MUSCLE ACTIVATION FOR THREE DIFFERENT PATIENT TRANSPORT CHAIRS ON RAMPS AND FLAT GROUND

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INTRODUCTION

Patients with limited mobility rely on caregivers or clinicians for assistance with their transportation needs. Patient transport chairs are one option that is used to enable persons with injury, illness, or disability to access various areas of their respective hospital or care facility. Patient transport personnel must be well trained and qualified to anticipate and manage any complications that may arise during the transport process (Kulshrestha & Singh, 2016).

Studies have shown that work-related pain and injury are prevalent among healthcare professionals (Oranye, 2016). Musculoskeletal injuries occur at the highest incidence in caregivers who manually handle patients, including those who perform transport tasks (Kothiyal, 2004). Transport tasks involve techniques that increase the risk of developing injuries due to musculoskeletal overuse, including repetitive flexion and extension of the elbow, trunk, and knee, prolonged or excessive handling activities, and extended or nonstandard work schedules (Oranye, 2016). While shoulder and upper extremity injuries are often reported, lower back pain is the most frequently documented work-related complaint amongst caregivers as it can result from a complex interaction between movement factors such as unnatural posture, the lifting of heavy objects, sustaining the same posture, momentary load bearing, inadequacies of the physical environment in medical treatment facilities, and individual caregiver factors such as lack of knowledge and experience (Daikoku, 2008).

Experienced caregivers will exert less energy by using larger, distributed muscle groups that effectively harness body mechanics and prevent excess exertion (Daikoku, 2008). However, caregivers are at a high risk for injury during patient handling tasks even when using proper technique. Any transport related accidents involving either patient or caregiver have the potential to financially burden the hospital or care facility. Steps have been taken to reduce the instances of patient transport related accidents. Recently, there has been increased focus on redesigning existing transport chairs to minimize caregiver effort, reduce hospital costs related to musculoskeletal injuries, and to maximize the patient's overall comfort (Lee, 2013).

One proposed method to improve chair design is through the ergonomic optimization of the chair features. Two patient transfer chairs specifically 1) Stryker® Prime TC (PTC) and 2) Staxi® Medical Chair (SXM) have recently been developed to minimize caregiver strain and musculoskeletal burden during patient transport in hospitals and clinics. Ergonomic features specific to the PTC include vertically oriented push handles that accommodate caregivers of any height and a one-touch central brake pedal that eliminates the need for excess bending. The SXM incorporates a fail-safe horizontal handlebar brake system. Both ergonomic chairs incorporate adjustable armrests and footrests for ease in patient ingress/egress, as well as rigid and highly maneuverable frames with anti-tip wheels. These features aim to reduce awkward motions and forces on caregivers by facilitating more natural postures and favorable joint angles during pushing tasks. These features should theoretically reduce the physical demands on caregivers and increase low-back safety (Vieira, & Kumar, 2009). The most prevalent transport chair in clinical settings currently is the depot-style chair which is appealing for hospitals primarily due to their relatively low price point. Although affordable, these chairs offer little to no adjustability for patients or caregivers, making them inappropriate for long-term use (Karmarkar, 2011). This study utilized a Breezy® Ultra 4 Wheelchair (STC), a typical depot-style chair, to serve as a control against which the ergonomic features of the PTC and SXM could be compared.

Few studies have examined how transport chair design impact caregiver musculoskeletal burden. One study demonstrated that for caregivers operating a transport chair, muscle activation in the upper extremities decreases as elbow flexion increases towards 90° (Lee, 2013). Additionally, low handles leave caregivers at risk for development of lumbar pain while pushing transport chairs. A handle height of 86.5% relative to the caregiver's shoulder height is recommended to be most favorable for mechanical loading (Van der Woude, 1995). The lower and nonadjustable handle height found in depot-style chairs may result in greater upper extremity and lumbar loading and may contribute to the increased incidence of musculoskeletal injuries seen in caregivers.

