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Assessing the Interplay Between the Shoulders and Low Back During Manual Patient Handling Techniques in a Nursing Setting

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The purpose of this research was to quantify shoulder demands during freestyle manual patient handling (MPH) tasks and determine whether approaches intended to prevent low back injury increased shoulder demands. Twenty females completed 5 MPH tasks found commonly in hospital settings before and after a training session using current workplace MPH guidelines. Most normalized muscle activity indices and ratings of perceived exertion decreased following training at both the low back and shoulders, but were more pronounced at the low back. There was little evidence to suggest that mechanical demands were transferred from the low back to the shoulders following the training session. The study generally supports continued use of the recommended MPH techniques, but indicates that several tasks generate high muscular demands and should be avoided if possible.

nursing electromyography shoulder low back ergonomics

1. INTRODUCTION

Although manual material handling is traditionally associated with lifting and moving boxes and assembly line parts, other work tasks involving nontraditional load manipulation also are accompanied by a high risk of musculoskeletal overexertion and injury risk. Specifically, nurses often must manually interact with patients to transfer or reposition them. Patients are differentially able to assist in this activity, while other patients are resistant to assistance, which presents often unexpectedly awkward and dangerous exertions [1, 2, 3]. Injury rates amongst nursing personnel are high. In 2009, in Ontario, Canada, health care and social services accounted for 13% of total lost time claims due to injury, second behind manufacturing with 15.5% of total claims [4]. In 2009, in the USA, nurses and nursing aides accounted for the second highest occupation requiring days away from work (50 620) and 455 injuries per 10 000 workers. Nearly half of the injuries in this group were attributed to overexertion, which is 9 times the national rate for musculoskeletal disorders in the USA and the highest among all professions [5].

Although patient handling tasks vary by clinical setting and are related to available assist devices, the injury risks associated with performing them manually, especially to the back, have been studied extensively. Consensus dangerous nursing tasks include transferring a patient from bed to chair, lifting a patient from a seated to a standing position, repositioning a patient on a hospital bed, and turning a patient toward or away from the nurse to apply a sling for a

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mechanical lift device [6, 7, 8]. Certain transfers (e.g., manual lifting and repositioning tasks completed by one person) consistently exceed National Institute for Occupational Safety and Health (NIOSH) spinal compression guidelines and other recommended shear recommendations on a patient handler, even doubling the limits in some cases [1, 9, 10, 11].

In response, many health units have adopted safe lifting policies, which often include mechanical lifts and specific manual lifting techniques intended to replace freestyle manual handling tasks, but the holistic effectiveness of these policies is equivocal. These alternatives demonstrably reduce the incidence of low back injuries while concomitantly improving rating of perceived exertion (RPE) scores and decreasing the number of lost time days [2, 11, 12]. However, the consequences of adopting these approaches for other body regions, including the shoulder, are unknown. Evidence suggests that they may not attenuate shoulder risk. For example, after implementing an ergonomics intervention, which included adding mechanical assistive devices and additional manual patient handling (MPH) training, associated task RPE scores decreased less for the shoulders than the low back [2]. Although the large muscle groups in both the shoulders and back are essential for lifting and load movement, many ergonomics interventions applied in hospitals historically focus on minimizing low back injuries [13, 14]. Concerns regarding potential physical demand transfers between joints in MPH have been often expressed [10, 15, 16].

While the shoulder has emerged as a site of substantial demand in patient handling, limited information regarding specific exposures is available, hampering their targeted mitigation. Some tasks, e.g., shifting the patient up or down the bed or turning the patient to one side, are known to be highly stressful on the shoulder [15]. The purpose of this research was to quantify shoulder demands during freestyle MPH tasks, and then determine whether approaches intended to prevent low back injury negatively affected shoulder demands while successfully mitigating low back exposures.

2. METHODS

2.1. Participants

Twenty healthy university-aged females participated; mean (*SD*) age 21.6 (1.3) years, height 166.6 (7.9) cm, weight 62.5 (9.4) kg. Exclusion criteria were any injury or pain in the past year to the upper extremity or back and previous experience or training in MPH. Informed consent was obtained prior to experimental data collection and the study was approved by the institutional Office of Research Ethics.

2.2. Procedure

The overall procedure consisted of a defined sequence (Table 1). These components progressed through participant preparation (including maximal voluntary contractions [MVC] for future data normalization), participant calibration, pre-training trials, a training period, post-training trials, and participant debriefing.

