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Differences in Nurses' Upper-Body Posture in Manual Patient Handling—A Qualitative Case Study

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Abstract: (1) Background: In the context of nursing challenges and workforce shortages, nurses experience significant physical and psychological strain due to manual patient handling. (2) Methods: This study investigates differences in nurses' upper body postures, patient turning acceleration, and perceived exertion during a typical repositioning process within two repositioning maneuvers. (3) Results: The results reveal variations in positioning duration, upper-body posture angles, and turning acceleration between nurses and sequences. Nurse 2 exhibits more extreme postures (e.g., lateral flexion $p < 0.001$) and accelerations (e.g., shoulder $p < 0.001$) but reports lower perceived exertion ($p = 0.03$). (4) Discussion: These findings emphasize the need for ergonomic adherence and targeted training to enhance patient repositioning. Comprehensive solutions are necessary for patient and nurse comfort, particularly in cases of higher patient weights. Against the background of ergonomic body posture, this study highlights the potential of innovative tools and ongoing research to alleviate physical strain and enhance patient care.

Keywords: nursing; bed-bound; care; positioning techniques; movement analysis

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1. Introduction

Nurses globally are faced with substantial challenges and workforce shortages in their daily work activities, with heightened significance due to the COVID-19 pandemic, leading to considerable physical and psychological strain [1–4]. These challenges predominantly stem from the physically demanding nature of manual patient handling tasks, encompassing repositioning, prolonged standing, uncomfortable postures, frequent lifting, carrying, and forceful exertions within a standard 12 h shift [5,6]. This routine contributes to heightened risks of spinal loading and prolonged physical strain, particularly chronic back pain [7–9], rendering nurses particularly susceptible to work-related musculoskeletal disorders (WMSDs) and work incapacities [6,10,11]. Particularly in the intensive care of individuals with special needs and disabilities and bed-bound elderly patients, standardized repositioning protocols executed by nurses are pivotal to preventing pressure sore formation [12,13]. However, the repetitive repositioning process, involving leaning over the bed and gently turning patients, may lead to various musculoskeletal discomforts in nurses [5].

To mitigate WMSDs and reduce the impact of forceful exertions, adhering to ergonomic guidelines is crucial. They recommend that manual lifting, carrying, or pulling should not exceed a maximum weight of 23–25 kg, especially if a high frequency of movement is performed per day [14–17]. Furthermore, forced postures are characterized by the surpassing of 15% of the maximum holding force and a duration exceeding 4 s. A forward-bent posture should not persist for more than 10 s if repeated or for more than 60 s at once [18]. Additionally, ergonomic risk assessment tools such as RULA [19], OWAS [20], and EAWS [21] consider both the intensity and duration of body postures to delineate risk factors and non-ergonomic stances. Guidelines for upper-body posture outlined in ISO and DIN EN standards, employing green, yellow, and red tolerance ranges [16,17], underscore the importance of maintaining optimal upper-body flexion within a range of 0° (neutral posture) to 20° (green tolerance range). Flexion beyond 60° enters the red tolerance range, indicative of non-ergonomic posture. Lateral flexion is advised to be constrained within −10° (left lateral flexion) to 10° (right lateral flexion), with a permissible range of −20° to 20° to mitigate overloading risks. Similarly, back torsion (rotation) should remain within −10° (left rotation) to 10° (right rotation), within a maximum range of −20° to 20°, to minimize strain risks. Adhering to these recommendations can effectively mitigate spinal overloads, provided sustained non-ergonomic postures and the concurrent handling of heavy loads are avoided.

While the literature includes some field studies investigating work-related spinal loads and assessing body postures in manual handling [22–26], the majority are situated within industrial contexts. In the nursing domain, evaluations of nurses' working postures mainly focus on manual patient bed-to-wheelchair transfers [27–31]. Studies addressing manual repositioning maneuvers in bed, particularly those assessing objective kinematic motion analysis for evaluating body postures, are scarce. Consequently, an analysis of the physical and psychological burdens borne by nurses, especially in intensive care settings for individuals with special needs and elderly bed-bound patients and residents, becomes imperative. This analysis is essential for enhancing overall well-being and upholding high standards of care.

