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The biomechanical evaluation of patient transfer tasks by female nursing students: With and without a transfer belt

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Abstract

This study was to examine the kinematics, muscle activities, and perceived physical exertion in different regions of the spine during patient transfers by nursing students between a bed and a wheelchair, with or without a transfer belt in a laboratory setting. Results showed that with the effect of the belt, the % maximum voluntary contraction of the lumbar erector spinae was reduced significantly by nearly 10%. Muscle activity was significantly increased in thoracic erector and multifidus spinae during wheelchair-to-bed transfer, compared to bed-to-wheelchair transfers. There was no significant effect of belt or task on the spinal angular displacement in different spinal regions. Using the transfer belt was associated with a significantly decreased score for perceived exertion. In conclusion, this study supports the use of a transfer belt contributing to lower muscle activity and lower perceived physical exertion in the low back.

Keywords: Low-tech patient transfer assistive devices; Electromyography; Kinematics

1 Introduction

Nursing tasks within healthcare settings involve demanding physical activities that can lead to the development of low back disorders (LBDs) (Cheung et al., 2018a; NIOSH, 2016; Trinkoff et al., 2002). LBDs have been reported to be the most common occupational problems in nursing personnel (Bos et al., 2006). Nursing students (NSs) are a particularly vulnerable group at risk of LBDs but, unfortunately, their needs have been neglected in the research to date. Cheung (2010) reported that the cumulative incidence of low back problems in NSs has caught up with that for working nurses by the time the 26 months of nursing study has been completed. Furthermore, NSs have high lifetime (70%), 12-month (68.4%), 30-day (46.5%), and 7-day (31.5%) prevalence of low back pain (Solomon et al., 2017). If NSs already start to experience back problems during their training, this may carry over into their working lives when they graduate and have an adverse impact on their health and the quality of patient care. Hence, there is a need to investigate the patient transfer techniques and postural habits of NSs.

Several studies found that patient handling is the most common risk factor contributing to LBDs in nursing personnel (Pour et al., 2016; Smith et al., 2006; Warming et al., 2009). Transferring patients between beds and wheelchairs is considered to be one of the high risk patient-handling tasks associated with LBDs (Callison and Nussbaum, 2012; Harcombe et al., 2009; Johnsson et al., 2004). A close association has been reported between patient transfers and musculoskeletal problems (mainly LBDs) in nursing personnel, based on injury data analyses in Australia (Ore, 2003), Sweden (Engkvist et al., 2001), and Canada (Yassi et al., 1995) as well as epidemiological studies in Hong Kong (Cheung, 2010; Cheung et al., 2006).

Although there has been a considerable amount of research analysing risk factors contributing to LBDs in nursing personnel, most of these studies have focused on self-reported or self-perceived data through cross-sectional (Alexopoulos et al., 2006; Carugno et al., 2012; Cheung, 2010; Choobineh et al., 2010; Golabadi et al., 2013) or cohort investigations (Herin et al., 2011; Kim et al., 2012; Schoenfisch et al., 2013; Warming et al., 2009). There is a lack of analyses of objective data, such as biomechanics and kinematics of body movements and muscular activities in patient-transfer tasks.

Previous studies have suggested that assistive devices for patient handling are recommended to reduce the risks of LBDs (Hodder, 2006; Holtermann et al., 2015; Koppelaar et al., 2013). Currently, biomechanical evaluations of patient-handling devices focus more on advanced mechanical lifting devices, such as ceiling and stand lifts (Dutta et al., 2012; Marras et al., 2009; Miller et al., 2006), while there is less research on low-tech, low-cost devices. There are many barriers in using advanced mechanical lifting devices, one of the major ones being the accessibility issue (Nobel and Sweeney, 2018). Furthermore, advanced assistive devices are seldom used in assisting daily activities such as transferring patients from bed to wheelchair/commode and vice versa (Nobel and Sweeney, 2018). On the other hand, it has been claimed that simple and low-tech devices, such as transfer belts, are easy to use or access for nursing personnel (Koppelaar et al., 2013; Weiler et al., 2013). They have also been rated as comfortable and safe by most patients when compared with mechanical lifts (Garg and Kapellusch, 2012), indicating their significance in practice. However, biomechanical studies of patient transfer tasks with the use of transfer belts have not produced any convincing evidence of their effectiveness in terms of reduced effort or reduced injuries in operators (Allen and De Stefano, 2007; Hess et al., 2007). In addition, the biomechanical evaluation method used in research to assess patient transfer tasks and risks for LBDs focuses mostly on force evaluation, such as spinal load (Allen and De Stefano, 2007) and external hand forces (Dutta et al., 2012) of the patient handler. Yet, Umer et al. (2016) argued that an acceptable load on the back might not represent safe practices if postures are awkward, which can also contribute to LBDs. Most of the beds in nursing homes are non-adjustable, with limited space for transfer tasks. However, there have been relatively fewer studies in the literature evaluating the use of transfer belts by means of examining the postural and muscle activity measurement on the low back.

