Relationship between the Center of Gravity Point in Spontaneous Standing and the Middle Point Calculated from the Center of Gravity Shifting Distance to the Non-paralytic and Paralytic Sides in Hemiplegics after Stroke

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Abstract. The purpose of this study was to clarify whether or not the center of gravity shifting to the non-paralytic side in hemiplegics after stroke was influenced by relative distances of the voluntary shifted center of gravity from the paralytic side to the non-paralytic side and vice versa. Using 55 hemiplegics, bilateral points of the voluntary shifted center of gravity in a standing position were measured by means of the stabilometer for 10 seconds, each with the eyes open and closed, and also the voluntary shifting of the center of gravity to the non-paralytic side and the paralytic side. Mean of X-axis was employed as an index for the bilateral points of the center of gravity. The middle of the mean of X calculated from the center of gravity shifted between the non-paralytic side and the paralytic side was used as the middle point. A significant positive correlation between the spontaneous standing point and the middle point was obtained when the eyes were open and closed. The result suggests that the bilateral centers of gravity in the standing position of hemiplegics can be determined relatively by active shifted distances of the centers of gravity between the non-paralytic and paralytic sides.

Key words: Hemiplegics, Center of gravity, Standing

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INTRODUCTION

In a standing position the center of gravity of hemiplegics after stroke is defined limited to the relative weight loading on the paralyzed leg1). Recent investigations into regulation of the standing position in hemiplegics, mostly focused on relative weight bearing, have revealed a decreased weight distribution ratio on the affected side in the hemiplegics2-5). Accordingly in physical therapy weight bearing exercises have frequently been applied to the paralyzed leg aiming at a uniform distribution of the weight on both legs, the effect of which has been identified6, 7). Due to the wide use of the stabilometer, other studies have been carried in view of not weight distribution but deviation of the central point of foot pressure8, 9). Using the stabilometer the principal indices for hemiplegics in a standing position are the amount of the body sway in a definite time obtained in length and area, and the central point of the foot pressure in rocking. Generally in a static state, the value of the shifting...
central point of foot pressure is noted as a value of the shifted center of gravity; therefore, the central point of foot pressure can be noted as a point of the center of gravity. Based on the fact that hemiplegics weight distribution on the affected side is lower, it is important to record the bilateral centers of gravity. Previously we reported a correlation of the center of gravity in a spontaneous sitting position with the middle point of two shifting centers of gravity obtained upon shifting the center of gravity bilaterally. It was clarified that the center of gravity in the sitting position is determined by the relative distance of the center of gravity shifted on both sides\(^\text{10}\). In this study we focused on the center of gravity in the standing position, the so-called central point of foot pressure, to study whether or not the center of gravity in a standing position is determined by relative distances of the optional center of gravity shifted between the paralyzed and non-paralyzed sides.

**SUBJECTS**

Fifty-five hemiplegics who could maintain a standing position for a long time participated in this study. Twenty-four subjects had right hemiplegia, and 31 subjects had left hemiplegia. Hemiplegics population in this study was a sample of convenience made up from subjects who were between 63 and 75 years of age (X=66.3, SD=9.1). The subjects ranged from 41 to 214 days post-stroke. All subjects had no previous record of higher cortical dysfunction and dementia. Subjects were able to understand instructions about the experiment and gave their informed consent.

**METHODS**

A stabilometer (GS2000, ANIMA. CO., LTD.) was used in this study. The subject’s center of gravity point was measured under three conditions: 1) spontaneous standing (spontaneous standing point), and maintained standing of maximal voluntary shifting the center of gravity to 2) the non-paralytic side (non-paralytic shifting point) and 3) the paralytic (paralytic shifting point) with the eyes open and closed for ten seconds. For measurement with eyes open, the subjects were directed to fix their eyes on an object 2 m ahead of them. The measurement was started with a delay of 5 sec after the start sign to exclude early sway.

The parameter used was mean of X (the right and left axis). Mean of X was calculated with the following formula:

\[
\text{mean of } X = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

Mean and standard deviation for each parameter analyzed were calculated. Also, the middle point was calculated from the non-paralytic shifting point and paralytic shifting point during eyes open and closed\(^\text{10}\) (Fig. 1). The non-paralytic side was indicated plus, and the paralytic side was indicated minus in order to unify the non-paralytic side and the paralytic side (the right and left). Statistics were calculated using Pearson’s rank correlation coefficient with a level of p<0.05 chosen as significant.

