Posturography in Patients With Stroke
Estimating the Percentage of Body Weight on Each Foot From a Single Force Platform

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Background and Purpose—Posturography in patients with stroke is widely based on the use of a single force platform and the weightbearing asymmetry quantified from the lateral shift of the center of pressure toward the sound leg. Because the percentage of body weight on each side is a more concrete variable, the present study analyzed the possibility of inferring percentage of body weight from center of pressure.

Methods—Forty-five hemiparetic subjects were asked to stand on a dual platform in a standardized position 3 months after a hemispheric stroke. First, the relationship between the %BW on each foot and the lateral shift of center of pressure was established. Second, the model was tested with a healthy subject standing on a single force platform.

Results—The percentage of body weight may be simply modeled from the center of pressure shift, a center of pressure displacement of 10 mm corresponding to a 5% increase in body weight on this side (r=0.97, P<0.001). This linear model is reliable, accurate, and may be generalized to other stand widths.

Conclusions—This finding should be useful for constructors and users of single force platforms, especially those involved in posturographic assessments of asymmetric conditions such as hemiparesis. (Stroke. 2008;39:489-491.)

Key Words: posturography ▪ stroke ▪ weightbearing asymmetry

Posturography in patients with stroke is widely performed with single force platforms,1,2 which may quantify the weightbearing asymmetry through the lateral shift of the center of pressure (CPRes) toward the sound leg but cannot directly measure the %BW on each foot, which requires dual force platforms. To infer the %BW from the data of one force platform, we have investigated the relationship between the %BW distributed between both legs and the shift of center of pressure (CP) in patients with stroke.

Methods
Subjects
Forty-five hemiparetic patients (12 females, 33 males) with a first, recent hemispheric stroke participated in the study: time since stroke 98.0±50.1 days, age 59.0±13.7 years, and 19 right and 26 left hemispheric lesions. All followed a rehabilitation program in a neurological rehabilitation unit and gave informed consent to the study in accordance with the guidelines of the local ethics committee. They were able to stand up for 40 seconds without technical or human aid. One healthy subject also participated in the study.

Posturography on a Dual Force Platform
Postural sway was measured with barefoot subjects placing their feet on 2 rectangular force platforms (width [w]: 21 cm, length [l]: 32 cm; PF02, Equi+) in a standardized position (heels 9 cm apart, toe out at 30°), arms hanging freely along the body, eyes open.3 They were instructed to sway as little as possible for 4 trials of 32 seconds separated by seated rest periods ranging from 1 to 3 minutes.

The %BW placed on each foot, the left and right foot CP displacements (CPLF and CPRF), and the CPRes were estimated according to the method described by Winter et al4 (see equations in figure captions). The CP positions were calculated with regard to a referential defined by the mediolateral axis passing behind the heels and the sagittal axis passing between the 2 feet. A positive CP position indicated a shift toward the more loaded leg.

Posturography on a Single Force Platform
One healthy subject stood barefoot on a commercial single force platform (Winposture NV 1.25; Medicapteurs) in the same position as the patients with stroke on the dual force platform (see previously). This subject was asked to successively stand 10 seconds on the left foot (100% of BW on left foot), 10 seconds symmetrically on both feet (50% of BW on each foot), and 10 seconds on the right foot (100% of BW on right foot).

Statistical Analysis
The relationship between %BW and the lateral CPRes position was analyzed using Pearson correlation and linear regression. The linear regression equation was then used to estimate BW distribution on the single force platform.
Figure 1. Typical weightbearing asymmetry and CP trajectories recorded from a left hemiparetic patient 2 months after his stroke. The CP_{paretic} and CP_{nonparetic} lateral shifts were estimated from the vertical forces $F_{i}$ recorded by the 4 load cells of each platform (left border: $F_{1}$ and $F_{2}$, right border: $F_{3}$ and $F_{4}$):

$$\text{CP} = \frac{1}{2} \sum_{i=1}^{4} \frac{(F_{i} + F_{i+1}) - (F_{i+2} + F_{i+3})}{W}. $$

The CP_{res} lateral shift was computed from CP_{paretic} and CP_{nonpar-}etic displacements and from the %BW (7)

$$CP_{res} = CP_{paretic} \times BW_{paretic} + CP_{nonparetic} \times BW_{nonparetic}. $$

Results

In patients with stroke, the %BW applied on the nonparetic leg in the standing position was on average $63 \pm 11\%$ resulting in a CP_{res} shift of $25.6 \pm 22.0 \text{ mm}$ in the same direction (Figure 1).

