Comparison of accuracy of steering by the upper and lower extremity

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1. Introduction

At many workplaces are activities related to the steering of the work place elements. Steering by upper extremity with a lever is used in most of the work processes. The lower extremities can also perform the work process steering purposes. It refers to such workstations on which steering is carried out with different types of pedals, relate mainly the jobs of drivers of cars, busses, tracks, trains. There are also quite unusual jobs, on which the working pedals can be used as a steering device for example, working pedals job of the surgeon [1]. Due to the fact that mainly upper extremities perform steering task there is a belief that the steering by the upper extremity (lever) is more precise than steering by the lower extremity (pedal). However the literature indicates that the foot has also the sensory function [2]. Research indicating upper extremities as more precise in steering tasks were done in conditions where both forces for upper and lower extremities were the same [3]. Taking into account that there is a difference in muscle force capabilities of upper and lower extremity the aim of the study was testing the accuracy of steering in various force on the lever and pedal. The steering can be done through displacement or through the force pressing the lever or pedal (without movement). Research suggests that steering by force may be as accurate as using the displacement of the lever or pedal [4, 5]. The tests were made using the force during the measurement of accuracy of steering. Due to the lack of movement of such measurements are not affected by the error resulting from the difference between static and dynamic friction of lever or pedal.

2. Methods

The study involved 10 healthy men aged 20 to 24 years. Before testing, each person has been examined by a doctor in order to assess the state of health and good enough conditions to participate in experiment. Subjects were informed about the possibility of interruption of the test at any time during the experiment. Characteristics of the study group are shown in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>22.2</td>
<td>1.1</td>
<td>20.2</td>
<td>23.8</td>
</tr>
<tr>
<td>Body height [cm]</td>
<td>181.1</td>
<td>2.6</td>
<td>176</td>
<td>184</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>76.4</td>
<td>6.1</td>
<td>70</td>
<td>86</td>
</tr>
</tbody>
</table>

To test the accuracy of steering there were used the equipment which allows testing accuracy of steering by the upper extremity by a lever and lower extremity by a pedal. Accuracy of steering was measured by the integral criterion, based on the shape characteristics measured during the measurement of force on the lever or pedal compared to the set point value [6]. Asked the force was set at the beginning of research and they are the same for all variants of tests for all subjects. Based on the difference between the set point and measured value of force at the time of error of regulation is calculated. On the basis of error of regulation there is a calculation of accuracy of steering regarding the best accuracy of the whole experiment.

Due to the method of calculating the accuracy of steering it has values in the range between 0 and 1 (0 ≤ Q ≤ 1). In the case of determining the accuracy of steering it is possible to compare the results of tests for upper and lower extremities and for different ranges of force, as well as optimal force for steering by the upper and lower extremity. In the study the error of regulation was calculated on the basis of registration of force on the lever or pedal, as the subject’s response to certain value - the line identifying the position indicator on the screen. Force value corresponded with the move the pointer on the screen and the difference between line and the pointer were measured.
3. Results

The results show differences between accuracy of steering by the upper and lower extremity. However, the accuracy of the best steering is at a similar level for both extremities. The scope of the best accuracy by the upper extremity is less dependent on the force during the measurement. In the case of upper extremity accuracy of steering is above the value of 0.6 for all measurements except the measuring range of 30-300N. In the case of lower extremity steering over the accuracy is only 0.6 for the four measuring ranges.

![Fig. 1](image)

**Fig. 1** Values of accuracy of steering by the upper and lower extremity, the higher value means better accuracy.

4. Discussion

The results of the 1,2-100N confirmed by the results in the published studies [3] providing a lower accuracy of lower extremity. The published studies evaluated the accuracy of steering by the force 30, 60 and 90N. The accuracy of steering of lower extremity above the 100N of force was similar to the accuracy by the upper extremity.

Steering of the lower extremity may be as accurate as the steering of the upper extremity. However, the condition for obtaining the best accuracy by the lower extremity depends on the appropriate selection of force or load on the pedal. The accuracy of steering by the upper extremity is almost completely independent from the range of force. When determining forces steering of the upper extremity should be taken into account the load and any worker fatigue while working.

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References