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The Effect of Seat Incline Angle in Hemiplegic Patients' Standing up Training

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Objective: This study analyzes the effect of angle conditions of rehabilitation equipment used for supporting hemiplegic patients on their rehabilitation training for standing action. The study was performed by adjusting the rear angle of seat inclination through a motion analysis.

Background: Owing to a loss of muscle rigidity and degradation of muscle control ability, hemiplegic stroke patients suffer from asymmetrical posture, abnormal body balance, and degraded balance abilities due to poor weight-shifting capacity. The ability to shift and maintain one's weight is extremely essential for mobility, which plays an important role in our daily life. Thus, to improve patients' ability to maintain weight evenly and move normally, they need to undergo orthostatic and ambulatory training.

Method: Using a motion analysis system, knee movements on both hemiplegic side and non-hemiplegic side were measured and analyzed in five angles (0˚, 10˚, 30˚, 50˚, 70˚) while supported by the sit-to-stand rehabilitation equipment.

Results: The knee movements on both sides increased as the angle increased in angle support interval to support a hemiplegic patient's standing up position. In standing up interval, a hemiplegic patient's knee movement deviations on both sides decreased, and the movement differences between hemiplegic and non-hemiplegic legs also decreased as the angle increased.

Conclusion: The results of this study showed that the rehabilitation effectiveness increases as the angle increases, leading to a balanced standing posture through the decrease of movement difference between hemiplegic and non-hemiplegic sides and an improved standing up ability through the increase of knee movement on both sides. However, angles higher than 50˚ didn't provide a significant effect. Therefore, a support angle under 50˚ was proposed in this study.

Application: The results of this study are expected to be applicable to the design of sit-to-stand support equipment to improve the effectiveness of the rehabilitation process of hemiplegic patients.

Keywords: Standing up training equipment, Hemiplegic patient, Knee moment, Motion Analysis

1. Introduction

Korea has entered an aging society (population aged 65 or over is more than 7%), with the aged people's ratio surpassing 11.0% in 2010. Korea is projected to enter an aged society (population aged 65 or over is more than 14%) and to enter a super aged society (population aged 65 or over is more than 20%) in 2026. According to the increase in aged population, cerebrovascular patients such as stroke patients increase socially, and the patients with post-disability of stroke are also on the rise.

Stroke refers to brain damage by cerebrovascular rupture or blockage and causes neurological symptoms including the loss of motor function, paresthesia, cognitive and linguistic disorders, and coma (Burnfield et al., 2012). To minimize the disabilities of those who suffer from functional disabilities and for fast return to daily life, rehabilitation exercise is needed. Repetitive training in the rehabilitation of stroke patients is essential to the induction and retention of brain plasticity (Cooke et al., 2010).

Butefisch et al. (1995) reported that the repetitive training of the curvature, and the expansion movements of the finger function at the hemiplegic side in 27 hemiplegic patients were more effective for finger function recovery such as grip than general treatment. Kawahira et al. (2010) reported that repetitive training repeating five types of motions of legs more than 100 times a day in high intensity was effective to the legs' motion function recovery among hemiplegic patients.

The Korea Critical Paths for the rehabilitation treatment of stroke in Korea reported that the increase in rehabilitation treatment time had an effect in increasing functional recovery in terms of treatment intensity. It reported that the differences in treatment time of the patients with stroke within six months of its occurrence caused significant functional recovery differences. The Korea Critical Paths recommended an opportunity to repeat functional training (Kim, et al., 2009).

As repeated exercise is needed to learn motor techniques in motor learning, repetitive training is also necessary to acquire new behaviors or learn past behaviors again. Although the increase of treatment intensity by increasing rehabilitation treatment time as much as possible is helpful to a patient's functional recovery, there are limitations to actual clinical application due to the issues of a patient's adaptation, the number of rehabilitation therapists, a therapist's interest, and a rehabilitation therapist's workload burden (Galvin et al., 2008). Therefore the rehabilitation training equipment, with which consistent and repetitive training can be performed and therapist's burden can be reduced, is being developed.

