

## Designing ergonomic interventions for emergency medical services workers—part III: Bed to stairchair transfers

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Received 10 February 2006; accepted 4 August 2006

### Abstract

The objective of the current work was to test interventions aimed at reducing the low-back musculoskeletal loads experienced by firefighters/paramedics (FFPs) providing emergency medical services (EMS) that involve transferring a patient between a bed and a stairchair. The interventions, developed or selected using focus groups, were a prototype Drew People Mover<sup>TM</sup>, and a Transfer Sling. These interventions changed the coupling between the EMS worker and the patient. They were compared with an under-axilla lift. Eleven FFP teams transferred a 75 kg dummy between a bed and a stairchair. Both interventions were tested using two-person transfers. In addition, the Transfer Sling was tested using a one-person transfer. Surface electromyographic (EMG) data were collected from 8 trunk muscles from each participant along with spine kinematic data. Additionally, ground reaction force data obtained from two forceplates were acquired for one member of each FFP team that was used to estimate directional spine moments using a 3D linked-segment model. In the two-person transfers, there was 19° less trunk flexion ( $p = 0.002$ ) for the FFP on the patient's left side and a trend towards less motion for the FFP on the patient's right side ( $p = 0.079$ ) when using the interventions. Both FFPs showed reductions in the ipsilateral Erector Spinae activity using the Drew People Mover and the Transfer Sling that averaged approximately 9% MVC, which corresponds to a 21% decrease in the muscle activation levels. While the overall EMG was greater when performing a single-FFP transfer, the Transfer Sling reduced the bilateral Erector Spinae activity by approximately 20%. During the two-person transfers, the FFP on the forceplate to the right side of the patient showed a reduction in the forward bending moment using the Drew People Mover relative to the Sling and under-axilla conditions. During the single-person transfers, only the twisting moment was significantly reduced through use of the Transfer Sling. These objective measures, when combined with the subjective ratings of perceived exertion and the verbal feedback lead us to recommend the use of these interventions for bed to stairchair transfers.

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**Keywords:** Low-back disorders; Emergency medical services; Intervention; Firefighter; Back pain

### 1. Introduction

Musculoskeletal injuries consistently account for about half of all injuries to firefighters/paramedics (FFPs) engaged in emergency medical service (EMS) operations as well as to EMS workers in the private sector (Karter and Molis, 2004; Reichard and Jackson, 2004). These injuries result in lost work time, permanent disability, and high

worker compensation costs (Karter and Molis, 2004; Walton et al., 2003). In a recent analysis of 1343 firefighter worker compensation claims, the per-claim average worker's compensation cost for sprain/strain injuries was over 50% greater than for claims overall (Walton et al., 2003). The back was the primary body part affected.

As the prevalence of obesity in the general population increases (CDC, NCHS, 2004), so does the risk for injury to the EMS workers who are responsible for transporting these heavier patients. Many EMS runs begin with a seated patient being transferred from the bed to a stairchair for

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downstairs transport (Conrad et al., 2000). A second transfer is then performed as the patient is moved from the stairchair to the ambulance stretcher. Previous research studying patient handling tasks used in health care settings has indicated that bed to wheelchair transfers result in very large spinal compression and shear loads, with the compression loads in excess of compression force used in the NIOSH action limit (3400 N) (Daynard et al., 2001; Marras et al., 1999) and the shear loads in excess of the 500 N action limit recommended by McGill et al. (1998).

The purpose of this work was to evaluate ergonomic interventions aimed at reducing biomechanical loads on the back as patients are transferred from the bed to a stairchair during simulated EMS operations. Typically, these transfers are performed by lifting the patient using an under-axilla lift and may be performed by one or two EMS workers. The ergonomic interventions described in this paper have been developed to facilitate lifting the patient, by essentially providing handles that facilitate the ability to grasp and handle the patient. In other health care settings, gait belts and slings are often used for this purpose; however, there is conflicting evidence regarding the benefits of that intervention (Hignett, 2003). It should be noted that while a gait belt is not intended for use when it is necessary to lift the patient's entire weight, a sling may be used to do so. Elford et al. (2000) report a reduction in the amount of angular deviation, velocity, and acceleration of the trunk, as measured with a lumbar motion monitor (LMM), when using a sling during chair-to-chair patient transfers,

suggesting that the use of one or two slings may reduce the risk of back injury.

The specific ergonomic interventions were developed through a series of focus group discussions with FFPs (Conrad et al., *in review*). Three groups, each with between 8 and 10 FFPs met twice to brainstorm and refine intervention ideas. An industrial designer sketched drawings of the concepts suggested by the participants. During these discussions, the ergonomic challenges of using the existing approach, the under-axilla lift was discussed and potential interventions were proposed for the ergonomic issues identified.