2.2.1. Participant preparation

Before experimental data collection, each participant was instrumented and calibrated for recording output variables. Each participant was trained to report her RPE using a continuous modified Borg's CR-10 scale [17]. Further, 16 bipolar Ag-AgCl surface electrodes (Ambu Blue Sensor N, Malaysia) were placed 2 cm apart bilaterally on the skin surface, overlying and parallel to the fibres of the muscle bellies (Table 2). Participants performed MVC for each muscle (16 muscles with three repetitions of each; the erector spinae were tested with one contraction) (see Table 1). A 2-min rest was provided between each set of MVC collections for each muscle to avoid fatigue [18, 19] (Table 2).

2.2.2. Experimental trials

Following these preparations, participants performed five defined MPH tasks in two sessions on the same day, before and after a training session (Table 3). The 20-min multimedia and hands-on training session included a self-paced computer presentation of recommended techniques (described graphically and verbally) and videos of proper lifting strategies for each task. The training session finished with familiarization and practice with the techniques, including manipulating the patient and feedback from the instructor. The task-specific recommended techniques were extracted from literature sources [11, 20]. Within each session, the five tasks were block-randomized and performed three times each consecutively for a total of 30 trials (15 each in both before and after training sessions), with rest breaks of up to 5 min allowed between individual task sets of three.

Task conditions were consistent across participants. Each task took place on an electrically adjustable cushioned table (56–88 cm above the floor) covered in a slider sheet similar to those

TABLE 1. Experimental Stages and Their Associated Activities

Experimental Stage	Associated Steps	Duration
Participant preparation	informed consent obtained EMG electrodes applied MVC exertions performed	~40 min
Participant calibration	initial MPH technique self-selected Borg's CR-10 scale [17] explained	~30 min
Pre-training trials	3 repetitions of 5 randomized MPH tasks RPE recorded after each repetition EMG recorded continuously	~25 min
Training protocol	participants instructed in recommended MPH techniques and allowed to practice these techniques	~40 min
Post-training trials	3 repetitions of 5 randomized MPH tasks RPE recorded after each repetition EMG recorded continuously	~25 min
Participant debriefing	electrodes removed	~5 min
total		~2.75 h

Notes. EMG = electromyography, MVC = maximal voluntary contractions, MPH = manual patient handling, RPE = rating of perceived exertion.

TABLE 2. Electrode and Maximal Voluntary Contraction (MVC) Exertions for Each Monitored Muscle Site [18, 19]

Muscle	Electrode Location	MVC Exertion
Biceps brachii	above center of muscle, parallel to long axis	elbow flexion (sitting)
Triceps brachii	on posterior portion of upper arm, located medially	supine, shoulder and elbow flexed to 90°; elbow extension against resistance (pushing up to ceiling)
Infraspinatus	parallel to spine of scapula, ~4 cm below it, over infrascapular fossa	side-lying, elbow bent to 90°, participant externally rotates
Middle deltoid	lateral aspect of the arm, ~3 cm below the acromion, parallel to muscle fibres	while standing, arm abducted to 90° (elbow extended, thumb points forward)
Middle trapezius	2 cm vertically above the trigonum spinae, T6 to T7 spinous process	prone, abducted to 120° elbow extended and thumb pointing towards ceiling, participant pushes up towards ceiling against resistance
Pectoralis major	between the scapular-clavicular joint and coracoidal process, 2 cm below clavicle, parallel when shoulder is abducted to 90˚, or down and out	sitting, shoulder flexed to 90°, participant horizontally adducts and flexes shoulder (up punch)
Thoracic erector spinae	5 cm lateral to T9 spinous process	prone with torso extended over edge of table, extended back against resistance
Lumbar erector spinae	3 cm lateral to L3 spinous process	same as thoracic erector spinae

used in hospitals. Table height for the recommended techniques was placed at each participant's waist height, except for the Sit-to-Chair task when the height of the table was moved to match the height of the seat pan of the chair. A 92-kg male was used as the "patient" throughout the data collection. The patient was 87th percentile based on anthropometry tables for weight, and 72nd percentile for stature [21]. The patient simulated a partial weight bearing patient, and only supported himself when in a seated or standing position. The participant always approached the bed on the left, with the head of the patient to the left and feet to the right. Specific instructions from the training session were emphasized during the task performances following the training session. Participants were instructed to stay as close to the bed as possible in an effort to minimize moment arms at the shoulder and back, and this distance from the bed was closely monitored by the instructor. Participants were also instructed to verbally count to three in preparation for each trial, while shifting their body weight between their feet on each count.

