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Special Topic
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Problem Analysis and Recommendations for Using Manual Wheelchair for One-hand Users

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Objective: This study was conducted for one-hand users including hemiplegic clients currently using general folding manual wheelchairs, so as to analyze their specific problems and recommend solutions regarding usage.

Background: Traditional manual wheelchairs require considerable use and control of both hands for operation, thus adaptations become necessary for individuals with asymmetrical use of hands.

Method: Thirty hemiplegic clients who were admitted to rehabilitation and convalescent hospitals participated as subjects. The research tools were general folding manual wheelchairs commonly used by people with impaired gait, and the Wheelchair Skills Tests (WST) WST-M/WCU 4.1 version was adopted as the assessment tool. All participants were asked to fill out questionnaires on demographics and wheelchair usage characteristics. Assessment procedures were performed with currently used manual wheelchairs and with/without the use of foot to control the wheelchair.

Results: When the participants drove folding manual wheelchairs without the use of foot, even the lowest failure rate among the WST items tested recorded 96.7%. On the contrary, with the use of foot in maneuvering the wheelchairs, failure rates dropped noticeably and success rate among the WST items tested was as high as 86.7%.

Conclusion: These findings imply that the use of one-arm (hand) propellable (drivable) wheelchair can be an active and effective solution in resolving problems for hemiplegic clients using existing manual wheelchairs. As such, the government should provide institutional support to further develop and distribute this device or technology, and promote relative research in tandem. For now, the supply of commercially available device to hemiplegic clients is deemed urgent and also a mechanism to provide the devices and relevant services.

Application: This study offers viable solutions for hemiplegic clients who rely on existing manual wheelchairs to increase their mobility and occupational performance.

Keywords: Wheelchair, Manual wheelchair, Wheelchair Skills Test (WST), Hemiplegia, Mobility, One-hand manual wheelchair

1. Introduction

Mobility is defined as the ability to move within the household and community (Radomski and Latham, 2008), and is essential to enabling performance of daily activities and social participation (Salminen et al., 2009). The Occupational Therapy Practice Framework: Domain & Process classifies mobility into functional mobility and community mobility. Functional mobility is moving from one position or place to another during performance of everyday activities, such as in-bed mobility, wheelchair mobility, and transfers (e.g., wheelchair, bed, car, tub, toilet, tub/shower, chair, floor), and includes functional ambulation and transporting objects. Community mobility is defined as moving around in the community and using public or private transportation, such as driving, walking, bicycling, or accessing and riding in buses, taxi cabs, or other transportation systems (Roley et al., 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 (Jung et al., 2005). 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).

Depending on how it is operated, a wheelchair is either a manual type or powered type. A manual wheelchair is suitable for users that operate simultaneously with both hands, one hand, one hand and one foot, and both legs (Radomski and Latham, 2008). The user rolls the wheels firsthand as the wheelchair is of simple structure without any driving mechanism, which allows easy maintenance and repair and low costs (Attali and Pelisse, 2001). 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 a bar, the wheelchair is operable with only one hand. There is, however, the difficulty with storage and portability because the wheelchair does not fold. Contrarily, 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 or the aged with weakened physical strength, or users lacking the ability to operate a manual wheelchair (Radomski and Latham, 2008). Even persons with extreme physical disabilities but have complete cognitive and perception skills can independently operate a powered wheelchair (Pedretti et al., 2006). However, the downsides are that it is heavy and high-priced, and there is great difficulty overcoming stairs or transporting the wheelchair by car for long distance (Seo et al., 2012; Ryu, 2003). Moreover, additional assessments are called for to check motility, means-result action, cognitive, and judgment skills, because a powered wheelchair requires a control panel and operates differently from that of a manual wheelchair (Batavia, 1998). 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 & Welfare Korea (2011), out of the total demand for physical and brain disabilities assistive devices, cane tops the list at 22.3%, followed by manual wheelchair at 9% and then placing third, powered wheelchair at 6.9%. In terms of current possession, cane accounts for the most at 23.3%, followed by manual wheelchair at 8.1%, and powered wheelchair was fifth at 3.6%, out of the total possession ratio. As noted, manual wheelchair shows not only higher demand but also higher possession ratio in comparison with powered wheelchair. Moreover, according to the usage and satisfaction survey of mobility assistive devices for stroke patients by Park et al. (2010), manual wheelchair was 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 (40%) use manual wheelchairs while one (1%) uses powered wheelchair (Mountain et al., 2010).