The first intervention, called the Drew People Mover™ (Drew Systems, LLC), was a piece of fabric 122 cm long that is narrower at the top (41 cm) and wider (76 cm) at the bottom and has multiple attachment points for the four handles (Fig. 1a). The Drew People Mover would be worked under the patient prior to moving, at which point the handles would be attached, and the patient lifted by two or more FFPs and transferred in essentially a fabric seat. The second intervention was termed the Transfer Sling. The Transfer Sling was comprised of a long webbed belt, essentially a very long and continuously adjustable seat belt that could be wrapped around a patient's back and under their thighs before reconnecting with itself to form a continuous loop. When lifting a patient, the FFPs would position themselves in front and to the side of the patient and would grasp the Transfer Sling approximately 1/3rd of the way down from the most superior point on the

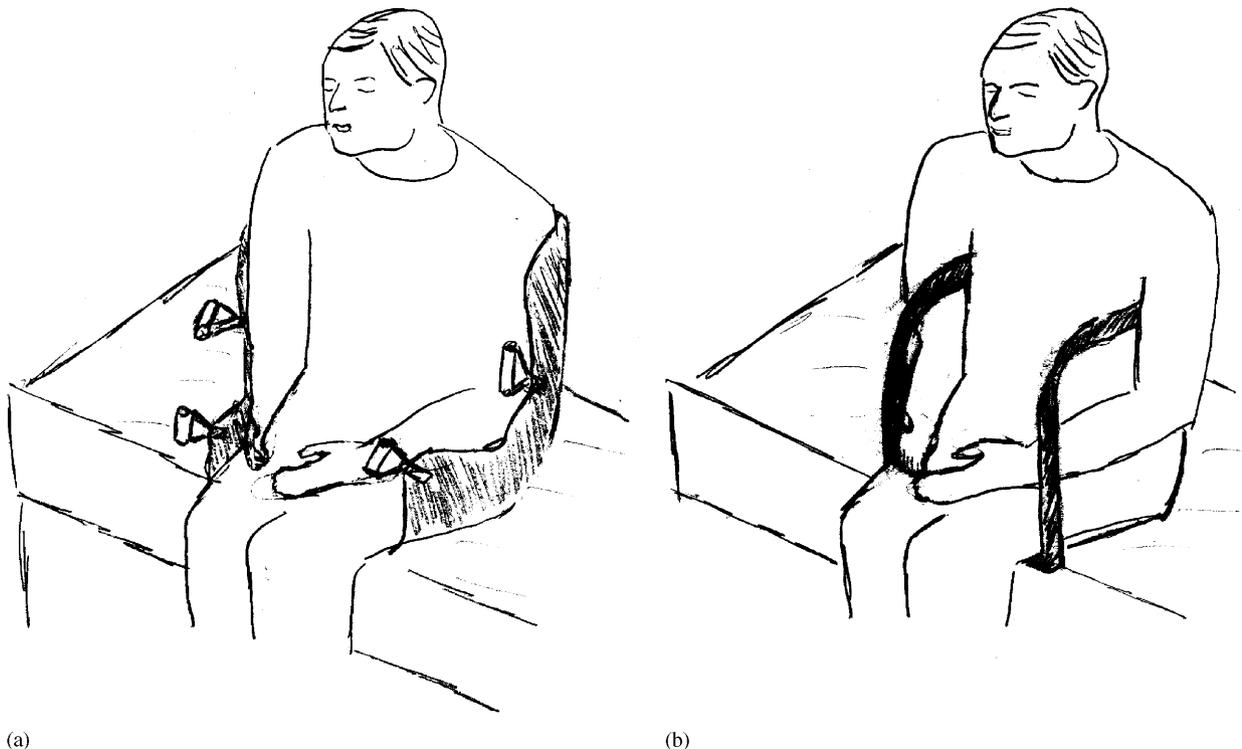


Fig. 1. The two interventions that were evaluated in this study were the Drew People Mover (a) and the transfer sling (b).

patient's back (Fig. 1b). Thus, the Transfer Sling formed a simple, easily grasped harness that provided an anterior lift point and prevented the patient from tipping backwards. An additional advantage of the Transfer Sling is that it required no repositioning of the seated patient prior to the lifting as did the Drew People Mover. While ideally the Transfer Sling would be used by two FFPs, due to its design, it could also be used by a single FFP. It should also be noted that both of these interventions could be used when transferring the patient from the stairchair to the ambulance stretcher following transport.

For each intervention, the hypothesis tested was that the intervention reduced the muscle activity and trunk moments relative to the under-axilla lift when transferring seated patients incapable of offering assistance. As these transfers are on occasion performed by just one FFP, the Transfer Sling was compared using both two-person and single-person transfers.

## 2. Methods

### 2.1. Subjects

Eleven two-person teams of FFPs were recruited from fire departments in the Chicago suburbs. All participants were employed fulltime as FFPs at their respective departments. Each participant signed an informed consent prior to participating in the study. Ten of the teams were comprised of two males. One team was comprised of two females. Assignment to a specific team was based on availability. Similar to actual work situations, the team members designated which FFP would perform the single-person transfers in addition to the two-person transfers. The mean age, height, and weight of the subjects was 37 years (28–51 years), 1.80 m (1.63–1.89 m), and 96 kg (70–123 kg), respectively. On average the FFPs had 12 years of experience in the EMS component of the job (<1–25 years). All had considerable experience transferring patients into and out of stairchairs. None were experiencing low-back pain at the time of the study.

