Calculation of the Area of Movements of the Center of Gravity in Sitting in Hemiplegic Patients by Mathematics

SHU MORIOKA, RPT, M.Ed.1)

1)Department of Physical Therapy, Kochi School of Allied Health and Medical Professions, and Department of Neuroscience, Doctoral Course of Medical Science, Kochi Medical School: 6012–10 Nagahama, Kochi 781-0270, Japan.
TEL +81 88-842-0412  FAX +81 88-841-1783  E-mail: morioka@kochi-iryogakuin.com

Abstract. The purpose of this study was to examine the degree of disorder of dynamic balance in sitting of stroke patients with hemiplegia by calculation of the area of movements of the center of gravity. Subjects were ten hemiplegic patients. Controls were ten young adults and ten elderly adults. The center of gravity point (mean of Y-axis and mean of X-axis) was measured during movements of the center of gravity toward eight points from the center. An octagon was described on section paper by the eight points. This octagon was divided into six triangles. The area of the octagon was calculated by the sum of the area of six triangles. Moreover, the Heron formula was used for calculation of the area of the triangles. The value of hemiplegic patients was significantly decreased compared to the value of controls. Also, there was a significant difference between eyes open and eyes closed in hemiplegic patients only. This study showed the area of movements of the center of gravity area and its characteristic in sitting of hemiplegia patients.

Key words: The area of movements of the center of gravity, Hemiplegia, Mathematics

INTRODUCTION

Stabilometry has been developed as a method which is capable of quantitatively evaluating the human balancing capacity, and is being actively introduced into the field of physical therapy1–9). The analysis mainly evaluates the static balance by measuring the traces of body swaying within unit time.

For the evaluation of the dynamic balance, on the other hand, the cross test which measures the distance of antero-posterior and left-right voluntary movements of the center of gravity has been developed. The usefulness of the cross test has already been demonstrated11–13). These analyses have been recognized as useful methods for judging the efficacy of balance disorder analysis and of rehabilitation particularly for central nervous diseases. However, these methods measure the distance of antero-posterior and left-right movements and not to measure the area of movements of the center of gravity. By utilizing the area, the calculation of a ratio to a loaded area becomes possible, and the capacity to move the center of gravity can be studied in more detail.

Thus, we devised a mathematical method to obtain the area of movements of the center of gravity as a means of evaluating the dynamic balance capacity observed using a stabilometer. The usefulness of this method in the standing position has already been reported4). The objective of the present study was to clarify the area of movements of the center of gravity in the sitting position of hemiplegic subjects.
SUBJECTS

The subjects were 10 hemiplegic patients who could maintain a sitting position with feet placed on the floor for a time long enough to participate in this study. Six subjects had right hemiplegia, and four subjects had left hemiplegia. Their mean age was 62.4 ± 6.8 years old. All subjects had no previous record of higher cortical dysfunction. A comparison group (controls) consisted of ten young age adults (23.6 ± 4.7 years old) and ten elderly adults (61.2 ± 7.1 years old).

METHODS

A center of gravity recorder (Gravicorder GS2000, Anima CO.) was used in this study. The center of gravity point was mean of deviation X-axis and mean of deviation Y-axis. The measurement position was sitting with both feet placed on the floor.

The subject center of gravity point was measured (1) maximal movement to the right, (2) maximal movement to the left, (3) maximal movement to the forward, (4) maximal movement to the backward, (5) maximal movement to the right oblique forward, (6) maximal movement to the left oblique forward, (7) maximal movement to the right oblique backward, (8) maximal movement to the left oblique backward with eyes open and eyes closed for ten seconds (Fig. 1).

The calculation of the area of movements of the center of gravity was entered in octagon form on the basis of the eight center of gravity points. These points were tied with a line. Next, the octagon form was divided into six triangles. The triangle area was calculated from the Heron formula as follows.

\[ S = \frac{1}{2} (a+b+c) \]
\[ a, b, c \text{ are the position vector of each point.} \]

A triangle area (S) = \( \sqrt{s(s-a)(s-b)(s-c)} \)

One way ANOVA and Fisher’s LSD test were used for comparison of hemiplegic patients and controls. Paired t-test was used for comparison of eyes open and eyes closed conditions.

RESULTS

The values of the area of movements of the center of gravity of each subject are indicated in the Table 1. The values of hemiplegic patients were significantly decreased than the value of controls. Also, the value of eyes closed significantly decreased compared to the value of eyes open in hemiplegic patients only.

DISCUSSION

Analysis items for stabilometric static balance include the length within unit time, rectangle area, and the means of X and Y (indices of the center of gravity). For dynamic balance analysis, on the other hand, there is the cross test which records the width of antero-posterior and left-right active movements of the center of gravity. A number of studies have been conducted in hemiplegic subjects using these evaluation parameters. In these previous studies, it was frequently reported that the swaying of the center of gravity increased in hemiplegia and the center of gravity shifted toward
the non-hemiplegic side. The cross test has been applied to cases of lower extremity amputation\textsuperscript{12}) and cerebral palsy\textsuperscript{13}). However, the cross test deals only with the distance of 4 directional (antero-posterior and left-right) movements of the center of gravity, and it may be said that only a rough evaluation can be obtained by such 4 directional measurements. Our method measured 8 directional ranges, including diagonal movements from the center in addition to 4 directional movements of the cross test and converts the results into the area. Since this method utilizes an octagon for area calculation, it is useful for visual judgment of the severity of dynamic balance disorder. In addition, this is a quantitative evaluation method owing to the use of area.

Using this method, we previously elucidated the area of movements of the center of gravity in the standing position in hemiplegic subjects. The area in hemiplegic subjects was about 1/10 of that in healthy adult subjects of similar age\textsuperscript{14}). In the present study, the severity of disorder in the area of movements of the center of gravity in the sitting position was clarified and the areas in hemiplegic subjects were found to be 1/3 to 1/5 of the areas in healthy adult subjects. This smaller difference from healthy adult subjects in the sitting position compared with the standing position is thought to be attributable to such dynamic factors as the lowered level of the center of gravity and the increase in supporting basal surface area. Only in hemiplegic subjects, did observed values become smaller in eyes closed. This is considered to be due to the decrease of somatosensory information from the buttocck etc., in hemiplegic subjects.

Nichols\textsuperscript{15}) developed a method to shift the center of gravity from the center to 8 directions for 10 sec as dynamic balance training for hemiplegic patients, and reported its effectiveness. Our method resembles Nichols’ method. Therefore, it may be suggested that our method will be useful for the evaluation of the dynamic balance.

**REFERENCES**


<p>| Table 1. The area of movements of the center of gravity during eyes open and eyes closed |
|----------------------------------------|---------------------------------|---------------------------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>young adult (n=10)</th>
<th>old adult (n=10)</th>
<th>hemiplegia (n=10)</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>eyes open</td>
<td>93.9 ± 19.8</td>
<td>87.7 ± 13.9</td>
<td>30.3 ± 1.7</td>
<td>48.9</td>
<td>0.001</td>
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<tr>
<td>eyes closed</td>
<td>92.4 ± 17.6</td>
<td>81.4 ± 23.9</td>
<td>17.8 ± 8.9</td>
<td>47.3</td>
<td>0.001</td>
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* p<0.001