The standing up training equipment among rehabilitation training devices helps maintain the standing posture or supports the standing motion of hemiplegic patients. Even though there are various previous studies on the use of the training equipment, they are mostly on clinical effectiveness according to a patient's rehabilitation use, or on human motions upon normal people's rehabilitation use. Therefore there are few studies on effect and support optimization according to the support provided by standing up training equipment. In this regard, this study aims to propose a suitable seat angle by analyzing standing support effect according to the seat angle of the training equipment, which supports standing up by increasing the seat angle.

2. Standing-up Training Equipment

The International Organization for Standardization (ISO) defines rehabilitation equipment as a thing, equipment, apparatus or system used by disabled people, especially manufactured for disabled people, or produced as ready-made goods, in order to prevent, preserve, relieve or neutralize disabilities, damages, and social disadvantages.

The standing up training equipment is mainly used for the rehabilitation of patients with brain lesions. A brain lesion means a complex disability due to damage to central nerves; therefore, people with brain lesions are restricted in walking or daily life because of a brain's organic lesion, causing such impairments as cerebral palsy, brain damage, and stroke. To be specific, stroke refers to brain damage caused by cerebrovascular rupture or blockage, causing neurological symptoms including the loss of motor function, paresthesia, cognitive and linguistic disorders, and comatose.

A stroke patient shows hemiplegic symptoms by which the muscles on the opposite side of the damaged brain are paralyzed. Due to muscle rigidity and degraded muscle control capacity at the hemiplegic side, about 51~81% of one's entire weight is concentrated in the non-hemiplegic leg (Sackeley and Bauley, 1993), motor ability is reduced, or the capacity to maintain weight symmetrically or to move decreases. Difficulties are entailed in taking dynamic posture such as walking or exercising because of the gradual weakness of the upper and lower extremities created by such an asymmetry. Therefore, daily life and social activities are reduced due to the abnormality of balance and walking, separation movement of truncus and four limbs, and to-and-fro pelvic movements (Dijkeman et al., 2004). Consequently, a post-stroke hemiplegic patient has a huge risk of fall during a shift exercise to stand from a sitting posture. Rehabilitation exercise is needed to minimize a hemiplegic patient's functional disability and for a quick return to daily life after a stroke.

According to Bruunstrom stage, the rehabilitation exercise of a hemiplegic patient is carried out in the six following stages: Stage 1 - No movement at all, Stage 2 - Rigidity appears, Stage 3 - Muscle rigidity reaches peak, Stage 4 - Muscle rigidity is reduced and movements are recovered, Stage 5 - Voluntarily movable, and Stage 6 - Rigidity disappears and individual joint movement is possible. From Stages 1 to 3, pain relief treatment is conducted, and from Stage 4, functional exercise starts.

Standing up training is the one prior to walking training, and is carried out for the patients in Stage 4. While standing up, training for ability to evenly distribute weight to both sides and exercise to support weight with the hemiplegic leg are performed. For functional recovery enhancement (functional recovery: mobility capacity and daily life behavioral function improving through a patient's efforts and rehabilitation therapy in the state of sustaining neurological damage), position maintenance training, passive/active joint movement exercise, and gradual resistance exercise are carried out, as well as standing up training (Paik, 2001).

Standing up training enables a patient to perceive the hemiplegic side and is effective for the improvement of the hemiplegic side's sensory function, normalization of muscle tension, and reduction of spasm. Standing up training also enables a patient to enhance his/her ability to maintain weight symmetrically and move. Standing up training prevents orthostatic hypotension and bedsore and is effective for a leg's weight load training, blood circulation promotion, joint building up, and transformation prevention. The type of standing up training equipment can be divided into standing up posture type and standing up motion support type according to support mode and purpose (Figure 1).

