Comparison of coordination in vertical jumping in adults and young children

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Introduction

A common conclusion in studies investigating performance of complex motor tasks has been that there are large overall similarities at different levels of development. On this basis it has been claimed that there are no significant differences in gross coordination between children and adults performing an identical task (Jensen et al., 1994; Fleisig et al., 1999). Yet, these similarities do not explain why young children do, compared to older children and adults, perform poorly in for example a vertical jump. Jumping height in children of around 4 years of age appeared to be extremely low (see results) and can hardly be explained by merely muscle weakness.

Most studies regarding comparison of motor behaviour between children and adults have been done at the kinematic level of analysis, eventually combined with kinetic data. Kinematic and kinetic variables describe only the observable movement pattern. This pattern is the outcome of highly correlated neural signals sent to the muscles, and it is not at all established if these similarities at the observable level indicate similar strategies in neuro-muscular coordination. Taking Bernstein’s (1967) principle of motor equivalence as the departure point, analysis at the muscular level may show whether the claimed similarities in gross coordination patterns during motor development are the result of identical fundamental activation patterns on the muscular level. The answer to this question yields a more thorough understanding of motor development.

Taking the special role of bi-articular muscles (Ingen Schenau, 1989) in regard, we focussed on the proximo-distal sequence of limb movements and timing of muscle activation during extension movements of the lower limb. This sequential way of movement and activation has been attributed to the constraints occurring as a result of the necessary transformation of joint rotations to segment translations. The bi-articular muscles are thought to play a special role by transferring energy from proximal to distal joint during the limb extension.

Methods

Eight adults (79.35 ± 10.38 kg) and seven 4-6 year olds (19.82 ± 5.01 kg) performed several vertical counter movement jumps. Up to six successful jumps (i.e. where the subject landed on the force platform at a maximal distance of 15 cm away from take-off position) were analysed. The subjects were asked to perform a solid vertical jump, that is, an intensive performance but not necessarily maximal, assuring good control. The children were helped by the use of an object, hanging from the ceiling above, that they were able to reach if they were jumping according the above given instructions to the adults.

Kinematic data were obtained digitally (ProReflex, Qualisys) at 200 Hz sample rate, with markers at the usual anatomically defined positions to obtain joint angles of hip, knee and ankle. Surface EMG of five muscles were obtained (Mark-6 system, BioSemi biomedical instrumentation) at 2000 Hz and processed according to international standards. Onset of muscle activation was performed graphically by hand. A blind test – re-test reliability ensured that effects of subjectivity in this method was minimal. Ground reaction force (GRF) was obtained using a force platform (Kistler 9286AA).

Results & Discussion

Exemplar time traces of force and calculated height of centre of mass, with several time variables indicated, are presented in Figure 1.

Results showed that children had the same proximo-distal sequence joint movement onset (Table 1) during the execution as adults, a pattern that is well explained within the unique bi-articular muscle function paradigm (Bobbert and Ingen Schenau, 1988; Ingen Schenau, 1989). Also, major timing events in the force profiles were similar after geometric scaling for mass (Figure 1 and Table 2).
Furthermore, both adults and children were well able to direct the normal force nearly perfectly vertically during the entire goal directed (i.e. upward) movement (force direction from 90 degrees, i.e. vertical, to 86 degrees). Thus, whereas the jumping height (of centre of mass) was considerably lower (0.07m vs. 0.38m), there are no clear differences in basic jumping technique between very young (novel) and adult (experienced) subjects.

However, peak force levels and rate of force development were significantly lower in children after geometric scaling for size. Within the small range of force direction, the children showed a significantly larger variation in each jump, both expressed as the range and standard deviation during one jump (Std). In other words, although like adults, children generated near vertical ground reaction force throughout the jump, the consistency of doing so (within a single jump) was less than in adults.

Furthermore, whereas the major sequence of onset muscle activation was from proximally to distally located muscles in both groups, some detailed differences were found in the exact sequence (Table 3). The most common order of onset of contraction in adults was vastus medialis, rectus femoris, gluteus maximus, biceps femoris, and gastrocnemius. A statistically significantly different most common order
was found in children, being rectus femoris, vastus medialis, gluteus maximus, biceps femoris and gastrocnemius. The gastrocnemius was the last muscle to be activated in both groups. The time of onset of activation was significantly later in children compared to adults. The variability of time of onset of muscle activity over various jump trials within subjects was significantly lower in children. On the other hand, the adults were more homogeneous as a group, i.e. performed more similarly among subjects. The difference is schematically presented in Figure 2.

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>First Adult</th>
<th>Child</th>
<th>Second Adult</th>
<th>Child</th>
<th>Third Adult</th>
<th>Child</th>
<th>Fourth Adult</th>
<th>Child</th>
<th>Fifth Adult</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus femoris</td>
<td>14.6</td>
<td>58.3*</td>
<td>25.0</td>
<td>9.5</td>
<td>2.1</td>
<td>2.4</td>
<td>0.0</td>
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<td></td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>75.0*</td>
<td>12.5</td>
<td>10.4</td>
<td>11.9</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>8.3</td>
<td>20.8</td>
<td>10.4</td>
<td>4.8</td>
<td>56.3*</td>
<td>61.9</td>
<td>22.9</td>
<td>28.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>2.1</td>
<td>8.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.4</td>
<td>25.0</td>
<td>31.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastrocnemius</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>25.0</td>
<td>31.0</td>
<td>75.0*</td>
<td>66.7</td>
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<td></td>
</tr>
</tbody>
</table>

**Table 3:** Order of onset of muscle activation in percentage of all observations (42 in children, 48 in adults). The highest occurrences are in italics. Boot-strapping techniques were used to find the non-coincidental highest occurrences, indicated by *.

From these results it is concluded that children do perform a vertical jump roughly using the same strategy as adults. Yet, a few small but systematic and possibly important differences are noticed. It is suggested that these differences may represent a lesser ability for the novices to exploit constraints, both inherent (neuro-musculo-skeletal) and external, which is contributing to a far lower jumping height. The larger individual variance in adults from trial to trial may be argued to be an expression of flexibility, rather than poor stability of performance. Given the fact that the condition from trial to trial will differ slightly, the system must constantly modify its organisation in seeking for the accurate motor solution. From this notion variance from trial to trial should be expected as an inherent feature of synergy formation, which is in line with Bernstein’s (1967) principle of repeating without repetition.

**References**