Considering these factors, the need to prevent nurses' overload in manual patient handling becomes evident. Longitudinal studies examining the effects of technical training on stress-tolerant work behavior yield conflicting evidence on back pain but demonstrate positive impacts in improving patient and resident repositioning quality [32–35]. A subset of studies exploring technical training's effects on aid usage consistently report reductions in work-related injuries [36,37]. Additionally, training ergonomic supervisors in repositioning processes has been linked to reductions in work-related injuries, neck and shoulder discomfort, and upper and lower back issues [38,39]. Although these studies identify effective technical training types, specific intervention content and their alignment with individual nurses' movement patterns remain unclear, necessitating further research to formulate intervention recommendations.

Motivated by these considerations and prior observations in nursing homes, we identified the prevalent use of bilateral 30° positioning maneuvers for bed-bound elderly patients and residents, which is one of the most common positioning maneuvers, especially in nursing home settings with older adults [40] (cf. Figure 1). This repositioning procedure involves the adjustment of the patient's body position by tilting them at a 30° angle and slowly rolling them onto one side while maintaining the angle. It has been shown that this positioning is most effective in reducing the pressure on different body segments and is therefore mostly recommended [41]. Adequate manual patient repositioning techniques, such as supporting the patient's limbs and body weight, are conducted to ensure secure and controlled repositioning for both sides (left and right positioning maneuvers). It is important to consider that the execution and the duration of the 30° repositioning process may vary based on individual patient needs and healthcare facility protocols. Moreover, due to the conditions of the positioning of the bed of the immobile persons, nurses have to work from both sides (left and right) in their daily routines. This might lead to unfavorable positions for the nurses if they have a preferred side due to their handedness. According to the actual situation in healthcare (e.g., time pressure, skill shortage, etc.; [42]) we wanted to explore this practice further with an explorative laboratory study. The specific research aims were the analysis of nurses' upper-body postures, their perceived exertion, and the bed-bound individual's turning acceleration during the implementation of this maneuver.

Left-sided 30° Right-sided 30°

Figure 1. Thirty-degree positioning.

Therefore, this exploratory case study aims to investigate differences between two nurses regarding upper body flexion, lateral flexion, and rotation angles as well as participants' turning acceleration and nurses' perceived exertion.

Against this background, we derived the following questions:

1. Do the nurses' durations of the repositioning process differ?
2. Do the nurses' body positions differ during the repositioning maneuver?
3. Does the acceleration of the participants lying in bed significantly differ between both nurses and does it change over time?
4. Does the perceived physical exertion significantly differ between nurses?

We assumed differences between the nurses considering their positioning technique and accompanying positioning durations, causing differing upper body positions in flexion, lateral flexion, and rotation. Furthermore, these variances in upper body positions may change over time during the turning maneuver. Additionally, we hypothesized that the nurses' positioning technique is related to the participants' turning acceleration and that it may change over time during the different turning maneuver sequences. Considering the expected differences in the individual nurses' positioning techniques, we assumed variances in physical perceived exertion between both nurses. These results could be used afterward for conducting additional field studies with bigger cohorts of nurses.

2. Materials and Methods

2.1. Trial Design

The experimental design followed a randomized crossover procedure. Accordingly, the positioning techniques (30° inclined position to the right, 30° inclined position to the left) were performed in randomly selected order by two nurses with all patient subjects. The laboratory experiment was performed on the premises of the University of Hamburg—Department of Movement and Exercise Science. The investigations took place between 6 June and 2 July 2020.

2.2. Participants

The subject sample included two trained professional female nurses, both aged 29 years, as well as 15 participants serving as patients (further named patient participants), covering the range of 5th to 95th height percentiles for representative results. All patient participants recruited through the University of Hamburg were healthy adults. For analysis, we matched 12 patient participants for left-sided positioning, and seven patient participants for right-sided positioning for each nurse. Tables 1 and 2 show the nurses' anthropometric data, as well as the patient subjects' anthropometric data for each positioning side.

