EVALUATION OF THE STABILITY OF SIT-TO-STAND

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INTRODUCTION

Sit-to-stand is one of the most common daily activities and is performed with no effort by healthy subjects. Once the health situation is impaired we can see quite a different situation. Thus successful performance of sit-to-stand becomes one of the vital factors for further possibilities of movement. Based on this we cannot evaluate rising from a chair as a simple movement. Berger et al. (1998) in Carr & Shepherd (2000), as well as Kerr et al. (1994) consider this activity to be one of the most mechanically challenging for a person. Véle (1997) sees the task as highly individual in performance and very dependent on previous sensorimotor experience. The sit-to-stand can be compared to walking, which is characterized as a movement stereotype. Task performance varies based on preliminary conditions (position of lower extremities, possibility to use hands for rising support, depth of the sitting, height and shape of the seat etc.). For the majority of the population sit-to-stand is an automatic activity that uses movement patterns in functional and economical task performance (Edwards, 1996; Trew & Everett, 1997).

From the biomechanical point of view sit-to-stand has a typically narrowed base of support (BOS) that is reached by the horizontal transfer of the center of mass (COM) above the area defined by the feet and the connecting line of their outer margins. Muscle force generated by simultaneous trunk and knee flexion initiates a reaction force which enables the forward movement of the thighs followed by the seat clearance. The horizontal movement of the body changes into vertical (continual movement of COM forward and upward; Carr & Shepherd, 2000). This is the moment when the feet become the BOS. This is considered a key point in the successful transfer of the body weight from the seat BOS (Riley et al., 1991).

As in walking, the sit-to-stand also has no clear separation of phases. This is highly dependent on the focus of each research and on the movement of the analyzed segments. Quiet often division into four phases is found in the literature (Schenkman et al., 1990). We use this four-phase division in our laboratory. The first phase (trunk flexion) is initiated with the first recognizable movement and ends just before rising. In the second phase (momentum transfer) the body continues the forward movement and maximal dorsal flexion in the ankle joint is reached. This is the beginning of the third phase (hip joint extension) which is completed with maximal extension in the hip joint. The fourth phase (movement stabilization), in which the angular velocity equals zero, completes the entire movement. The principal problem in the movement analysis is the matter of the number of trials necessary for evaluation in order to objectively evaluate the task performance. The number varies for different groups of people with various health problems. Presumably, for the majority of people the daily activities, including the sit-to-stand movement, are sufficiently simple to perform and may lead to possible variability in their performance. In some of the studies dealing with sit-to-stand analysis, we also found, along with the general 3D analysis, the evaluation of the body marks movement in the sagittal plane. Certain anatomical and morphological asymmetry of the movement system suggests that these considerations are not quiet right.

OBJECTIVES

Based on the above stated information this study is trying to answer the following questions:

How stable is sit-to-stand performance in repeated trials?
Are there any differences in the sit-to-stand movement on the right and left side of the body?

METHOD

The test group consisted of 21 women (aged 24±4 years, weight 61±15 kg, height 168.5±11.5 cm). All the subjects were healthy, without any acute or chronic problems of the musculoskeletal system.
From the case history of each subject no neurological, visual or vestibular deficits were found. Sedentary activities predominated in their daily lifestyle. Case history and kinesiological evaluation was performed prior to the movement analysis.

3D videography analysis (APAS) was used for the movement analysis. 22 body markers were placed on anatomical prominences after their palpation. The seat height was individually adjusted to gain the horizontal position of thighs parallel to the ground. The initial position was determined so the distance of the popliteal space was approximately 4 cm from the edge of the seat; knee joint angle was 90 degrees. The speed of the individual’s sit-to-stand movement was not altered – spontaneous task performance. The position of the upper extremities was not standardized; subjects were not allowed to use them to support rising. The video recording was obtained from 4 video cameras (25 Hz). Digitalization of the recordings enabled an increase of the frequency to 50 Hz. The number of positions in each task sequences performed was about 100. The main parameters observed were as follows: range of movement of the hip and knee joint, angular differences in trunk positions, angular velocity in the hip and knee joint, and trajectory of the spinous process C7 (Fig. 1).