The Korean government currently provides support for wheelchair users. According to the Welfare of Disabled Persons 2012 Project Title 1 by the Ministry of Health & Welfare Korea (2012a), the base amount of manual wheelchair is set as KW 480,000 with durability life of five years, and users may receive 80-100% support depending on insurance type and disability grade. So, only users diagnosed with a disability grade are granted government support. However, the Decision Standard of Disability Grade (Ministry of Health & Welfare Korea, 2012b) states that hemiplegic patients may only be evaluated six months after the stroke occurrence in order to be diagnosed with brain disability. As such, many hemiplegic patients have no other choice but to rent wheelchairs from rental companies for certain periods. Rentals will not always work out because a wheelchair suitable for that person's disability level or physical measurements may be unavailable. Therefore, the current wheelchair service mechanism will likely limit hemiplegic patients' independent ability to move within a hospital environment during the first six months of hemiplegia occurrence.

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; Park et al., 2010a). 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. However, this type of wheelchair is designed to fold and does not have a bar to drive the wheels on opposite sides, and therefore, turning only one wheel will not move the wheelchair forward or backward. If another person is around to help move the wheelchair, problem is solved. Unfortunately, in trying to move short distances versus longer distances, the user will have to drive the wheelchair by oneself most of the time. As a compensatory method, users who have some experience with manual wheelchairs use the foot to skillfully and adequately maneuver the manual wheelchair. Still, inexperienced users cannot utilize the foot and moving independently remains difficult (Kim and Chang, 2013).

Problems persist even when hemiplegic patients can make use of the foot to drive the wheelchair. Such hemiplegic patients, according to Tsai et al. (2008a) and Kirby et al. (1999), will apply asymmetric force to the body's left or right side and be at a risk of slipping down from the wheelchair seat. To minimize such risks, ankle-propelled wheelchair and knee-propelled wheelchair have been developed. One-arm drive wheelchair was also developed to enable driving with only one hand, by installing an additional lever on one side or attaching two handles to drive forward or change direction simultaneously (Drivemedical, 2012; Masclet, 1998; Nina et al., 2009). However, these wheelchairs are stationary and unfolding, which cause portability and storage issues. These folding wheelchairs, on the other hand, are priced almost as high as powered wheelchairs and incur cost-effect issues. The user with a manual wheelchair may end up having to purchase an additional wheelchair.

As such, this study aims to analyze problems associated with usage of general folding manual wheelchairs by one-hand users, including hemiplegic patients, and suggest improvements based on the findings and also other related studies conducted locally and internationally. This study, thereby, seeks to promote mobility of hemiplegic patients, and to urge more related research and provision of a national support mechanism.

2. Method

2.1 Participants

Thirty hemiplegic patients who have been admitted to rehabilitation and convalescent hospitals located in a metropolitan city were selected for the purpose of an in-depth analysis of problems experienced by hemiplegic patients using general folding manual wheelchairs. For comparative assessment with hemiplegic patients who are one-hand users, an additional 17 patients, who are paraplegic due to impaired spinal cord but can use both hands, were selected. Participant selection was limited to individuals using general folding manual wheelchairs and with three or more months of wheelchair experience, and with normal visual/perception and cognitive functions for accurate assessments. Among hemiplegic patients, only those who have retained normal function of an upper limb, regardless left or right, were selected, as the existing manual wheelchairs will be driven with only one hand.

2.2 Evaluation tools

2.2.1 Folding manual wheelchair

The first folding manual wheelchair was invented by Everest (1937), and further developed to the general folding manual wheelchair of today. Users mostly prefer the folding manual wheelchair over the stationary manual wheelchair for better storage and portability. A folding manual wheelchair can be driven with both hands, one hand, one hand and one foot, one foot, or both feet, but most commonly with both hands. Pricing depends on the manufacturer, additional function, size, design, etc., but prices are relatively lower than those of powered wheelchairs. A wheelchair is structured with rear wheels, tires, casters, armrests, front rigging, hand rims, wheel lock, etc. (Batavia, 1998).

