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Assessment of alternative methods for informal caregivers to perform patient repositioning tasks

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ABSTRACT

Manual patient handling tasks put formal and informal caregivers at risk of musculoskeletal injury. Intervention research to reduce risks to informal caregivers is limited. This study examined effects of slide sheet use when individual informal caregivers performed patient boosting and turning tasks. Three methods of slide sheet use and a baseline method (no slide sheet) were compared, to reposition a 70 kg individual. Muscle activity, ground reaction force, posture, and rating of perceived exertion were significantly affected by task method. Erector Spinae activity was reduced in boosting and turning away tasks with the slide sheet. Shoulder elevation, torso angle, and normalized vertical ground reaction force were also reduced with the slide sheet during boosting. The turn towards task was generally not improved with the slide sheet. Overall, using a slide sheet provided biomechanical benefits to individual caregivers performing two common patient handling tasks: boosting and turning patient away from caregiver.

1. Introduction

Informal caregivers are individuals who provide consistent unpaid care for a spouse, child, friend, or others with whom they have an established social relationship (Schulz and Tompkins, 2010). Approximately 43.5 million adults provided unpaid care to an older adult or a child in the 12 months preceding the 2015 Caregiving in the US survey (AARP Public Policy Institute and the National Alliance of Caregiving, 2015). One in five caregivers reported a high level of physical strain as a result of caregiving. Caregivers are most likely to help their care recipients with at least one activity of daily living (ADL), and high-hour caregivers often help with all ADLs (AARP Public Policy Institute and the National Alliance of Caregiving, 2015). Darragh et al. (2015) recognized transfers, bathing and dressing as the most frequent activities performed by informal caregivers. Low back and shoulder areas were reported as the most common sites of musculoskeletal discomfort, respectively affecting 76% and 43% of their participants (Darragh et al., 2015). Suzuki et al. (2016) found that activities involving body repositioning were among the factors contributing to the development of low back pain in female family caregivers in Japan. In informal care settings, some patient repositioning tasks such as transfers and manual lifting may be performed by one individual, and the forces required to perform these tasks are consistently above the 3400 N recommended limit (Garg et al., 1991; Marras et al., 1999; Nelson and Baptiste, 2004; Weiner et al., 2017). Moreover, family caregivers are often untrained, and do not receive adequate guidance from official health care providers (Bucher et al., 2001; Schumacher et al., 2000).

Two common repositioning tasks investigated in the current study are turning and boosting. Patients who tend to slide towards the foot of the bed need to be returned to the head of the bed ('boosting'). In a professional care setting, two care providers stand opposite each other, on the left and right sides of the patient, and work together to boost the patient. In a home setting, a single informal caregiver may work from the head of the bed to boost the patient. Turning may be performed every 2 h, and based on the patient's situation, can alternate between prone, right-side lying, supine, and left-side lying (Waters et al., 2007). Caregivers turn patients to clean them, change bed sheets, inspect wounds, position bedpans, relieve discomfort, and prevent pressure ulcers and other adverse health outcomes (Fragala and Fragala, 2014).

Patient repositioning has been recognized as a high risk task that can cause occupational health issues among professional caregivers (nurses, nursing assistants, home health aides) (Waters et al., 2007). Since caregivers frequently need to reposition patients who are lying in a bed, caregivers will often perform these tasks in awkward postures (affected

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by height and width of the bed) and at substantial risk of overexertion, which could lead to overexertion injuries (Fragala and Fragala, 2014). Pompeii et al. (2009) found that 26.3% of patient handling injuries at a large medical center involved turning and boosting tasks.

In formal care settings, ergonomic tools such as powered hospital beds, powered lifts, slide sheets, inflatable transfer equipment, and slide boards have been introduced to reduce mechanical loading while performing patient handling tasks (Drew et al., 2015; Evanoff et al., 2003; Skotte and Fallentin, 2008). Among these devices, slide sheets may be the least costly and most readily accessible intervention for informal caregivers. A number of studies have documented benefits of using slide sheets, including reduced ratings of perceived exertion, reduced calculated spine compression and shear loading, reduced activity in some muscles, and reduced peak force required to move patients (Bartnik and Rice, 2013; Drew et al., 2015; Fragala, 2011; Fragala and Fragala, 2014; Theou et al., 2011; Weiner et al., 2017). However, most of these studies have engaged experienced caregivers (e.g. nurses) rather than informal, untrained caregivers; in some the height of the bed was adjusted based on participant anthropometry; boosting was performed from the side of the bed, most often by two people, but occasionally by one person; and turning was also performed by two people. These studies provide useful information for formal care settings, but results may differ for informal care settings where the bed height is not adjustable and there is only a single care provider performing the tasks. Therefore, the purpose of this research was to investigate the efficacy of using a slide sheet by individual informal caregivers, based on effects on biomechanical measures and subjective ratings. It was anticipated that the slide sheet would provide some biomechanical benefits and that performing the tasks when using the slide sheet would be perceived as requiring less physical effort, in comparison to performing the tasks without a slide sheet.

2. Methods

2.1. Participants

Twenty individuals, 9 females and 11 males, were recruited to participate in the study. Exclusion criteria included formal patient-handling training experience, pregnancy, and any pain, injuries or surgeries in the back, legs, arms, hands or shoulders in the past 12 months. Mean age, weight, and height of the male participants were 28.2 yrs (±4.2), 75.4 kg (±10.7), and 179.0 cm (±7.4), respectively; for females the respective mean values were 26.2 yrs (±7.3), 55.7 kg (±8.9), and 161.2 cm (±4.4).

2.2. Experimental design

A within-subject experimental design was used to investigate the effects of task method (traditional method and using a slide sheet in different ways) while performing three patient repositioning tasks on shoulder and trunk posture and muscle activity, ground reaction force, and perceived exertion. The three repositioning tasks were boosting (caregiver performed from the head of the bed), turning away (turning away from the caregiver at the side of the bed; patient was turned from supine onto his left side and a pillow was placed against his back to support him there), and turning towards (turning towards the caregiver at the side of the bed; patient was turned from supine onto his right side and a pillow was placed to support him there). The three methods of grasping/using the slide sheet were rolled (rolling the edge of the sheet up to the patient's head or side to improve the grasp and control of the sheet), topsheet (grasping the top layer of the slide sheet and pulling it towards the caregiver, so that the sheet's top layer moved relative to the bottom layer of the slide sheet, thereby reducing frictional resistance), and stick (rolling the end of the sheet around a lightweight stick, thereby creating a handle by which to more easily grasp the sheet (Lavender et al., 2007)). The topsheet method was only used for the boosting and turn away tasks; it required the participant to pull the topsheet relative to the bottom sheet. The turn towards task only involved turning the patient, so the topsheet technique was not feasible to use for the turn towards task. Steps performed for each Method of each Task are illustrated and annotated in the Appendix. Task order was counter-balanced across participants; within each task, the order of the methods was randomized. Two repetitions of each task-method combination were performed.