These 2 variables were highly correlated ($r = 0.97, P < 0.001$) and well related by linear regression ($F = 590.121, P < 0.001$; Figure 2). The coefficient of determination was 0.93 showing that approximately $93\%$ of BW variation was explained by the model. The regression equation (BW_{charged} = $0.5 \times CP_{res} + 50$) means that a CP_{res} displacement of 10 mm indicates a 5% increase of BW on that side. The error of the estimate with this linear regression was 0.03.

Figure 3, in a healthy subject, shows that the %BW variations on the right foot estimated from the linear regression equation were identical to the CP_{res} variations measured by the single force platform.

Discussion

Posturography is routinely performed as a guide for stroke rehabilitation. It makes it possible to quantify postural asymmetry and instability and to analyze the recovery course of the standing posture. Posturography is mainly performed with single force platforms. Posturography can measure the %BW of each foot, with heels 9 cm apart, toe out at 30°, and 10 seconds on the right foot. The upper axis shows the corresponding %BW on the right foot calculated from the linear regression equation BW_{charged} = $0.5 \times CP_{res} + 50$ established from the results obtained with 45 patients with stroke on a dual force platform.

Posturography is mainly performed with single force platforms that cannot measure the %BW on each foot but quantify the weightbearing asymmetry from the CP_{res} lateral shift. The %BW can be calculated from the position of the CP under each foot. When one needs more precise and documented assessments of both %BW and postural instability over a longer period of time (>30 seconds), with a view to monitoring a follow-up for instance, posturography is required. Posturography is mainly performed with single force platforms that cannot measure the %BW on each foot but quantify the weightbearing asymmetry from the CP_{res} lateral shift. The %BW can be calculated from the position of the CP under each foot and their result according to a linear relationship.

To get the %BW from the CP_{res}, obtained with a single force platform, it was necessary to calculate the slope of the linear regression between the 2 variables. Because the weightbearing asymmetry of patients with stroke ranges from 50% to 90% of the BW on the sound leg, patients with stroke were the ideal subjects for such a study. The present study revealed that, with heels 9 cm apart, toe out at 30°, the additional %BW on one foot can be simply obtained by dividing the

$$BW_{y} = \frac{(R_{x}y) - (R_{x} + R_{y})}{y = 0.5x + 50, R^2 = 0.93}. $$

Figure 2. Linear regression between the mean CP_{res} position and the %BW on the nonparetic leg ($n=45$ patients with stroke). The equation of the linear regression and the coefficient of determination ($R^2$) are given. The %BW placed on each foot was computed from the vertical reaction forces of left ($R_{x}$) and right feet ($R_{y}$):
CP_{ref} shift by 2, a very convenient model for a clinical context. Could this model be generalized for any stance width? From a theoretical point of view, adaptation of the slope coefficient would be enough to generalize the model. Based on the results obtained in the healthy subject, the total BW on one foot corresponds to a CP shift of 100 mm from the midline or of 55 mm from the heel, the heels being 45 mm off the midline (9 cm apart) when the foot is placed at toe out 30°. The model could thus be: \%BW=[50/(D/2+55)]×CP_{ref}+50 \quad (D=distance \text{ between \ the \ heels}). This does not take into account the possible variation of the mean position of the CP under each foot or a different orientation of the foot, but it may be negligible if the feet are oriented identically.

These findings could be useful for constructors and users of single force platforms, the most widely used postural assessment tool in stroke. Recently, some papers have pointed out the interest of carefully analyzing the behavior of the CP under each foot in patients with stroke, which requires a dual force platform. Interpretation of these data remains relatively complex for a clinical context, and such a technique is so far rather dedicated for research.

Disclosures
None.

References