Table 1. Nurses' age and anthropometric data (N = 2) *†.

Nurse (n)	Age (y)	B_M (kg)	B_H (cm)
Total	29.0 ± 0.0	69.0 ± 2.8	174.5 ± 5.0
1 (female)	29	67	170
2 (female)	29	71	177

* BM = body mass; BH = body height. † Values are mean ± SD.

Table 2. Patient subjects' anthropometric data (N = 15) *†.

Positioning Side	N	Age (y)	B_M (kg)	B_H (cm)
Right	7	35.6 ± 15.0	72.7 ± 11.4	172.6 ± 7.7
	2 males	29.0 ± 2.0	80.5 ± 0.5	183.0 ± 4.0
	5 females	38.2 ± 17.0	69.6 ± 12.2	168.4 ± 3.9
Left	12	31.8 ± 16.5	73.1 ± 15.1	173.2 ± 9.6
	6 males	32.8 ± 16.0	83.3 ± 11.9	181.5 ± 4.5
	6 females	30.8 ± 16.9	62.8 ± 10.2	164.8 ± 5.1

* BM = body mass; BH = body height. † Values are mean ± SD.

2.3. *Measurements and Test Instruments*

The following standardized instruments were used.

2.4. *Three-Dimensional Motion Analysis*

The 3D motion analysis was performed via Xsens MVN 2018, a three-dimensional kinematic motion measurement system using a constant frame rate of 60 Hz. The nurses' body movements were analyzed using 17 inertial sensors on various body segments such as the head, sternum, both sides of the shoulder, upper arm, forearm, hand, thigh, lower leg, feet, and pelvis. This setup allowed a three-dimensional analysis of the body segments in a Cartesian coordinate system [43]. The system showed strong correlations compared to the gold standard "vicon motion analysis" (Vicon Motion Systems, INC, Vicon, Oxford, UK) for measuring kinematics [44]. Based on its biomechanical model, the trunk flexion (forward lean angle of the trunk including pelvis tilt with respect to the vertical axis), the lateral flexion of the trunk (side lean angle of the trunk with respect to the pelvis), and the trunk's rotation (offset of the shoulder girdle with respect to the position of the pelvis) were used for upper body kinematics. The data from inertial sensors on their hands were used to analyze the acceleration of the repositioning process. This attachment allowed the acceleration of the repositioning to be recorded at the points of application (shoulder and hip) of the bed-bound patient participant (Figure 2) in X (transverse), Y (sagittal), and Z (longitudinal) directions. In the left-sided 30° inclined positioning, the right hand mainly guided the shoulder, while the left hand guided the hip area. In the right-sided 30° inclined position, the right hand guided the hip area and the left hand guided the shoulder area.

Figure 2. Xsens sensor coordinates placed on nurses' hands.

2.5. Subjective Perceived Exertion—Borg Scale

A 15-point Borg scale (6–20) was used to subjectively assess the general and specific (neck, shoulders, arms, upper back, lower back, legs) exertion. Here, 6 points correspond to very, very light exertion and 20 points to very, very heavy exertion [45,46].

2.6. Study Procedure

Each nurse performed the manual 30° positioning maneuver three times to the left and the right side with each patient's participant. The positioning technique followed the nursing standards for geriatric care and thus represented common repositioning from everyday professional life in the nursing sector [47]. Prior to performing the positioning process, the individual bed height was set to ensure an ergonomic posture, following the ISO and DIN EN guidelines [16,17]. They started from the neutral supine lying position. A fixed randomization schedule determined the order of the sides. Before each measurement session, nurses received instructions on the sequence and extent of positioning techniques. Each positioning technique was performed 3 times, and the mean value was calculated. After each positioning, the nurses assessed their general and specific perceived exertion via the Borg scale. Participants were instructed to mimic immobile patients, meaning that they were not allowed to actively move during the positioning maneuver.