The dependent variables included peak (90th percentile) normalized electromyographic (EMG) statistics from activity collected from surface electrodes placed bilaterally over the biceps (1/3 distance on line from fossa cubit to medial acromion; BICR, BICL), upper trapezius (2 cm lateral to midpoint of acromion-C7 line; TRPR, TRPL), and erector spinae (L4 level; ESR, ESL) muscles. Peak (90th percentile) torso flexion angle and shoulder angles of elevation were evaluated from motion capture data, and peak vertical ground reaction force, normalized to the participant's weight, was assessed from force plate data. Torso flexion angle refers to the angle from the vertical made by a line between the hip and shoulder joints (Chaffin and Andersson, 1984). Shoulder elevation angle (SHEL) describes the angle the upper arm makes with a vertical line centered through the shoulder. The elevation angle is 0° when the arm is down by the side and it is 90° when the arm is parallel with the ground (Doorenbosch et al., 2003). Subjective ratings of perceived exertion (Borg, 1998) were also collected.

2.3. Procedure

Each subject attended a training session prior to his/her data collection session. Written informed consent was secured prior to starting the training session; the protocol was approved by the University's Institutional Review Board. During training, the participant watched training videos, containing visual and audio instruction, and practiced performing each of the three tasks, using each of the methods, until the researcher determined that the participant could follow and execute all the instructions and details proficiently. Participants were required to remain on the forceplate while performing each task, but could move their feet. They were shown how to wrap the sheet around the stick (for the stick method), how to roll the end of the sheet (for the rolled method), and how to readily grasp the top sheet for that method. They were instructed to use the sheet to first pull the patient towards them and then turn the patient, for the turn away task, so that the patient would still be in the middle of the bed after being repositioned onto his left side. Participants were told to treat the patient as if he was a relative that the participant was assisting. Otherwise, instructions were limited to allow participants to perform the tasks in ways that were more suitable for their individual anthropometry and strength capacities. Participants were not restricted from contacting the vertical side of the bed when performing the tasks. During training, the participant could review the video instruction more than once and the researcher would also provide guidance to aid the participant as he/she learned how to perform each task using each method. For practice and data collection sessions participants worked with a 70 kg standardized patient who was instructed to be compliant, but not to assist the participant; the exception to this was that the patient's arms and lower legs/ankles were crossed in the starting position for the turn towards task (left over right) and for the turn away tasks (right over left). The bed height was fixed, to simulate a home environment. Bed height was 67 cm from the top surface of the force plate.

Written informed consent was also secured prior to starting the data collection session. Anthropometric data were collected first. Next, electrodes were placed over muscles via measurement and location was confirmed by palpation. Sites were prepared by shaving and then cleaning with isopropyl alcohol, and then Delsys brand single differential electrodes were placed over the muscles of interest. Participants performed a series of brief isometric maximum voluntary contractions (MVC) for the purpose of EMG normalization. They completed two replications of maximum contraction activities for each muscle with a 2 min break in between contractions. The following isometric exertions were performed to elicit maximum muscle activity from the muscles of interest: for trapezius muscles, with the arm positioned at the side, generate a maximum upward shoulder shrug while grasping a fixed handle; for biceps, maximum elbow flexion with the elbows flexed 75–90 deg while grasping a fixed handle; for erector spinae, a Biering–Sorensen type back extension exertion (Pitcher, Behm and MacKinnon, 2008). After collecting the MVCs, Xsens sensors were placed on the head, thorax, and sacrum, and bilaterally on the upper arms and forearms. The participant's model was created using the Motion Monitor xGen software (Innovative Sports Training, Chicago, IL) based on the participant's height and default scaling. Prior to beginning each task, the participant reviewed the relevant training videos for each method for that task. After completion of a given task-method combination, the participant was asked to provide a rating of perceived exertion. The Borg CR-10 scale was shown to assist them (Borg, 1998).

2.4. Data collection and processing

The data were acquired with a Motion Monitor xGen data acquisition and analysis system (Innsport, Chicago, IL, USA). EMG data were obtained using a multi-channel system (Bagnoli-8, Delsys, Boston, MA, USA). EMG data were filtered (20 Hz high pass, 500 Hz low pass, and notch filters at 60, 120, and 180 Hz) and sampled at 1000 Hz. EMG data were further processed using a custom Matlab program that smoothed the rectified data through a 75 ms moving average window and a Hanning filter. Kinematic data were collected at 100 Hz using Xsens Awinda wireless motion tracking sensors. Ground reaction force data were was obtained from a Bertec force plate (FP4060-05-PT-1000 with AM6800-4 amplifier), at 1000 Hz. Kinematic and force plate data were also processed using a custom MATLAB code. One female participant's EMG data and another female participant's posture data were not included in the analysis due to problems with the data.

2.5. Statistical analysis

The three tasks were analyzed separately, as were data for male and female subject groups. MANOVA preceded analysis of variance (ANOVA) procedures that were used to examine the effects of task method on 90th percentile values of the EMG, ground reaction force, and shoulder and trunk kinematic data and the RPE, using Proc Mixed in SAS 9.4. Pairwise comparisons of methods were conducted with the Tukey–Kramer post-hoc test, within each task. A significance level of 0.05 was selected.

3. Results

Method had a significant effect on the dependent measures. Biomechanical benefits of using the slide sheet were evident, particularly for the boosting task. A number of benefits of using the slide sheet were also seen for the turn away task, but few benefits were seen for the turn towards task.

