Effect of Ageing on Quadriceps Muscle Strength and on the Forward Shift of Center of Pressure during Sit-to-stand Movement from a Chair

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Abstract. The purpose of this study was to investigate the effect of ageing on body sway during sit-to-stand movement from a chair and on quadriceps muscle strength in the elderly population. A total of 275 community dwellers volunteered to participate in this study. All subjects signed an informed consent statement prior to participating in this study. They were required to be able to perform a sit-to-stand movement from a chair independently. The postural sway for the subjects during the sit-to-stand movement from the chair was measured using a stabilometer. The analog signals of the subjects’ center of pressure in the anterior-posterior direction (%Y-axis) derived from the stabilometer were recorded. The maximum isometric muscle strength of knee extension was measured using an isometric dynamometer at 90 degrees flexion of the knee joint. Our results demonstrate that as age increased, lower extremity muscle strength decreased, and forward shift of the center of pressure also decreased. It is possible that the elderly subjects could not use their propelling power because of decreased lower extremity muscle strength. Therefore, the forward shift of the center of pressure of elderly subjects also decreased causing them difficulty in standing up from a chair. Therefore, we believe that there is a need to educate elderly people about accurate sit-to-stand movement and the importance of lower extremity muscle strength exercise.

Key words: Ageing, Sit-to-stand movement, Stabilometry

INTRODUCTION

One of the most common activities of daily living is to stand from the sitting position. In our daily life, when we get up from the bed, when we leave the dining table, when we stand up from the toilet seat, and when we use a train, bus, or car, stable standing movement is required.

The task of standing from a seated position is often associated with falling in older adults1). It has been reported that 8% of community-dwelling older adults over 65 years of age show some problems in rising from a chair or bed2).

Nuzik et al.3) have divided the sit-to-stand movement into two phases. The first phase, the flexion phase of the trunk, occurs during the first
35% of the movement cycle. The second phase consists of the extension phase of the trunk and lower extremities.

Millington et al.\(^4\) have divided the sit-to-stand movement into three phases. Phase I, the flexion phase of the trunk; Phase II, the transition phase: the phase of separation of buttocks from seat of chair and trunk flexion; and Phase III, the lifting phase: the phase of extension of the lower extremities.

On the other hand, Schenkman et al.\(^5\) and Riley et al.\(^6\) have divided the standing up movement into four phases. The first phase begins with the initiation of the movement and ends just before the buttocks are lifted from the seat of the chair. The second phase begins as the buttocks are lifted from the seat of the chair and ends when maximum ankle dorsiflexion has been achieved. The third phase is initiated just after maximal ankle dorsiflexion and is completed when the hip first ceases to extend. Finally, the fourth phase begins just after the hip-extension velocity reaches 0\(^{\circ}\)/sec and continues until all motion associated with stabilization from rising has been completed. However, the end point of phase IV is not easily defined (Fig. 1). As a result, there have been very few studies which have investigated the fourth phase.

In a previous study\(^7\), it was reported that many elderly people have difficulty in standing up from a toilet seat, couch, or dining room chair, etcetera.

Miyoshi et al.\(^8\) previously reported that the time taken for body sway to stabilize immediately after standing was significantly longer in elderly people than in young people. Also, the center of pressure was significantly posterior in elderly people than in young people. However, these results only investigated the static characteristics of the center of pressure immediately after the sit-to-stand movement, and there is a need to investigate the relationship between dynamic characteristics of center of pressure during sit-to-stand movement and quadriceps muscle strength.

The purpose of this study, therefore, was to investigate the effect of ageing on body sway during sit-to-stand movement from a chair and on quadriceps muscle strength in the adult population.

**METHODS**

**Subjects**

Participants in this study were recruited from a Community Health Education class, Nagano Prefecture, between October 2003 and March 2004. A total of 275 community dwellers (226 women and 49 men) volunteered to participate in this study. All subjects were required to stand up from a chair independently.

The exclusion criteria for this study included people with Meniere’s disease, and any musculoskeletal or neuromuscular disease which affected their ability to stand or to balance during the sit-to-stand movement.