The biomechanical analyses of LBDs have mainly targeted nurses (Hess et al., 2007; Mitchell et al., 2008; Smith and Leggat, 2004; Smith et al., 2003), but there have been limited studies on nursing students (NSs) (Solomon et al., 2017). The aim of this study was to evaluate the spinal biomechanics of female NSs using and not using a transfer belt, with following hypotheses:

1. The muscle activity of female NSs' lower backs, while handling patients from bed to wheelchair (BTW) and vice versa with a transfer belt was significantly lower than that of without a transfer belt.
2. The spinal kinematics (spinal angular displacement) of female NSs' spines, while handling patients from BTW and vice versa with a transfer belt was significantly lower than that of without a transfer belt.
3. The perceived physical exertion rating on female NSs' lower backs after handling patients with a transfer belt was lower than that without a transfer belt.

2 Methods

2.1 Study design and setting

This was an experimental study conducted in a laboratory setting in 2017 to examine the kinematics and muscle activities in different regions of the spine during standardised patient transfer tasks. Direct measurement techniques included use of 3D motion sensors and electromyography (EMG) to measure kinematics and muscle activities. Prior to starting the study, human ethical approval was obtained from the Hong Kong Polytechnic University (HSEARS20170530001).

2.2 Sampling

Ten female NSs were recruited from two local government-funded universities through convenience sampling. Only female full-time NSs who had completed at least two clinical placements were included. Furthermore, they were required to be of 158.6 cm (±5.6 cm) in height and 51.3 kg (±8.1 kg) in weight, thus representing typical physical characteristics of Hong Kong females aged 18 or above (Sung et al., 2009). NSs who were pregnant, had previous back and neck pain within three months prior to the study, or had history of severe cardio-pulmonary diseases (Rozenberg, 2008) were excluded from the study. A short questionnaire was used to collect the NSs' demographic data, including gender, age, height, weight, the university in which they were studying, year of study, number of clinical placements they had undertaken, history of low back pain, history of cardio-pulmonary diseases, and pregnancy status.

In order to reduce the risk of injury (Schooling et al., 2007), no real patients were recruited in this study. According to the statistical report from the Hospital Authority (2015), seniors aged 60 or above account for over half of the total inpatient patient days (52.3%), with female patients in the majority. Therefore, a female retired registered nurse aged 62 with an average body build, including body mass index (BMI) of 22.9, was recruited to simulate typical physical characteristics of an elderly Hong Kong female. To ensure consistent acting as a right-sided hemiplegic patient requiring one-person transfer, the simulated patient was required to put on a hemiplegia-simulation suit. A 1-h training session was provided to prepare her to simulate the patient characteristics. For performance evaluation and quality maintenance of the study, a return demonstration was required after the training.

2.3 Patient transfer tasks

The NSs were required to perform four patient transfer tasks: (1) wheelchair to bed (WTB) with transfer belt; (2) bed to wheelchair (BTW) with transfer belt; (3) WTB without transfer belt; and (4) BTW without transfer belt. The tasks involved transferring from sitting in wheelchair to sitting in bed, and vice versa. The same female simulating a right-sided hemiplegic patient was involved in all the tasks. Concurrent data for muscle activity and spinal kinematics were recorded during all the tasks, while perceived exertion rating was reported by all participants after each task. In order to limit the carry-over effect of the same types of trials, the sequences of four different patient transfer tasks were assigned randomly by drawing lots, with a 5-min break between tasks.

The participants were given a 1-h training session to ensure they could perform proper one-person transfers of the simulated patient from BTW or vice versa. Based on the literature review (Berman et al., 2012; Chao and Henshaw, 2009; Doyle and McCutcheon, 2012; Labour Department, 2000), protocols for proper transfer and return demonstration were developed to standardize the patient transfer procedure. Prior to the start of the study, content validity was evaluated by six professionals in the field of mechanical lifting (including registered nurses, physiotherapists, and occupational health professionals), with an acceptable content validity index of 0.977.

2.4 Biomechanical data collection

2.4.1 Surface electromyography (sEMG)

To collect the muscle activity data, a 12-channel wireless TeleMyo EMG system (Noraxon USA, Scoosdale, Arizona) was used to measure the activities of three pairs of muscles, namely, the thoracic erector spinae (TES), lumbar erector spinae (LES) and multifidus spinae (MFS) muscles (Fig. 1). Bipolar surface electrodes were placed in the standardized positions on these muscles and the normalization procedures were conducted according to the SENIAM Guidelines (Freriks and Hermens, 2000). Prior to applying the electrodes, skin preparation procedures were performed to prepare the electrode application by cleaning it with water, fine sandpaper, and 75% alcohol (and shaving if necessary). Electrode impedance was checked to ensure a good skin impedance condition (<2000 Ω). Prior to starting the patient transfer trials, each participant had to perform the maximum voluntary contraction (MVC) trials for the spinal muscles to establish normalization procedures.