### 2.2. Experimental design

The experiment used a randomized block design wherein each team served as a block and experienced all the interventions in a randomized sequence. There were five conditions. These included the two-person and the one-person under-axilla lifts, the two-person and the one-person sling transfers, and the two-person Drew People Mover transfer. Each team had one team member consistently lift the patient's left side and one team member consistently lift the patient's right side. The FFP who lifted the patient's right side also performed the single-person transfers.

The primary-dependent measures were the surface electromyographic (EMG) signals from eight trunk muscles recorded from each FFP. The muscles sampled

included the left and right Latissimus Dorsi (LATL and LATR), Erector Spinae (ERSL and ERSR), External Oblique (EXOL and EXOR), and Rectus Abdominus (RABL and RABR). After normalizing each muscle relative to a maximal contraction, the mean and 90th percentile level of each muscle's activity was extracted for analysis.

In addition to the EMG recordings, the subjects were instrumented to obtain three-dimensional measures of torso motion and, for the FFP performing the single-person lifts and lifting the patient's right side in the two-person transfers, the external three-dimensional trunk moments at L5/S1.

### 2.3. Apparatus and instrumentation

In each transfer task a 75 kg dummy, similar to one used by the fire service for training exercises, was moved. The transfers were initiated with the dummy sitting on a simulated bed 54.6 cm above the forceplates. A strap was used to keep the dummy in the seated posture throughout the transfer. The height of the stairchair was the same as the bed. The stairchair was positioned at the foot of the bed. The angle of the stairchair relative to the bed was determined by each FFP.

The FFP performing the single-person lifts was instrumented with magnetic sensors (Accension) on each shank, each thigh, the pelvis (S1), and at the top of the thorax (T1). The FFP connected to the magnetic sensors stood on two Bertec forceplates. The FFP performing only the two-person transfers was instrumented with an LMM to quantify trunk postures.

Each FFP was connected to an eight-channel telemetered EMG system (Noraxon). The RMS output from the Noraxon amplifiers was sampled along with the kinematic and kinetic data using InnSport<sup>TM</sup> Motion Monitor data collection software at 120 Hz for 6 s.

### 2.4. Testing protocol

After reading and signing the informed consent documents and watching an instructional video that demonstrated how to use the experimental interventions, each member of the team was instrumented with disposable surface electrodes (Cleartrace<sup>TM</sup> 1700–030) at standard muscle sites as described by Marras (1987). For the Erector Spinae, the electrodes were positioned approximately 5 cm lateral from the midline at the L3 level. The Latissimus Dorsi electrodes were positioned at the T7 level over the belly of the muscle, approximately 13–15 cm lateral from the midline. The External Oblique electrodes were positioned at the level of the umbilicus and centered approximately halfway between the iliac crest and the anterior superior iliac spine at an angle of 45°. The Rectus Abdominus electrodes were placed just above the umbilicus approximately 2.5 cm lateral from the midline.

Prior to conducting the study, the subjects performed two types of maximal voluntary exertions to obtain maximal EMG signals for normalization purposes. In the trunk extension exertions, subjects pulled up on a handle positioned at approximately mid-thigh level. This resulted in a modest degree of spine flexion ( $\sim 20^\circ$ ), similar to what we expected during the more strenuous points in the task. This task was repeated until maximal EMG values were obtained from both the Erector Spinae and Latissimus Dorsi muscles. The trunk flexion exertions were completed by connecting a cable between a chest harness and a reference frame apparatus (Lavender et al., 1992). These provided maximal signals from both sets of abdominal muscles. In reality, because of the weight of the dummy, often these “maximal” values were exceeded during the testing protocol. When this occurred, the maximal values were replaced with the highest observed EMG value from the experimental trials. This occurred for approximately half the muscles sampled, but varied considerably across subjects.

Prior to collecting data for each exertion, the team members positioned themselves for the transfer according to the prescribed conditions. The team was in charge of coordinating the timing of each transfer. During each task, the FFPs were encouraged to verbally communicate with each other as they typically would on the job. Immediately after the completion of each exertion, the subjects were asked to provide a rating of perceived exertion using the Borg CR10 (Borg, 1998). The team was given a 1–2 min rest period as the data were checked, and while members of our research team returned the dummy to the bed in preparation for the next experimental condition.

### 2.5. Data analysis

The EMG readings were normalized to relative maximum and resting levels. The kinetic and kinematic data for the FFP on the forceplates were used in a linked-segment biomechanical model that calculated the L5/S1 moments by working up from the ground reaction force data through the ankles, knees, and hips. The model has been described previously (Lavender et al., 2000). For each exertion, the 90th percentile value from each muscle’s normalized EMG data and the 90th percentile value from each moment direction were extracted from the data. It was these 90th percentile values for these variables that were subsequently analyzed using the statistical analysis described below.

