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Reach Distance and Movement Strategy Patterns During the Functional Reach Test of Psychiatric Patients

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Abstract. [Purpose] Ability in activities of daily living of psychiatric patients is decreased because of postural control and voluntary movement disorders, and the quality of life of inpatients is also decreased. As preliminary research for evaluating standing balance of psychiatric patients, the purpose of this study was to investigate reach distance and movement strategy while subjects performed the functional reach test. [Subjects] Thirty-eight psychiatric patients and 38 healthy elderly control volunteers participated in this study. [Methods] Reach distance and movement strategy patterns were measured while subjects performed the functional reach test. [Results] The reach distance of the psychiatric patients was significantly shorter than that of the controls. The hip strategy was most often used by both patients and controls. Patients were more likely to select the ankle movement strategy than controls. [Conclusion] Based on the above findings, we speculate that the hip strategy is the ideal movement strategy for safely extending the reach distance of both psychiatric patients and controls. However, psychiatric patients were more likely to select the ankle movement strategy than controls.
Key words: Psychiatric patients, Functional reach test, Movement strategy

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INTRODUCTION

Effective treatment of psychosis involves the use of antipsychotic medication. Schizophrenia is an especially serious chronic illness that requires lifelong medication[1,2]. However, various side effects are caused by antipsychotic medication. For example, extrapyramidal symptoms (EPS) are often induced by typical antipsychotic medication that is effective for schizophrenic patients[1,2]. In addition, EPS can result from atypical antipsychotic medications[3]. EPS such as Parkinsonism, dystonia, and tardive dyskinesia cause postural control and voluntary movement disorders in psychiatric patients[4–8]. Psychiatric patients' ability to perform activities of daily living (ADL) is decreased because of postural control and voluntary movement disorders, and the quality of life (QOL) of inpatients is also decreased. In addition, hyperprolactinemia is induced by antipsychotic medication[2,9] and leads to osteoporosis in some patients[10,11]. Bone fractures may occur if osteoporotic patients fall.

In schizophrenic patients, postural control and voluntary movement disorders are also associated with the illness itself and are not always side effects of antipsychotic medication[12–14]. Schizophrenic patients also face problems with regard to postural control when standing[15]. If patients suffer bone fractures due to falls, then disuse syndrome may occur, resulting in a decrease in ADL. Although determining the cause of postural control or voluntary movement disorders is difficult, physical therapy (PT) for psychiatric patients can improve postural and movement control. Therefore, to prevent decline of ADL ability, we have to develop objective evaluation methods for standing balance of psychiatric patients.

While many methods are available for the evaluation of standing balance, the functional reach test (FRT) is an effective assessment of dynamic stability in the standing posture. FRT, developed by Duncan et al.[16], measures the maximal distance a subject can reach forward beyond arm's

length while maintaining a fixed base of support in the standing position. The test can be easily performed in homes, hospitals, nursing homes, and outpatient clinics; it demonstrates excellent precision and interobserver reliability. Although some reports state that reach distance is correlated with fall risk and ADL level[17–20], some reports also state that reach distance is not correlated with ADL level[21]. This discrepancy may relate to differences in movement strategy in FRT. Therefore, we believe that analyzing movement strategy in addition to measurement of reach distance in FRT is important to fully evaluate dynamic stability in the standing position.

Ankle and hip movement strategies are used during forward reach in the standing position. The ankle strategy is one of the first to be identified for controlling upright sway by restoring the center of mass (COM) to a position of stability through body movement centered primarily about the ankle joints[22]. In the ankle strategy, both COM and center of pressure (COP) shift in the anterior direction during forward reach in the standing position. On the other hand, the hip strategy controls the COM motion by producing large and rapid motions at the hip joints with antiphase rotations of the ankles[22]. In the hip strategy, although COM shifts in the anterior direction with hip flexion, COP shifts in the posterior direction with ankle plantar flexion. Therefore, the ankle strategy is considered more difficult than the hip strategy for the control of dynamic stability in FRT.

We have to develop an objective evaluation of dynamic standing balance for psychiatric patients to use in PT. As preliminary research for evaluating standing balance of psychiatric patients, we investigated reach distance and movement strategy in FRT.

SUBJECTS AND METHODS

This study was approved by the ethical committee of Sephiroth Health Care, Nagahama Seijukai Hospital. The study procedures, risks, and benefits were explained both verbally and in writing to all participants. All participants provided their written informed consent prior to their participation.