Figure 1. Standing up training equipment

Kuznetsov et al. (2013) evaluated rehabilitation effects according to the use of standing up training equipment using blood pressure, electrocardiogram (ECG), and blood flow rate over three months targeting post-stroke hemiplegic patients. Rea et al. (2013) researched normal standing up motion by analyzing the center of gravity (COG) upon standing movement from a chair targeting normal people, and studied the development of standing up training equipment. Burnfield et al. (2012) analyzed whether standing up training equipment supports standing up motion with accurate motion through a comparative analysis of human body motion mechanism and general standing up motion mechanism according to the use of the standing up training equipment in the mode of existing standing up motion support.

Jeyasurya et al. (2013) studied standing up support effects according to representative standing up support modes (seat assist, waist assist belt, arm assist, and bar assist) of the currently distributed standing up training equipment through motion analyses targeting normal people. Most previous studies on standing up support equipment were carried out to check whether accurate standing up motion support was made by comparing human body motion's mechanisms for standing up. They were mostly carried out targeting normal people, rather than patients with disabilities, who are the main users of standing up training equipment. Also, studies on standing up support effects according to seat angle, which is an important design variable in the support of standing up motion support, were lacking.

Therefore this study aims to examine standing up support effects according to seat angle support conditions among standing up motion support modes targeting post-stroke hemiplegic patients, who are the main users of standing up training equipment. Consequently, this study aims to provide results that can be utilized as an important guidance for future standing up training equipment design.

3. Experiment Method

3.1 Subjects

Standing up motion is for hemiplegic patients' standing up training, and is the training prior to the training for walking. To analyze the effects of the standing up support angle of the standing up training equipment, which is an independent variable, this study selected hemiplegic patients with more than six months of occurrence of the disease, who could stand up independently without using a handle or stick that can affect the experiment result.

Ten subjects with hemiplegia participated in the experiment, and their mean age was 58.9 (58.9±4.9), their mean height was 145cm (1450.4±446.9mm), their mean weight was 65.4kg (65.4±12.5kg), and their mean Body Mass Index (BMI) was 25.88kg/m^2 (25.8±2.8kg/m^2). The subjects consisted of four left side hemiplegic patients and six right side hemiplegic patients. Out of those 10 subjects, five experienced a fall accident, five were using support equipment, and three had sensory disability.

3.2 Experiment method

The experimenter collected basic information among the subjects, such as their disease history, experience of fall accident, walking state, status of pain, status of sense, daily life and social activities, and basic physical information including weight and BMI. Afterwards, the subjects were instructed to wear clothes for experiment, while reflection markers were attached to the subjects for motion analysis. The experimenter explained the sitting position and location for the experiment, and the experiment was carried out after experimental motions were practiced.

To analyze standing up support effects according to the seat incline angle of the standing up training equipment, the experiment was carried out with five seat angles (0˚, 10˚, 30˚, 50˚, and 70˚). When a subject sits, the seat is tilted and thus the standing up motion is supported (Figure 2). The experiment motion was set up as standing up motion after each seat angle support condition is finished in the sitting state with 0˚ in seat angle. This study set up the seat height as a subject's popliteal height, based on previous studies, in consideration of subjects' various body types (Schenkman et al., 1990).

Figure 2. Experiment scene

4. Results

For standing up motion analysis of hemiplegic patients according to the seat incline angle of the standing up support equipment, this study divided the subjects' motion into ① angle support section and ② standing up section. The seat support section is the section receiving angle support from the equipment as much as the set up incline angle by sitting on the seat with 0˚ in seat angle. The section refers to the beginning to the ending section of angle support. The standing up section is the section where a subject stands up after he/she receives standing up support as much as the set up seat incline angle from the standing up support equipment. The section refers to the beginning to the ending section of standing motion.

In the angle support section, this study identified how the ease of standing up for standing up training changes according to angle through knee movement analysis occurring to the knee at non-hemiplegic and hemiplegic sides, while a subject receives standing up support as much as the set up seat angle. In the standing up section, this study grasped the hemiplegic patients' standing up motion characteristics by analyzing hip flexion angle and non-hemiplegic side and hemiplegic side knee movement change according to standing up support angle.