The EMG data from each FFP, the spine moment data from the right-side FFP and the spine kinematic data were analyzed using the PROC GLM (analyses of variance) in the SAS software (version 8.0). Where significant effects ( $p < 0.05$ ) were found in the two-person test, the REGWQ multiple comparison procedure (SAS, 1985) was used, as it controls the experiment-wise error rate, to make comparisons between the three intervention conditions tested (Drew People Mover, Transfer Sling, control). The ratings

of perceived exertion (RPE) data were analyzed using the SPSS (version 11.5) Wilcoxon signed ranks test and the Friedman Tests for the one- and two-person transfers, respectively.

## 3. Results

### 3.1. Two-person transfers

When lifting the patient the FFPs adopted a forward flexed posture, which, for the FFP on the patient’s *left* side, was significantly reduced when using the Transfer Sling or the Drew People Mover versus when using the under-axilla lift (Table 1, Fig. 2a). A similar trend ( $p = 0.079$ ) was found for the FFP standing on the forceplate on the patient’s *right* side (Fig. 2b). In neither FFP were there statistically significant changes in the amount of lateral bending or twisting motion (Table 1). For the FFP on the forceplate, we did observe a significant ( $p = 0.012$ ) change in the 90th percentile forward bending moment acting on the spine (Fig. 3). Post hoc analyses revealed that the Drew People Mover had a significantly lower forward bending moment (294 Nm, SD = 54 Nm) than either the Transfer Sling (347 Nm, SD = 54 Nm) or the under-axilla lift (356 Nm, SD = 79 Nm). During the two-person transfers, the lateral bending moment data ranged from 56 to 73 Nm across the three experimental conditions; however, none of these changes approached statistical significance. Likewise, the twisting moments remained relatively consistent across conditions ranging between 35 and 37 Nm.

For the FFP positioned on the forceplate, to the patient’s *right* side, the 90th percentile normalized EMG data show that there was significantly less recruitment in three of the contra-lateral muscles sampled due to the interventions (Table 2). For this FFP, the Transfer Sling was found to reduce the recruitment of the ERSL, and the RABL relative to the under-axilla condition, whereas the LATL recruitment was reduced for both the Drew People Mover and the sling conditions (Fig. 4). The trend in the ERSR data was similar to that found for the ERSL, although there were no significant differences detected by the post-hoc test.

There was much less change in the EMG data for the FFP positioned on the patient’s *left* side (Table 2). The only significant change in muscle recruitment was a reduction in the ERSR (contra-lateral) recruitment when using the Drew People Mover as compared with the under-axilla condition (Fig. 5). There was a similar trend in the findings for the LATR.

Looking across both FFPs, the rankings derived from the ratings of perceived exertion indicated that the FFPs reported it was easier to move the patient using either the Transfer Sling (mean rank = 1.81) or the Drew People Mover (mean rank = 1.86) as compared with the under-axilla lift (mean rank = 2.33) ( $p = 0.035$ ).

Table 1  
P-values from the statistical analysis of the spine kinematic data for the two-person and the single-person bed to stairchair transfers

Number of lifters	Location	Test	Direction of postural deviation		
			Forward bending	Lateral bending	Twisting
Two-person	FFP on patient's right side	ANOVA	0.079	0.091	0.109
	FFP on patient's left side	ANOVA	0.002	0.277	0.433
	—	Post-hoc	(dpm & sl) < ua	—	—
One-person	Front	ANOVA	0.955	0.003	0.037

dpm, Drew People Mover; sl, sling; ua, under-axilla.