2.2.2 Wheelchair Skills Test (WST)

Wheelchair Skills Program (WSP, 2008) was developed by Dalhousie University in Halifax, Nova Scotia, Canada. The WSP includes the Wheelchair Skills Test (WST), the questionnaire version of the WST (WST-Q) and the Wheelchair Skills Training Program (WSTP). This study applied the WST version 4.1 (WSP, 2008). It is an evaluation to test the skills of wheelchair operation, and apply the findings to identify what maneuver skills to focus on during rehabilitation. It is used to assess and train both manual and powered wheelchair users and/or their caregivers and clinicians. There is a total of 39 test items on the WST version 4.1 master list, and the test items vary according to subject (user/caregiver) or wheelchair type (manual/powered).

This study referred to the WST-M/WCU (Manual/Wheelchair User) version 4.1 (WSP, 2008), which evaluates the operation skills of a manual wheelchair user. The WST-M/WCU has a total of 32 test items: 9 indoor skills, 12 community skills, 11 advanced skills. Results are measured with the Scale for Scoring Skill Performance and the Scale for Scoring Skill Safety. Performance results are recorded as pass and fail, and Safety results are recorded as safe and unsafe (Jo, 2010; Kirby, 2004; Kirby et al., 2005). With reference to the WST study by Jo (2010), Kirby (2004), Kirby et al. (2005), a total of 10 test items were selected in line with the purpose and experiment conditions of this study. Chosen from the 9 indoor skills are: rolls forward 10m, rolls backward 5m, turns 90˚ (left) while moving forward, turns 90˚ (right) while moving forward, turns 90˚ (left) while moving backward, turns 90˚ (right) while moving backward, turns 180˚ in place (left), and turns 180˚ in place (right). Two skills similar to parallel car parking were added: maneuvers sideways (left) and maneuvers sideways (right). Test results were measured only with the Scale for Scoring Skill Performance.

Whereas the existing WST does not restrict how a wheelchair is driven, whether using one hand, one foot or both hands; this study, for purpose of identifying problems with one-hand operation of existing folding wheelchairs, conducted assessment procedures dually without the use of foot and with the use of foot. The existing WST total score calculates as number of items passed divided by the value obtained by subtracting items failed and error items from total count of items which is 32, and multiplying the result value by 100 (Total Performance Score = number of passed skills/(number of possible skills - number of no part - number of testing error x 100%). However, in this study, the total score is the value obtained by multiplying 10 to the number of items passed (total score = items passed x 10).

2.3 Procedure

All participants were informed of the purpose and procedures of this study, and signed informed consents prior to actual participation in the experiment. Also, a survey was conducted on the general characteristics (demographics) and wheelchair usage characteristics, thereafter, all participants were asked to take the WST with the type of wheelchair presently used, prior to actual participation in the experiment.

The test items for the participants' general characteristics and wheelchair usage characteristics were revised to conform to this study's purpose and experiment conditions. General characteristics were composed of five items: gender, age, dominant hand, disease period, paretic side. Wheelchair usage characteristics comprised four items: hours of use and daily average hours of use, based on Koo et al. (2005); frequency of use, from Jung et al. (2005); and independence of use, from Shah et al. (1989).

The participants of this study, who are 30 hemiplegic patients and 17 spinal paralysis patients with use of both hands, were all

Table 1. Participant demographics

		One-hand user (n/%)	Two-hands user (n/%)
Gender	Male	14 (46.7)	10 (58.8)
	Female	16 (53.3)	7 (41.2)
Age group (years old)	Under 50	2 (6.7)	3 (17.6)
	50~59	6 (20.0)	11 (64.7)
	60~69	9 (30.0)	3 (17.6)
	70~79	12 (40.0)	-
	80 and over	1 (3.3)	-
Dominant hand	Right hand	20 (66.7)	13 (76.5)
	Left hand	9 (30.0)	-
	Ambidextrous	1 (3.3)	4 (23.5)
Paretic side	Right sided hemiplegia	12 (40.0)	-
	Left sided hemiplegia	18 (60.0)	1 (5.9)
	Upper diplegia	-	2 (11.8)
	Lower diplegia	-	12 (70.6)
	Other	-	2 (11.8)
Diagnosis	Encephalopathy	30 (100.0)	3 (17.6)
	Spinal cord impaired	-	12 (70.6)
	Other	-	2 (11.8)
Disease period (years)	Under 1	8 (26.7)	-
	1~under 2	6 (20.0)	3 (17.6)
	2~under 3	4 (13.3)	3 (17.6)
	3 and over	12 (40.0)	11 (64.7)

surveyed, and the results are shown in Table 1 for participants' general characteristics and in Table 2 for wheelchair usage characteristics.