3.1. Boosting task

All four methods were tested for the boosting task: baseline (no slide sheet; bb), top sheet (bt), stick (bs), and rolled (br). MANOVA tests were significant ($p < 0.001$ for Wilks' Lambda, Pillai's Trace, and Hotelling–Lawley Trace) for both groups, male and female. There was a significant effect of task method on all muscles for the male subjects and for all muscles except the TRPL for the female subjects (Table 1; Fig. 1 a and b). For the male participants, the three sheet methods (br, bs, bt) elicited similar levels of peak activity, for each respective muscle, and all were markedly less than the baseline (bb) method ($p \leq 0.001$). In the female participant group, the peak activity in the erector spinae muscles was also markedly reduced when using any of the sheet methods ($p < 0.0001$), as was the activity in the BICR ($p \leq 0.020$). However, for the TRPR, only the topsheet method was different from the baseline method ($p = 0.007$). For the BICL only the rolled and stick methods were significantly different ($p = 0.025$) amongst the four methods.

Table 1
Boosting task: Type 3 tests of fixed effects of task method.

	Female		Male	
	F	p	F	p
Muscle				
BICL	3.21	0.0314	23.83	<0.0001
BICR	13.01	<0.0001	26.01	<0.0001
TRPL		ns	11.72	0.0001
TRPR	4.07	0.0112	20.10	<0.0001
ESL	32.32	<0.0001	55.44	<0.0001
ESR	39.00	<0.0001	32.88	<0.0001
Posture				
SHEL-L	109.2	<0.0001	91.6	<0.0001
SHEL-R	148.48	<0.0001	148.37	<0.0001
Torso ang	35.17	<0.0001	72.01	<0.0001
Fznorm	15.26	<0.0001	32.17	<0.0001
RPE	4.62	0.0124	9.0	0.0002

In the boosting task, the left and right shoulder elevation angles were significantly higher in the baseline, than in all other methods, for both female and male participants ($p < 0.001$; Fig. 1 c and d). Notably, peak elevation angle for the baseline method exceeded 105°, for both groups of participants, for both arms. All sheet methods were equally effective in reducing mean peak shoulder elevation angle, by about 40° in the female participants and 35–40° in the male participants. Peak torso angle (Torsoang) was significantly less using any of the sheet methods (by about 15–20°) than using any the baseline method, among female subjects ($p < 0.001$). For the group of male subjects, reduction in the torso angle was 16-22 deg when using the sheet methods, when compared with the baseline method ($p < 0.001$). Participants had to reach to the patient's axillae to perform the baseline method, whereas their hands were positioned near the patient's head when using the sheet methods, which explains the marked differences in the posture.

Peak normalized ground reaction force was significantly affected by method for the boosting task. All three sheet methods resulted in lower normalized vertical ground reaction force (Fznorm; 6–12%) compared with the baseline method's peak value ($p < 0.005$), for both groups (females and males; Fig. 1 c and d). Among the sheet methods, Fznorm with the stick method was significantly less than the other two sheet methods, for both groups of participants. Regarding perceived exertion, all sheet methods with the males produced similar RPE values (2.5–3) and these were all lower ($p \leq 0.011$) than the mean baseline rating (4.2). For females, only the RPE for the topsheet method (4.1) was significantly different (less than) the RPE for the baseline method (5.4; $p = 0.032$).

3.2. Turn away task

All four methods were tested for performing the turn away task: baseline (no slide sheet; ab), topsheet (at), stick (as), and rolled (ar). MANOVA tests were significant ($p < 0.001$ for Wilks' Lambda, Pillai's Trace, and Hotelling–Lawley Trace) for both groups, male and female. There was a significant effect of task method on all muscles for both groups of subjects (Table 2; Fig. 2 a and b). For the male participants, for the erector spinae and the biceps muscles, all sheet methods (ar, as, at) elicited similar levels of peak activity, for each respective muscle, and all were less than the baseline (ab) method ($p \leq 0.002$). Peak left trapezius activity was lower when using the stick or rolled sheet methods in comparison to the baseline or the topsheet methods. The peak activity elicited in the right trapezius during the baseline was not different from any of the sheet methods, though there were significant differences among the sheet methods, with the rolled method eliciting a lower peak