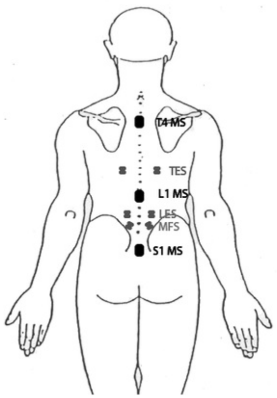


Fig. 1 Diagram showing the positions of the EMG electrodes and the 3 motion sensors*

MS: motion sensor; T4: the 4th Thoracic column; L1: the first lumbar column; S1: sacrum; TES: thoracic erector spinae; LES: lumbar erector spinae, MFS: Multifidus spinae.

alt-text: Fig. 1

The raw EMG signals obtained from both the MVC trial and the task trial were processed for ECG reduction and a FIR bandpass filter at 10–500 Hz. The root mean square (RMS) value was obtained at 50 ms moving windows for the smoothing of signals. The maximum RMS of MVC was calculated by taking the mean of the highest signal of 1 s's moving window from the whole MVC trial. The percentage of muscle activity was calculated by dividing the muscle activity exerted in each patient transfer task with the corresponding MVC of that muscle for the participant.

A mean percentage of muscle activity was calculated. We divided the muscle activity data for the patient-handling procedure into three phases according to the nature of the movement in the whole transfer process. Phase 1 started when the participants bent their hips, knees and ankles to approach and lift up the simulated patient. Primary back extensors (TES, LES) acted as agonists for concentric contraction in this phase. Phase 2 started when the participants assisted the simulated patient to turn from left to right, when the muscles on the right were the primary agonists. Phase 3 started when the participants assisted the simulated patient to sit down. Eccentric work was the main movement type for back extensors in this phase. Since the movement nature of transferring the patient from WTB and BTW is similar, these phase definitions were applied in both transfers.

2.4.2 Spinal kinematics

For spinal kinematics, the MyoMotion system (Noraxon USA, Scoosdale, Arizona) was used to measure the participants' spinal flexion at T4, L1 and S1 spinal processes. These three sensors provided kinematic data for the thoracic and lumbar segments (Fig. 1). The participant was asked to stand upright to record the reference standing position for the calibration of the kinematics data. Peak and minimum spinal flexion during the task trial were then calculated by the angle that deviated from the upright position.

2.4.3 Perceived exertion rating

The Borg CR10 Scale (Borg, 1998) was used to measure the perceived exertion on five body parts, which were upper arms, lower arms, shoulders, knees and lower back. The scale ranged from 0 (nothing at all), to 3 (moderate), 5 (strong), 7 (very strong) and 10 (extremely strong).

2.5 Experimental procedures

A briefing session was conducted to provide information about this study to both the participants and the simulated patient. A questionnaire, with a consent form, was given during this briefing session. A 1-h training session and return demonstration were conducted with the participants to familiarize them with our patient transfer protocol. After obtaining a satisfactory performance on the return demonstration, the sensors for muscle activity and spinal kinematics were attached to the participant. Upright posture and the MVC trial were captured. It took about 90 min to prepare a participant. At the same time, the simulated patient would put on the hemiplegia simulation suit. The suit would limit the movement and strength of right arm and leg. Thus, the simulated patient could only use her left side (unaffected side) of the body to assist the transfer. She was instructed to sit on the edge of the bed/wheelchair, with left knee flexed and left foot placed flat on the floor; while her right leg extended (Fig. 2a). As described above, four patient transfer tasks were selected randomly for each participant. The Comfylift handling belt with four loop handles (Fig. 2b) was used in this study. For the transfer with the transfer belt, the participant would hold the belt with both hands (Fig. 2c); or grab the waistband at the back of the patient's trousers (Fig. 2d). At the same time, the patient was instructed to use her left arm to wrap around the participant's right shoulder. On the count of “one, two, three and up”, the patient would use her left leg muscle to stand up, and then left hand reached the arm of the wheelchair/mattress of the bed. The participant would assist the patient in the standing up and pivoting movement to sit on the wheelchair/bed, and the amount of assistance would be described as “moderate”. As the patient was well trained before the study, she would participate in the transfer with bearing 30–40% of her body weight through her left leg, while the participant would assist to lift the remaining parts of her body weight in the standing up phase. Each task was performed for three trials. A 3-min break was provided after each trial. During the break, the participant was asked to rate perceived exertion on different body parts. The experiment took 1 h to complete. After performing all the tasks, an interview was conducted with both the participant and the simulated patient about their preferences for using a transfer belt and the adequacy of the 3-min break time. An interview was also conducted with the simulated patient about the overall experience of the transfers.