4.1 Knee movement analysis in standing up support interval

Figure 3 shows the graphs of non-hemiplegic side and hemiplegic side knee movement change in the angle support section from the beginning to the end of standing up support. The blue graph shows the subjects' non-hemiplegic side knee movement, and the green graph shows the hemiplegic side knee movement. As the angle support condition increases, knee movement continuously increases, but it was confirmed that knee movement increased after angle support began at 70˚, but the knee movement did not increase any more at higher than a certain angle, and was converged. From Figure 4 indicating the maximum value of knee movement with seat angle, the maximum value of knee movement increased as support angle increased, and then the increase was minimal at higher than 50˚. Although standing up motion becomes easier as knee movement increases, the increase becomes minimal at higher than 50˚ as angle support increases, and no further effect is shown. Such a result can be confirmed from the ANOVA result.

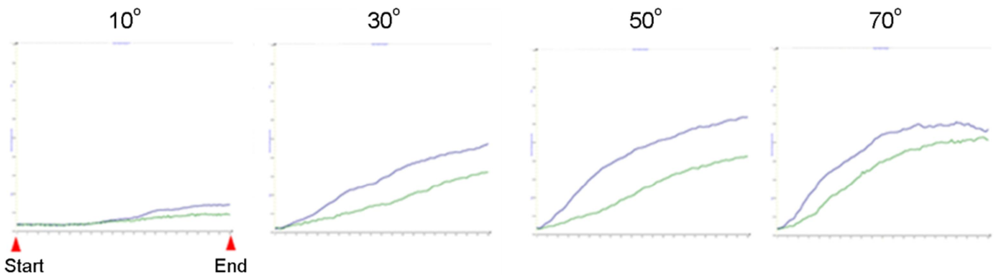

Figure 3. Knee movement with seat angle in standing up support interval

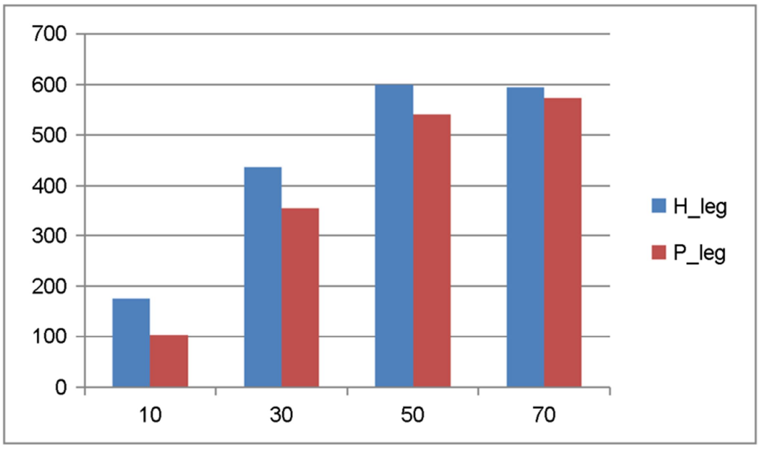

Figure 4. Maximum knee movement with seat angle

Upon looking at the ANOVA result on the maximum value of knee movement (Table 1), support angle significantly created effect at the significance level of 0.05 (non-hemiplegic side: $p=0.000<0.05$, hemiplegic side: $p=0.000<0.05$). Upon looking at the Duncan's result as a post-hoc analysis (Table 2), the angles of 50° and 70° were classified into the same group at non-hemiplegic and hemiplegic sides.

