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The Analysis of Tracking Motion in Standing Posture Using Multiple Regression Analysis Method

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SUMMARY In order to investigate the dynamic balance function, we have studied about the tracking motion in standing posture. We have analyzed the motion using the multiple regression analysis method. It is found that the regression coefficients indicate the characteristics of the motion.

1. Introduction

Postural control is widely studied by various methods. But there are few reports about the dynamic balance in standing posture except Ohnishi's study(1). Dynamic balance function is basic and important ability for activities of our daily life including locomotion.

Therefore, we have studied about the tracking motion of the point of application of floor reaction force (zero moment point, ZMP(2)). The purpose of our study is to investigate dynamic balance function of normal and pathological persons.

For this study, we have developed a system using a micro computer with a force plate which can measure floor reaction force. The experiment is that the subject on the force plate shifts his body weight according to the reference point on the CRT display.

We have performed the experiment and analyzed the results using the evaluation parameters, rise time and mean absolute error, which are calculated from the input and output signal. Though the parameters indicate the learning effects, the reproducibility and the clinical symptoms, they can't prove the affect by aging(3). And the detailed characteristics can't be discussed by the parameters sufficiently.

Then, we have proposed a model of the motion and analyzed the characteristics by the multiple regression analysis method. There is no study which analyzes the dynamic balance function using this method and discusses the characteristics of the motion by the regression coefficients.

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2. System and Experiment

A block diagram of the system is shown in Fig. 1. The floor reaction force data are inputted to the computer through the amplifier and the A-D converter. During the experiment, the reference point and ZMP are shown on the display. The reference point is shown as a circle, and moved right or left from the center, according to a random step input signal. ZMP is calculated from floor reaction force data, and shown as a cross.

The subject, for preparation, should stand erect on the force plate with his legs open and adjust the position of foot to set his ZMP to the reference point on the display. The subject is instructed to track the reference point as fast and accurately as possible by shifting his body weight right or left. The duration of each trial is 60 sec. The subject shifts his body weight 6 or 8 times in one trial.

As for the normal subjects, we performed the experiments on 20 subjects in their 20s (the mean age is 25.8). To investigate the learning effect and the aging problem, the data of the 1st to the 10th trial of 9 normal subjects (20-23 years old) and of the subjects in their 30s to 60s (8 persons per each decade) have been recorded.

As for the patients, though we have recorded various disordered cases, in this report we introduce the result of the 10 patients with sensory and motor disturbance due to cervical myelopathy.

3. Multiple Regression Analysis Method

The multiple regression analysis is the method

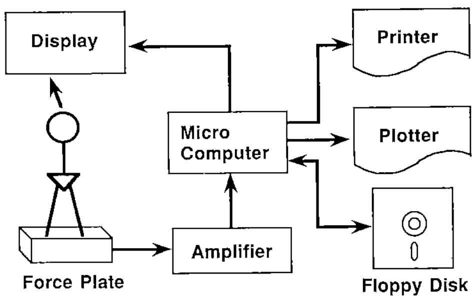

Fig. 1 Block diagram of the system. The subject stands erect on the force plate.

Table 1 Results of the multiple regression analysis. The standard regression coefficients b_1^*-b_3^*, the dead time τ, and the correlation coefficient R (mean±S. D.). The underlines mean significant difference compared with the data of the normal subjects.

subject	b^*_1	b^*_2	b^*_3	τ	R
Normal	0.968±0.010	0.164±0.036	-0.064±0.012	0.81±0.13	0.982±0.005
1st	0.958±0.017	0.187±0.079	-0.064±0.020	0.93±0.13	0.973±0.007
2nd	0.965±0.011	0.156±0.030	-0.068±0.017	0.82±0.12	0.982±0.003
3rd	0.964±0.011	0.158±0.030	-0.065±0.010	0.80±0.06	0.983±0.004
30s	0.966±0.013	0.163±0.031	-0.065±0.028	0.88±0.11	0.979±0.006
40s	0.959±0.012	0.181±0.023	-0.070±0.012	0.89±0.12	0.978±0.005
50s	0.961±0.006	0.152±0.016	-0.054±0.004	0.95±0.09	0.977±0.004
60s	0.944±0.024	0.187±0.070	-0.053±0.012	1.01±0.11	0.970±0.010
C. M.	0.958±0.013	0.157±0.032	-0.049±0.010	1.11±0.16	0.975±0.008