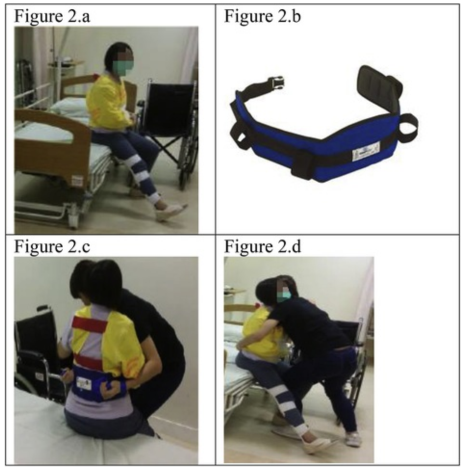


Fig. 2 (left to right) a: The simulated patient with a hemiplegia simulation suit; b: transfer belt; c: photo showing the patient being transferred by the NS with belt; and d: photo showing the simulated patient being transferred by the NS without belt.

alt-text: Fig. 2

2.6 Fidelity of the study

The data collection process was monitored by the first (principle investigator) and second (with experience of biomechanical studies) authors, to ensure the data collection procedure was conducted as planned. During the training session, two researchers used the protocol to teach, and assess the participants' return demonstrations. During the experimental laboratory study, two researchers were assigned to monitor the participants’ performances against the protocol, and the transferring process was videotaped. Additional trials were required if the participants failed to follow the protocol. 33 sets of data were discarded due to improper posture (13 cases), technical problems (2 cases) or bad data (18 cases).

2.7 Data analysis

The demographic data were summarized using descriptive statistics such as means, standard deviations and percentages. The kinematics and muscle activity data were synchronized using Noraxon MR3.8 software, which can also be used for offline data analyses. The dependent variables consisted of the mean muscle activity of 6 muscles, namely, bilateral TES, LES and MFS muscles; as well as the minimal and maximum angles of the thoracic and lumber spinal regions. All data sets underwent Shapiro–Wilk tests to determine if they were normally distributed or not. A generalized linear mixed model (GLMM) was used for the data analysis. For the EMG data, first the main effects of Belt (with belt/without belt) and Task (WTB/BTW) factors were examined. With the added main effects, which reduced the model's residual significantly, a post hoc test was carried out by applying the same model to separate phases (Phases 1, 2 and 3). For the kinematics data and perceived exertion scores, the main effects of Belt and Task were also tested. Peak lumbar flexion/extension and peak thoracic left/right rotation were applied to test whether the belt had an effect on lifting posture. All tests were conducted to ensure the residual was normally distributed after the model was fitted. All statistics were computed using Matlab, statistics and machine learning toolbox (The MathWorks, U.S.). The significance value of $p < 0.05$ was used for the statistical analyses.

3 Results

3.1 Characteristics of participants

Participants with a mean age of 22.3 years (SD 1.34) from two universities participated in the study (Table 1). The mean height and weight were similar to the distribution for Hong Kong females (Sung et al., 2009). The participants had completed from two to nine clinical placement experiences.

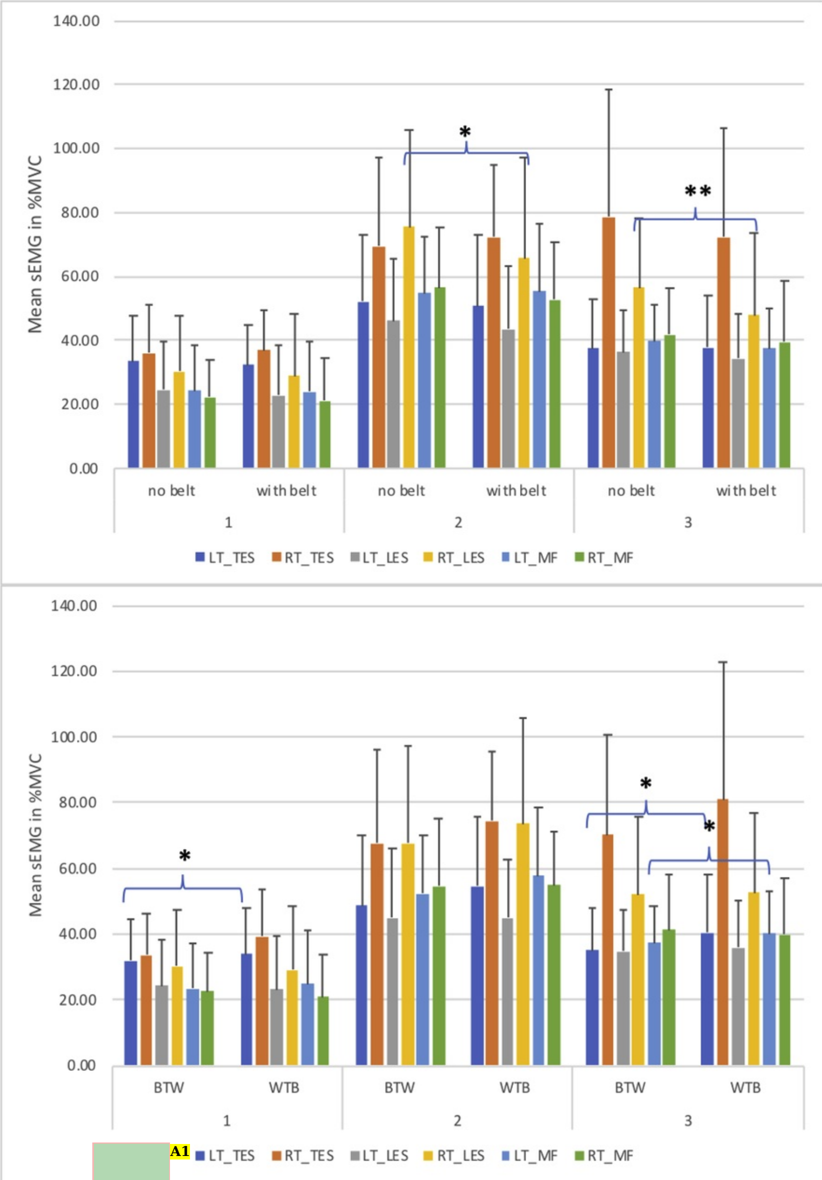
Table 1 Characteristics of nursing students (N = 10).