The purpose of this study was to compare the muscle activation in the arms and lower back between the Stryker® Prime TC, Staxi® Medical Chair, and Breezy® Ultra 4 Wheelchair (STC) during ramp incline and decline trials. It was hypothesized that the two ergonomically designed chairs (Stryker® Prime TC and Staxi Medical chair) would require less muscle activity on ramps than the Breezy® Ultra 4 Wheelchair due to their advanced designs.

METHODS

Subjects: This study received approval from the VA Pittsburgh Healthcare System's Institutional Review Board. Eleven subjects were recruited for the study. All participants signed informed consent forms before any testing procedures were performed. Inclusion criteria for participation were defined as: 1) At least two years of experience with patient transport 2) eighteen years of age or older. Subjects were excluded from the study if they had recent history of back pain or injury that could be intensified by bending over or by pushing a transport chair.

Figure 1: A) Stryker® Prime TC Chair, B) Staxi® Medical Chair, C) Breezy® Ultra 4 Wheelchair

Experimental Protocol: Subjects were asked to perform a series of tasks that were designed to emulate the routine clinical transport duties of typical caregivers that would test maneuverability and functionality of the two transport chairs. The Stryker® Prime TC and the Staxi® Medical Chair (shown in Figure 1) were each loaded with a 50th percentile test dummy which weighed 185 pounds. Each chair was loaded with this test dummy for all transport tasks performed.

Table 1: Abbreviations for EMG Muscle Groups

E.S.	Erector Spinae
Lat	Latissimus Dorsi
Pec	Pectoralis Major
ADelt	Anterior Deltoid
Bic	Biceps Brachii
FlexDig	Finger Flexors
WrFlex	Wrist Flexor Carpi Ulnaris
ExtDig	Extensor Digitorum

Subjects were outfitted with electromyography (EMG) surface electrodes which were placed bilaterally on eight muscles (erector spinae, latissimus dorsi, pectoralis major, anterior deltoids, biceps brachii, finger flexors, wrist flexor carpi ulnaris, and extensor digitorum). The placement of all EMG electrodes was in agreement with standards documented for EMG surface electrode placement (Basmajian, 1980). Prior to performing transport tasks, manual muscle tests were performed to confirm that electrode placement was correct and to measure the subjects' maximum voluntary contractions (MVC) which would be used in the normalization of their EMG signals. Abbreviations for the specific muscles analyzed in this study are found in Table 1.

Before performing the transport tasks, each subject was given a short overview of each chair and its specific features. Subjects were also allotted time to push each chair around the lab space to become familiar with their functions. Each subject was allowed to operate each chair in ways that maximized personal comfort. Chair order between subjects was randomized.

Three transport-tasks were completed for each chair. EMG data were recorded for each task, which included walking in a straight line over level ground and walking on a 4.2 m, 6° inclined and declined ramp. Each task was performed in a separate trial with time for rest between trials as needed. The straightaway walking task was performed with steps synchronized at 60 beats per minute in order to normalize gait speed between subjects. Muscle activation was recorded using a 16-channel electromyography system's bipolar electrodes (Noraxon Telemyo 2400T) for the entire duration of each task at 1500 Hz.

Data Analysis: Muscle activation was normalized to and reported as a percentage of the MVC recorded for that individual muscle via custom Matlab (Version 7.4) code. A two-way repeated measures Analysis of Variance (ANOVA) was used to compare integrated muscle activation for caregivers when operating each chair. Both main and interaction effects were examined. Post-hoc Bonferroni correction factors for paired comparisons were planned to control for type 1 error if a significant main effect was found. The level of significance was set to a p-value of 0.05 however due to the small sample size trends were noted when p was ≤ 0.1. All statistical analysis was performed using SPSS Version 24 (SPSS Inc, Chicago).

RESULTS

The twenty subjects analyzed in the study consisted of 9 males and 11 females. The average (± standard deviation) age, weight, height, and years of transport experience of the participants were 41.0 (±18.8) years, 170.4 (±37.42) lbs., 67.4 (±4.5) inches, and 7.89 (±8.6) years, respectively.