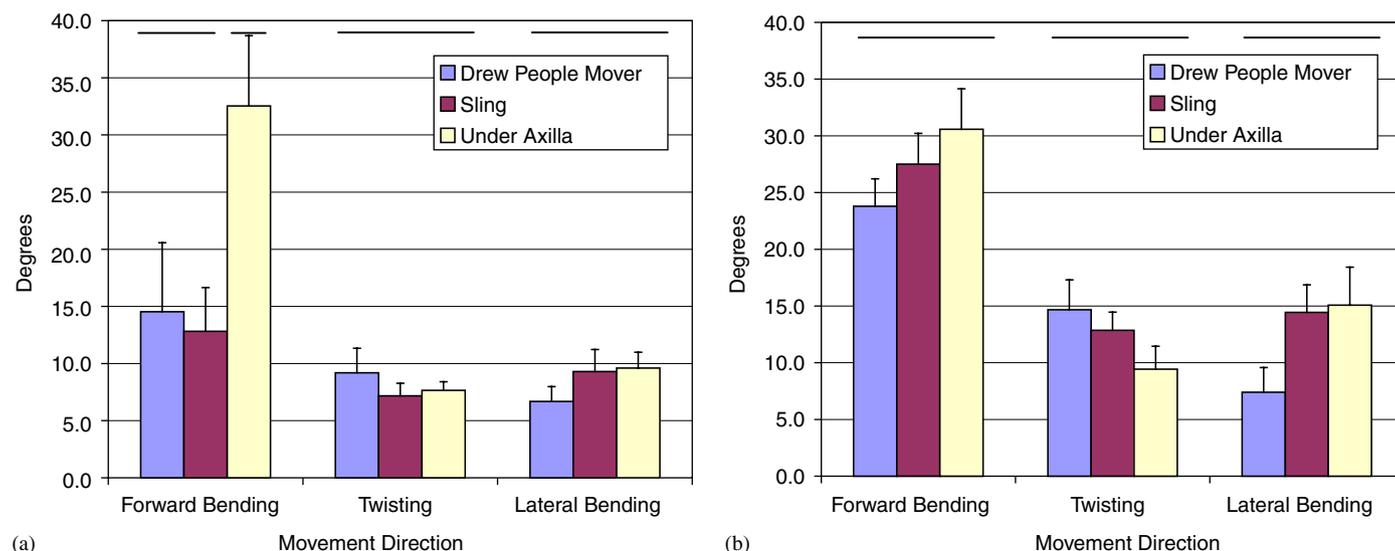


Fig. 2. The amount of trunk motion in each of the three cardinal planes for (a) the FFP on the patient's left side wearing the LMM and (b) the FFP on the patient's right side with the electromagnetic sensors. Conditions linked by an unbroken line were not significantly different ( $p > 0.05$ ).

### 3.2. Single-person transfers

The postural data from the single-person transfers indicate that while the forward bending remained at approximately  $25^\circ$  for both conditions, the amount of lateral bending and the twisting motion was significantly reduced through the use of the Transfer Sling (Fig. 6, Table 1). On average, the lateral bending and twisting motions were reduced  $10^\circ$  and  $6^\circ$ , respectively.

As would be expected, the forward bending moment was larger with the single-person transfer, averaging approximately 500 N m, but there was no significant reduction with the use of the Transfer Sling. The twisting moment, however, was significantly lower ( $p = 0.019$ ) when the Transfer Sling (35 N m, SD = 17 N m) was used as opposed to the under-axilla method (52 N m, SD = 29 N m) was used (Fig. 3). While a similar trend was seen in the lateral bending moment, this change was not statistically significant.

Similar to the large forward bending moments observed in these single-person transfers, the overall recruitment of

the Erector Spinae was also increased, averaging 54% MVC across conditions and bilateral muscle groups. Both the ERS L and ERS R muscles showed significantly (Table 2) less activity when using the sling during the single-person transfer (Fig. 7). Similarly, there was also a trend towards a reduction in the activation of the LATL muscle when using the sling.

The ratings of perceived exertion were larger in the single-person transfers (mean rating = 3.9) than observed in any of the two-person methods (mean = 2.1). For the single-person transfers there was no significant difference ( $p = 0.098$ ) between the rankings for the Transfer Sling and the under-axilla method in the Wilcoxon signed ranks test. Although, in 7 out of 11 subjects the transport sling exertion had a lower RPE rating than the under-axilla lift.

## 4. Discussion

Results from this study show that incorporating some simple ergonomic interventions can potentially reduce the demands placed on the musculoskeletal system when FFPs