alt-text: Table 1

Characteristics	n (%)
University	
A	2 (20)
B	8 (80)
Program of study	
BSN (5-year programme)	4 (40)
BSNAY (3-year articulation programme)	6 (60)
Year of study	
4	2 (20)
5	8 (80)
	Mean ± SD (Range)
Age, year	22.3 ± 1.34 (21–25)
Height, cm	158 ± 3.89 (153–163)
Weight, kg	49.34 ± 2.98 (46.5–54.6)

3.2 sEMG

Investigating the effect of the transfer belt, the separate mean EMGs for the transfer phases, with or without a belt, were found to range from 22.95 to 78.77 %MVC (Fig. 3a). In general, the %MVC was higher in the condition of not using a transfer belt in all three phases.



* *p* value significant at <0.05; ** <0.01

Fig. 3 a(above). Mean EMG of each transfer phase @%MVC with/without Belt. b(below). Mean EMG of each transfer phase @%MVC Bed to Wheelchair/Wheelchair to Bed;

* *p* value significant at *<0.05; ** <0.01.

alt-text: Fig. 3

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When the effect of task was calculated, the mean EMGs for the individual tasks, with or without a transfer belt, ranged from 20.96 to 80.92 %MVC (Fig. 3b). It was observed that the %MVC was higher in the right TES than in any of the other muscles across all three phases, with higher muscle activities in WTB.

3.2.1 Main effect: Belt

Of the three pairs of muscles, with the effect of a belt, the %MVC of the right LES was reduced significantly (Table 2). A post hoc test showed that, by using a transfer belt, the sEMG activity was reduced by nearly 10%, that is, 75.5%–65.5% in phase 2, and 56.6%–47.9% in phase 3 (Table 3). No statically significant difference was found in any other muscles across the three phases.

Table 2 Statistics of sEMG and kinematics data on the main effects of Belt and Task.

alt-text: Table 2

Main effect:	Belt				
Variables	B	SE	tStat	DF	pValue
EMG %MVC					
LT_TES	−0.80	1.80	−0.44	117.00	0.66
RT_TES	−0.84	3.42	−0.25	117.00	0.81
LT_LES	−1.99	1.85	−1.07	117.00	0.29
RT_LES	−6.69	2.39	−2.79	117.00	0.01*
LT_MFS	−0.61	1.33	−0.46	117.00	0.65
RT_MFS	−2.42	2.26	−1.07	117.00	0.29
Kinematics					
Lx_Flexion	−0.26	0.41	−0.64	37.00	0.53
Lx_Extension	−0.09	0.31	−0.30	37.00	0.77
Left_Tx_Rot_max	−0.50	0.71	−0.70	37.00	0.49
Left_Tx_Rot_min	−0.40	0.56	−0.72	37.00	0.48
Main effect:	***Task***				
EMG %MVC					
LT_TES	4.40	1.80	2.44	117.00	**0.02***
RT_TES	7.71	3.42	2.26	117.00	**0.03***
LT_LES	−0.01	1.85	−0.01	117.00	0.99
RT_LES	1.79	2.39	0.75	117.00	0.46
LT_MFS	3.18	1.33	2.39	117.00	**0.02***
RT_MFS	−0.87	2.26	−0.39	117.00	0.70
Kinematics					
Lx_Flexion	0.57	0.41	1.41	37.00	0.17
Lx_Extension	0.31	0.31	0.97	37.00	0.34
Left_Tx_Rot_max	−0.03	0.71	−0.05	37.00	0.96

Left_Tx_Rot_min	0.50	0.56	0.90	37.00	0.37

Remark: Lt: left; Rt: right.

*p value significant at<0.05.