Thirty-eight psychiatric patients (21 males and 17 females, mean age and SD: 63.7 (10.4) years) and 38 healthy elderly control volunteers (15 males and 23 females, mean age and SD: 68.0 (0.9) years) participated in this study. The psychiatric patients included 34 inpatients with schizophrenia, 1 inpatient with mild mental retardation, 1 with depression, and 2 experiencing the effects of alcohol diagnosed using ICD-10. The patients could walk without canes or other support devices in the ward. Although all patients were taking some antipsychotic (typical or atypical and mixed), antianxiety or antidepressant medications, patients could walk without severe side effects of medication. Therefore, we considered that the patients' standing balance was unlikely to have been influenced by differences in kind or quantity of antipsychotic medication. The mean illness history and SD of the patients was 32.3 (12.3) years.

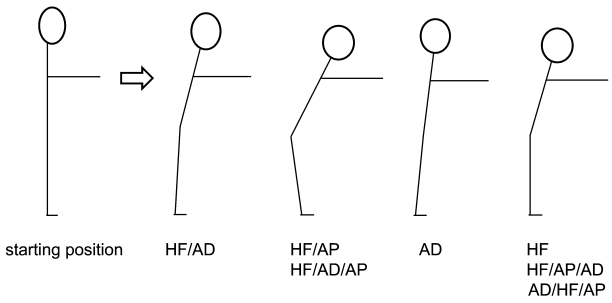

Fig. 1. Movement strategy patterns during FRT
These stick pictures show the terminal phase of standing postures in FRT. The order of joint movements differed, although HF/AP and HF/AD/AP resulted in almost the same posture in the terminal phase of FRT (HF→AP and HF→AD→AP). Also, the order of joint movements differed, although HF, HF/AP/AD and AD/HF/AP resulted in almost the same posture in the terminal phase of FRT (only HF, HF→AP→AD and AD→HF→AP).

FRT was performed using the "yardstick" method reported by Duncan et al.[16]. Subjects were asked to remove their shoes and socks and assume an upright standing position with their feet separated at shoulder width. Subjects elevated their left arm horizontally at approximately 90 degrees with extended elbow and grip hand at the starting position in FRT. Then, subjects were asked to reach as far as they could without losing their balance or taking a step. Each subject was given 2 practice trials and 3 test trials as described by Duncan et al.[16] and the results of the 3 trials were analyzed (38 patients × 3 test trials, 38 controls × 3 test trials, total 228 sets of FRT data). To investigate movement strategy during FRT, the subjects were recorded in the sagittal plane using a digital video camera (Xacti SANYO, Japan) at a frequency of 60 Hz. The order of joint movement was analyzed using the pictures recorded by the digital video camera, and movement strategy patterns during FRT were determined. Patterns were analyzed by 2 physical therapists and classified into 7 patterns during forward reach (Fig. 1): only hip flexion (HF); hip flexion followed by ankle plantarflexion (HF/AP); hip flexion followed by ankle dorsiflexion (HF/AD); hip flexion followed by ankle dorsiflexion and ankle plantarflexion (HF/AD/AP); only ankle dorsiflexion (AD); ankle dorsiflexion followed by hip flexion (AD/HF); and ankle dorsiflexion followed by hip flexion and ankle plantarflexion (AD/HF/AP).

After data normality was confirmed using the Shapiro-Wilk test, reach distances of the psychiatric patient and control groups were compared using the Mann-Whitney test. Furthermore, reach distances for each movement strategy pattern were compared using the Kruskal-Wallis test and Scheffé's post hoc test. Statistical analyses were performed using SPSS version 17.0 (SPSS Inc. Chicago, IL, USA).

RESULTS

The mean reach distances and SD of the patient and control groups were 29.6 (7.9) cm and 35.2 (4.9) cm, respectively. The mean reach distance of patients was

significantly shorter than that of controls ($p<0.001$). Table 1 shows the mean reach distances of males and females. For males, the mean reach distances and SD of patients and controls were 31.1 (7.9) cm and 35.0 (5.1) cm, respectively, and for females, they were 27.7 (7.5) cm and 35.3 (4.7) cm, respectively. The mean reach distance of patients was significantly shorter than that of controls regardless of gender (males: $p<0.05$, females: $p<0.001$).

Movement strategy patterns are shown in Table 2. For the patients, movement strategy patterns were as follows: HF/AP, 58.8% (67 times/114 times); AD/HF/AP, 17.5% (20 times/114 times); AD/HF, 8.8% (10 times/114 times); HF, 6.1% (7 times/114 times); HF/AD, 6.1% (7 times/114 times); AD, 1.8% (2 times/114 times); and HF/AP/AD, 0.9% (1 time/114 times). For controls, movement strategy patterns were as follows: HF/AP, 77.2% (88 times/114 times); AD/HF/AP, 2.6% (3 times/114 times); AD/HF, 1.8% (2 times/114 times); and HF, 18.4% (21 times/114 times). The HF/AD, AD, and HF/AP/AD movement patterns used by patients were not used by controls. Thus, ankle movements were fewer in controls than in patients.