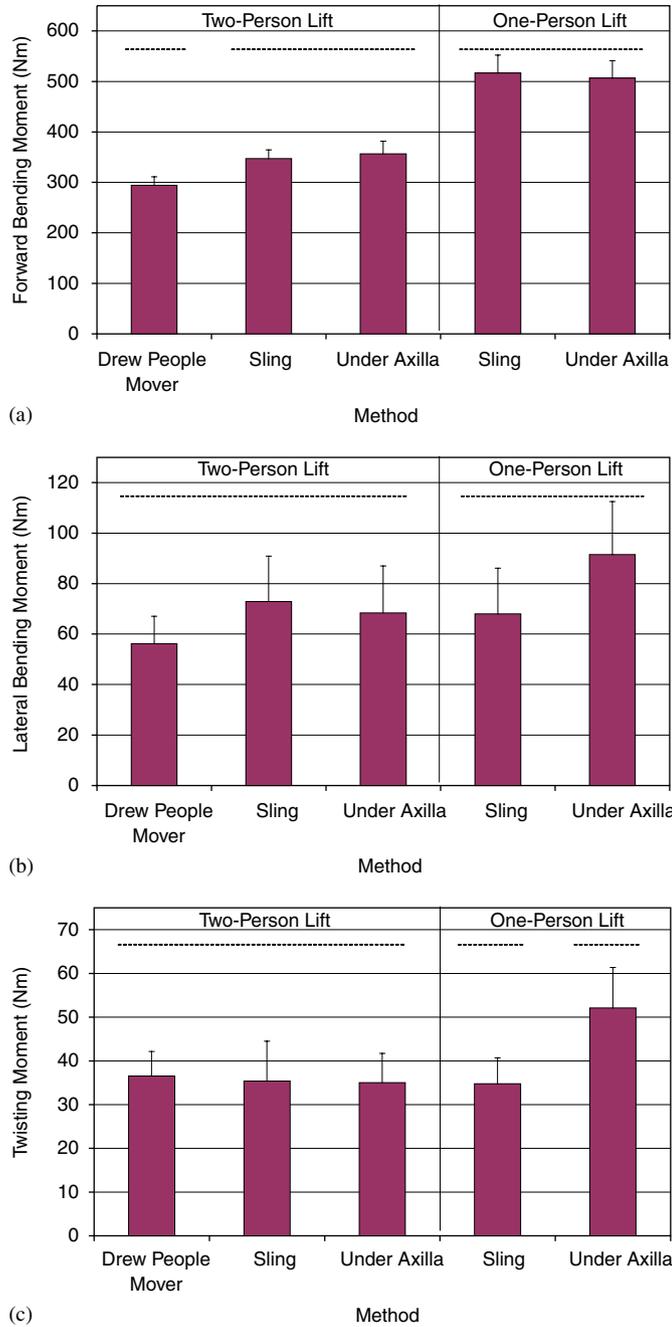


Fig. 3. The mean 90th percentile three-dimensional spine moments in Newton-meters experienced by the FFP standing on the patient’s right side during the two-person and one-person lifts with and without (under axilla) the interventions. Conditions linked by an unbroken line were not significantly different ( $p > 0.05$ )

transfer patients from a bed to a stairchair. Both the objective and subjective measures tend to support the use of both the Drew People Mover and the Transfer Sling; however, the data are not unequivocal. One must look across both the statistically significant effects and the direction of the apparent trends to determine the potential for these interventions.

One would expect many of the observed changes to be inter-related. The reduced flexion observed with the Drew

Table 2  
P-values from the statistical analysis of the EMG data for the two-person and single-person bed to stairchair transfers

Number of lifters	Location	Test	LATR	LATL	ERSR	ERSL	RABR	RABL	EXOR	EXOL
Two-person	FFP on patient’s right side	ANOVA	0.273	0.015	0.053	0.051	0.208	0.016	0.427	0.300
		Post-hoc		(dpm & sl) < ua		sl < ua			sl < (dpm&ua)	
Single-person	FFP on patient’s left side	ANOVA	0.083	0.154	0.049	0.552	0.288	0.776	0.516	0.124
		Post-hoc			dpm < ua					
	In front of patient	ANOVA	0.64	0.08	0.019	0.017	0.521	0.279	0.523	0.111

Dpm, Drew People Mover; sl, sling; ua, under axilla.

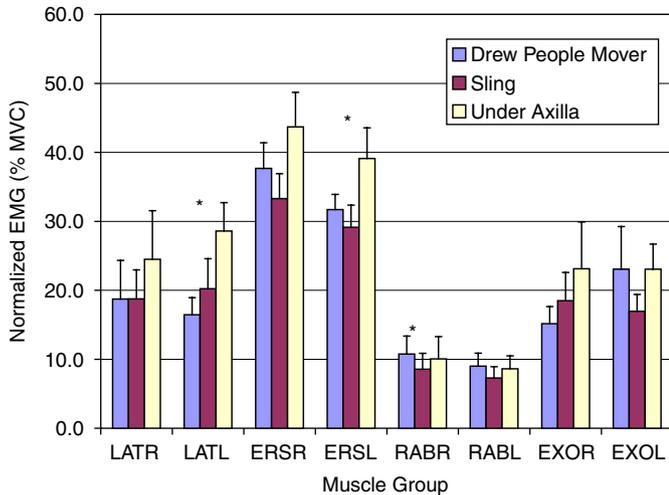


Fig. 4. The mean normalized 90th percentile EMG responses from the eight trunk muscles in the FFP positioned on the patient’s right side. LATR and LATL refer to the right and left Latissimus Dorsi, ERSR and ERSL refer to the right and left Erector Spinae, RABR and RABL refer to the right and left Rectus Abdominus, and the EXOR and EXOL refer to the right and left External Oblique. The “\*” indicates where there was a statistically significant difference ( $p < 0.05$ ).

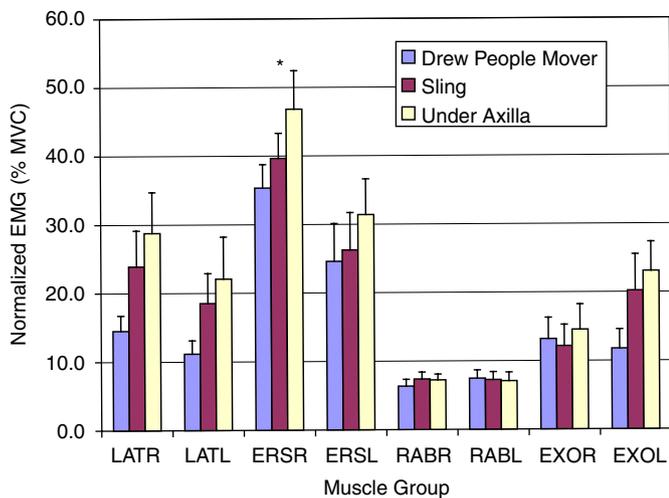


Fig. 5. The mean normalized 90th percentile EMG responses from the eight trunk muscles in the FFP positioned on the patient’s left side. LATR and LATL refer to the right and left Latissimus Dorsi, ERSR and ERSL refer to the right and left Erector Spinae, RABR and RABL refer to the right and left Rectus Abdominus, and the EXOR and EXOL refer to the right and left External Oblique. The “\*” indicates where there was a statistically significant difference ( $p < 0.05$ ).