2.7. Statistical Analysis

The recordings were analyzed and divided into four sequences by defining six time points during the respective 30° inclined positioning (cf. Figure 3). These were (1) the start of the overall positioning process (initial position—supine position), (2) the start of sequence 1 in the positioning process, (3) the end of sequence 1 in the positioning process, (4) the start of sequence 2 in the positioning process, (5) the end of sequence 2 in the positioning process, and (6) the end of the overall positioning process (final position—oblique position). For data analysis, we divided the whole turning maneuver into two sequences. The first sequence included the start of the positioning process until the participant was moved into a lateral posture and the nurse placed a blanket as a back support structure behind the participant. The second sequence included the positioning of the participant at the aiding blanket at their back until the end positioning. Data analysis included the calculation of maximum acceleration values in a Cartesian coordinate system (X, Y, Z; cf. Figure 2) and maximum upper-body postures in flexion/extension, lateral flexion, and rotation using MATLAB (MATLAB R2019b, Natick, MA, USA). Furthermore, data were cropped at the start and end points and smoothed with a moving average. An interpolation for 101 data points resulted in a time normalization (100%) for each sequence.

Statistical analysis included a two-way analysis of variance to compare between nurses and sequences. The alpha level was set at 0.05 for all analyses with Bonferroni correction for multiple testing. Effect sizes were calculated by partial eta square (ηp^2). SPSS version 25.0 was used for all statistical analyses.

To detect significant differences between both nurses' continuous trunk motions, as well as for accelerations, a two-step statistical parametric mapping (SPM) was used. Firstly, Hotelling's T2 (SPM{T2}) test was used to identify if statistically significant differences between both nurses' motions occurred, combining flexion, lateral flexion, and rotation of the trunk as a three-component vector, with changing values over time. If significant differences were found, secondary post hoc analysis using a paired-t-test (SPM{t}) was conducted for all three trunk movements separately to reveal differences for each motion of the trunk (flexion, lateral flexion, and rotation). The null hypothesis was rejected if the computed T2 (or t-value, respectively) for the trajectories exceeded the critical threshold values. All SPM analyses were conducted using the open-source code provided by Pataky et al. (version 0.4.7) (www.spm1d.org, accessed on 1 January 2021) in Matlab 2019a.

Missing data values occurred due to technical errors during data collection.