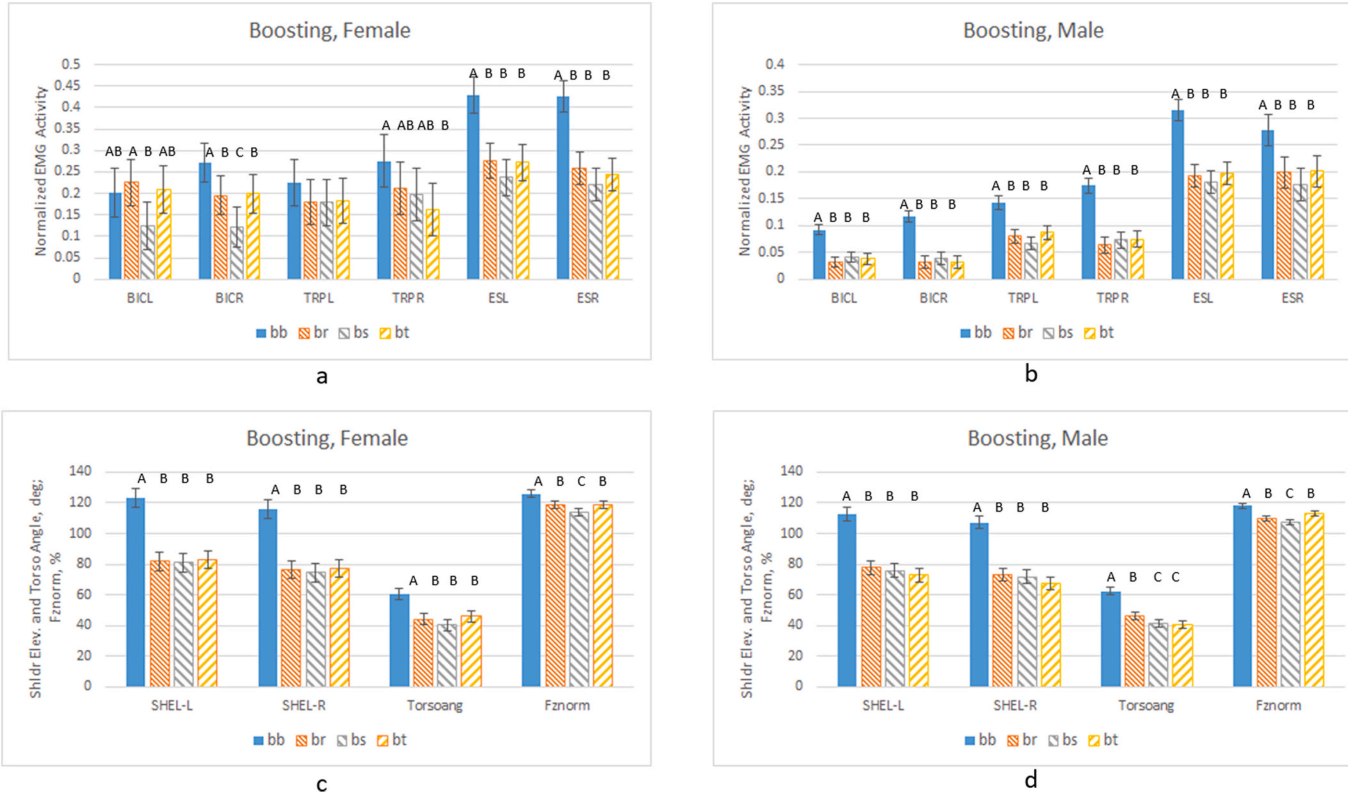

Fig. 1. Results for boosting task. Peak normalized EMG activity (range 0–1; female group, a; male group, b); peak shoulder elevation (SHEL) and torso angles (deg.) and normalized vertical ground reaction force (%) female group, c; male group, d). No significant differences were found between methods with the same letter. Boosting methods: baseline (bb), rolled (br), stick (bs), topsheet (bt).

Table 2
Turn away task: Type 3 tests of fixed effects of task method.

	Female		Male	
	F	p	F	p
Muscle				
BICL	12.46	<0.0001	37.49	<0.0001
BICR	8.92	<0.0001	18.90	<0.0001
TRPL	7.03	0.0004	6.53	0.0005
TRPR	11.21	<0.0001	5.87	0.0012
ESL	13.43	<0.0001	8.67	<0.0001
ESR	22.37	<0.0001	11.54	<0.0001
Posture				
SHEL-L		ns	4.03	0.0104
SHEL-R		ns	2.9	0.0405
Torso ang	59.09	<0.0001	23.11	<0.0001
Fznorm	19.38	<0.0001	10.58	<0.0001
RPE		ns		ns

activity ($p \leq 0.003$) than the other two sheet methods.

For the female participants, each of the sheet methods reduced mean peak erector spinae muscle activity significantly from the baseline method ($p \leq 0.037$). For the peak activity in the TRPL and TRPR, the topsheet and rolled methods were significantly less than the baseline method ($p \leq 0.005$), while the stick method was not different from baseline. Peak activity in the BICL was significantly reduced from baseline when using any of the sheet methods ($p \leq 0.020$). For the BICR, only the stick and rolled methods were less than the baseline method. In summary, for the female participant group, using the rolled sheet method elicited peak activity in each muscle that was significantly lower than the baseline method, for the turn away task.

The left and right shoulder elevation angles were not affected by task method during the turn away task for the female group (Fig. 2c). For the male participants, the differences in shoulder elevation angle were modest, with mean values across all four methods within a range of 7–9 degrees of each other (Fig. 2d). For female participants using the sheet (any method) during the turn away task reduced the torso angle by 18–20 deg); for males the range was 11-14 deg. To turn the patient away using the baseline method participants needed to put their hands under the patient to lift and roll him away from them and onto his left side. In contrast, when using the sheet in any method the participants only needed to reach to the surface of the mattress, to the right of the patient. Consistently the peak torso angle occurred when pushing to roll the patient, in the baseline condition. There was greater variability in when the peak torso angle occurred when using the sheet methods. Some participants adopted a consistent torso angle throughout the task when using the sheet, whereas the peak occurred for some participants when they were preparing the sheet (rolling it or wrapping it around the stick), and for others it was when they were holding the patient with their right hand/arm while grasping for and positioning the pillow behind the patient's back.

Peak normalized ground reaction force was significantly affected by method for the turn away task. For both male and female groups, the topsheet method resulted in modestly higher peak normalized ground reaction force than the stick or baseline methods; 5% higher for the female group ($p < 0.001$), and 3–4% for the male group ($p \leq 0.003$). The rolled method was not different from the topsheet method for either group and was also not different from the stick method for the male group. Ratings of perceived exertion were not affected by method for either group of participants. Mean ratings were 3.5–4.5 for the female group across the four methods and 3.0–3.4 for the male group.

3.3. *Turn towards task*

Three methods were tested for performing the turn towards task: baseline (no slide sheet; tb), stick (ts), and rolled (tr). MANOVA tests