Following each task trial, the participant's calibrated RPE was recorded for the left shoulder, right shoulder, and low back. Electromyography (EMG) data was collected continuously during the experimental trials at 2048 Hz.

2.3. Data Processing

EMG and RPE data were reduced through further processing. Raw EMG was high pass filtered at 30 Hz to remove heart rate contamination, full wave rectified, and digitally filtered with a 3-Hz low pass second order Butterworth filter [22]. Trial EMG was normalized for each muscle with the maximal values obtained from the performed MVC trials (described in section 2.2.1), to yield a percentage of maximal activity. Mean muscle activity and maximal (peak) muscle activity for each muscle and each trial were calculated. Cumulative EMG was calculated

TABLE 3. Recommended Manual Patient Handling Techniques Taught in Training Session, Stratified by Task

Task	Patient Position	Participant (Nurse) Position
Lie-to-Sit	lying supine, arms crossed over chest, left leg crossed over right	Standing with neutral spine, bent knees and feet shoulder-width apart, place left hand under neck of patient and right hand on his top knee. While shifting body weight from right leg to left leg, pivot and rotate body while pulling on knee and lifting up under patient's upper thorax.
Reposition (assisted task)	lying supine, chin tucked, arms crossed over chest	Take sliding sheet in both hands, feet spread shoulder-width apart with bent knees and neutral spine. Shift weight from right foot to left foot and shift patient towards head of bed using sliding sheet.
Sit-to-Chair	seated upright with feet touching the floor, hands around participant's waist	Place folded sliding sheet firmly around patient's low back, put patient's right knee between bent knees and staggered feet. Keep spine neutral, lean forward and squeeze patient's knee. Shift weight from front foot to back foot, lifting using sheet while straightening legs and pivoting feet. Slowly lower in squat position into chair beside bed.
Turn Away	lying supine, arms at the side	Cross patient's left arm over trunk and place right knee in flexed position. Stand in walking position with slightly bent knees with left foot in front. Place right hand on patient's bent knee and left hand under patient's right shoulder. Shift weight from back leg to front leg, keeping neutral spine, and turn the patient away to face the opposite side of the bed.
Turn Toward	lying supine, arms at the side	Cross patient's right arm over trunk and place left knee in flexed position. Stand in walking position with slightly bent knees with right foot in front. Place right hand on patient's bent knee and left hand on patient's left shoulder. Shift weight from front leg to back leg, keeping neutral spine, and turn patient towards to face closest side of the bed.

Notes. Each transfer was completed with the participant standing to the right of the supine "patient", with the participant's left foot closest to the head of the bed.

from the normalized data using a trapezoidal integration method multiplied by the sampling period to yield %MVC × second. The three trial repetitions of each task (before and after training) were averaged to yield 10 trials for each participant for subsequent analysis. Similarly, the RPE values from the repetitions collected for each task and condition were averaged.

All statistical analyses were performed with JMP 8.0 software (SAS Institute, USA). A post hoc p of .05 was used to determine significance with Tukey's test. Each of the five tasks and associated outcome variables were analyzed separately using training state as an independent factor. For the perceived exertion data, RPE of the right shoulder, left shoulder, and low back were treated as dependent variables analyzed with separate one-way (training state) repeated measures analyses of variance (ANOVAs). The EMG analysis included mean, peak, and cumulative characterizations of normalized muscle activity. These were evaluated separately to assess acute, average, and total muscular demand. Dependent variables included activity levels of the 16 muscles collected; total muscle activity of these 16 muscles; and total activity of all muscles of the left shoulder, right shoulder, and low back independent of one another. One-way ANOVAs were performed to test for the effect of training state. Bonferonni corrections were made to adjust for multiple comparisons. The results of the statistical tests were amalgamated to assess the overall influence of training on muscular demands and perceived effort across the tasks.

3. RESULTS

Decreases in RPE occurred following training for most tasks at the right shoulder and low back, while changes at the left shoulder were less consistent (Table 4). The highest untrained RPE occurred at the left shoulder during Reposition (3.73 ± 1.77) and the lowest during Turn Toward at the low back (2.02 ± 1.28), while the highest trained RPE occurred at the left shoulder during Lie-to-Sit (2.99 ± 1.15) and at the low back during Turn Toward (1.34 ± 1.13).