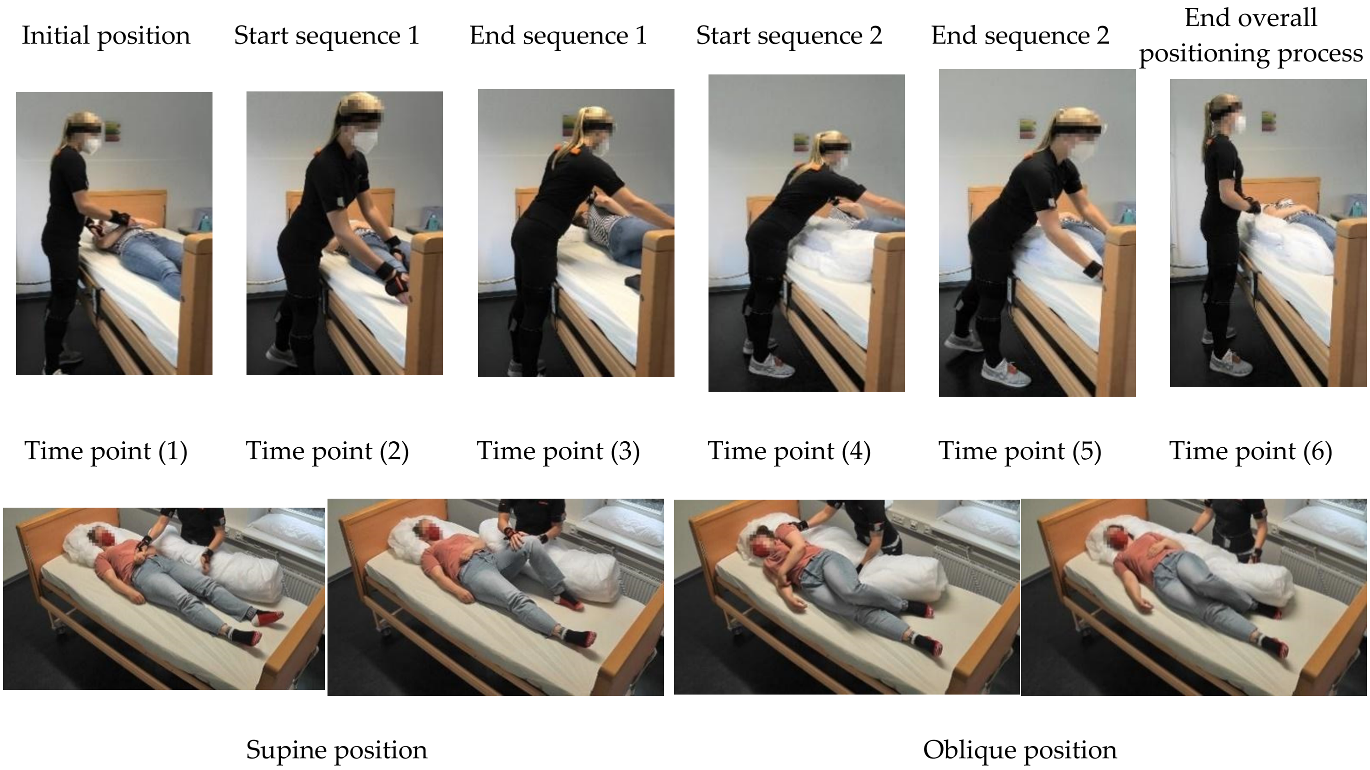


Figure 3. Nurses' upper body posture during the turning maneuver.

3. Results

3.1. Duration of the Turning Process

Table 3 shows the duration time for the left- and right-sided positioning for both nurses, as well as sequence 1 and sequence 2 (cf. Table 3). We found a significant main effect for left-sided and right-sided positioning between nurses and sequences ($p < 0.001$) after correction for multiple testing, with overall shorter durations in sequence 1, as well as shorter overall durations in nurse 1. Statistical analyses also showed significant results in between-subject effects for nurses (left: $p < 0.001$, $\eta p^2 = 0.258$; right: $p = 0.0045$, $\eta p^2 = 0.157$), as well as for sequences (left: $p < 0.001$, $\eta p^2 = 0.836$; right: $p < 0.001$, $\eta p^2 = 0.865$). There was no significant interaction effect between nurse and sequence.

Table 3. Time comparison between nurses and sequences for left- and right-sided positioning; two-way analysis of variance, main effects (ME), interaction of nurse x sequence (IA), and between-subject effect of nurses (BE). (N = 19) *†.

Positioning Side	**Seq**	**Nurse 1 (s)**	**Nurse 2 (s)**	**ME**		**IA**	**BE(n)**	**BE (seq)**
				p	η_p^2	p	η_p^2	η_p^2
Left (N = 12)	1	1.88 ± 0.18 (1.64–2.34)	2.24 ± 0.39 (1.52–3.07)	**<0.001**	**0.845**	0.263	**0.258**	**0.836**
	2	3.67 ± 0.52 (2.32–4.30)	4.33 ± 0.53 (3.72–5.62)					
Right (N = 7)	1	1.83 ± 0.29 (1.29–2.33)	2.10 ± 0.23 (1.88–2.59)	**<0.001**	**0.868**	0.672	**0.157**	**0.865**
	2							

* BM = body mass; BH = body height. † Values are mean ± SD.

3.2. Upper-Body Posture

Figure 3 shows the exemplary sequences and nurses' upper body posture, as well as the positioned participants. Furthermore, Table 4 shows the maximum upper-body angles during the turning maneuver in the analysis of the time course.

Table 4. Comparison in upper-body positions in left- and right-sided positioning between nurses and sequences; two-way ANOVA, main effects (ME), interaction of nurse x sequence (IA), and between-subject effect (BE) *†.