Table 2. Wheelchair usage characteristics of study participants

		One-hand user (n/%)	Two-hands user (n/%)
Years of use	Under 1	12 (40.0)	-
	1~under 2	6 (20.0)	4 (23.5)
	2~under 3	4 (13.3)	13 (76.5)
	3~under 4	4 (13.3)	-
	4~under 10	4 (13.3)	-
	10 and over	-	-
Frequency of use	Less than once per week	3 (10.0)	-
	More than twice per week	2 (6.7)	-
	Daily	25 (83.3)	17 (100.0)
Daily average hours of use	Under 1	5 (16.7)	1 (5.9)
	1~2	9 (30.0)	-
	3~4	7 (23.3)	6 (35.3)
	5~6	4 (13.3)	10 (58.8)
	7 and over	5 (16.7)	-
Independence of use	Total dependence	6 (20.0)	-
	Maximum assistance	4 (13.3)	-
	Moderate assistance	5 (16.7)	5 (29.4)
	Minimum assistance	4 (36.7)	-
	Independent	11 (36.7)	12 (70.6)

Prior to WST evaluation, with Kim and Chang (2013) as reference, the researcher asked participants to sit evenly left and right on the wheelchair seat, and also to sit the pelvis rear to the back of the seat. The Wheelchair Skills Test (WST) provided by WSP (2008), the Wheelchair Skills Training Program (WSTP) Manual, and the Wheelchair Skills Program 4.1 Obstacle Course Guidelines (Dalhousie University, 2013), Kirby (2004), Kirby et al. (2005), Jo (2010) among other studies were taken as reference in setting the environment for WST evaluation, but revised to conform to this study's purpose and testing conditions (Figure 1).

The participants in the one-hand user group were evaluated in two ways: without the use of foot (foot constrained) and with the use of foot (use of foot) when driving the wheelchair (Figure 2). Participants in the ambidextrous group, that does not need the use of foot, were only allowed to use the two hands. To ensure that all participants adapted to the built testing environment, prior to the WST evaluation, the participants were asked to switch to the experimental manual wheelchair and test drive it for five minutes to roll forward, roll backward, turn 90° while moving forward (left, right), turn 180° in place (left, right), and maneuver sideways (left, right).

Rolls forward and backward section

Turns 90° section

Turns 180° in place section

Maneuvers sideways section

Figure 1. Wheelchair Skills Test (WST) environment

Figure 2. Manual wheelchair maneuvered by right-sided hemiplegic patient (left photo: foot constrained; right photo: use of foot)

To analyze the experiment results, descriptive statistics analysis was used for the WST results, and *t*-test and one-way ANOVA were conducted to ascertain WST results variance depending on the participants' general characteristics and wheelchair usage characteristics. Two-way ANOVA at the 0.05 significance level was used to investigate the correlation of WST scores depending on the general characteristics and wheelchair usage characteristics.

3. Results

3.1 WST pass/fail success rate (%)

Table 3 shows the pass/fail frequency analysis on the WST items. When foot use was constrained for the hemiplegic patients of the one-hand user group during the WST evaluation, all items were failed except one participant (3.3%) passed "rolls backward 5m" and one participant (3.3%) passed "turns 90° (left) while moving backward". On the contrary, with the use of foot, more than 15 (50%) out of the 30 participants passed in total six items: rolls forward 10m (86.7%) being the highest pass rate, rolls backward 5m (76.7%), turns 90° while moving forward (left 80.0%, right 83.3%), turns 90° while moving backward (left 66.7%, right 56.7%). Even with the use of foot, however, more than 15 (50%) out of the 30 participants failed four items: turns 180° in place (left 70.0%, right 60.0%) and maneuvers sideways (left 80.0% being the highest fail rate, right 83.3%). Finally and as expected, ambidextrous participants recorded 100% pass rate on all WST items.