All subjects signed an informed consent statement prior to participating in this study.

**Procedure**

(1) Measurement of Forward Body Sway

The postural sway for all the subjects during the sit-to-stand movement from a chair was measured using a stabilometer (SG-1, ANIMA Co., Japan). Analog signals of the subjects’ center of pressure in the anterior-posterior direction (Y-axis) derived from the stabilometer were recorded.

The subjects were initially positioned sitting on an armless and backless chair, with the height of the seat being adjustable. The subjects were positioned sitting with the hip and knee joint at 90 degrees flexion, and the ankle joint in the neutral position (0 degrees). The subjects were then instructed to stand up with their feet together on the stabilometer.
Subjects were instructed to initiate the sit-to-stand movement with their arms held by their sides. To prevent a fall during the measurement, we explained the procedure thoroughly as well as providing a short practice session prior to testing. The examiners stood beside the subjects and were prepared to assist if there was a possibility of the subject losing balance during the measurement.

After completion of the standing up movement, subjects were instructed to maintain a quiet standing position for about 30 seconds on the stabilometer. They were also instructed to keep their visual focus on a target on the wall 2 m in front of the subject and 1.5 m height from the floor.

Subjects were allowed to stand up freely at their preferred speed. All subjects practiced the sit-to-stand movement task a few times prior to actual data collection. An electro-goniometer (SG150, Biometrics Ltd., England) was attached to the anterior position of the hip joint in order to identify the end point in the standing movement.

(2) Measurement of Quadriceps muscle strength
The maximum isometric muscle strength of knee extension (Quadriceps muscle) was measured using an isometric dynamometer (GT-30, OG Giken Co., Ltd., Japan) at 90 degrees flexion of the knee joint. Subjects were seated with their hips and knees in 90 degrees flexion. Measurements were executed twice with both legs, with the order of testing being randomized, and the higher value of the two measurements was selected for analysis.

The Strength to Body Weight Index (WBI) was calculated by dividing individual subjects’ maximum isometric muscle strength (in kilograms) with their own body weight (in kilograms).

(3) Data processing
The analog signals from the stabilometer and electro-goniometer were converted to digital signals by an A/D converter at a sampling frequency of 500 Hz. The digital data were then processed using bio-information signal processor software (BIMUTAS II, KISSEI COMTEC, Co., Ltd., Japan) (Fig. 2).

(4) Statistical analysis
The maximum anterior shift of Y-axis was recorded by the stabilometer and analyzed by BIMUTAS. The recorded Y-peak value (in cm) was normalized with the subject’s foot length (in cm) and expressed as a percentage (%Y-peak).

Subjects were divided into age groups corresponding to their age in decades: that is, 30s, 40s, 50s, 60s, 70s and 80s.

All statistical analyses were carried out using SPSS 11.0J for Windows (SPSS Inc., Chicago, USA). Pearson’s correlation coefficient was used to analyze the relationships between % Y-peak, WBI and age. The level of statistical significance was set at 0.05.

RESULTS

Subjects
Of the 275 subjects, 49 were male and 226 were female. Table 1 shows a summary of the subjects’ characteristics. The age of the subjects ranged from 30 to 86 years, with a total of 20 subjects in their 30s, 24 in their 40s, 31 in their 50s, 64 in their 60s, 108 in their 70s and 28 in their 80s (mean age: 65.1 years) (Table 1).

Relationship between % Y-peak and age (Fig. 3, Tables 2, 3)
Subjects in their 30s showed the highest mean value for %Y-peak (56.8 ± 18.1%), while subjects in their 60s showed the smallest mean values (42.2 ± 7.1%) (Table 2). The correlation value was small, but nonetheless there was a significant negative correlation between % Y-peak and age (r=−0.325, p<0.01) (Fig. 3).

Relationship between WBI and age (Fig. 4, Tables 2, 3)
Subjects in their 30s showed the highest mean values for WBI (0.63 ± 0.2), while subjects in their
80s showed the smallest mean values (0.26 ± 0.1) (Table 2). There was a significant negative correlation between WBI and age (r=–0.648, p<0.01) (Fig. 4).

