EVALUATION OF DIFFERENT PATIENT TRANSFER DEVICES IN REDUCING BIOMECHANICAL EXPOSURES AMONG PROFESSIONAL CAREGIVERS

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This study systematically investigated the efficacy of commercially-available patient transfer devices (a slide sheet, slide board, air-assisted device, and conventional draw sheet) in reducing biomechanical exposures during standardized lateral patient transfer tasks. A repeated-measures laboratory study with 10 experienced caregivers (9 females and 1 male) was conducted to measure the muscle activity in the upper extremity (flexor digitorum superficialis, extensor digitorum communis, biceps, triceps, and trapezius) and low back (erector spinae), and hand pull force and during standardized lateral patient transfer tasks with four different commercially-available transfer devices. The results showed that there were significant differences between the transfer devices in muscle activity (p's < 0.01) and hand pull force (p < 0.01). The air-assisted device showed the largest reduction of muscle activities and hand pull force. The slide board also showed lower muscle activities and hand full force as compared to the slide sheet and conventional draw sheet; however, limited differences in muscle activity and hand pull force were found between the slide sheet and conventional draw sheet. These findings indicate that the air-assisted device and slide board may be effective engineering controls to reduce the biomechanical exposures and associated injury risks in the upper extremity and low back among caregivers.

INTRODUCTION

Professional caregivers suffer from a high prevalence of occupational injuries (Davis and Kotowski, 2015; Mbaisi et al., 2013) and ranked as one of the highest-risk occupations in terms of occupational injuries (Bureau of Labor Statistics, 2016). Among the injuries, musculoskeletal disorders (MSDs) particularly in the low back and shoulder regions have been one of the largest components in worker's compensation claims (Bureau of Labor Statistics, 2016). An estimated annual MSDs-related injury cost among professional caregivers is $1.6 billion in the US which creates substantial economic burdens on various stakeholders including caregivers (Alexopoulos et al., 2011). Manual patient handling (e.g. transferring and repositioning) involves various physical risk factors associated with MSDs, including forceful exertion, awkward postures, and repetition, which are common in manual material handling. Previous studies showed that the risk of MSDs in caregivers increased with the frequency of the manual patient transfer, especially when the patients were overweight or obese (Choi and Brings, 2016). Given rapidly growing obese population in the US (Strum and Hattori, 2013), caregivers are expected to be at even greater injury risks than ever.

Various patient transfer devices such as friction-reducing slide sheets, slide boards, and air-assisted transfer devices have been developed as engineering controls to reduce the biomechanical stress during patient handling tasks. Previous studies showed some of these engineering control (e.g., friction-reducing slide sheets and carrier) may be more effective in reducing biomechanical exposures compared to a conventional cotton draw sheet widely used in field settings (Owen et al., 2002; Weiner et al., 2017). However, there is still a lack of studies to biomechanically evaluate the potential benefits of the air-assisted transfer devices and slide boards to reducing physical stresses among caregivers compared to slide sheets and conventional cotton draw sheet. A direct comparison of four devices would provide the convincing evidence to choose the most preventive device for caregivers.

Therefore, this study evaluated whether friction-reducing patient transfer devices (engineering control) further reduced muscle activity and hand pull force as compared to a conventional draw sheet during lateral transfer task.

METHODS

Subjects

Ten subjects (9 females and 1 male) were recruited via e-mail solicitations and printed flyers. Gender distribution was to reflect a real working population in health care that male population is about 9% of the total nursing personnel (U.S. Census Bureau, 2013). The inclusion criteria for subjects included 1) at least 6 months of caregiving experience, 2) no restriction in physical activity, 3) no current (past 7 days) musculoskeletal pain; and 4) no current medication related to musculoskeletal disorders or cardiovascular diseases. All subjects were experienced caregivers (Mean $\pm$ SD: 2.6 $\pm$ 1.6 years of experience), and the average age (SD) was 24.2 (3.1) years.

One healthy male subject (Age: 26 years old; Weight: 71 kilograms; Height: 1.74 meters) was recruited to serve as the mock bedridden patient during the entire study as the biomechanical exposures are affected by a patient's characteristics including demographics and health conditions.

As patient transfer tasks required at least two caregivers (Weiner et al., 2017), one assistant caregiver was recruited to help actual study subjects the patient transfer tasks from the other side. To minimize any potential confounding effect from using different assistant caregivers, this assistant caregiver participated in all the sessions for all the subjects throughout the study period.

The experimental protocol was approved by the University's Institutional Review Board.