Table 3 Post Hoc tests of the sEMG data.

alt-text: Table 3

POST HOC	Belt @Phase 1				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	−1.32	2.30	−0.58	37.00	0.57
RT_TES	1.00	2.45	0.41	37.00	0.69
LT_LES	−1.61	1.53	−1.05	37.00	0.30
RT_LES	−1.44	2.22	−0.65	37.00	0.52
LT_MFS	−0.21	1.24	−0.17	37.00	0.87
RT_MFS	−1.15	1.73	−0.67	37.00	0.51
POST HOC	**Belt @Phase 2**				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	−1.50	3.49	−0.43	37.00	0.67
RT_TES	2.86	4.57	0.63	37.00	0.54
LT_LES	−2.46	2.31	−1.07	37.00	0.29
RT_LES	**−9.94**	**4.20**	**−2.37**	**37.00**	**0.02***
LT_MFS	0.66	2.12	0.31	37.00	0.76
RT_MFS	−3.83	3.52	−1.09	37.00	0.28
POST HOC	**Belt @Phase 3**				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	0.43	2.34	0.19	37.00	0.85
RT_TES	−6.38	7.06	−0.90	37.00	0.37
LT_LES	−1.89	1.74	−1.09	37.00	0.28
RT_LES	**−8.69**	**2.84**	**−3.06**	**37.00**	**<0.01****
LT_MFS	−2.27	1.29	−1.76	37.00	0.09
RT_MFS	−2.27	2.07	−1.10	37.00	0.28
POST HOC	**Task @Phase 1**				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	1.81	2.30	0.79	37.00	0.44
RT_TES	**5.52**	**2.45**	**2.25**	**37.00**	**0.03***

LT_LES	−1.03	1.53	−0.67	37.00	0.50
RT_LES	−1.13	2.22	−0.51	37.00	0.61
LT_MFS	1.27	1.24	1.02	37.00	0.31
RT_MFS	−1.61	1.73	−0.93	37.00	0.36
POST HOC	**Task @Phase 2**				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	5.98	3.49	1.71	37.00	0.10
RT_TES	6.92	4.57	1.51	37.00	0.14
LT_LES	−0.21	2.31	−0.09	37.00	0.93
RT_LES	5.83	4.20	1.39	37.00	0.17
LT_MFS	**5.23**	**2.12**	**2.47**	**37.00**	**0.02***
RT_MFS	0.24	3.52	0.07	37.00	0.95
POST HOC	**Task @Phase 3**				
VARIABLES	B	SE	tStat	DF	pValue
LT_TES	**5.40**	**2.34**	**2.31**	**37.00**	**0.03***
RT_TES	10.69	7.06	1.51	37.00	0.14
LT_LES	1.20	1.74	0.69	37.00	0.50
RT_LES	0.67	2.84	0.24	37.00	0.81
LT_MFS	**3.04**	**1.29**	**2.36**	**37.00**	**0.02***
RT_MFS	−1.25	2.07	−0.60	37.00	0.55

Remark: Lt: left; Rt: right; **p* value significant at *<0.05; ** <0.01.

3.2.2 Main effect: Task

There was a larger significant increase in muscle activities shown in both the TES and left MFS during WTB than during BTW. The main differences in the left TES were in Phases 2 and 3, and the left MFS as well, while this was only shown in Phase 1 for the right TES (Tables 2 and 3).

3.2.2.1 Kinematics During the whole lifting procedure, none of the participants' spinal movements were in any extreme posture. In the lumbar region, the means of the peak flexion angles ranged from 14.43 to 15.29°, while in the thoracic region, i every case the spine was kept in a left rotation posture (Fig. 4). There was no significant effect of belt or task in the kinematic variables (Table 2).

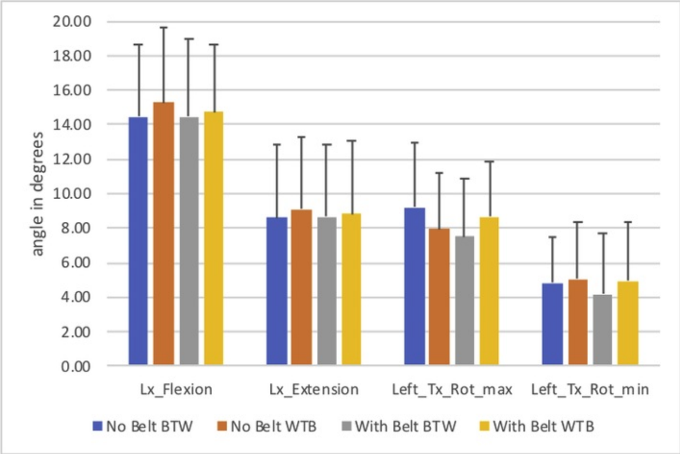

Fig. 4 Max and Min angle in Lumbar Flexion and Thoracic Rotation in Degrees.

alt-text: Fig. 4

3.3 Perceived exertion rating

In the four conditions, the participants' perceived exertion ratings for all body parts (2 tasks * 2 belts conditions) ranged from 1.22 to 1.84 (Fig. 5) (i.e, within "light" to "very light" categories). The only significantly decreased score (0.39) was noticed for the lower back when the belt was used (Table 4).

