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Development and evaluation of one-hand drivable manual wheelchair device for hemiplegic patients

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ABSTRACT

This study was conducted for one-hand users including hemiplegic clients currently using standard manual wheelchairs, so as to analyze their specific problems and recommend solutions regarding usage. Thirty hemiplegic clients who were admitted to rehabilitation and convalescent hospitals participated as subjects. The research tools were standard manual wheelchairs commonly used by people with impaired gait and a “one-hand drivable manual wheelchair,” which was developed for this study. The Wheelchair Skills Test (WST) was adopted for the objective assessment tool, while drivability, convenience, difference, and acceptability were developed for the subjective evaluation tools. The assessment procedures comprise two phases of pre-assessment and post-assessment. In the pre-assessment phase, the WST and subjective evaluation (drivability, convenience) were conducted using the existing standard manual wheelchair and with/without use of a foot to control the wheelchair. In the post-assessment phase, the WST and subjective evaluation (drivability, convenience, difference, acceptability) were also carried out using the developed one-hand drivable manual wheelchair. The results showed that the highest pass rate recorded for the WST items was 3.3% when the participants drove standard manual wheelchairs without the use of either foot and 96.7% when using the manual wheelchairs equipped with developed device. As compared to the existing wheelchair, statistical results showed significant effects on the WST, drivability, convenience, difference and acceptability when the participants drove wheelchairs equipped with the developed device. These findings imply that the one-hand drivable wheelchair equipped with the developed device can be an active and effective solution for hemiplegic clients using existing manual wheelchairs to increase their mobility and occupational performance.

1. Introduction

Stroke, also referred to as cerebrovascular accident (CVA), results from anoxia and brain necrosis. According to WHO (2013), stroke mortality in 2011 reached 6.2 million people and stroke is now the second leading cause of death. Also noticeable is the stronger emphasis placed on rehabilitation for stroke sequelae, due to the severity of the resulting impairment. Approximately two out of three stroke survivors suffer from permanent functional disability, and most stroke patients experience hemiplegia for more than six months after stroke occurrence (Kim et al., 2009; Korea Centers for Disease Control and Prevention, 2012; Williams et al., 1999). The Ministry of Health and Welfare (2011) reports that stroke, at 70.6%, is the leading cause of brain disability in Korea, and stroke occurrence shows persistent increase since the 2005 survey. Stroke patients with impairments and disabilities need much assistance with their basic daily activities and movements.

Hemiplegia that follows a cerebrovascular accident means weakness of functions on one side of the body. The ability to maintain appropriate muscle tension and posture is weakened, control in carrying out selective movements appears abnormal, and various functional disorders are detected depending on the impaired part of the brain, size and cause of occurrence (Kim and

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Chang, 2013; Knesek, 2009). In addition to the physical disabilities of walking, climbing up the stairs, rising from a seated position, turning, decreased balance, etc., hemiplegia leads to a variety of problems such as cognitive disorder, visual perception disorder, language disorder, social disorder and limited participation in daily activities (Ahn et al., 2011; Peurala et al., 2007).

Mobility is defined as the ability to move within the household and community, and is essential to enabling performance of daily activities and social participation (Radomski and Latham, 2008; Salminen et al., 2009). The Occupational Therapy Practice Framework: Domain and Process classifies mobility into functional mobility and community mobility (AOTA, 2008). Radomski and Latham (2008) contended that both aspects of mobility should be considered during the assessment and intervention of occupational therapists, and proposed adaptation methods to enhance mobility skills during intervention and guidelines to build knowledge of compensatory strategies. According to Salminen et al. (2009), when moving becomes difficult or impossible due to limitation of mobility, wheelchair intervention enables such activities and participation.

A wheelchair, as an assistive device for paralyzed patients whose gait is no longer safe or effective or for the aged with weakened physical strength (Radomski and Latham, 2008; Seo et al., 2012), is utilized not only to enhance mobility, but also to prevent, complement and correct the disabilities of the user (Ham et al., 1998). A wheelchair employed for such purposes will facilitate the user to engage in work of personal value as well as community activities (Bell and Hinojosa, 1995; Kim and Chang, 2013). As such, for a hemiplegic patient with impaired function of the lower body and difficulty in walking safely as a result of physical or brain disability, a wheelchair becomes an invaluable assistive device.