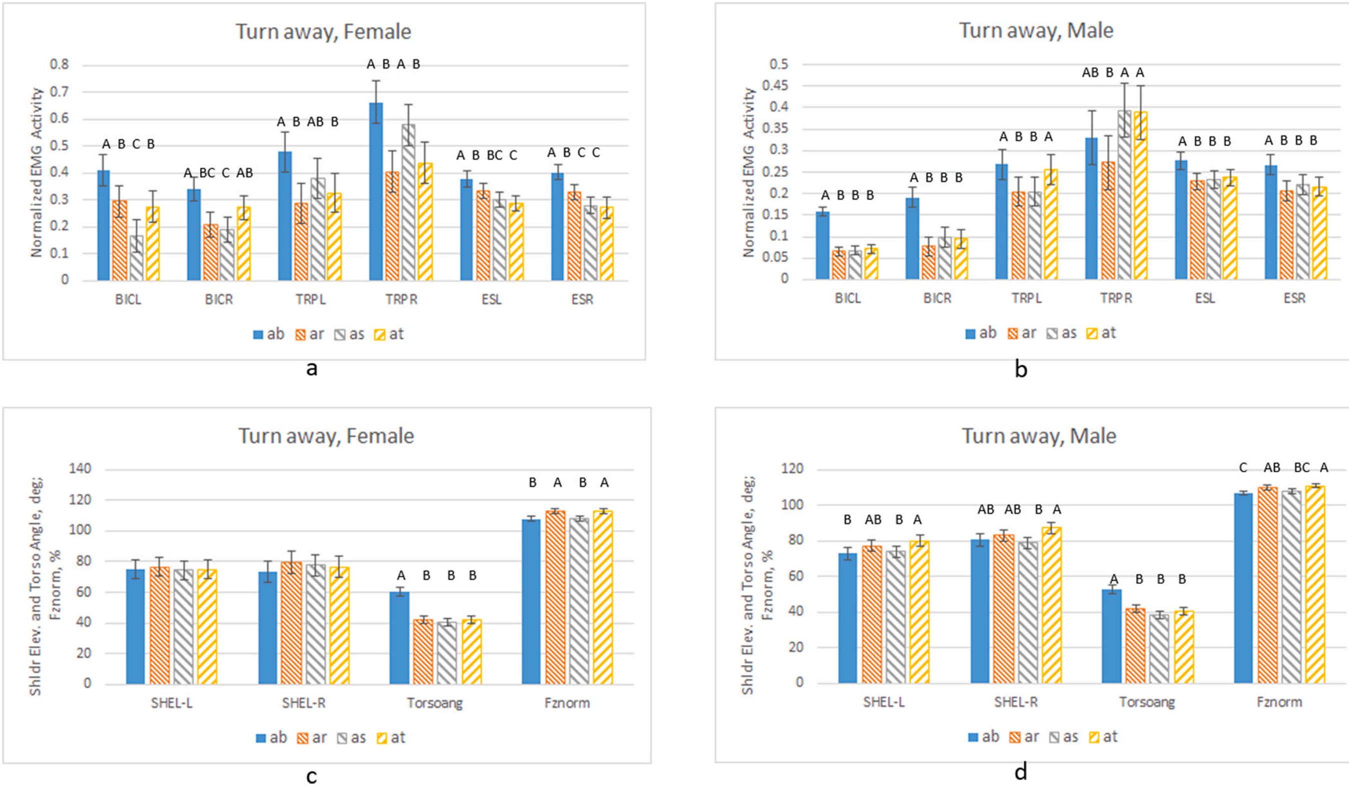

Fig. 2. Results for turn away task. Peak normalized EMG activity (range 0–1; female group, a; male group, b); peak shoulder elevation (SHEL) and torso angles (deg.) and normalized vertical ground reaction force (%) female group, c; male group, d). No significant differences were found between methods with the same letter. Turn away methods: baseline (ab), rolled (ar), stick (as), topsheet (at).

were significant ($p < 0.001$ for Wilks' Lambda and Hotelling–Lawley Trace, and $p = 0.0002$ for Pillai's Trace) for the male and female groups. Among female and male participants, in the turn towards task, there was no effect of method on the peak erector spinae muscle activity (Table 3). For the biceps ($p \leq 0.006$) and trapezius ($p \leq 0.040$) muscles, the stick method elicited higher levels of activity than the baseline, in both groups (Fig. 3 a and b), with the rolled method eliciting peak activity that was most often similar to the baseline method.

In this task, method had a statistically significant, but modest, effect on peak shoulder elevation. The two sheet methods elicited lower shoulder elevation (4–10°) for the left side for both groups of participants ($p \leq 0.030$) and the right side only for the male group ($p \leq 0.05$). However, all mean peak shoulder elevation values were at or above 90° (Fig. 3 c and d). Peak torso angle flexion was reduced, compared with baseline, when using either sheet method for females (12–13 deg; $p <$ 0.0001) and for males (about 11 deg; $p < 0.0001$). Each method required reaching over the patient, though the baseline method required reaching somewhat further than the sheet methods and that is reflected in the posture differences.

For both groups, the peak normalized vertical ground reaction force when using the stick method was greater than when using the baseline method, by a small amount (2–3%; $p \leq 0.030$). The rolled method was similar to baseline for the female group and was similar to the stick method for the male group. In all cases, the range of peak values across the three methods was small for both groups (1-2%; Fig. 3 c and d). With regards to perceived exertion, similar to the turn away task, for the turn towards task there was no effect of method on RPE in either group. Mean ratings were 2.7–3.4 for the female group across the three methods and 2.2–2.7 for the male group.

Table 3
Turn towards task: Type 3 tests of fixed effects of task method.

	Female		Male	
	F	p	F	p
Muscle				
BICL	18.07	<0.0001	16.57	<0.0001
BICR	7.24	0.0022	5.69	0.0058
TRPL	3.75	0.0318	7.60	0.0013
TRPR	9.80	0.0004	15.68	<0.0001
ESL		ns		ns
ESR		ns		ns
Posture				
SHEL-L	8.84	0.0006	21.9	<0.0001
SHEL-R		ns	10.83	0.0001
Torso ang	60.22	<0.0001	31.13	<0.0001
Fznorm	6.46	0.0035	11.36	<0.0001
RPE		ns		ns

4. Discussion

Results from the current study show that a single caregiver could experience biomechanical benefit from using a slide sheet when performing two common repositioning tasks, boosting and turning a patient onto his/her side to face away from the caregiver. In the boosting task, the baseline method (without slide sheet) produced higher values for almost every dependent variable for the male group and for the majority of dependent variables for the female group. Importantly, peak erector spinae activity, normalized peak vertical ground reaction force, peak torso angle, and peak shoulder elevation were all reduced when using any slide sheet method for the boosting task in comparison with the baseline method (Fig. 1). For the turn away task the baseline method elicited higher peak values for the erector spinae muscles in both participant groups, as well as greater peak torso angle. For the other dependent variables, there were fewer differences between the slide sheet methods and baseline (Fig. 2).