Integrated EMG values were averaged across three gait cycles from ramped walking and five gait cycles for level-ground walking for each muscle group. Statistically significant main effects of surface type were found for 9 of the 16 muscle groups. Muscle activation in these muscles was greater for walking up the ramp compared to walking level and/or downhill. Three of the 9 muscle groups also showed higher activity walking level than downhill. The wrist extensor digitorum muscle group (both sides) showed a main effect of chair type (Table 2). Post hoc analyses revealed a trend towards higher activation when using the SXM compared to STC (both sides) and the PTC (right side) (Figure 2). A significant interaction effect was found for the wrist flexor carpi ulnaris right side (p = 0.049) (Figure 2) and a trend toward significance on the left side (p =0.067). The left plot shows that while muscle activation was reduced between ramp ascent and descent with the PTC and STC, operating the SXM required as much or slightly higher muscle activation to descend the ramp as it did to push it up the ramp.

Table 2. Integrated EMG values (%MVC*sec) for the PTC, SXM, and STC during level straightaway pushing tasks and ramped pushing tasks. P-values for muscles with significant effects are shown. I = Incline; D = Decline; and L = Level

		PTC	SXM	STC	P-Value
Muscle		Mean (STD)	Mean (STD)	Mean (STD)	Main Effects
E.S.R	Level	532.3 (558.0)	482.5 (257.2)	414.1 (228.0)	Condition 0.008 L > D: 0.046 I > D: 0.012
	Incline	438.2 (322.2)	501.6 (259.6)	490.4 (298.8)	
	Decline	302.5 (202.2)	345.0 (148.4)	331.1 (250.7)	
E.S.L	Level	553.9 (458.0)	540.0 (578.4)	424.6 (362.5)	
	Incline	460.5 (417.8)	538.9 (367.9)	585.1 (591.7)	
	Decline	382.6 (379.1)	391.8 (320.4)	487.4 (747.5)	
ADelt R	Level	50.2 (33.9)	39.5 (27.2)	48.0 (33.5)	Condition <0.001 I > L: 0.001 I > D: 0.001
	Incline	271.6 (373.9)	280.1 (258.9)	243.6 (210.5)	
	Decline	39.5 (30.7)	43.9 (32.1)	65.0 (100.6)	
ADelt L	Level	89.3 (92.7)	122.8 (99.5)	178.6 (157.3)	Condition < 0.001 I > D: <0.001 I > L: < 0.001 L > D: 0.010
	Incline	302.8 (274.1)	364.2 (378.8)	314.0 (247.8)	
	Decline	49.7 (32.8)	87.6 (101.3)	85.1 (84.8)	
Bic R	Level	63.4 (72.4)	86.0 (116.9)	122.0 (201.8)	Condition <0.001 I > L: 0.002 I > D: 0.007
	Incline	280.6 (399.0)	189.3 (186.7)	201.7 (190.2)	
	Decline	101.1 (139.7)	88.3 (80.8)	88.8 (88.1)	
Bic L	Level	54.7 (50.7)	52.8 (42.8)	73.6 (54.0)	Condition < 0.001 I > L: 0.003 I > D: 0.005
	Incline	112.3 (93.2)	124.3 (127.2)	143.4 (95.7)	
	Decline	60.9 (44.4)	55.8 (43.5)	78.2 (119.7)	
ExtDig R	Level	178.2 (180.7)	318.1 (256.1)	203.3 (168.6)	Chair = 0.023 STX > STC: 0.103 STX > PTC: 0.07
	Incline	211.1 (164.5)	243.5 (160.1)	224.0 (142.5)	
	Decline	177.6 (142.8)	315.1 (206.2)	169.9 (137.0)	
ExtDig L	Level	143.3 (162.2)	182.2 (173.1)	123.5 (127.2)	Chair = 0.046 STX > STC: 0.097
	Incline	209.9 (171.3)	202.3 (169.2)	195.3 (145.0)	
	Decline	151.0 (79.9)	286.4 (156.7)	139.6 (122.0)	