Table 1. ANOVA for knee movement

		SS	df	MS	F	Sig.
H_movement	B-G	831997.789	3	277332.596	20.304	.000
	W-G	327811.118	24	13658.797		
	Sum	1159808.907	27			
P_movement	B-G	979651.886	3	326550.629	17.551	.000
	W-G	446548.770	24	18606.199		
	Sum	1426200.656	27			

Table 2. Duncan's analysis (top: non-hemiplegic leg, bottom: hemiplegic leg)

Angle	N	Subgroup at significance level = 0.05		
		1	2	3
10.00	7	175.7467		
30.00	7		437.3241	
70.00	7			595.1080
50.00	7			599.8029
Sig.		1.000	1.000	.941

Angle	N	Subgroup at significance level = 0.05		
		1	2	3
10.00	7	103.0540		
30.00	7		355.5863	
50.00	7			539.8894
70.00	7			574.3987
Sig.		1.000	1.000	.640

4.2 Knee movement analysis in standing up interval

As for knee movement in the standing up section, it rapidly increases after a subject moves the center of gravity by lowering the upper body, his/her hip is off the seat, and motion amount is sent. Afterwards, the knee movement decreases, as standing up is completed. The change amount in the section of rapid increase in knee movement can be the energy required for standing up. Figure 5 shows the graphs of knee movement change from the beginning to the end of the standing up section. The blue graph shows the non-hemiplegic side, and the green graph shows the hemiplegic side.

From the graphs, the non-hemiplegic side knee movement was bigger than the hemiplegic side knee movement. From this, it is known that hemiplegic patients stand up with more weight load to the non-hemiplegic side. As left side incline angle increases, standing up starts with higher knee movement, while the knee movement decreases as standing up proceeds. The difference in knee movement at the non-hemiplegic side and hemiplegic side decreases, as incline angle support increases.

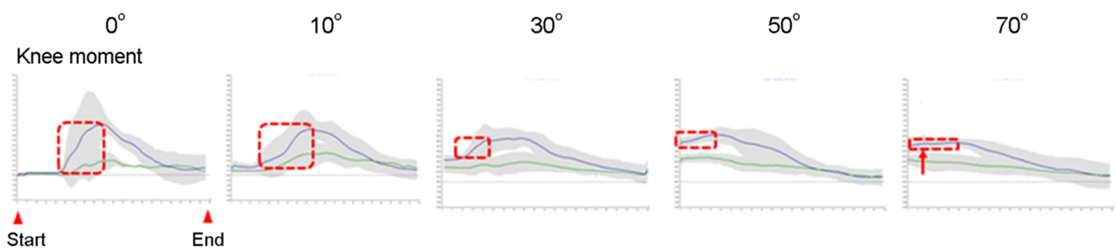

Figure 5. Knee movement with seat angle in sanding up interval

As a result of a significance analysis on the non-hemiplegic side and hemiplegic side knee movements, standing up support incline angle significantly affected the knee movement difference at the non-hemiplegic side and hemiplegic side ($p=0.004<0.05$). The knee movement decreased as incline angle increased. According to Duncan's analysis result for the same group analysis, the 50° and 70° conditions were classified into the same group. Therefore, from the knee movement result in the standing up section, the standing up support equipment's seat incline angle support improves the hemiplegic patient's knee movement prior to standing up, and makes standing up training easy. Also, the seat incline angle support enhances standing up training effects on the hemiplegic side leg by reducing the difference in the non-hemiplegic side knee movement and hemiplegic side knee movement. However, the effect increase at higher than 50° condition is not high.

5. Conclusion

This study evaluated the standing up training effects according to seat angle change of standing up training equipment through a motion analysis. The effect on standing up motion was confirmed from the result that energy required for standing up is reduced according to knee movement increase, as standing up support angle increases. As support angle increases, standing up motion's stability can be improved from the point that asymmetric weight load is reduced at the non-hemiplegic side and hemiplegic side. Also, standing up training effect was confirmed to be improved by putting more weight on the hemiplegic side leg. However, the standing up training effect did not sharply increase in the section of higher than 50° of support angle in the standing up support equipment.

As a result of the analysis in this study, rehabilitation effects can be enhanced by increasing balanced standing up and weight load at the hemiplegic side as support angle increases. However, the effect of standing up support through higher than 50° of angle support is minimal. Therefore it is not desirable to set up the standing up incline angle at higher than 50° of the standing up supporting equipment. The results of this study are expected to be applied to standing up training equipment design to enhance hemiplegic patients' standing up training effects.

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