Reach distances of each movement strategy pattern are shown in Table 3. The reach distance using HF was the shortest and was significantly shorter than those of HF/AP, AD/HF/AP and AD/HF performed by patients ($p<0.01$, $p<0.001$ and $p<0.01$, respectively). The reach distance of controls when using HF was also the shortest and it was significantly shorter than that of HF/AP ($p<0.001$).

Table 1. Reach distances of the patient and control groups

	patients	controls	
male	31.1 (7.9)	35.0 (5.1)	*
female	27.7 (7.5)	35.3 (4.7)	***

Upper values indicate mean reach distance (cm) and the lower values indicate SD. Reach distance of the patient group was significantly shorter than that of the control group. *$p<0.05$, ***$p<0.001$.

DISCUSSION

FRT can be easily performed in homes, hospitals, nursing homes, and outpatient clinics. It demonstrates excellent precision and interobserver reliability[16]. Reach distance correlates with fall risk and ADL level[17,18,20]. A relationship between extension of reach distance and improvement of the functional independence measure (FIM) has also been shown in the rehabilitation of patients with cerebrovascular disease[19]. In this study, the mean reach distance of the psychiatric patients was significantly shorter than that of controls, for both males and females.

Duncan et al.[16] reported that the mean reach distances of males and females are 38.1 (5.6) cm (14.98 (2.21) inches) and 35.1 (5.6) cm (13.81 (2.20) inches), respectively, for subjects aged 41–69 years. Although the mean reach distance of controls in this study was similar to the data reported by Duncan et al., the mean reach distance of the patients in this study was shorter. Based on reports of a relationship between reach distance and ADL level[17,18,20], we speculate that ADL levels of the patients were lower than those of the controls.

Duncan et al.[17] also investigated the relationship between reach distance and falling. As part of their original cohort studies of falls, subjects received a brief mobility screen to establish a risk category for falls. Subjects who could ascend and descend stairs step over step without support (rails, human, or device), were categorized as having a low risk of falls. Subjects with more impaired mobility were considered to be at higher risk of falls. Duncan et al. reported that the mean reach distances in the

Table 2. Number of times of each movement strategy pattern in 114 FRT results

	HF/AP	AD/HF/AP	AD/HF	HF	HF/AD	AD	HF/AP/AD
patients	58.8 (67)	17.5 (20)	8.8 (10)	6.1 (7)	6.1 (7)	1.8 (2)	0.9 (1)
controls	77.2 (88)	2.6 (3)	1.8 (2)	18.4 (21)	0 (0)	0 (0)	(0)

Upper values indicate % and lower values indicate number of times.

Table 3. Reach distance of each movement strategy pattern

	HF/AP	AD/HF/AP	AD/HF	HF	HF/AD	AD	HF/AP/AD
patients	30.3 (7.1)	33.7 (6.2)	30.2 (7.0)	17.0 (2.9)	27.5 (8.9)	14.5 (0.7)	29.0 (0)
controls	36.1 (4.1)	40.2 (1.9)	38.3 (0.4)	30.4 (5.4)	–	–	–

Upper values indicate mean reach distance (cm) and lower values indicate SD. The reach distance when patients used HF was the shortest and it was significantly shorter than those of HF/AP, AD/HF/AP or AD/HF ($p<0.01$, $p<0.001$ and $p<0.01$, respectively). The reach distance when controls used HF was also the shortest and it was significantly shorter than that of HF/AP ($p<0.001$).

low and high risk of falls groups were 30.8 (6.9) cm (12.14 (2.7) inches) and 18.8 (11.9) cm (7.4 (4.7) inches), respectively. Furthermore, they reported that the risk of falls increased more below a reach distance of 25.4 cm (10 inches). The mean reach distance of patients in this study was 29.6 (7.9) cm. Although the mean reach distance was longer than that of the high risk falling group reported by Duncan et al., some individual short reach distances were observed among these patients.

The patients used 7 movement strategies in FRT, but only 4 patterns were observed in controls. The most frequently used pattern in both the patient and control groups was HF/AP (patients: 58.8%, controls: 77.2%). Movement strategies other than HF/AP used by both the patient and control groups were AD/HF/AP, AD/HF, and HF. The frequencies of use for these other movement patterns were 17.5%, 8.8%, and 6.1% for AD/HF/AP, AD/HF, and HF, respectively, for patients, and 18.4%, 2.6%, and 1.8% for HF, AD/HF, and AD/HF/AP, respectively, for controls. The frequency of use of the ankle dorsiflexion movement strategy was low in controls.