People Mover along with the handles on the seat should reduce the external spine bending moment associated with the mass of the torso itself just as reduced flexion is typically associated with smaller bending moments while lifting (Lavender et al., 2003). Moreover, the moment should be further reduced due to the reduced moment arm between the handles and the spine. Likewise, the reduced moment is in agreement with the EMG results, which show reduced recruitment, at least for the contra-lateral Erector

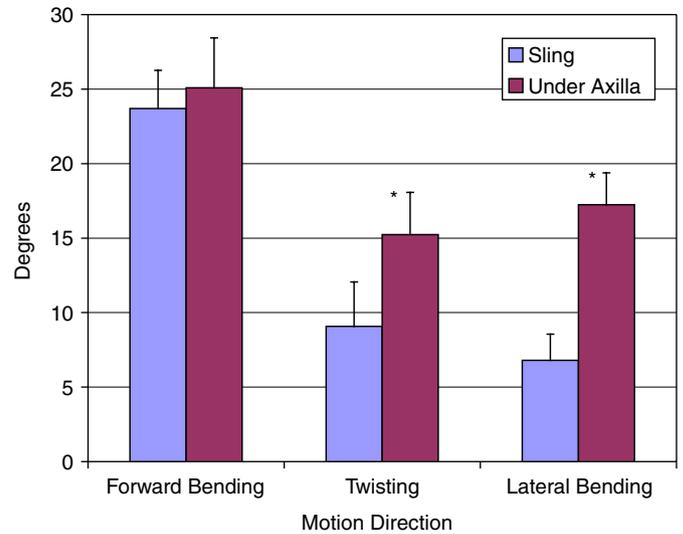


Fig. 6. The amount of trunk motion in each of the three cardinal planes when performing the single-person transfers.

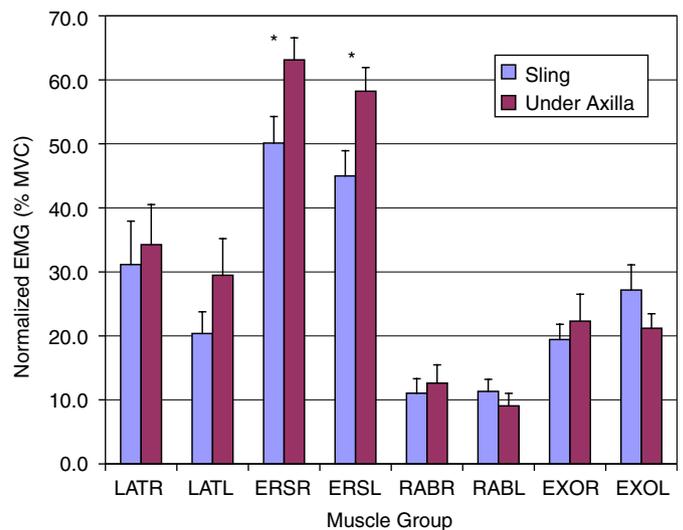


Fig. 7. The mean normalized 90th percentile EMG responses from the eight trunk muscles during the single-person transfers. LATR and LATL refer to the right and left Latissimus Dorsi, ERSR and ERSL refer to the right and left Erector Spinae, RABR and RABL refer to the right and left Rectus Abdominus, and the EXOR and EXOL refer to the right and left External Oblique. The “\*” indicates where there are statistically significant differences ( $p < 0.05$ ).

Spinae muscles in the two-person transfers. These findings are consistent with prior work quantifying muscle recruitment during asymmetric loading of the torso while in flexed postures (Lavender et al., 1994).

Clearly, based on the absolute magnitude of the spine moments and the muscle response, single-person transfers should be strongly discouraged. Should they need to occur, the data support the use of the Transfer Sling. Even though there is no appreciable change in the amount of forward bending or the forward bending moment, the 22% reduction in the Erector Spinae recruitment suggests that the Transfer Sling would lessen the likelihood of muscle

Table 3  
Subjective evaluations of the transfer sling and the Drew People Mover provided in closing interviews conducted with the last nine teams