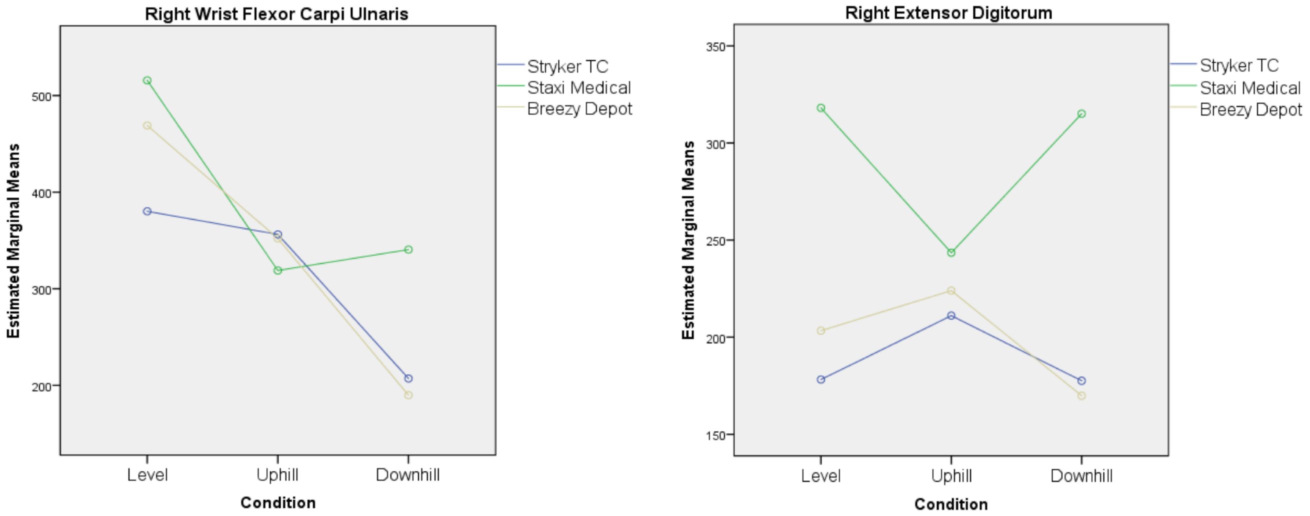

Figure 2: Marginal mean plots for two wrist muscles (right side) for all chairs and conditions

DISCUSSION

This study demonstrated that the SXM required greater wrist extensor activity than the STC and PTC across all three surfaces. In addition, ramp descent required elevated levels of wrist carpi ulnaris activity when using the SXM similar to that found when pushing up the ramp whereas the other two chairs showed decreased effort in this muscle group between ramp ascent and descent. Both results may be explained by the way that the operator must maintain activation of the handle bar brake for the chair to remain in motion. Activation may be higher going down the ramp because the operator must not only squeeze the handles but also steer and maintain control over the chair and 'patient'.

This study found that not surprisingly pushing uphill requires significantly higher muscle activation than level and/or downhill conditions. It is worth noting that the PTC is significantly heavier than the SXM and STC. This initial weight difference would assume that more muscle activation would be required to push the device up and down the ramp but that about the same amount of activation was used as the other devices suggests that the unique PTC features may mediate the effects of the chair being heavier in construction.

Limitations and Future Work:

There was large inter-subject variability among observed in the EMG data which likely impacted being able to detect more statistically significant differences between the chairs. In addition, the flat ground trials had a regulated gait cycle timing whereas subjects walked at their own comfortable pace up and down the ramp. The level walking trial also had a substantially longer pathway compared to the ramp allowing for more gait cycles and hence a more representative amount of data to be analyzed. The amount of force used to push the chairs at the hand/handle interface was not measured in this study and could provide additional insight into the effort required to move a patient in these devices. Further study is needed to investigate the joint angles of the caregiver to extend the understanding of the benefits and risks of the patient transport chairs included in this study.

CONCLUSION

The Stryker® Prime TC, Staxi® Medical Chair, and the Breezy® Ultra 4 Wheelchair had comparable muscle activations in most muscle groups, with the exception of two wrist muscles which showed higher activation for the Staxi Chair when compared to the other two devices. Higher muscle activations were observed for ramp ascent in a majority of muscle groups tested regardless of the type of chair used. An analysis of the trunk positioning and joint angles may shed additional insight into the use and benefits of ergonomic chairs for patient transport.

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