Experimental protocol

Prior to the study, all subjects gave their written consent form. Researchers instructed the subjects how to use transfer devices based on Occupational Safety and Health Administration (OSHA) 3182 guidelines and the product instructions from the manufacturers. Subjects were asked to practice transfer devices to familiarize themselves with the tasks and devices and minimize potential learning effect.

We recruited a relatively lightweight male subject for the mock patient in order to minimize a risk for over exertions during patient transfer task. The mock patient was instructed to cross his arms, and have a minimum support to assist the transfer.

Two hospital stretchers (Prime Series; Stryker; Portage, MI) were used to conduct lateral transfer tasks in the laboratory (Figure 1). Four different transfer devices were utilized: 1) draw sheet (Patient Bath Blanket; Linteum Textile Supply; Little Ferry, NJ), 2) slide sheet (Comfort Glide Sling; Medline; Northfield, IL), 3) slide board (Pro-Slide; Pro-Lite; Ivyland, PA),

and 4) air-assisted device (PPS Glide; PPS; Eugene, OR).

Subjects laterally pulled the patient toward the subjects from one stretcher to the other stretcher. This lateral transfer task was repeated twice per transfer device (Figure 1). The order of four transfer devices was randomized to minimize any systematic bias due to the experimental order.

The muscle activity (electromyography: EMG) was measured at 1,000 Hz using a wireless data logger (WBA; Mega Electronics; Kupio, Finland) and Ag/AgCl surface electrodes (Blue Sensor N; Ambu; Ballerup, Denmark) from: the 1) flexor digitorum superficialis (FDS), 2) extensor digitorum communis (EDC), 3) biceps (BIC), 4) triceps (TRIC), 5) trapezius (TRAP), and 6) erector spinae (ES). The skin preparation, muscle identification, and electrode placement were conducted per the European Recommendation for Surface Electromyography (Hermens et al., 1999).

At the end of the experiment, maximum voluntary contractions (MVCs) were collected from the upper extremity muscles (FDS, EDC, BIC, TRIC, and TRAP). To avoid back injuries, submaximal reference voluntary contractions (RVC) of low back muscles were recorded during 30 degree forward bending (Soderberg and Knutson, 2000). Three MVCs/RVCs were collected for each muscle, and each contraction lasted for three seconds with a 2 minute break between contractions.

The band pass filter of 10-350 Hz was applied to the raw EMG data. The filtered EMG data was rectified and averaged using a 125-millisecond moving window (MegaWin; Mega Electronics; Kupio, Finland). The processed EMG data was normalized as a percentage of the MVCs for the corresponding muscles. The amplitude Probability Density Function (APDF) was used to evaluate the peak (90th percentile) muscle activities.

The hand pull force from the right side was measured at 1,000 Hz using the six-degree-of-freedom load cell (PY6; Bertec; Columbus, OH). The load cell attached to a customized handle was clamped to provide stable and consistent grip and posture during the transfer tasks (Figure 1). The offset between the load cell handle and each device was 25cm.
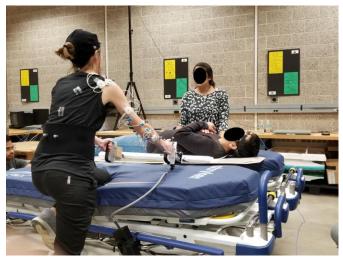
Figure 1. Experimental setup.

Data analysis

The one-way repeated-measures ANOVA in SPSS (version 24; IBM Corporation; Armonk, NY) was used to determine whether there were differences in muscle activity and hand pull force among the different patient transfer devices. The transfer device was set as the fix effect and subject as a random effect. Any statistical significance was followed-up with a Tukey HSD post-hoc test to determine which transfer device could have lower biomechanical exposures. Statistical significance was denoted when $p < 0.05$.

RESULTS

Muscle activity (Electromyography)

In general, muscle activities were significantly lower with the slide board and air-assisted device as compared to the slide sheet and draw sheet (p's < 0.01) whereas there were limited differences in muscle activity between the slide sheet and draw sheet except for TRAP and ES muscles (p's > 0.10) (Table 1). The draw sheet showed the highest muscle activities in FDS and ES muscles. The slide sheet required the greatest muscle activities in EDC, BIC, TRIC, and TRAP. The air-assisted device showed the lowest muscle activities in all the muscles among all the devices.