Boosting. Other studies that have examined the effects of a slide sheet

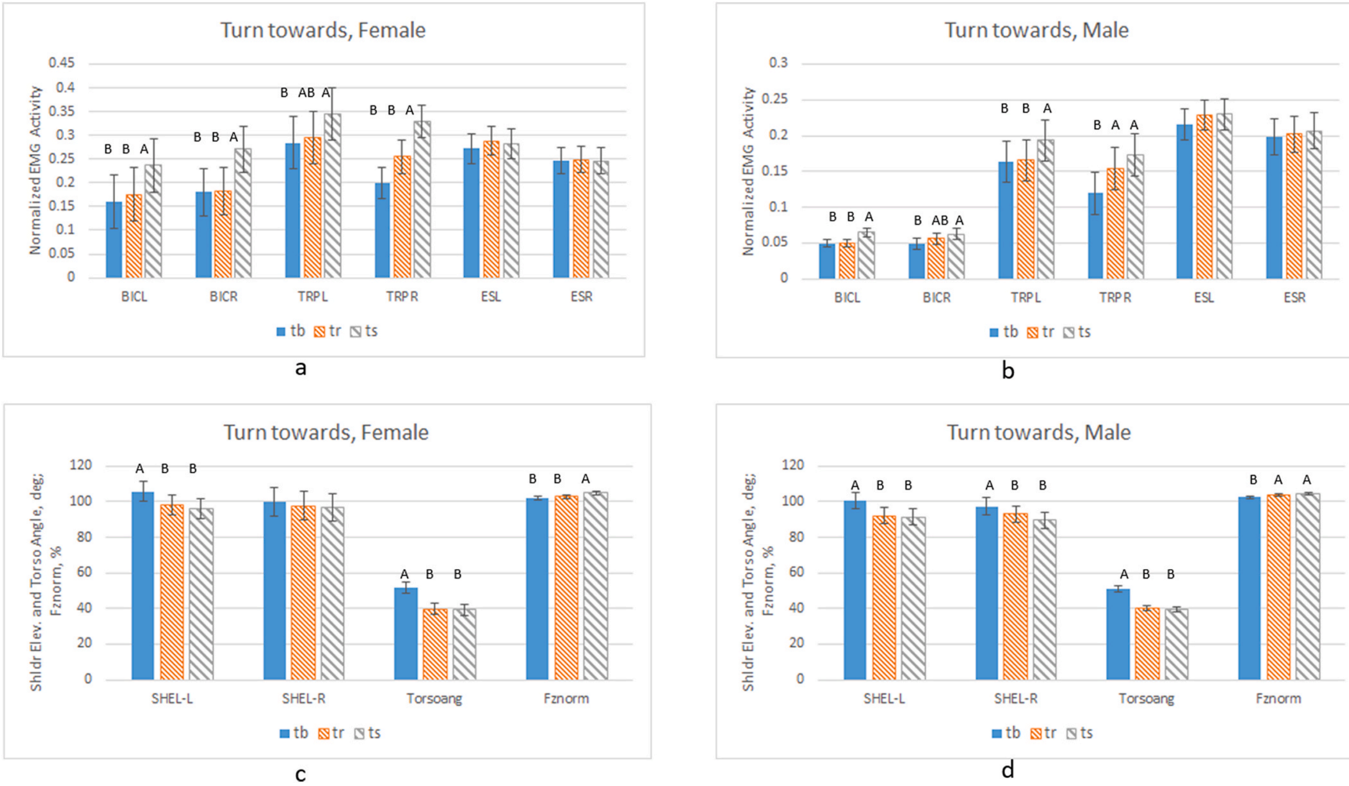

Fig. 3. Results for turn towards task. Peak normalized EMG activity (range 0–1; female group, a; male group, b); peak shoulder elevation (SHEL) and torso angles (deg.) and normalized vertical ground reaction force (%) female group, c; male group, d). No significant differences were found between methods with the same letter. Turn towards methods: baseline (tb), rolled (tr), stick (ts).

used to aid boosting have involved professional caregivers working as a team of two, positioned on either side of the patient. The exception was the study from Weiner et al. (2017), which also included a single caregiver, though still standing at the patient's side. Some studies were performed with mannequins (Fragala, 2011; Weiner et al., 2017), some with human 'patients' (Bartnik and Rice, 2013; Theou et al., 2011). Similar to the current study, perceived exertion ratings were lower for the slide sheet compared to the standard method (Theou et al., 2011; Weiner et al., 2017). The results of the current study are similar to Theou et al. (2011) regarding reduced muscle activity with the slide sheet. Fragala (2011) performed a simulated boosting task to measure the force required to move a 200 lb (91 kg) mannequin. Compared to baseline, peak pull force was reduced by 33% when using a slide sheet. Interestingly, this decrease was similar to the decrease realized when testing the effect of angling the bed 8° downward towards the patient's head in that same study. It is interesting to see that a low cost solution (slide sheet) can be equally as effective as a high cost solution (adjustable patient bed) in reducing boosting/pulling force. In both males and females in the current study, all sheet methods reduced the maximum shoulder elevation during boosting, from well over 100 deg to about 80 deg. This would result in a shift from an upper arm score of 4 to a score of 3 if analyzing the task with RULA or REBA (Hignett and McAtamney, 2000; McAtamney and Corlett, 1993). Similar score reductions would occur for the torso angle. The effect on spinal loading in the current study is not known. Other studies, employing different protocols from the current study, have reported reduced compression loads below 3400 N with use of a slide sheet for some patient repositioning or transfer tasks (Jager et al., 2013; Lloyd and Baptiste, 2006). It is important to recognize that the size of the patient and extent to which the patient can assist are among the factors that will affect the spinal loading experienced by the caregiver.

Another important benefit to using the slide sheet for boosting is the reduction in risk of injury to the patient. In the current study, the caregiver was positioned at the head of the bed to perform the boosting task. In the baseline condition, this required grasping the patient under the axillae and then pulling, which risks compressing the patients' arteries and damaging the brachial plexus (Metzler and Harr, 1996), or aggravating or inflicting shoulder joint injuries (Lavender et al., 2020). Using the slide sheet for boosting eliminates direct contact with the patient while pulling. It also reduces the risk of skin tears, because the slide sheet moves with the patient, rather than the patient moving relative to the sheet in the baseline method. Lastly, given the task was perceived as requiring less effort could mean that it would be performed on a regular basis (as needed), which would also benefit the patient.

Turn away task. The practical benefit of the slide sheet is also noted by Drew et al. (2015), where using a slide sheet was compared with no slide sheet conditions, while pulling sandbags of different weights to simulate patient handling. Their lateral pulling task was similar to the first step in the turn away task in the current study. In the current study, the initial pull towards the participant ensured that the patient would remain in the middle of the bed when turned onto his side. Both studies showed that muscle activity was significantly reduced when using the slide sheet, though unlike the current study, Drew et al. (2015) did not find a reduction in erector spinae activity. This may be due, in part, to the height of the bed. In Drew et al. (2015) bed height was adjusted to the hip height of the participants (simulating the adjustability of a hospital bed), while in the current study the bed height was fixed at 67 cm to simulate a standard bed in a house or apartment. Drew et al. (2015) also found the slide sheet reduced the mean RPE score, while the current study found no difference in mean RPE scores across methods. Importantly, Drew et al. (2015) demonstrated that using a slide sheet directly under a patient (as in the current study) or using a slide sheet placed under a regular sheet produced similar biomechanical benefits during a lateral pulling task. Such placement could improve patient comfort (skin touching cotton sheet v. slide sheet).

Performing both of the turning tasks involved an upward pull near the end to make room for placing the wedge-shaped pillow to support the patient in side lying. This was the main reason for the higher values of normalized vertical ground reaction force when using the slide sheet, in comparison to the baseline method. However, the differences were modest. The differences ranged from 4 to 5% for the turn away task and 1-2% for the turn towards task.