The ankle movement strategy restores COM to a position of stability through body movement centered primarily about the ankle joints, while the hip strategy controls the COM motion by producing large and rapid motions at the hip joints with antiphase rotations at the ankles[22]. For example, when asked to stand on a narrow beam while experiencing anterior-posterior platform displacement, most subjects shifted from an ankle to a hip strategy, and when returned to a normal support surface, they shifted back to an ankle strategy[22]. With regard to this result, both COM and COP shift in the anterior direction with ankle dorsiflexion in the ankle strategy. On the other hand, although COM shifts in the anterior direction with hip flexion, the degree of the COP motion can be decreased with ankle plantarflexion in the hip strategy. Therefore, to maintain the standing posture on the narrow and unstable platform, the hip strategy was considered an easier choice because the COM motion was controlled by the decreasing COP motion.

Some researchers have previously examined movement strategies used in FRT[23–25]. Liao et al.[23] reported that reach distance was extended when healthy adults used the hip strategy, but became shorter when they used the ankle strategy. Furthermore, the COM motion and reach distance showed correlation in the ankle strategy but not in the hip strategy. Jonsson et al.[24] showed that to extend reach distance, the anterior tilting angle of the trunk is more important than the COP motion when healthy elderly subjects used the hip strategy. Wernic-Robinson et al.[25] showed that reach distance of healthy elderly people was determined by the distance of COP to COM motion in FRT. For the above reasons, we believe that HF/AP was the hip strategy most often selected by both the patients and controls in this study as it provided the greatest reach in a safe manner in FRT. We also believe that the ankle dorsiflexion strategy was not frequently used by controls because it was easy to lose standing balance in FRT. This is most likely because both COM and COP shift in the anterior direction when the ankle dorsiflexion strategy is used.

Reach distance was longest when the AD/HF/AP strategy was used and it was significantly longer than that of the patients who used the HF/AP and HF movement strategies. Ankle dorsiflexion was the first movement in the AD/HF/AP pattern. Both COM and COP were shifted in the anterior direction by ankle dorsiflexion, and the hip then flexed to tilt the trunk forward. COM was shifted further in the anterior direction by the hip flexion. To extend reach distance, the ankle dorsiflexion and hip flexion pattern is the ideal strategy. However, COM shifts to the anterior part of the base of support in this movement strategy, and if COM deviates from the base of support, the subjects will lose their balance. Therefore, we consider that COM motion was regulated to shift COP in the posterior direction through ankle plantarflexion. Based on the above findings, we speculate that AD/HF/AP is the ideal movement strategy for extending reach distance safely for both patients and controls.

In this study, the movement strategy of ankle dorsiflexion was often used by patients, though movement strategies using ankle dorsiflexion were seldom used by controls (AD/HF/AP, 3 times; AD/HF, 2 times). Although AD, i.e., the ankle strategy and AD/HF or HF/AD are ideal movement strategies for extending reach distance, it is easy to lose standing balance using these strategies because both COM and COP shift largely to the anterior of the base of support. We wondered why patients often used the ankle dorsiflexion movement strategy. COP of schizophrenic patients possibly sways more in the anterior-posterior direction during standing than that of healthy subjects because of the structural abnormalities of the cerebellar vermis of these patients[12]. We also believe that standing balance is easier to maintain using the ankle strategy as the main movement strategy because both COM and COP sway in the anterior-posterior direction during upright standing. Therefore, to reach forward from the upright standing posture, we consider the ankle strategy was the easiest for the patients to use. To extend reach distance, it is necessary for COM to be shifted in the anterior direction first using ankle dorsiflexion. However, patients could not maintain COM and COP on the base of support using the ankle plantarflexion strategy during the second step. The ankle plantarflexion of schizophrenic patients may not be able to regulate COM and COP motions in FRT because schizophrenic patients may exhibit a disturbance in the control of muscle force[13], and also because psychiatric patients have difficulty maintaining standing balance[15].

According to the results of this study, coordinated movements of the ankle and hip appear to be important for extending reach distance safely in FRT. Therefore, performing range of motion exercises and muscle strengthening exercises of the ankle and hip followed by static and dynamic balance exercises is important for PT. However, PT for psychiatric patients is not performed very actively in our country. Based on our findings, we consider that active therapeutic exercises for the hip and ankle joints are very important for improving the ADL and QOL of psychiatric patients.

A limitation of this study was that the influence of side

effects of medication could not be clarified because the patients' illness histories were long and patients were taking various kinds of antipsychotic medication. In the future, we will also investigate the effects of PT considering the relationship between standing balance and antipsychotic medications.

In conclusion, as preliminary research for evaluating the standing balance of psychiatric patients, we investigated reach distance and movement strategy in FRT. Reach distance of the psychiatric patients was significantly shorter than that of controls. HF/AP, i.e., the hip movement strategy was most often used by both patients and controls. Patients were more likely to select the ankle movement strategy than controls.

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