Decreases in muscle activity using the recommended techniques occurred for most muscles for each task, however, not universally (Tables 5–6). Different results existed for the various characterizations (mean, peak, and cumulative) of the EMG signals.

TABLE 4. Rating of Perceived Exertion (RPE) Results in Trained and Untrained States, Stratified by Task, *M* (*SD*)

Task	Location	Untrained	Trained	Change[a]	*p*
Lie-to-Sit	right shoulder	3.15 (1.49)	2.12 (1.07)	↓	.043
	left shoulder	3.48 (1.23)	2.99 (1.15)	—	.288
	low back	3.03 (1.59)	1.88 (1.31)	↓	.013
Reposition	right shoulder	3.75 (1.84)	2.26 (1.24)	↓	.002
	left shoulder	3.73 (1.77)	2.10 (1.29)	↓	.001
	low back	3.18 (2.02)	1.71 (1.13)	↓	<.001
Sit-to-Chair	right shoulder	2.22 (2.06)	2.12 (1.19)	—	.769
	left shoulder	2.27 (2.16)	2.13 (0.98)	—	.586
	low back	2.75 (1.62)	2.15 (1.37)	—	.106
Turn Away	right shoulder	2.73 (1.43)	1.78 (0.99)	↓	.006
	left shoulder	3.15 (1.41)	2.21 (1.12)	↓	.002
	low back	2.31 (1.64)	1.37 (1.05)	↓	.010
Turn Toward	right shoulder	2.13 (1.31)	1.59 (1.00)	↓	.013
	left shoulder	2.21 (1.46)	1.93 (1.12)	—	.240
	low back	2.02 (1.28)	1.34 (1.13)	↓	.019

Notes. a = significant changes in RPE between the untrained and trained states.

TABLE 5. Mean (*M*), Peak (*P*) and Cumulative (*C*) Normalized Muscle Activity for Muscles on Right Side of Body, Stratified by Task