Depending on how it is operated, a wheelchair is divided into a manual type or a powered type. A manual wheelchair is suitable for an individual whose upper extremities are functioning well (good muscular strength), who has control of the trunk muscles (good coordination) and able to use both hands, one hand, one hand and one foot, or both legs to move the wheelchair. This manual type has a simple structure, of which the wheels are driven by the user him/herself, and with easy maintenance and low costs (Attali and Pelisse, 2001; Choi et al., 2006; Radomski and Latham, 2008). Manual wheelchairs are divided into stationary and folding types depending on portability. A stationary manual wheelchair refers to an unfolding frame, which generally has higher durability than a folding frame (Batavia, 1998), and as the two rear wheels are connected to an axle, the wheelchair is operable with only one hand. There is, however, the difficulty with storage and portability because the wheelchair does not fold. On the contrary, a folding manual wheelchair has a folding frame that folds in the center much like an accordion, and transport and storage in small space are simple (Batavia, 1998). The problem with this type of wheelchair surfaces when it is driven with only one hand and will not roll forward or backward but only turn in place, because the two rear wheels are not connected.

A powered wheelchair is run by an electric motor, and the rolling wheels make it convenient for the disabled with impaired upper limbs, the aged with weakened physical strength, or users lacking the ability to operate a manual wheelchair (Radomski and Latham, 2008). Given current sophisticated technology, assuming intact cognition and perception, even a person with the most severe physical limitations is capable of independently driving a powered wheelchair (Pedretti et al., 2006). Mountain et al. (2010a) reported that the stroke patients with visuospatial neglect trained to use powered wheelchairs improved their WST-P (Wheelchair Skills Test, Power Mobility version 3.2) scores to the same extent as the participants without neglect, although their pre-training and post-training scores were lower. The group's total mean WST-P scores improved from 25.5% of skills passed at baseline to 71.5% post-training ($P = .002$). The conclusion reached was that many people with stroke, with or without visuospatial neglect, can learn to use powered wheelchairs safely and effectively with proper training. However, the downsides are that it (a powered wheelchair) is heavy and high-priced, and there is great difficulty overcoming stairs or transporting the wheelchair by car for long distances (Ryu, 2003; Seo et al., 2012). Moreover, additional assessments are called for to check mobility, means-result action, cognitive, and judgment skills, because a powered wheelchair requires a control panel and operates differently from a manual wheelchair. Users of a powered wheelchair should have skills that enable them to look left and right to avoid hazards, and to precisely stop the wheelchair when slowly approaching a door (Batavia, 1998).

According to the demand and status report of assistive devices for persons with disabilities released by the Ministry of Health and Welfare (2011), out of the total demand for physical and brain disabilities assistive devices, canes top the list at 22.3%, followed by manual wheelchairs at 9%, and then placing third, powered wheelchairs at 6.9%. In terms of current possession, canes account for the most at 23.3%, followed by manual wheelchairs at 8.1%, and powered wheelchairs were fifth at 3.6%, out of the total possession ratio. As noted, manual wheelchairs show not only higher demand but also higher possession ratio in comparison with powered wheelchairs. Moreover, according to the usage and satisfaction survey of mobility assistive devices for stroke patients by Park et al. (2010a), manual wheelchairs were the leading choice for Korean stroke patients using mobility assistive devices: 74 (57.8%) out of 100 patients. Similar results were reported in Canada: out of 100 stroke patients, 40 people (40%) were using manual wheelchairs, 1 person (1%) was using a powered wheelchair, and 59 (59%) were not using a wheelchair (Mountain et al., 2010b).

Current wheelchair usage in Korea shows that most of the wheelchairs operated by stroke patients are folding (X type frame) manual wheelchairs (Koo et al., 2005; Ministry of Health and Welfare, 2011; Park et al., 2010a). This kind of standard manual wheelchair is widely used because of the ease of storage and portability with low costs. However, for various reasons, one hand of the user may not move freely, or the limbs on one side of the body may be paralyzed much like in the case of hemiplegia. Such patients will not be able to move both hands freely, and have only one hand to maneuver the folding manual wheelchair (Kang et al., 2011; Tsai et al., 2007, 2008a, 2008b). The reason is, this type of wheelchair is designed to fold and does not have driving axle to propel the wheels on opposite sides; therefore, turning only one wheel will not move the wheelchair forward or backward.

If a caregiver is around to help move the wheelchair, the problem is solved. Unfortunately, in trying to move short distances, the user will have to drive the wheelchair independently most of the time. As a compensatory method, users who have some experience with manual wheelchairs can use a foot to skillfully and adequately maneuver the manual wheelchair. Still, inexperienced users cannot utilize their foot and moving independently remains difficult. Problems persist even when hemiplegic patients can make use of a foot to drive the wheelchair. According to Kirby et al. (1999) and Tsai et al. (2008a, 2008b), “In general, most hemiplegic stroke patients use the unaffected arm and leg to propel their wheelchairs. To facilitate this propulsive pattern, the leg rest of the wheelchair on the unaffected side is usually removed so that they can produce propulsive force and guide the chair's direction by stamping the unaffected foot on the ground. This asymmetrical propulsion, however, may cause the wheelchair to stray toward the affected side on a level surface, and even cause danger on a slope.”