Time to perform the tasks was not measured because all of the participants were new to all of the tasks and would likely develop proficiency with practice, that would reduce their time to perform the tasks. That said, the sheet methods inherently involved additional steps over the baseline method for each task. Sheet preparation (rolling the sheet to create a handle, wrapping the sheet around the stick, or grasping the topsheet) added time to each repositioning task, though the time was a few seconds. In some cases, though, that meant the participants were spending those few seconds in an awkward posture, such as when they were rolling the sheet or wrapping the sheet around the stick, in preparation for the turn towards task. The participants were standing with torso angled forward while unsupported and with arms extended reaching out over the patient while preparing to perform the task using those sheet methods. Though only for a few seconds, this may provide additional contraindication for using either of those sheet methods for the turn towards task.

Recommendations. The results of this study, when considered collectively, suggest that for boosting there was a clear advantage in using a slide sheet, for both male and female study participants. This is based on reductions in muscle activity, particularly for the erector spinae muscles, peak arm elevation angles, peak torso angle, and normalized peak Fz. For the turning towards task, using the sheet generally did not reduce the various biomechanical measures, other than peak torso angle, and in the case of using the stick, resulted in somewhat higher upper extremity muscle activity for both males and females. As such, the slide sheet, as used in this study, is not recommended over the baseline method for the turning towards repositioning task.

For turning away, the results were mixed. The female participants experienced benefits from using the slide sheet with regards to meaningful lower peak muscle activity for all monitored muscles with the rolled and top sheet methods. For the male group, the rolled method also produced lower peak activity across the sampled muscles. Both groups displayed reduced peak torso angle with the slide sheet. As for shoulder elevation and normalized Fz, there was no benefit to using the slide sheet. Various sheet methods produced peak values that were similar to baseline or slightly greater in magnitude where a significant difference was identified. Due to these mixed results, the recommendation for the turn away task would be to use the slide sheet and vary the method, because no one sheet method was consistently better than the others, though muscle activity was generally lower with the slide sheet than without it.

Limitations and strengths of the study. As with all studies, there were limitations to this study. The study was conducted with a relatively modest number of participants, although the groups were sufficiently large to identify statistically significant differences among test conditions and the number of participants was similar or larger than some prior slide sheet studies. Forty-eight percent of informal caregivers are between the ages of 18–49, with the other 52% being between the ages of 50–74 (AARP Public Policy Institute and the National Alliance of Caregiving, 2015). All of the participants in the current study would be categorized in the younger portion of that population. Future studies should include participants that represent a wider range of age and experience with informal caregiving.

Contact with the vertical side of the bed was made by some participants during some trials; this would have some effect on the force plate data. It is also important to note that participants in this study were not required to place the slide sheet underneath the patient. The slide sheet that was used in the study was made of breathable fabric. These types of slide sheets can be left under a patient for some time. Slide sheets that are made of other materials are not meant to be left under a patient. For those types of slide sheets, a repositioning task would include the non-trivial added steps of placing the slide sheet underneath the patient and removing it after the patient was repositioned.

The amount of time that participants were introduced to the tasks and methods was limited; although for each task, participants reviewed standardized instructional videos and practiced under a researcher's supervision to ensure they were able to perform each task successfully using each method. It is important to note that they were still novices, and their proficiency in performing the tasks would likely have improved further over time.

Though not unique, an important strength of the study was the employment of a standardized patient, rather than in inanimate object (mannequin or sandbags). Another important strength was the use of multiple measures to capture the effects of the different methods of performing the tasks. As discussed by Wilson (1995), triangulation, or the use of multiple measures, provides a more complete evaluation of the task of interest and the effects of potential improvements. An example of this is that the highly significant reductions in the biomechanical measures when using the slide sheet did not tend to be matched by reductions in the ratings of perceived exertion. In order for an intervention to be adopted, users have to perceive its benefits (Weiler et al., 2012). This signals that additional work might be needed to refine the methods used in the current study, in order to make the slide sheet a viable intervention for use in the home by informal caregivers.

5. Conclusion

The value of using new technologies for safe patient handling among professional health care workers in formal care settings has been examined in several prior studies. Given the large number of informal caregivers, it is also important to determine the effectiveness of technologies and interventions, across the spectrum of cost and availability, that can aid informal caregivers who perform patient handling tasks. The results from this study, which examined informal caregivers working alone, show that the stress of the boosting task, as assessed by peak muscle activity in the upper extremity and lower back, normalized vertical ground reaction force, torso angle, and shoulder elevation angle, could be reduced by using a slide sheet. The study also showed that, on balance, the stress of the turn away repositioning task, as assessed by peak muscle activity in the upper extremity and low back, particularly for female participants, could be reduced by using a slide sheet, with a concomitant reduction in torso angle and little or no increase in normalized vertical ground reaction force. The turn towards task was determined not to benefit from use of a slide sheet. These results may also be useful to home health care workers, formal caregivers who work alone in a client's home.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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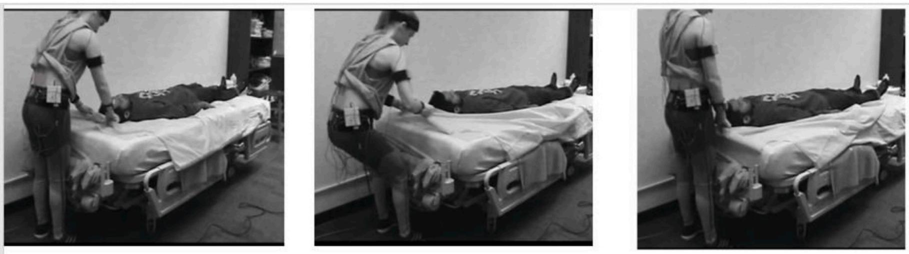
Appendix. Steps in Boosting Task, for each Method