which can explain the relation of the criterion variable and the prediction variables by using least squares. In this study, the prediction variables are the input information used for the control by the subjects and the criterion variable is the output. And characteristics of the motion are explained by the proportion of the input information used by the subjects[4].

The inputs considered in this study to the subject are as follows:

r : reference input

e : error between input and output

$\dot{c}$: velocity of output c

Because of the step response, there are some dead time and the subjects are supposed to use the input r which was given before the dead time τ. Therefore, the regression model is given as follows:

$$\hat{c}(t)=b_0+b_1r(t-\tau)+b_2e(t)+b_3\dot{c}(t)$$

τ is decided when the correlation coefficient between the output c and the estimated output $\hat{c}$ becomes maximum. Then, the regression coefficients and the standard regression coefficients are calculated.

4. Results

The multiple regression analysis was performed on the data of the 1st to the 3rd trial, of the subjects from 30s to 60s, of the patients with cervical myelopathy as well as the normal subjects. The correlation coefficient between the output c and the estimated output $\hat{c}$ is 0.982 in the normal subjects. Therefore, the proposed model provides a good description of the tracking motion of ZMP. The results of the multiple regression analysis are shown in Table 1. And the example of simulation results is shown in Fig. 2.

Fig. 2 Example of the simulation results. The solid line and the dotted line show the output c and the estimated output, $\hat{c}$, respectively. As for c, only the first half of data are shown.

5. Discussion

We have thought that the regression coefficients, the dead time and the correlation coefficient mean as follows:

(1) The regression coefficient b_1^* indicates the contribution of the reference input to the movement of ZMP in the tracking motion. Its contribution is explained by the feedforward control[5] triggered by visual confirmation of a target.

(2) The regression coefficient b_2^* means how the visual feedback control contributes to the determination of ZMP by correction of the error between input and output.

(3) The regression coefficient b_3^* shows negative and very small values. Therefore, the information of the velocity can hardly influence the movement of ZMP in this experiment, though the negative value of b_3^* may indicate that the velocity can be used as an inhibition factor for the movement of ZMP.

(4) The dead time means the delay of the motion.

(5) The correlation coefficient R indicates the proportion of the remnant that can't be explained by the proposed model.

Therefore, the following are supposed:

(1) The subjects of the 1st trial are poor at using the reference input to shift body weight and the delay of the motion is more.

(2) The subjects in their 40s are poor at using the reference input to shift body weight.

(3) The elderly subjects (50s and 60s) and the patients with cervical myelopathy are poor at using the reference input and the information of velocity of their own body sufficiently, and the delay of the motion is more.

(4) Because of the inaccuracy of the motion, the correlation coefficients of these subjects are smaller.

6. Conclusion

We have performed the experiment of the tracking motion of ZMP in order to investigate the dynamic balance function of normal and pathological persons, and analyzed the characteristics of the motion using the multiple regression analysis.

We have found that the characteristics of the motion can be explained quantitatively by the regression coefficients, the dead time and the correlation coefficient.

From the results, we have observed that the input information is differently used in the cases of the 1st trial on the learning process, of the elderly subjects (40s to 60s), and of the patients with cervical myelopathy. Then, we indicate the probability for the clinical application.

Therefore, we can say that the multiple regression analysis is effective for this study. However, as there is the remnant that can't be explained by the proposed model, we must examine the model more profoundly. And we will analyze the difference of the dynamic balance function between the patients and the elderly persons.

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