Musculoskeletal simulations: a complementary tool for classification of athletes with physical impairments

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Dear editor,

The purpose of classification of physical impairments in sports is stated by the IPC classification code as\(^1\):

Classification is undertaken to ensure that an athlete’s impairment is relevant to sports performance and to ensure that the athlete competes equitably with other athletes.

We focus on biomechanical impairments (or physical impairments) and their effects on classification. A difficult question today is how much the impairment of a person impacts upon sports performance, while avoiding influence of technique, fitness and training. In Nordic skiing, a set of standardized tests for functional assessment are performed for classification of sitting skiers. The tests are done indoors, testing limb function, strength, flexibility, coordination, range of motion, sitting balance etc. This is followed by a functional

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Table 1: Biomechanical simulation results of one double-poling cycle.

<table>
<thead>
<tr>
<th>MEASURE (units)</th>
<th>NO MUSCLES BELOW RIGHT KNEE</th>
<th>ABLE-BODIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skiing work (Nm)</td>
<td>111</td>
<td>111</td>
</tr>
<tr>
<td>Metabolic muscle work, total (Nm)</td>
<td>3004</td>
<td>2463</td>
</tr>
<tr>
<td>Skiing efficiency (%)</td>
<td>3.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Metabolic muscle work, lower-body (Nm)</td>
<td>1382</td>
<td>1192</td>
</tr>
<tr>
<td>Metabolic muscle work, lower-body (%)</td>
<td>46</td>
<td>48</td>
</tr>
<tr>
<td>Metabolic muscle work, upper-body (Nm)</td>
<td>1622</td>
<td>1271</td>
</tr>
<tr>
<td>Metabolic muscle work, upper-body (%)</td>
<td>54</td>
<td>52</td>
</tr>
<tr>
<td>Metabolic work, Rectus Femoris* (Nm)</td>
<td>6.73</td>
<td>1.24</td>
</tr>
<tr>
<td>Metabolic work, Gluteus Maximus* (Nm)</td>
<td>68.90</td>
<td>57.96</td>
</tr>
</tbody>
</table>

\* Right leg.

observation when skiing outdoors. These tests are necessary for functional classification. Nonetheless, the influence of the impairment on performance may be wrongly mixed with factors such as technique and fitness level.

There is a critical need for research that describes the extent to which impairments of varying type, severity and distribution impact performance in Paralympic sports. It is of great importance that the judgement on how the impairment affects performance is evidence-based.¹ In the following, we show a complementary evidence-based tool for classification.

Biomechanical simulations of cross-country skiing (double-poling) were carried out using the AnyBody Modeling System™ 3.0, AnyBody Technology A/S, Aalborg, Denmark. The simulation method, musculoskeletal inverse dynamics, computes the muscle forces of a body model when external forces and kinematics are given.² Two full-body simulation models with the same anthropometric data were implemented: one with full muscle setup and one without muscles in the right lower leg and foot. By excluding muscles, it is possible to show how a lower leg prosthesis may affect the muscular work. The simulation models have the same kinematics and external kinetics, i.e. perform the same task.

Simulation kinematics and computed muscle forces for one time step are visualized in Figure 1. Note that more bulging and darker muscles means higher muscular activity, e.g. compare the calf muscles. Based on simulation output, metabolic muscle work and skiing efficiency were computed.³ Results indicate that, without muscles in the lower right leg and foot, the cross-country skiing motion uses more muscle work in total for the same external work and is hence less effective, see Table 1. By simulating different impairments, quantitative data on the effect of different impairments can complement the classification.

To conclude, this is a pre-pilot study using musculoskeletal simulation for
the purpose of understanding performance effects of impairment. The body model have predetermined range-of-motion, strength etc. which means that results are independent of performance level as well as interpersonal differences. Also, the method rule out psychological factors, which is impossible in experimental studies. A simulation study of this kind may increase understanding about how one type of impairment affects the performance in a specific sport. What we have shown have a potential to become a complementary tool to existing methods in classification.

References