Starting position

Grasp pt under axillae and begin to boost

Release grasp when pt is at top of bed

Task: Boosting
Method: Baseline
Acronym: bb



Start: grasp top sheet in preparation for pulling it

Pull top sheet to boost pt

End boost when pt is at top of bed

Task: Boosting
Method: Top sheet
Acronym: bt

Start: rolling sheet around stick to create handle

Once handle is created, begin to boost pt

End boost when pt is at top of bed

Task: Boosting
Method: Stick
Acronym: bs

Start: roll top sheet in preparation for pulling it

Pull top sheet to boost pt

End boost when pt is a top of bed

Task: Boosting
Method: Rolled
Acronym: br

Appendix. Steps in Turn Away Task, for each Method

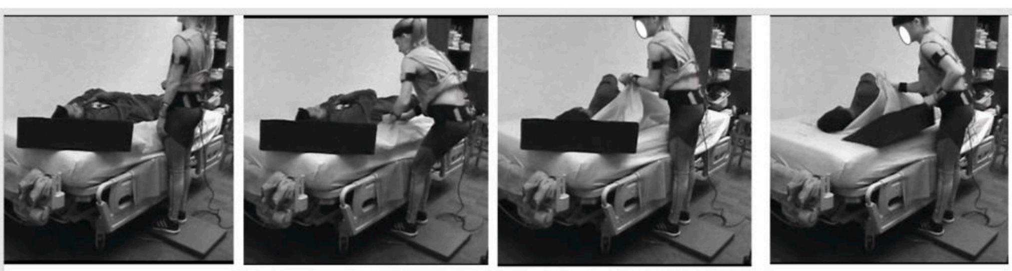
Starting position

Reach under pt, position hands and begin to turn (roll) pt away from caregiver

Hold pt in position with right hand/arm) and reach for support pillow with left hand

Place pillow behind pt to maintain left side-lying position

Task: Turn away
Method: Baseline
Acronym: ab



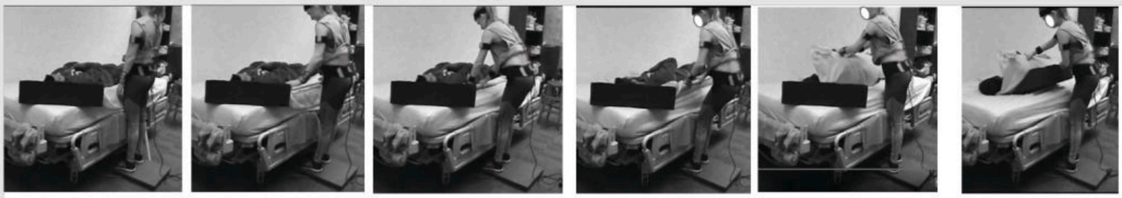
Starting position

Grasp top sheet and begin to pull pt towards caregiver, to maintain pt in center of bed

Turn (roll) pt away from caregiver

Hold pt in position (using sheet grasped by right hand) and position support pillow with left hand to maintain left side-lying position

Task: Turn away
Method: Top sheet
Acronym: at



Starting position | Position stick on sheet | Roll sheet around stick to create handle | Once handle is created, begin to pull pt towards caregiver, to maintain pt in center of bed | Turn (roll) pt away from caregiver | Hold pt in position (stick rolled in sheet held by right hand/arm) and position support pillow with left hand to maintain left side-lying position

Task: Turn away
Method: Stick
Acronym: as

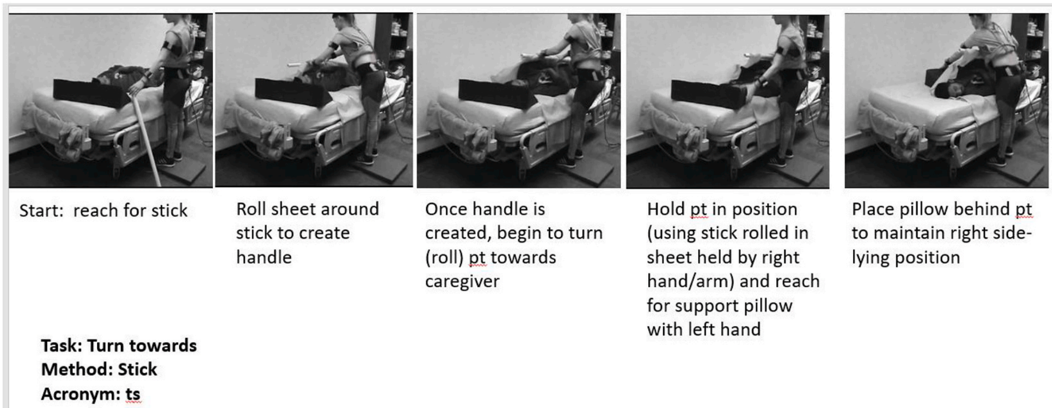
Start to grasp sheet | Roll sheet up to create a handle | Once handle is created, begin to pull pt towards caregiver, to maintain pt in center of bed | Turn (roll) pt away from caregiver | Hold pt in position (rolled sheet held by right hand/arm) and position support pillow with left hand to maintain left side-lying position

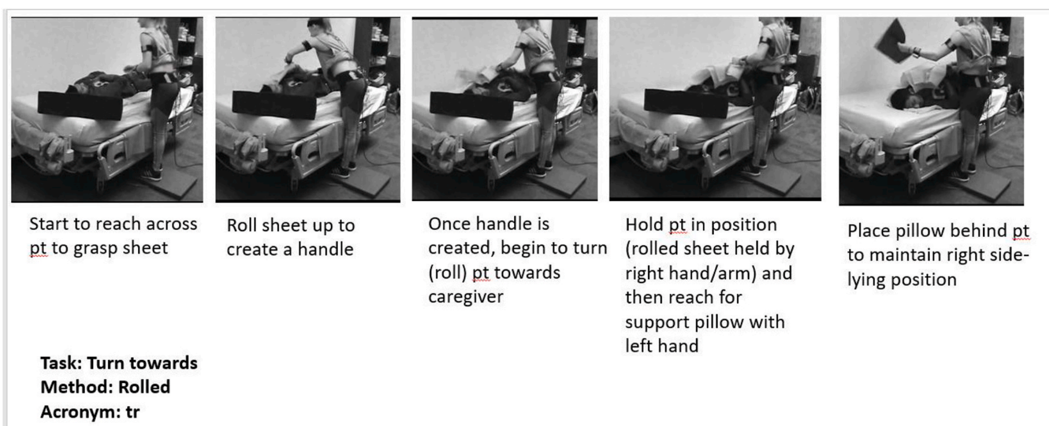
Task: Turn away
Method: Rolled
Acronym: ar

Appendix. Steps in Turn Towards Task, for each Method

Starting position | Reach across pt, position hands and begin to turn (roll) pt towards caregiver | Hold pt in position (with right hand/arm) and reach for support pillow with left hand | Place pillow behind pt to maintain right side-lying position

Task: Turn towards
Method: Baseline
Acronym: tb





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