Task and	Type of Analysis	BB		TR		INF		MD		MT		PECT		TES		LES	
		T	UT	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT
A	M	13.62 (5.32)	6.51 (2.50)	9.18 (5.15)	8.14 (4.15)	12.38 (6.14)	7.71 (3.35)	8.61 (4.69)	6.20 (3.21)	14.39 (4.41)	11.30 (3.06)	12.09 (8.56)	6.79 (3.63)	18.35 (5.04)	14.55 (5.81)	23.07 (8.48)	19.23 (8.45)
	P	71.31 (26.87)	38.85 (12.2 5)	41.16 (21.73)	50.49 (27.91)	59.27 (30.39)	35.61 (18.87)	46.69 (22.02)	37.95 (20.41)	64.31 (27.01)	48.27 (5.98)	66.18 (28.20)	43.62 (23.32)	68.12 (22.69)	70.41 (28.68)	82.00 (29.98)	72.15 (25.52)
	C	219.91 (104.2)	118.33 (58.37)	146.72 (31.01)	146.04 (87.50)	196.94 (108.3)	140.27 (72.65)	132.20 (67.88)	111.06 (57.55)	232.96 (106.5)	199.26 (59.03)	192.84 (116.6)	121.51 (77.64)	294.93 (116.8)	264.74 (135.0)	381.07 (177.7)	353.94 (204.1)
B	M	16.37 (7.36)	7.82 (3.39)	10.03 (5.85)	5.24 (3.35)	10.36 (5.26)	7.14 (4.95)	6.74 (3.94)	5.37 (4.34)	11.87 (5.65)	9.24 (3.75)	13.28 (8.10)	6.97 (4.58)	17.17 (7.71)	11.34 (4.23)	20.92 (11.01)	16.28 (8.70)
	P	83.50 (35.45)	60.89 (21.52)	42.99 (26.25)	21.05 (12.97)	41.65 (18.22)	25.95 (17.15)	28.21 (18.30)	22.65 (18.59)	42.39 (22.15)	33.11 (13.13)	63.79 (41.18)	60.03 (36.89)	53.57 (27.89)	36.78 (14.68)	55.20 (25.67)	40.48 (14.45)
	C	167.09 (91.31)	77.87 (31.54)	99.90 (58.90)	53.81 (35.56)	105.55 (56.60)	69.67 (38.59)	72.57 (47.46)	52.45 (35.99)	125.94 (82.21)	92.21 (31.59)	134.38 (90.00)	71.11 (47.64)	177.55 (112.6)	117.63 (51.76)	213.81 (130.5)	166.44 (30.70)
C	M	16.05 (7.07)	4.79 (2.57)	5.32 (3.59)	10.31 (4.78)	10.95 (5.94)	8.84 (4.24)	8.72 (4.45)	6.43 (3.11)	12.94 (2.87)	9.66 (3.11)	14.32 (6.49)	6.59 (3.96)	16.01 (6.28)	13.13 (3.89)	20.84 (9.27)	17.84 (8.60)
	P	69.09 (36.19)	24.57 (11.48)	20.97 (15.00)	50.25 (23.85)	44.78 (22.80)	37.52 (16.69)	34.44 (18.61)	29.72 (16.78)	46.04 (20.35)	36.01 (14.36)	59.72 (23.74)	30.23 (18.57)	49.38 (19.08)	44.90 (17.69)	52.35 (20.52)	45.47 (15.18)
	C	199.68 (146.2)	75.94 (42.17)	65.82 (22.00)	167.90 (87.60)	135.95 (101.7)	141.29 (66.59)	105.64 (73.17)	104.40 (54.13)	157.78 (96.66)	154.50 (57.29)	168.12 (68.59)	107.94 (72.77)	196.02 (113.6)	217.67 (90.93)	271.69 (226.2)	296.56 (183.5)
D	M	12.23 (5.00)	6.80 (3.44)	6.39 (3.58)	3.90 (2.26)	11.40 (3.98)	6.61 (3.07)	8.17 (4.06)	6.23 (3.08)	14.33 (4.42)	7.99 (2.99)	13.16 (6.86)	6.97 (4.50)	14.64 (5.14)	10.38 (4.61)	18.88 (9.84)	14.45 (8.92)
	P	57.32 (25.52)	45.99 (19.18)	25.45 (18.04)	16.55 (13.39)	44.08 (16.92)	25.94 (13.83)	37.18 (14.36)	30.13 (16.22)	50.69 (14.51)	28.65 (11.85)	58.74 (25.29)	39.70 (22.69)	46.19 (16.65)	28.90 (12.87)	47.80 (19.11)	33.34 (14.43)
	C	105.85 (45.66)	82.83 (48.66)	54.80 (29.80)	47.99 (30.04)	98.59 (34.59)	80.22 (40.38)	70.85 (33.25)	76.43 (43.27)	126.35 (54.22)	97.55 (42.40)	109.29 (49.50)	85.38 (65.92)	130.46 (59.97)	128.43 (68.07)	171.17 (102.9)	181.41 (126.5)
E	M	5.17 (2.62)	6.34 (2.46)	9.82 (3.87)	5.28 (3.32)	8.19 (4.31)	6.92 (2.63)	5.76 (3.24)	5.78 (2.45)	9.32 (3.20)	8.13 (2.51)	5.80 (3.28)	6.75 (3.81)	14.13 (5.21)	12.94 (5.30)	16.08 (9.10)	17.53 (8.20)
	P	28.61 (19.66)	42.96 (18.94)	48.67 (20.37)	27.99 (22.18)	31.03 (16.62)	28.91 (12.10)	25.46 (10.77)	29.85 (9.71)	33.29 (14.81)	30.46 (7.30)	25.34 (14.81)	41.80 (22.69)	43.89 (17.06)	36.32 (13.76)	38.90 (16.70)	39.34 (12.88)
	C	47.48 (30.18)	76.87 (31.86)	87.12 (40.96)	66.23 (46.23)	71.98 (38.44)	85.47 (39.12)	51.07 (30.24)	68.52 (25.52)	83.05 (37.67)	98.32 (31.84)	52.24 (32.89)	84.20 (52.20)	127.89 (60.92)	159.01 (73.14)	150.17 (103.3)	219.31 (116.7)

Notes. BB = biceps brachii, TR = triceps, INF = infraspinatus, MD = middle deltoid, MT = middle trapezius, PECT = pectoralis, TES = thoracic erector spinae, LES = lumbar erector spinae; T = trained condition, U = untrained condition; A = Lie-To-Sit, B = Reposition, C = Sit-to-Chair, D = Turn Away, E = Turn Toward. Standard deviation for each value is shown in parentheses; shaded areas show significant changes after training: light shading = decrease, dark shading = increase.