Team	Transfer sling	Drew People Mover
4	Would consider using the two-person sling if person covered in feces	Thought there would be a problem with cleaning it
5	Single-person okay but not helpful for two FFPs	Handles need to be adjustable—too much slack
6	Liked it	Would use if patient were soiled
7	Felt too close to patient's face	Was a pain—getting it under the patient would be a problem
8	Two-person sling was the easiest	Could use to carry down the stairs or to carry up an embankment
	Two-person sling liked—it scooped and supported pt's back	These FFPs use something similar at their Fire Depts (a rescue seat and a soft stretcher)
	Single-person under axilla was easier than the single-person sling	
9	Liked	Awkward position Recommend webbing with Velcro that could be drawn up b/w the pt's legs and "velcroed" to the sides to keep the patient from slipping
10	This was a favorite	Would use with an elderly patient
	Small, easy to carry and could be put in a jump kit	Hard to set up
11	Easy to apply	No difference between this and rescue seat that they use
	Improvement over grabbing patient arms	Would be easier to use with one FFP in front and one behind compared to the way it was done here
12	Would typically use on elderly	Needs handles closer to patient body
	Recommend that it be wider with more padding	Problem is getting seat under patient
	Needs to be cleanable or disposable	

injury and injury to other spinal tissues that result from the biomechanical loads created by these muscles (Chaffin et al., 1977; Marras et al., 1999).

Aside from the biomechanical issues, the subjective feedback regarding these interventions indicates that they were generally received favorably (Table 3). The Transfer Sling was recognized as a means for dealing with soiled patients and was generally well received. The most frequent comment for the Drew People Mover addressed the challenge of working the seat under the patient in preparation for transport. Several FFPs commented that both devices allowed the FFPs to keep their face further away from the patient, thus minimizing the closeness of the

contact and the potential disease transmission. Our interpretation of this feedback is that the interventions provided a benefit that was worthwhile even if the biomechanical measures were not found to be unequivocal. However, given that we have significant reductions and trends in the objective measures, we believe that the benefits of the tested interventions could be realized without any apparent adverse consequences.

The handle configuration on the Drew People Mover is similar to that encountered when using more standard patient handling slings. Likewise, the magnitude of the reduction in forward bending, at least for the FFP standing on the patients left that was wearing the LMM, was similar to the reductions noted when using the standard patient handling sling (Elford et al., 2000). It should be noted that while our transfer sling and the device used by Elford et al. (2000) are both termed "slings", the construction was quite different. Hence, the position of the FFPs and the location where they grasped the sling were quite different from those shown by Elford et al. (2000). Nevertheless, both types of slings appear to have facilitated the patient transfer process.

There were several limitations about this work that should be acknowledged. First, the training dummy used for the transfers weighed only 75 kg. This is just below the 50th percentile body weight value obtained from a sample of the working population in the U.S. (Marras and Kim, 1993). Hence, in practice, a large proportion of the bed to stairchair transfers are performed on heavier individuals. We would like to believe that the benefits of using the Transfer Sling or the Drew People Mover would continue with heavier patients but this remains to be tested.

Along these lines, given that several of the exertions were two-person lifts, we recognize that a limitation of our methodology is that we cannot say how much of the load was being handled by each individual. Hence, we have to expect that the amount of weight actually handled by each person likely varied somewhat from one condition to the next and from one team to the next. We expect that this increased the inter-team variation in the data, thereby reducing the level of significance of the findings. Nevertheless, the trends in muscle recruitment were generally similar across the participants located on each side of the patient, giving us confidence that similar loads were experienced between the two FFPs.

Perhaps one of the most significant limitations was that the results were based on a single trial from each team under each experimental condition. This was done due to the large number of heavy exertions required during each team's testing session and the requisite need to manage fatigue. One would anticipate that with increased experience the techniques used when working with the interventions would become more refined, further reducing the muscle recruitment required. While Granata et al. (1999) have shown inexperienced subjects had lower spine compression forces than experienced subjects performing the same manual lifting task, Chaffin et al. (1999) found

their subjects showed a trend, albeit a weak one, towards reduced spine compression forces when working with material handling devices over 40 trials. We believe that the motor learning associated with the use of these new transfer aids would be similar to that found by Chaffin et al. (1999). Hence, we view the single trial as a conservative test of the interventions tested.

An additional limitation was imposed for the FFP standing on the forceplate in this study. The constraint of being on the forceplate may have prevented the FFP from stepping in as close to the patient as he or she normally would. Along these same lines, it was not possible to straddle the patient's leg when lifting as it was necessary to keep the patient's leg from contacting the forceplate. We believe, however, that these adaptations necessary to accommodate the data collection process led to a conservative evaluation of the interventions. Without the spatial restrictions imposed due to the forceplate, we believe that the postural and EMG results would have been more supportive of the interventions.

## 5. Conclusions

Relative to the under-axilla transfer, the Transfer Sling and the Drew People Mover were shown to reduce the recruitment of selected back muscles and potentially improve spinal posture. While the degree to which the interventions affected these measures varied across the FFP's position and the number of FFPs involved, the data consistently changed in the hypothesized direction. It should be recognized however, that even with these devices, these are strenuous lifting tasks and must be approached cautiously.

## Acknowledgment

This publication was supported by R01 OH 007490 from the National Institute for Occupational Safety and Health (NIOSH). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

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