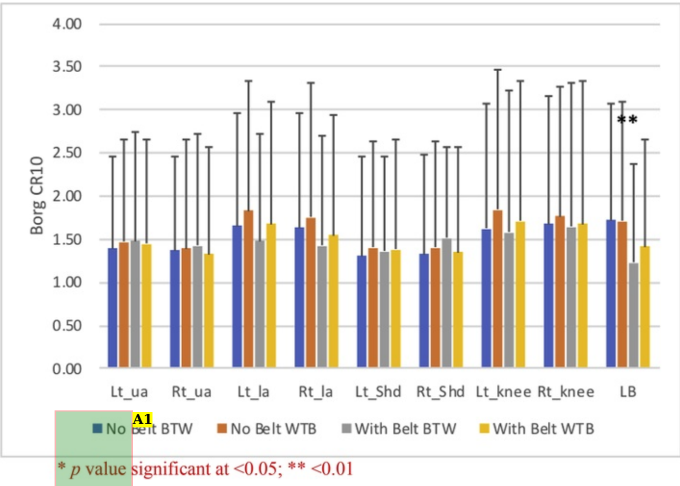

Fig. 5 Borg CR10 in different body regions after 4 transfer tasks;

* *p* value significant at *<0.05; ** <0.01.

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Table 4 Statistics for Borg CR10 scale.

alt-text: Table 4

MAIN EFFECT	Belt				
VARIABLES	B	SE	tStat	DF	pValue
LT_UPPER ARM	0.03	0.12	0.25	37.00	0.81
RT_UPPER ARM	−0.01	0.12	−0.06	37.00	0.96
LT_LOWER ARM	−0.16	0.16	−0.99	37.00	0.33
RT_LOW ARM	−0.21	0.16	−1.31	37.00	0.20
LT_SHOULDER	0.02	0.08	0.23	37.00	0.82
RT_SHOULDER	0.06	0.11	0.58	37.00	0.56
LT_KNEE	−0.08	0.09	−0.89	37.00	0.38
RT_KNEE	−0.06	0.11	−0.51	37.00	0.62
LOWER BACK	**−0.39**	**0.12**	**−3.22**	**37.00**	**<0.01****
MAIN EFFECT	Task				
VARIABLES	B	SE	tStat	DF	pValue
LT_UPPER ARM	0.02	0.12	0.19	37.00	0.85
RT_UPPER ARM	−0.04	0.12	−0.30	37.00	0.76
LT_LOWER ARM	0.19	0.16	1.17	37.00	0.25
RT_LOW ARM	0.12	0.16	0.77	37.00	0.45
LT_SHOULDER	0.06	0.08	0.73	37.00	0.47
RT_SHOULDER	−0.04	0.11	−0.40	37.00	0.69
LT_KNEE	0.17	0.09	1.84	37.00	0.07
RT_KNEE	0.06	0.11	0.54	37.00	0.60
LOWER BACK	0.09	0.12	0.75	37.00	0.46

*p value significant at *<0.05; ** <0.01.

3.4 Subjective opinions

Seven (70%) of the participants considered patient-handling tasks to be better with the belt than without. One student considered there was no difference between using and not using the belt. In addition, nine of them (90%) thought the 3-min break was enough.

In the interview conducted after performing all patient-handling tasks, the simulated patient stated that she had not felt much difference when the transfer belt was used and when it was not. She responded that good communication and cooperation were more important than the usage of the transfer belt during the patient-handling process. The more trials the patient completed with each NS, the more competent she found the NS to be. With regard to patient-handling techniques, she thought that leaning closer and not rushing the process were effective strategies. She felt more safe and secure to be lifted by participants whose heights were similar to hers.

4 Discussion

To our knowledge, our study is the first experimental attempt to quantify the biomechanical characteristics of kinematics and muscle activity objectively in NSs performing patient transfer tasks. The present findings have provided evidence to support the effectiveness of using a transfer belt in reducing the low back musculoskeletal risk for NSs. Our study has also provided useful data that can be compared in future research to studies of working nurses or nursing assistants working in nursing homes.

4.1 Effects of the transfer belt

The comparison of the mean muscle activity with and without the belt during transfers suggested that the belt had significantly reduced lower back muscle activity during Phases 2 and 3. In Phase 2, the mid-phase of the transfer, the lumbar erector spinae are expected to exert the greatest effort and assist the patient with the body weight being moved in between the bed and the wheelchair. Phase 3 involves the lowering of the patient's body weight onto the new surface and the nurse's muscles will have to work eccentrically against the effects of gravity. These factors may account for the significant differences in the lumbar erector spinae muscles, which are the main back extensor muscles for performing these tasks. The objective biomechanical EMG result was supported further by the significantly lower subjective perceived exertion rating at the low back when the transfer belt was used.

Moreover, the patient in our study expressed that her feeling of safety and security during the transfer came from the participant leaning closer without rushing. The perception of transfer belts being better than mechanical lifts (Garg and Kapellusch, 2012) might be partially because of the nurse's encirclement of the patient's body.