TABLE 6. Mean (*M*), Peak (*P*) and Cumulative (*C*) Normalized Muscle Activity for Muscles on Left Side of Body, Stratified by Task

Task and Type of Analysis)		BB		TR		INF		MD		MT		PECT		TES		LES	
		T	UT	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT
A	M	15.53 (5.98)	10.94 (5.15)	8.47 (4.96)	5.71 (2.85)	8.40 (5.12)	6.90 (2.84)	6.01 (4.33)	6.54 (2.98)	10.80 (4.22)	6.47 (1.98)	15.20 (7.98)	11.87 (6.00)	17.26 (6.17)	10.98 (3.44)	17.87 (6.85)	13.84 (4.86)
	P	80.22 (26.05)	70.16 (32.57)	37.41 24.81)	27.32 16.13)	42.54 (23.90)	40.71 (21.81)	31.04 (18.44)	42.96 (13.85)	45.13 (14.09)	38.70 (11.76)	75.56 (30.75)	72.22 (29.01)	58.35 (26.84)	36.17 (16.23)	53.71 (23.45)	40.77 (12.70)
	C	249.46 (122.3)	199.45 (109.8)	140.96 (98.82)	102.50 (59.27)	133.15 (79.18)	117.43 (46.15)	96.24 (67.22)	116.49 (55.80)	169.03 (71.02)	115.95 (47.26)	225.71 (115.4)	213.99 (110.7)	280.04 (125.5)	199.98 (84.07)	291.20 (150.2)	250.00 (114.1)
B	M	13.18 (7.94)	6.36 (3.28)	9.88 (3.59)	7.12 (3.38)	10.26 (4.36)	8.12 (3.15)	7.56 (4.18)	7.47 (5.68)	10.27 (4.19)	9.29 (6.14)	7.82 (4.82)	3.89 (2.16)	17.51 (5.93)	12.50 (4.45)	18.50 (7.80)	13.86 (5.67)
	P	60.28 (30.53)	35.32 (17.22)	45.95 (24.05)	38.99 (26.68)	44.84 (24.10)	62.23 (29.45)	41.03 (15.94)	46.45 (19.61)	45.13 (15.29)	52.84 (15.71)	38.64 (22.00)	17.35 (8.57)	58.91 (20.68)	47.66 (16.17)	58.19 (22.24)	49.29 (17.53)
	C	138.34 (95.61)	63.54 (31.28)	100.39 (52.26)	73.07 (38.53)	105.72 (55.45)	81.41 (30.68)	73.01 (31.23)	73.86 (51.53)	106.30 (53.25)	92.39 (25.70)	81.19 (67.78)	38.64 (20.14)	175.21 (90.40)	127.94 (52.66)	184.42 (110.3)	142.57 (64.41)
C	M	14.32 (7.88)	5.32 (2.72)	7.03 (3.83)	11.55 (4.73)	7.32 (3.52)	8.77 (3.45)	4.61 (2.69)	6.71 (3.86)	4.61 (2.69)	6.71 (3.86)	16.39 (9.93)	7.25 (4.92)	17.82 (7.40)	14.36 (4.63)	17.44 (7.39)	13.29 (5.00)
	P	60.63 (29.25)	32.01 (16.33)	25.00 (18.63)	49.68 (21.27)	32.17 (21.71)	36.63 (16.94)	20.28 (13.38)	33.26 (14.37)	34.21 (12.15)	29.22 (13.15)	64.32 (34.34)	37.42 (15.20)	52.43 (22.61)	42.67 (11.60)	49.19 (24.12)	40.74 (14.46)
	C	171.12 (111.4)	85.43 (44.76)	89.09 (76.11)	185.75 (82.52)	91.10 (29.41)	138.56 (61.34)	55.68 (39.64)	104.12 (56.81)	116.03 (59.92)	120.37 (51.23)	179.95 (104.4)	116.25 (74.52)	219.91 (140.3)	233.94 (102.5)	223.02 (164.7)	219.64 (101.0)
D	M	12.86 (5.03)	10.08 (5.08)	7.70 (3.30)	5.51 (2.77)	7.97 (3.42)	5.97 (2.82)	5.84 (3.79)	4.80 (3.23)	9.80 (4.25)	6.87 (2.77)	12.92 (7.11)	9.69 (4.13)	15.18 (4.36)	9.78 (4.58)	15.42 (6.06)	10.04 (4.28)
	P	63.99 (24.79)	50.09 (23.22)	28.34 (16.79)	23.51 (12.36)	31.38 (15.00)	26.88 (16.05)	24.50 (15.80)	24.82 (14.12)	36.42 (16.68)	30.29 (13.62)	61.39 (29.54)	55.98 (15.89)	46.02 (14.81)	28.39 (22.51)	43.20 (19.35)	25.68 (12.82)
	C	115.23 (54.39)	123.97 (69.22)	67.54 (33.69)	68.07 (39.99)	69.87 (33.24)	71.76 (36.19)	50.47 (33.17)	58.04 (37.15)	84.45 (35.34)	81.99 (35.89)	113.33 (67.99)	115.39 (50.17)	133.89 (56.13)	120.16 (69.96)	136.66 (69.52)	123.83 (62.53)
E	M	5.64 (2.70)	5.49 (2.18)	9.69 (5.53)	5.54 (2.63)	7.23 (2.21)	6.22 (2.02)	5.11 (3.71)	4.79 (2.52)	7.57 (2.75)	6.80 (1.92)	6.25 (4.37)	6.27 (3.71)	13.60 (4.73)	12.16 (4.29)	12.90 (5.41)	12.68 (4.80)
	P	28.13 (14.89)	27.45 (10.72)	45.77 (27.19)	27.20 (13.67)	29.30 (13.87)	28.00 (12.91)	25.37 (16.61)	27.67 (14.26)	28.77 (11.37)	32.89 (13.38)	28.42 (20.26)	29.97 (13.49)	40.35 (12.95)	41.49 (14.53)	33.44 (14.89)	36.00 (15.00)
	C	50.58 (28.84)	68.15 (32.91)	88.77 (60.43)	67.94 (36.05)	64.13 (26.04)	75.43 (27.77)	46.17 (34.40)	58.05 (32.07)	66.84 (24.96)	81.77 (23.47)	58.98 (48.81)	74.70 (29.11)	123.61 (55.73)	146.73 (56.23)	121.01 (64.69)	156.73 (67.96)