Table 3. WST pass/fail success rate (%)

Item		Foot constrained		Use of foot	
		Pass (%)	Fail (%)	Pass (%)	Fail (%)
Rolls forward 10m		0 (0)	30 (100)	26 (86.7)	4 (13.3)
Rolls backward 5m		1 (3.3)	29 (96.7)	23 (76.7)	7 (23.3)
Turns 90° while moving forward	(left)	0 (0)	30 (100)	24 (80.0)	6 (20.0)
	(right)	0 (0)	30 (100)	25 (83.3)	5 (16.7)
Turns 90° while moving backward	(left)	1 (3.3)	29 (96.7)	20 (66.7)	10 (33.3)
	(right)	0 (0)	30 (100)	17 (56.7)	13 (43.3)
Turns 180° in place°	(left)	0 (0)	30 (100)	9 (30.0)	21 (70.0)
	(right)	0 (0)	30 (100)	12 (40.0)	18 (60.0)
Maneuvers sideways	(left)	0 (0)	30 (100)	6 (20.0)	24 (80.0)
	(right)	0 (0)	30 (100)	5 (16.7)	25 (83.3)

3.2 WST scores related to participants' general characteristics

WST score variance depending on the participants' general characteristics is shown in Table 4. Significant variance was found only with age (F=3.471, p=0.022), and all other characteristics of gender, dominant hand, paretic side, and disease period did not show significant variance.

3.3 WST score analysis related to wheelchair usage characteristics

Table 5 shows WST score variance related to wheelchair usage characteristics. Significant variance of WST scores was found only with independence of use (F=7.135, p=0.001), and all other characteristics of years of use, frequency of use, and daily average hours of use did not show significant variance. As such, hemiplegic patients' independence of use and wheelchair operation skills is highly correlated.

Table 4. WST scores related to participants' general characteristics

		WST score	
		Mean (SD)	t(p) / F(p)**
Gender	Male	66.4 (26.8)	1.077 (0.290)
	Female	55 (30.8)	
Age (years old)	Under 50	80.0 (28.3)	3.471 (0.022)*
	50~59	75.0 (28.8)	
	60~69	70.0 (30.4)	
	70~79	40.0 (17.6)	
	80 and over	90.0	
Dominant hand	Right hand	59.0 (29.5)	0.394 (0.678)
	Left hand	65.6 (30.0)	
	Ambidextrous	40.0	
Paretic side	Right-sided hemiplegia	65.0 (29.0)	0.507 (0.482)
	Left-sided hemiplegia	57.2 (29.5)	
Disease period (years)	Under 1	45.0 (23.9)	1.715 (0.188)
	1~under 2	78.3 (28.6)	
	2~under 3	67.5 (27.5)	
	3 and over	59.2 (29.1)	

*p<.05, ** t(p)=Independent t-test (probability), F(p)=ANOVA (probability)

Table 5. WST score analysis related to wheelchair usage characteristics

		WST score	
		Mean (SD)	F(p)*
Years of use	Under 1	59.2 (31.2)	0.565 (0.690)
	1~under 2	75.0 (26.6)	
	2~under 3	47.5 (35.9)	
	3~under 4	57.5 (23.6)	
	4~under 10	57.5 (29.9)	
	10 and over	–	
Frequency of use	Once or less per week	83.3 (28.9)	1.120 (0.341)
	Twice or more per week	65.0 (49.5)	
	Daily	57.2 (27.8)	
Daily average hours of use	Under 1	82.0 (24.9)	1.825 (0.156)
	1~2	60.0 (32.0)	
	3~4	58.6 (31.3)	

Table 5. WST score analysis related to wheelchair usage characteristics (Continued)

		WST score	
		Mean (SD)	Mean (SD)
Daily average hours of use	5~6	67.5 (25.0)	1.825 (0.156)
	7 and over	36.0 (11.4)	
Independence of use	Total dependence	31.7 (14.7)	7.135 (0.001)**
	Maximum assistance	37.5 (17.1)	
	Moderate assistance	92.0 (8.4)	
	Minimum assistance	60.0 (31.6)	
	Independent	70.0 (24.9)	

