Instrumented six degree-of-freedom paramedic mannequin neck design, informed by adult passive neck stiffness and range of motion data

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Introduction

Cervical spine injuries may be exacerbated by suboptimal neck immobilisation1. Immobilisation practise may be improved by training with patient simulator mannequins (PSMs). The limited fidelity and utility of current PSMs could be overcome by a design incorporating human-like passive neck stiffness and range of motion (ROM), and real-time user feedback.

Aims

1. Determine passive neck stiffness and ROM, in flexion, extension, lateral bending and axial rotation.
2. Examine age- and sex-effect on stiffness and ROM.
3. Develop a PSM neck with real-time head-torso motion feedback, and human-like stiffness and ROM.

Methodology

Table 1: Human and PSM passive neck ROM, stiffness (mean ± S.D.) and stiffness yearly increase rate from linear models for males (M) and females (F).

<table>
<thead>
<tr>
<th>Human ROM (deg)</th>
<th>Human Stiffness (N/mm/deg)</th>
<th>Stiffness Increase rate (N/mm/deg/yr)</th>
<th>PSM ROM (deg)</th>
<th>PSM Stiffness (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>46 ± 11</td>
<td>63 ± 14</td>
<td>64 ± 11</td>
<td>57 ± 16</td>
</tr>
<tr>
<td></td>
<td>19 ± 18</td>
<td>19 ± 14</td>
<td>22 ± 11</td>
<td>18 ± 12</td>
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<td></td>
<td>30 ± 26</td>
<td>57 ± 40</td>
<td>32 ± 24</td>
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<td></td>
<td>26 ± 10</td>
<td>56 ± 60</td>
<td>26 ± 60</td>
<td>32 ± 60</td>
</tr>
<tr>
<td></td>
<td>M/F: 1.1†</td>
<td>M/F: 1.3†‡</td>
<td>M/F: 1.6†</td>
<td>M/F: 1.2†‡</td>
</tr>
<tr>
<td></td>
<td>2.1%</td>
<td>1.7%§</td>
<td>2.4%†</td>
<td>2.2%§</td>
</tr>
</tbody>
</table>

Discussion

• Passive ROM for lateral bending was similar to that in the literature4, but flexion and axial rotation ROM was lower5, 6.
• Passive ROM did not depend on age (0.05<ρ<0.49) or sex (0.21<ρ<0.97).
• Lateral bending and axial rotation stiffness was similar to other studies3, 6, but flexion and extension stiffness was lower6.
• Stiffness did not depend on sex, contrary to young persons in McGill et al. 6.
• Stiffness in extension (zone 2, 3), lateral bending and axial rotation, increased with age (Table 1). Rate of increase with age was higher for males than females in extension zone 3, lateral bending zone 2 and 3.
• Some participants apparently failed to reach their “actual” ROM, so their zone 2 or 3 stiffness may not reflect stiffness near full ROM. Further analysis will consider normalising to active ROM.
• The PSM neck (Fig 7) had similar ROM to human in flexion, lateral bending and axial rotation, but the stiffness was generally lower than for humans.

References


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Conclusions & Future Work

• Passive neck ROM was not age-dependent, but passive stiffness increased with age in most directions; rate of increase was usually not sex-dependent.
• The PSM neck requires further modifications to increase stiffness and improve extension ROM.