Notes. BB = biceps brachii, TR = triceps, INF = infraspinatus, MD = middle deltoid, MT = middle trapezius, PECT = pectoralis, TES = thoracic erector spinae, LES = lumbar erector spinae; T = trained condition, U = untrained condition; A = Lie-To-Sit, B = Reposition, C = Sit-to-Chair, D = Turn Away, E = Turn Toward. Standard deviation for each value is shown in parentheses; shaded areas show significant changes after training: light shading = decrease, dark shading = increase.

4. DISCUSSION

The results support previous findings of decreased low back exposures when applying recommended manual handling techniques [11, 19, 24]. Indeed, training resulted in decreased exposures for both shoulders and the low back across most measures, supporting the use of the recommended task techniques. Across tasks, low back exposures decreased both in terms of muscle activity and RPE after training. For the Lie-to-Sit task, the low back exposures decreased by 40% for RPE, and nearly 20% for mean and peak muscle activity averaged across muscles. Conversely, the Turn Toward task had similar decreases for RPE, but only a 3% decrease and no change for mean and peak activity averaged across muscles. Some exceptions occurred for cumulative activity for both Turn Toward and Sit-to-Chair, where there was a 30% increase at the low back and a 6% increase averaged across low back muscles.

Novel shoulder exposure data collected in this study revealed a less consistent training effect, which varied by task. Although decreases in RPE occurred in both the left and right shoulders following training within nearly every task, the decrease was lower than for the low back. Exceptions occurred in the Lie-to-Sit and the Turn Toward tasks in the left shoulder, while neither shoulder RPE changed for the Sit-to-Chair task. Right shoulder decreases, when averaged across the muscles were 20%–30% MVC, while left shoulder decreases were ~15%–20% MVC. This discrepancy between shoulders may be due to the right shoulder experiencing higher initial loading in the self-selected techniques and a shift towards a more balanced distribution between shoulders in the recommended techniques.

However, some tasks created concomitant increases and decreases in specific muscular activity after training, suggesting potential trade-offs or demand transfer. The combination of increases at the shoulders and decreases at the back in the Sit-to-Chair task suggests a joint-level transfer of demand following training. This task is considered high risk, and is frequently targeted for replacement with mechanical lift assists [25]. The recommended technique for Turn Toward as a task was the most variable among all measures. Cumulative total muscle activity increased at all three joints, with the back increasing the most. This is likely due to the increased amount of time recommended to complete the transfer during this task.

