td>$r_s$</td>
<td>1:2.04±0.15</td>
<td>1:1.66±0.06</td>
<td>1:1.31±0.09</td>
<td>1:1.01±0.18</td>
<td>1:1.00±0.12</td>
<td>1:1.04±0.06</td>
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<tr>
<td>$f_{p,\text{max}}$ (N)</td>
<td>1,022±74</td>
<td>1,088±67</td>
<td>1,162±93</td>
<td>145±159</td>
<td>238±160</td>
<td>448±190</td>
</tr>
<tr>
<td>$f_{r,\text{max}}$ (N)</td>
<td>1,232±105</td>
<td>1,250±84</td>
<td>1,294±92</td>
<td>440±97</td>
<td>612±97</td>
<td>816±89</td>
</tr>
<tr>
<td>$r_f$</td>
<td>0.83±0.08</td>
<td>0.87±0.08</td>
<td>0.89±0.05</td>
<td>0.29±0.26</td>
<td>0.37±0.19</td>
<td>0.53±0.17</td>
</tr>
<tr>
<td>$\Delta t$</td>
<td>0.08±0.03</td>
<td>0.08±0.04</td>
<td>0.08±0.06</td>
<td>0.70±0.38</td>
<td>0.47±0.25</td>
<td>0.34±0.14</td>
</tr>
</tbody>
</table>

Chapter 2: Calculated torques in body joints presented for different stroke rates. The beginning of the drive was assigned as value of -100 at the abscissa, the end of the pull and the start of the recovery as value 0 and the end of the recovery as a value of 100.

ACKNOWLEDGEMENTS

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