This finding about the effectiveness of a transfer belt in reducing musculoskeletal risk to the low back is encouraging. Our study serves as a preliminary step to further investigate the mechanism of low-cost low-tech devices in decreasing the risk of musculoskeletal problems.

4.2 Effects of proper patient transfer techniques

Proper education about patient transfer techniques is another important message from our study. Our findings indicated an insignificant effect between the belt and the task in the kinematics analysis, with small angular displacements in lumbar flexion and thoracic rotation. These displacements were far from the recommended lumbar flexion limit of 60° (Umer et al., 2016). Furthermore, the perceived physical exertion rating was in the category of “very light to light”, which is consistent with the findings of Hess et al. (2007). It is most likely that these positive results were related to the well-controlled experimental study design in the laboratory setting. Both the participants and the patient were well trained to ensure consistent performances. Furthermore, additional trials were required if awkward postures such as stooping or bending of the back were observed. These awkward posture data were excluded from the analysis. Furthermore, a 3-min break was provided in between the two trials. According to the formula of effort and recovery time, the recovery time for the three pairs of muscles in our study was about 3 min. Furthermore, Hess et al. (2007) found that participants receiving adequate training before a biomechanical study had lower LBD risk than those receiving minimal training. Solomon et al. (2017) found that NSs’ awareness of body mechanics (such as correct standing, sitting postures, and correct patient transferring techniques) was lower than that demonstrated by physiotherapy students, hence they recommended further studies on the awareness and practice of body mechanics for NSs. Perhaps, proper patient transfer techniques with adequate rest should be emphasized as a fundamental concept to reduce LBDs. Even though advanced mechanical lifting devices are used, nursing personnel still cannot avoid some manual procedures when lifting patients.

However, in reality, nursing personnel perform different patient handling tasks within limited timeframes. These tasks include transferring, repositioning, bathing, and lifting (Cheung et al., 2018b). Consequently, they tend to perceive these tasks as heavy and physically exerting (Cheung et al., 2018a). Due to heavy work demands, health-care workers have commonly reported the experience of muscle fatigue (Ching et al., 2017), which is defined as a decrease in the force-generating ability of a muscle during repetitive activation (Bevan et al., 1992; Fitts, 1994). If repetitive activation of muscles occurs, the force output declines gradually to a state of fatigue (Binder-Macleod et al., 1999). Furthermore, nursing personnel need to handle patients with different body builds. In such cases, it is expected that the muscle activities of the low back, spinal kinematics and ratings of perceived physical exertion would be considerably higher than in our present study findings. Future studies are needed to conduct biomechanical evaluations of low-tech devices in real working conditions.

There were some limitations in our study. Convenience sampling was used to recruit the participants. This can limit the generalizability of results and make them highly vulnerable to selection bias (Polit and Beck, 2014). However, the quality of the experiment was enhanced by the fidelity of the intervention. Future research can involve a larger sample size and include student nurses with different body builds, especially those who are very tall or very short who may encounter more difficulty in performing patient handling tasks. Although a controlled laboratory setting can control extraneous and independent variables to examine causal relationships, this controlled setting could also have induced unnatural behaviors that would not reflect a real situation. In addition, the potential Hawthorne effect is an unavoidable bias. Furthermore, fastening the transfer belt around the patient might impose extra work to the NSs, as well as slight discomfort for the patient.

5 Conclusion

The present study examined the spinal kinematics and muscle activity in the nursing students when they performed patient handling tasks with and without a transfer belt. With proper patient transfer techniques, the use of a transfer belt could lead to lower muscle activity and lower perceived physical exertion in the area of the low back. Proper posture, kinematics and communication with patients in each transfer should be emphasized in the training of patient-handling in university education programmes as well as staff training in health-care settings. The results support the positive benefits of using a transfer belt if available. If NSs can integrate the proper patient handling techniques in their training programmes, it is more likely that they would maintain effective body mechanics in their work duties and avoid serious injuries to the spine.

Contributors

KC: Planned and supervised the study, and finalized the manuscript.

JD: Planned the study, monitored the data collection procedure, performed statistical analysis, revised the data analysis and results of the manuscript.

CLC: Recruited participants, data collection and draft manuscript.

HKC: Recruited participants, data collection and draft manuscript.

YLC: Recruited participants, data collection and draft manuscript.

KYF: Recruited participants, data collection and draft manuscript.

WSL: Recruited participants, data collection and draft manuscript.

HLCL: Recruited participants, data collection and draft manuscript.

SYN: Recruited participants, data collection and draft manuscript.

MYN: Recruited participants, data collection and draft manuscript.

GS: Planned the study and provided guidance to the study.

All authors reviewed and approved the final manuscript for submission.

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Conflicts of interest

None.

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Highlights

- Transfer belts can reduce muscle activity and perceived physical exertion in the low back region.
- Proper posture and correct techniques in patient transfers are key elements in reducing the risk of low back disorders.
- Low-tech patient transfer assistive devices can be used to reduce the risk of low back disorders.

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