![Fig. 1. The calculation method of the middle point\(^\text{10}\).]
RESULTS

The average value of the center of gravity point of spontaneous standing was $1.37 \pm 1.46$ cm, the non-paralytic shifting point was $4.55 \pm 2.09$ cm, and the paralytic shifting point was $2.47 \pm 2.29$ cm. The middle point calculated from the non-paralytic shifting point and the paralytic shifting point was $1.27 \pm 1.16$ cm with eyes open. The coefficient of correlation between each parameter is shown in Table 1. A significant correlation was not observed between the spontaneous standing point and center of gravity shifting width. However, there was a significant correlation between spontaneous standing point and other parameters. Therefore, there was a significant correlation between the spontaneous standing point and the middle point (Fig. 2-a).

The average value of the center of gravity point of spontaneous standing was $1.56 \pm 1.34$ cm, the non-paralytic shifting point was $4.03 \pm 2.15$ cm, and the paralytic shifting point was $2.09 \pm 2.11$ cm. The middle point calculated from the non-paralytic shifting point and paralytic shifting point was $1.09 \pm 1.06$ cm with eyes closed. The coefficient of correlation between each parameter is shown in Table 2. A significant correlation was not observed between spontaneous standing point and center of gravity shifting width. However, there was a significant correlation between spontaneous standing point and other parameters. Therefore, there was a significant correlation between the spontaneous standing point and the middle point (Fig. 2-b).

DISCUSSION

Bilateral centers of gravity in the standing
position of hemiplegics have been studied in view of the loaded weight and the central points of foot pressure projected on both legs\(^1\textsuperscript{-8})\). According to these investigations the center of gravity in hemiplegics deviates to the non-paralytic side, being influenced by the decreased weight distribution on the paralyzed side due to motor and sensory functions. Originally the center of gravity on the body axis is centered on the mass, which can be obtained kinetically by measuring a partial mass using a measuring device for the center of gravity. Besides, for measurements of the centers of gravity on the bilateral (X) axis, the central point of foot pressure within the measuring time is used as a substitute for the center of gravity\(^1\textsuperscript{11})\). The mean of deviation in the X axis, the index used in this study, can be considered as the two-dimensional point of the center of gravity on the bilateral axis.

In this study using hemiplegics in a spontaneous standing position a relation between the point of the center of gravity and the middle point on the bilateral axis was revealed. The middle point is the center of two central points of foot pressure when the center of gravity is shifted maximally between the non-paralytic and paralytic sides and retained. Meanwhile, when the distances of the shifted centers of gravity are equal, the middle point is located in the center. Based on this result, a significant correlation was noted between the middle points obtained from the center of gravity and the distance of bilaterally shifted centers of gravity in a standing position with the eyes open and closed respectively. A similar result was obtained in a previous study into the point of the center of gravity in a sitting position. The results suggest that even in a standing position the bilateral points of the centers of gravity in hemiplegics are influenced by the functional state of the paralyzed leg, and although it is rather deviated to the non-paralytic side, basically it is determined by the relative positions indicated by two indices: the distance of the centers of gravity shifted in maximum activity to the non-paralytic side and another to the paralytic side. In other words, it might be possible to say that the center of gravity in the standing position of hemiplegics is determined by the patient’s own recognition of possible relative behavior presented by the paralytic and non-paralytic sides. Thus, the greater the distance of the center of gravity shifting to the non-paralytic and paralytic sides, the further the center of gravity deviates to the other side. This suggests that in physiotherapy, even if the functions on the non-paralytic side are sufficient, there is a risk of producing a greater distance of shift by the repeated exercise of shifting the center of gravity to the non-paralytic side. Thus, in physiotherapy for hemiplegics, it is recommended not to emphasize the practice of shifting the center of gravity, but to have much more concern for body symmetry. In future it will be necessary to study relations to other factors influencing the center of gravity in the standing position of hemiplegics. In addition, it will also be necessary to analyze the differences between eyes open and closed to study precisely the influence of visual sense.

**REFERENCES**

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