**Fig. 1** Evaluated parameters in the sagittal plane

\[
\alpha - \text{the angle in the knee joint} \\
\beta - \text{the angle in the hip joint} \\
\gamma - \text{the angle between the trunk and vertical} \\
\omega_1 - \text{the angular velocity in the knee joint} \\
\omega_2 - \text{the angular velocity in the hip joint}
\]

The kinematic analysis results were supplemented by data obtained from the force platforms.

**RESULTS AND DISCUSSION**

The basic statistical characteristics of repeated trials obtained from the right and left side of the body are represented in table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Right1 Mean</th>
<th>Right1 SD</th>
<th>Right2 Mean</th>
<th>Right2 SD</th>
<th>Left Mean</th>
<th>Left SD</th>
<th>Z1</th>
<th>Z2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)</td>
<td>74.7</td>
<td>4.39</td>
<td>73.6</td>
<td>4.13</td>
<td>73.4</td>
<td>3.56</td>
<td>1.31</td>
<td>0.71</td>
</tr>
<tr>
<td>(\beta)</td>
<td>106.4</td>
<td>8.51</td>
<td>108.4</td>
<td>8.89</td>
<td>106.3</td>
<td>8.80</td>
<td>0.44</td>
<td>0.24</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>49.4</td>
<td>7.64</td>
<td>49.3</td>
<td>8.67</td>
<td>48.7</td>
<td>8.71</td>
<td>0.44</td>
<td>0.71</td>
</tr>
<tr>
<td>(\omega_1)</td>
<td>113.2</td>
<td>21.86</td>
<td>111.5</td>
<td>29.76</td>
<td>108.5</td>
<td>23.9</td>
<td>0.87</td>
<td>1.18</td>
</tr>
<tr>
<td>(\omega_2)</td>
<td>164.9</td>
<td>24.06</td>
<td>171.7</td>
<td>30.18</td>
<td>162.8</td>
<td>24.3</td>
<td>1.75</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Legend: Right1,2 – values obtained from the right side of the body; Left – values obtained from the left side of the body; \(\alpha\) – range of movement in the knee joint; \(\beta\) – range of movement in the hip joint; \(\gamma\) – range of movement of the trunk; \(\omega_1\) – maximal angular velocity in the knee joint; \(\omega_2\) – maximal angular velocity in the hip joint; \(Z1\) – value of the testing criteria for comparison of various trials on the right and left side of the body; \(Z2\) – value of the testing criteria for the comparison of the right and left side of the body.

The results acquired in our study correspond with findings of other authors. For example Roebroeck, et al. (1994), Gross et al. (1998) report maximal angular velocity in the knee joint between 92.3-151.7°.s\(^{-1}\), for the hip joint 130.3-192.7°.s\(^{-1}\). Data in table 1 show that in comparisons of individual trials we found significant differences on \(p<0.05\) level of statistical significance. When considering these results we have to take into account the size of the test group and the possible
evaluation method. This leads to a very individual approach to each tested person. Figure 2 depicts the trajectory of spinous process C7 in repeated trials in two subjects. While trajectories of the C7 in the first person were almost identical, the second person’s trajectories show even visually distinguishable differences.

**Fig. 2** Trajectory of the spinous process C7 in repeated trials

Overall comparison of the measured data from the right and left side of the body in one trial proved no statistically significant differences (p<0.05). Focusing on the body position in key points which divide the whole task into individual phases we found these differences for the angle of knee joint in all key points. Ikeda (1991) in his research found the greatest side differences in the area of the knee joint. Véle (1995, 66) says that “… the leading movement for sit-to-stand is the knee extension…”. Figure 3 depicts the time-lapsed of selected subjects for comparison of the right and left side of the body.

**Fig. 3** Graphic comparison of body position evaluated by the body markers of right and left side

**CONCLUSIONS**

1. The visual assessment of sit-to-stand enables the finding of only “rough” differences in the performance of the movement.
2. The determination of the basic phases of sit-to-stand is the most crucial for the analysis.
3. Due to low physical demand, healthy subjects perform this motion with few differences.
4. When comparing data from the right and left side of the body statistically significant differences were found (p < 0.05) for the range of motion in the knee.
REFERENCES

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