*F(p)=ANOVA (probability), ***p*<.01

4. Discussion and Recommendations

This study conducted WST in order to investigate problems with wheelchair maneuver skills when one-hand users including hemiplegic patients used general folding manual wheelchairs. The findings were that without the use of foot, the average fail rate for all WST items was over 93%, but with the use of foot, the average fail rate plummeted to 44.3%. This means that if one-hand users operated the existing manual wheelchairs, it would be impossible to move independently said by Kang et al. (2011). It was also mentioned that, it would be impossible to move independently with manual wheelchairs only with one hand and without the use of foot. WST shows high scores the younger the age and higher the independence of use. This implies that user's age and independence of wheelchair use are vital factors to be considered in wheelchair intervention.

Preceding studies have conducted WST evaluations on hemiplegic patients for driving with one hand and foot. According to Kirby et al. (2005), 50% of the patients driving with the paretic side succeeded in trying to turn 180° in place while 60% of the patients driving with the non-paretic side successfully passed the same operation. Now, this study showed 40% pass rate for driving with the left paretic side to maneuver left turns 180° in place, and 60% pass rate for driving with the right paretic side to maneuver right turns 180° in place. The pass rate for driving with the right paretic side was slightly higher than the results noted from Kirby et al. (2005), but the overall average for driving with the paretic side calculates 50%, which ends up to be similar to that of Kirby et al. (2005). Continuing on, this study also showed 86.7% pass rate for rolls forward 10m, 80% pass rate for left turns 90° while moving forward, and 83.3% for right turns 90° while moving forward; whereas Charbonneau et al. (2013) recorded 100% pass rates for the same test items. Difference in success rates may be a result of differences in research method or study subject. Precedent studies include Coolen et al. (2004), Jo (2010), Kirby et al. (2004), MacPhee et al. (2004) among others, but their test subjects were not hemiplegic patients or these were studies that do not correspond with the purpose and intention of this study. Nevertheless, the preceding studies did show 100% pass rates for most of the WST indoor items.

The photos of Figure 3 describe wheelchair driving with and without the use of foot. Solid line indicates the center of the surface area that touches the ground. A closer look shows that when foot use is constrained, two surface areas touch the ground; whereas when foot is used, the surface areas that touch the ground increase to three. This observation is also noted in Tsai et al. (2008a), which is an indication that a hemiplegic patient uses the unimpaired foot to appropriately guide the wheelchair's direction and driving with one hand and one foot is possible.

Tsai et al. (2008a), however, explains that this way of driving may be inefficient use of time and energy. Now, this study took

Figure 3. Comparison of maneuvering postures of right-sided hemiplegic patient without use of foot (left photo) and with use of left foot (right photo)

reference of Kim and Chang (2013) prior to WST evaluations, and asked the subjects to sit evenly left and right on the wheelchair seat, and also to sit the pelvis rear to the back of the seat. Nevertheless, when the foot is used to drive the wheelchair, as shown in Figure 2, right away the patient's posture becomes asymmetrical and the pelvis rear is moved forward toward the seat center.

This observation corresponds with the findings of Park et al. (2010b), who states that the asymmetrical posture of hemiplegic patients is noticed in their wheelchair sitting posture, and those of Kirby et al. (1999), who claims that the wheelchair sitting posture of hemiplegic patients is more deviated to the paretic side. Moreover, Kim and Chang (2013) reports that if the asymmetrical posture continues, that may lead to higher chances of deformity such as scoliosis or kyphosis, or bedsore, etc. Also in agreement are Kirby et al. (1999) and Tsai et al. (2008a), who report of risks of slipping caused by asymmetrical strength, if this way of driving continues. This may incur risks of secondary accidents such as falling. Therefore, wheelchair interventionists need to become more knowledgeable with safer adaptation methods and compensatory strategies in prevention of such secondary alterations or accidents, and the interventionists should be given the responsibility to do the educating and training. Unfortunately, at present, research on such risks is insufficient. So, analysis should be conducted from the perspectives of physics, biomechanics and kinematics, focusing on problems with ground reaction force that occurs when driving a wheelchair with the use of foot, degree of joint or joint movement, center of mass, etc. It is further suggested that more research is needed, such as survey on secondary accidents caused by driving existing manual wheelchairs in order to conduct risk factor analysis and investigate effects on the musculoskeletal system.