The potential musculoskeletal exposures a nurse may encounter include acute and cumulative loading, making prediction and prevention or elimination of injury causality difficult. While only a small fraction (1.4%–2.5%) of a typical 8-h shift is spent transferring and lifting patients, the weight lifted is often prohibitive, especially for bariatric patients [26]. For this reason, analyzing peak normalized muscle activity provides valuable insight into the exposure experienced at the shoulders during MPH transfers. The relationship between cumulative loading and low back pain has also emerged as a major issue, and recent meta-analyses have reported that workers with low back pain were more likely to have been exposed to cumulative spinal loading than those without back pain [27]. In addition to these transfer tasks, other types of tasks performed by nurses also increase cumulative loading, such as regular patient care or miscellaneous tasks [28].

While MPH techniques decreased the general and specific demands for five different MPH tasks, many muscles had increases in cumulative muscular activity when using these techniques. This coincides with documentation that recommended patient handling techniques may increase time requirements to complete various handling tasks [10, 29]. The erector spinae increased in cumulative normalized muscle activity for Turn Toward and Sit-to-Chair, indicating an extended period of muscular activity, despite decreased mean activity during the task. Muscles of the shoulder experienced variable responses to adoption of the recommended techniques, with many muscles increasing in cumulative normalized muscle activity. The recommended techniques for the Turn Toward task produced significant increases, but only for muscles on the right side of the body. This may be due to a shift towards a more balanced distribution of patient loading between the two shoulders when using the recommended techniques. Post-training increases in cumulative activity for the Sit-to-Chair task were found in the left triceps brachii, infraspinatus, and middle deltoid. These increases were likely caused by the patient rotation technique taught during the training session, as participants were trained to keep the patient close to their body throughout the transfer and to use their own body weight to externally rotate the patient to the left, thus increasing activity in the infraspinatus and these muscles around the shoulder.

The magnitude of a force exerted by a worker is a known cause of low back injury, and high peak normalized muscle activity at this joint was observed in the MPH exertions [30, 31]. Lie-to-Sit, with the highest reported values out of all the tasks, reported nearly 80% normalized peak muscle activity for the right thoracic and lumbar erector spinae, along with the left biceps and pectoralis major, even while decreasing from self-selected magnitudes. While mechanical lift assists are frequently acquired to reduce the need to perform the more stressful tasks, there is no guarantee these devices will be used due to psychosocial and time pressures [29, 32, 33]. Another concern is increased exposures in the Turn Away and Turn Toward tasks for sling application and mechanical lift assist use. Not only did the Turn Toward task increase many muscles in peak muscle activity, but also mean and cumulative muscle activity for the right biceps brachii and pectoralis major, and the left middle deltoid and lumbar erector spinae. Increases in cumulative and mean measures were also present. The increase in exposure for all three measures for this task may create both short- and long-term risks.

Several aspects of this study should be considered when interpreting and applying the findings in applied settings. The range of recommended MPH techniques examined in this study was not exhaustive, as there are many alternatives. Each participant was limited to approaching the left side of the bed for each task, which may have influenced the self-selected techniques. If the patient and participant had been oriented to the other side and end of the bed, it is possible that the opposite effect may have been seen at the left and right shoulder joints for each measure. However, similar muscular activity levels are produced regardless of the side of the bed used [8]. Finally, only one patient body size was used in this investigation. However, based on the patient's anthropometrics (87th percentile for weight and 72nd for stature), only a small percentage of the population would be unaccounted for, as the male patient used for all participants represented the majority of the population for height and weight. With this in mind, it is likely that patients whose stature and weight are less than the participant used in this study would result in similar or decreased muscular activity levels during MPH tasks experienced by the participants in similar investigations.

5. CONCLUSIONS

This study generally supports continued use of the recommended manual handling techniques, and suggests that no substantial musculoskeletal joint-level demand transfers are associated with their use. However, caution is warranted for specific patient handling tasks due to the high demands associated with them. Sit-to-Chair and Turn Toward were the most demanding for the shoulder. While the evaluated techniques were designed to lower low back injury risks, several techniques did not modify the measured physical demands at the low back. While the results encourage continued use of the recommended techniques, consideration of potentially injury risk transfer between joints should be included.

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