**Relationship between % Y-peak and WBI (Fig. 5, Tables 2, 3)**

The correlation value was small, but nonetheless there was a significant correlation between % Y-peak and WBI (r=0.234, p<0.01) (Fig. 5).

**DISCUSSION**

The results of this study demonstrate that the forward shift of center of pressure (% Y-Peak) decreases as age increases during the sit-to-stand movement from a chair. In a previous study by Maeda et al.9), it was reported that elderly subjects had short maximum forward shift of center of pressure, and when in the standing position, their body weight remained posterior to the heel. Kojima et al.10) reported that elderly subjects showed a decrease in the maximum horizontal velocity of center of pressure during sit-to-stand movement from a chair. It is possible that young subjects shift forward their center of pressure by using their propelling power during standing up from a chair. However, the propelling power for elderly subjects is diminished. Hence, it is possible that elderly

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**Table 1.** Subject characteristics

<table>
<thead>
<tr>
<th>Age distribution</th>
<th>Age mean ± SD</th>
<th>Sex</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–39 years</td>
<td>34.3 ± 3.0</td>
<td>8/12</td>
<td>20</td>
</tr>
<tr>
<td>40–49 years</td>
<td>45.1 ± 2.9</td>
<td>8/16</td>
<td>24</td>
</tr>
<tr>
<td>50–59 years</td>
<td>54.5 ± 2.7</td>
<td>3/28</td>
<td>31</td>
</tr>
<tr>
<td>60–69 years</td>
<td>65.0 ± 3.0</td>
<td>6/58</td>
<td>64</td>
</tr>
<tr>
<td>70–79 years</td>
<td>74.0 ± 3.0</td>
<td>17/91</td>
<td>108</td>
</tr>
<tr>
<td>80+ years</td>
<td>82.0 ± 1.9</td>
<td>7/21</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>49/226</td>
<td></td>
<td>275</td>
</tr>
</tbody>
</table>

**Table 2.** Results of Y-peak, %Y-peak and WBI

<table>
<thead>
<tr>
<th>Age distribution</th>
<th>Y-peak (cm) mean ± SD</th>
<th>%Y-peak mean ± SD</th>
<th>WBI mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–39 years</td>
<td>13.7 ± 4.4</td>
<td>56.0 ± 18.1</td>
<td>0.63 ± 0.2</td>
</tr>
<tr>
<td>40–49 years</td>
<td>12.1 ± 3.6</td>
<td>49.6 ± 13.2</td>
<td>0.55 ± 0.1</td>
</tr>
<tr>
<td>50–59 years</td>
<td>10.5 ± 2.8</td>
<td>44.0 ± 10.2</td>
<td>0.47 ± 0.1</td>
</tr>
<tr>
<td>60–69 years</td>
<td>9.9 ± 1.9</td>
<td>41.7 ± 8.0</td>
<td>0.41 ± 0.1</td>
</tr>
<tr>
<td>70–79 years</td>
<td>10.1 ± 1.8</td>
<td>42.2 ± 7.1</td>
<td>0.34 ± 0.1</td>
</tr>
<tr>
<td>80+ years</td>
<td>10.2 ± 1.9</td>
<td>42.8 ± 8.0</td>
<td>0.26 ± 0.1</td>
</tr>
</tbody>
</table>

**Table 3.** Table of correlations

<table>
<thead>
<tr>
<th></th>
<th>age</th>
<th>% Y-peak</th>
<th>WBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>1.00</td>
<td>0.325**</td>
<td>-0.648**</td>
</tr>
<tr>
<td>% Y-peak</td>
<td>1.00</td>
<td>0.234**</td>
<td>1.00</td>
</tr>
<tr>
<td>WBI</td>
<td></td>
<td></td>
<td>**: p&lt;0.001.</td>
</tr>
</tbody>
</table>

Fig. 3. Correlation between age and %Y-peak.
subjects have difficulty in shifting their center of pressure forward since they are less able to utilize their propelling power. Therefore, in this study, it was not a surprising result that the forward shift of center of pressure of the elderly decreased as age increased.