In seeking solutions for problems arising from manual wheelchair used by one-hand users including hemiplegic patients, Drivemedical (2012), Masclet (1998), Nina et al. (2009), and Tsai et al. (2008b) suggested and developed various types of manual wheelchairs that can be effectively operated only with one hand and without the use of foot.

The leading commercial wheelchairs are one-arm drive wheelchair (Drive Medical Design and Manufacturing Inc., NY, USA), two-hand-rim propelled wheelchair (Sunrise Medical Inc., Torrance, CA, USA), and One Arm Drive Systems (MobilityBasics, Ontario, Canada). In most cases, two hand rims are placed on the patients' unaffected side (Figure 4). To drive this device, the patient uses the unaffected hand to propel ambilateral wheels by pushing the two hand rims simultaneously. The outer (larger) hand rim controls the wheel on that side of the wheelchair and the inner (smaller) hand rim controls the wheel on the opposite side of the wheel chair. The inner hand rim is connected to the wheel by way of a bar or scissor mechanism between the hand rim and the wheel (Figure 5). The patient may either push both hand rims at the same time or each hand rim alternately to move the wheelchair forward, backward, or to turn. One Hand (Arm) Drive Systems can be used on either the right or left hand side of the wheelchair as long as the user has good strength and dexterity on that side.

Figure 4. Manual wheelchair with two hand rims (inner/outer hand rim)

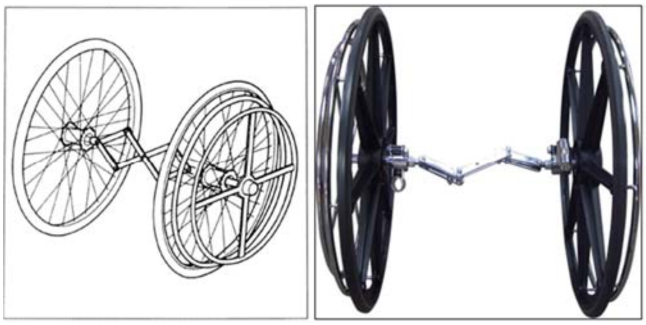

Figure 5. Folding mechanism for a one-hand drive wheelchair

Another type of wheelchair has two propellable wheels, but the bar is stationary and unfolding, which raises portability and storage issues. Due to its structure, the wheelchair is manufactured in a way that the wheels and the seat can be disassembled with tools and loaded onto a car for transport, and later reassembled for use. However, this is a set of procedures that the patient will not be able to do alone or likely be inconvenient. Even the manual wheelchairs designed for hemiplegic patients, even if they are foldable, most will have installments that are too big and heavy, and also the high costs. Not only are these hard to purchase locally, but it will be a waste of expense for having to purchase an additional specially designed wheelchair aside from the existing wheelchair. These many drawbacks lead manual wheelchair users to purchase powered wheelchairs despite the weight, lack of portability and cost issues.

As such, the most ideal method would be to develop a universal one-arm (hand) propellable (drivable) manual wheelchair kit (unit) that can simply be attached to the existing folding manual wheelchair. This way, one-hand users may resolve expense issues arising from having to purchase an extra wheelchair, conveniently store and transport the wheelchair, and no longer have driving problems due to absence of bar.

5. Conclusion

This study analyzed the problems associated with usage of general folding manual wheelchairs by hemiplegic patients, and provided recommendations to resolve these problems. For this purpose, this study verified by experiment that hemiplegic patients, without the use of foot and without the help of another individual, cannot independently move the folding manual wheelchair. Therefore, if without assistance, the existing manual wheelchair should only be used for moving short distances if possible. It is also considered that assistive technology practitioners or occupational therapists should be the ones to educate and train patients the skills involved with using the non-paretic limb to safely operate the wheelchair.

The one-hand propellable folding manual wheelchair, as suggested by this study, is deemed more effective in terms of operability, drivability and convenience in comparison with the existing folding manual wheelchair. As such, the introduction and widespread supply of this one-hand propellable folding manual wheelchair is urgent, and as well, promotion of related R&D (research and development) and a mechanism to provide the devices and relevant services. It is anticipated that in the coming years, more financial support at the national level will promote mobility and occupational performance of one-hand users including hemiplegic patients.

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