Upper-Body Position	**Seq**	**Nurse 1 (°)**	**Nurse 2 (°)**	**ME**		**IA**	**BE (n)**	**BE (Seq)**
				p	η_p^2	p	η_p^2	η_p^2
Left-sided (N = 12)								
max flexion	1	30.1 ± 3.1 (24.7–35.7)	32.9 ± 3.9 (26.2–38.4)	**0.001**	**0.301**	0.167	**0.240**	**0.065**
	2	30.6 ± 4.5 (21.6–36.7)	36.7 ± 4.3 (29.1–45.8)					
max lateral flexion	1	−1.1 ± 1.3 (−3.2–1.4)	3.3 ± 10.5 (−7.5–32.1)	**<0.001**	**0.552**	0.354	**0.178**	**0.499**
	2	10.4 ± 5.2 (4.5–22.9)	18.5 ± 6.3 (6.0–28.4)					
max rotation	1	8.3 ± 2.9 (4.9–14.3)	15.5 ± 7.6 (−3.1–25.7)	**0.001**	**0.323**	0.329	**0.223**	**0.145**
	2	14.2 ± 4.3 (7.9–20.7)	18.3 ± 5.3 (8.1–25.3)					
Right-Sided (N = 7)								
max flexion	1	33.4 ± 3.0 (30.6–40.0)	34.6 ± 3.1 (30.9–40.8)	0.845	0.033	0.863	0.008	0.024
	2	32.3 ± 7.8 (17.7–41.2)	32.8 ± 3.4 (27.9–39.0)					
max lateral flexion	1	3.5 ± 6.2 (−9.8–12.4)	19.5 ± 7.0 (7.3–28.6)	**<0.001**	**0.616**	**<0.001**	**0.210**	**0.397**
	2	3.7 ± 3.9 (−3.8–7.6)	0.0 ± 6.4 (−8.2–11.0)					
max rotation	1	4.1 ± 6.6 (−0.7–19.9)	3.6 ± 4.0 (−4.3–8.1)	**<0.001**	**0.828**	0.177	**0.056**	**0.824**
	2	25.5 ± 6.7 (15.3–34.4)	32.5 ± 5.1 (25.8–39.6)					

* seq = sequence; n = nurse; ° = degree; † = values are mean ± SD (range). Results in bold type indicate significance at the $\alpha \leq 0.05$ level.

3.2.1. Maximum Upper-Body Angles

The maximum upper body angles measured in left-sided positioning achieved by the two nurses with N = 12 participants and in right-sided positioning performed with N = 7 participants are shown in Table 4 as well as Figure 3.

Upper-Body Flexion

For left-sided positioning, we found more pronounced flexion angles within both nurses in sequence 2, as well as overall less pronounced flexion angles in nurse 1 compared to nurse 2. The between-subject effect of the nurses was significant ($p = 0.001$, $\eta p^2 = 0.240$). Both nurses showed an ergonomically acceptable upper body flexion, as long as this was not maintained over a longer period of time according to guidelines ISO 11226 [17] and the DIN EN 1005-4 [18]. For right-sided positioning, we found comparable angles for both nurses but more pronounced flexion angles within sequence 1 (cf. Table 4).

Upper-Body Lateral Flexion

For left-sided lateral flexion, we found more pronounced positions to the right side within both nurses in sequence 2. Nurse 1 showed an ergonomically optimal upper-body position in lateral flexion in sequence 1 but a partly not-quite-optimal posture in sequence 2. Nurse 2 showed predominantly an acceptable ergonomic upper body posture but partially extreme postures in upper-body lateral flexion according to the guidelines. The statistical analysis showed a significant between-subject effect for nurses ($p = 0.004$, $\eta p^2 = 0.178$), as well as for sequences ($p < 0.001$, $\eta p^2 = 0.499$). For right-sided lateral flexion, we found smaller angles in nurse 1 and more pronounced angles in nurse 2 within sequence 2. Nurse 1 mainly stayed in an optimal ergonomic upper-body position in lateral flexion within both sequences, whereas nurse 2 only showed an ergonomically optimal upper-body posture in sequence 1. In sequence 2, nurse 2 showed lateral flexion angles within a tolerable range, but partially poor posture, according to the guidelines. The statistical analysis showed a significant interaction effect between nurse and sequence ($p < 0.001$, $\eta p^2 = 0.405$) and a significant between-subject effect for nurses ($p = 0.019$, $\eta p^2 = 0.210$), as well as for sequences ($p = 0.001$, $\eta p^2 = 0.397$).