Table 1. Comparisons of mean (standard error) normalized muscle activity (%MVC) by transfer device: draw sheet (DS), slide sheet (SS), slide board (SB), and air-assisted device (AD). [N = 10]

Muscle (%MVC)	Transfer Device				
	DS	SS	SB	AD	P-value
FDS	27.2^A (2.6)	26.9^A (2.2)	21.7^B (2.5)	15.0^C (2.2)	< 0.01
EDC	48.8^{AB} (5.5)	50.9^A (6.6)	39.7^{BC} (5.3)	33.7^C (5.6)	< 0.01
BIC	26.5^A (3.6)	26.8^A (3.5)	19.5^B (2.4)	11.8^C (2.1)	< 0.01
TRIC	19.1^{AB} (1.5)	26.9^A (4.6)	17.8^B (3.5)	14.2^B (2.4)	0.06
TRAP	68.8^B (6.6)	92.7^A (11.0)	71.1^B (9.5)	51.9^B (7.5)	< 0.01
ES	182.4^A (11.3)	152.0^B (13.7)	126.8^C (8.7)	106.0^D (14.4)	< 0.01

Columns with different superscripts denote significant difference in normalized muscle activity among transfer devices with $\alpha = 0.05$.

Hand pull force

The hand pull force data showed that the draw sheet and slide sheet required higher hand pull force as compared to the air-assisted device (p's < 0.01) (Table 2). However, no differences in the hand pull force were found between the slide sheet and draw sheet ($p = 0.69$).

Table 2. Comparisons of mean (standard error) hand pull force (Newton) by transfer device: draw sheet (DS), slide sheet (SS), slide board (SB), and air-assisted device (AD). [N = 10]

	Transfer Device				
	DS	SS	SB	AD	P-value
Hand Pull Force (Newton)	127.9^A (4.5)	122.1^A (6.7)	105.4^B (7.4)	40.2^C (5.2)	< 0.01

Columns with different superscripts denote significant difference in variables among transfer devices with $\alpha = 0.05$.

DISCUSSION

This study compared the muscle activity in the upper extremities and low back regions, and hand pull force during standardized lateral transfer tasks across four different patient transfer devices: a draw sheet, slide sheet, slide board, and air-assisted device. The study findings indicate that the slide board and air-assisted device can be effective engineering controls to further reduce biomechanical exposures as compared to the conventional draw sheet and slide sheet, given significantly lower muscle activity and hand pull force.

The muscle activity was approximately 25-55% lower on the air-assisted device compared to the draw

sheet and slide sheet (Table 1). Despite the limited differences in the upper extremity muscle activities, the low back (ES) muscle activity was 17-30% lower with the slide board as compared to the slide sheet and draw sheets. These results mirrored the differences in hand pull force among the different transfer devices. Since the air-assisted device required significantly lower hand pull force as compared to the other transfer devices (Table 2), muscles in the upper extremities and low back may have generated significantly less force with the air-assisted device, and therefore the muscle activities were lower as compared to the other device. This finding is consistent with the trend of lower rates of perceived exertion in using the slide sheet compared to the draw sheet reported in previous studies (Fragala and Fragala, 2014; Weiner et al., 2017). Thus, both objective and subjective measures supported that the slide board and air-assisted device could substantially reduce the effort of caregivers to transfer the patient.

The hand pull force (40 N) with the air-assisted device was approximately 69% lower as compared to the draw sheet (128 N) and slide sheet (122 N) (Table 2). These differences can be explained by substantial reduction in the coefficient of friction on the surface when using the air-assisted device. The air-assisted device reduces friction between the stretcher and the device by releasing the low pressure, high volume air through the micro perforations underneath the mattress, which creates an air cushion between the device and surface of the stretcher. This low friction helped reducing the substantial amount of pulling force required by caregivers. The slide board also showed 14-17% reduction in the hand pull force as compared to the slide and draw sheets. This force contrast can also be explained by the materials of slide boards designed to reduce the friction. Our results, however, showed the total hand force by all transfer devices except the air-assisted device would exceed the 35-pound limit for safe patient handling (Waters, 2007). Thus, unless the air-assisted device is utilized, it would be safe to require additional caregiver(s) to manually transfer a patient.

In order to measure the hand pull force, the load cell with the handle was implemented in this study. This might change the hand coupling and posture as compared with gripping each device. However, we consistently applied this equipment across four devices, and it would be still effective to understand the relative impact of biomechanical exposures among different devices.

In conclusion, the substantially lower muscle activity and hand pull force indicates that the air-assisted device and slide board can be an effective engineering control to reduce biomechanical exposures (force and muscular loadings) and associated risks for overexertion injuries during lateral patient transfer.

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