During Phase I (initiation) and Phase II (buttocks off the chair) of the sit-to-stand movement, it has been reported that there is an increase in the flexion angle of the trunk in the elderly, as compared with the young subjects. This increase in trunk flexion angle was necessary to bring the center of pressure closer to the base of support. The forward propelling power is associated with the lower extremity muscle strength during the extension in Phase III (upward shift) of the sit-to-stand movement. However, because the elderly subjects could not use their forward propelling power as well as the young during the sit-to-stand movement from a chair, it is possible that they would need to depend more on their lower extremity muscle strength. The results of this study demonstrate that the lower extremity muscles strength, such as the quadriceps, decreases with age. It is possible that the difficulty experienced by elderly subjects during the sit-to-stand movement could be related to their decreased lower extremity muscle strength.

It has been reported that in general, during phase II of the sit-to-stand movement (buttocks off the chair) the ground reaction forces in this phase are greater than the subject’s body weight in the vertical direction. Hence, in elderly subjects where the WBI values are small (indicating weakness in the muscle), there is a possibility they may be unable to support their weight in this phase of the standing up movement, resulting in collapse of the knees.

If the maximum horizontal velocity of center of pressure during sit-to-stand movement from a chair was slow and the forward propelling power was decreased, they would have to depend on their lower extremity muscle strength. Because of this, the elderly have no choice but to increase the load to their lower extremity during the sit-to-stand movement. This can be seen in the extended time needed by elderly people in the sit-to-stand movement from a chair.

Shumway-Cook et al. investigated the time taken to rise from sitting among young adults, older adults who were able to rise without armrests (old able), and older adults who were unable to rise without armrest (old unable). They reported that the average time to rise from a chair were similar in the young and old able groups (1.56 versus 1.83) but significantly longer in the old unable group (3.16 seconds).

Yokogawa et al. and Corrigan et al. reported that lower extremity muscle strength was important in the extension phase of the sit-to-stand movement (Phase III). They reported that the weaker the lower extremity muscle strength, the longer the sit-to-stand movement time in elderly people.

When using propelling power during sit-to-stand movement from a chair, dynamic balance is needed. However, it has been reported that dynamic balance ability in elderly subjects is decreased. One reason given for the decrease in the dynamic balance ability of the elderly subjects was a decrease in lower extremity muscle strength. It is possible that a decrease in dynamic balance ability in the elderly would result in an increased incidence of
forward falls in this group.

An important factor of dynamic balance is lower extremity muscle strength. The results of this study showed that with increasing age, WBI of elderly subjects decreased as compared with the young subjects. When the WBI is small, it is expected that the maximum forward shift of the center of pressure would also be small. Accordingly it was important that sufficient forward shift of center of pressure and lower extremity muscle strength was achieved by elderly subjects during the sit-to-stand movement.

The results of this study suggests that Physical Therapists have to teach anti-gravity muscle strength exercises, such as those for the quadriceps, and to correct posture, in order to decrease falls and fear of falling during the sit-to-stand movement from a chair in the elderly group.

Future studies are needed to validate the results of this study. The subjects in this study varied in age from their thirties to eighties. However, the distribution of the subjects across the different age groups was not even. This might have affected the results of the statistical analysis. Future studies should also take into account the measurement of angle and speed in trunk flexion, foot position and seat height because the sit-to-stand movement is affected by many factors such as these.

CONCLUSION

We investigated the effect of ageing on body sway during standing up from a chair and the quadriceps muscle strength in the adult population. Our results demonstrate that as age increases, the lower extremity muscle strength decreases, and the forward shift of center of pressure also decreases. In addition, the weakness in the lower extremity muscle strength was associated with a smaller forward shift of center of pressure. As the subjects’ age increased, they had difficulty in shifting their center of pressure forward due to diminished forward propelling power. Hence, since the elderly are unable to generate forward propelling power accompanied by trunk flexion, they must depend on lower extremity muscle strength during the sit-to-stand movement from a chair. It is common for elderly subjects to have lower extremity muscle weakness, therefore, we believe that we need to educate elderly people about correct sit-to-stand movement and lower extremity muscle strength exercises.

REFERENCE