Upper-Body Rotation

For left-sided positioning, we found more pronounced upper-body rotations within sequence 2 but overall smaller rotation angles in nurse 1. Nurse 1 mainly stayed in an ergonomically optimal upper-body posture in rotation within sequence 1, but in a posture that was no longer ergonomically tolerable in sequence 2. Nurse 2 mainly stayed in a just barely acceptable tolerance range within sequence 1 but partially showed a poor upper-body posture in rotation within sequence 2, according to the guidelines. The statistical analysis revealed significant between-subject effects for nurses ($p = 0.001$, $\eta p^2 = 0.223$), as well as for sequences ($p = 0.009$, $\eta p^2 = 0.145$). For right-sided positioning, we found more pronounced upper-body rotations within sequence 2 with poor upper-body postures for both. Within sequence 1, both nurses mainly showed an ergonomically optimal upper-body posture in rotation according to the guidelines. The statistical analysis revealed a significant interaction effect for nurse and sequence ($p = 0.177$, $\eta p^2 = 0.075$) and a significant between-subject effect of nurses ($p = 0.246$, $\eta p^2 = 0.056$), as well as for sequences ($p < 0.001$, $\eta p^2 = 0.824$).

3.2.2. SPM Analysis for Upper-Body Kinematics

SPM analysis (Figure 4) showed upper-body position changes over time during the turning maneuvers. Hotelling's T2 test revealed a significant difference for sequence 1 between 0% and 28% of the cycle as well as for 51% and 100% of the cycle. For the second sequence, significant differences occurred between 0% and 28%.

A Shapiro–Wilk test revealed a non-normal distribution for all angles. Therefore, for the post hoc tests, a non-parametric equivalent SnPM{t} to the SPM{t} analysis was conducted. To account for multiple tests, a Bonferroni correction set the alpha value at 0.167. We detected significant differences between the movement of both nurses in specific parts of the movement cycles for the flexion in sequence 1 (51–100%), the flexion in sequence 2 (0–31%), the lateral flexion in sequence 1 (0–30%), and the rotation in sequence 1 (55–87%).

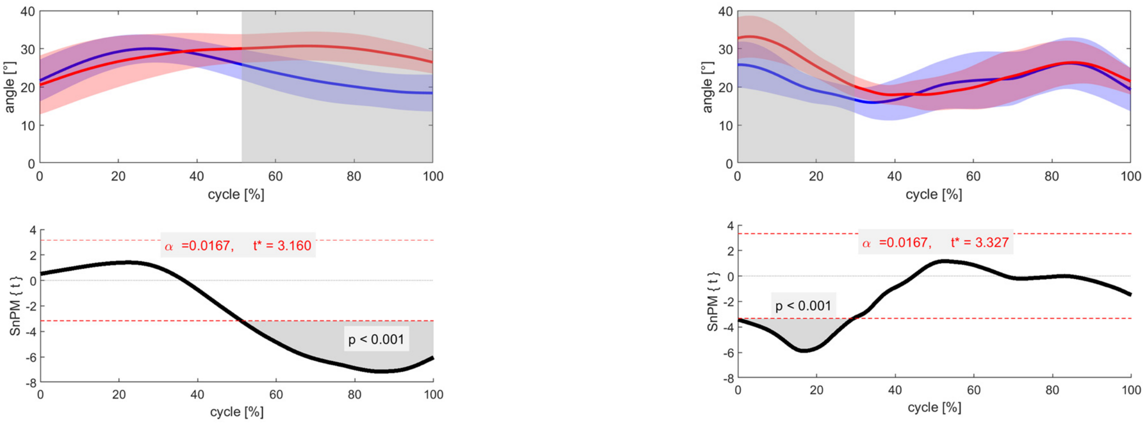
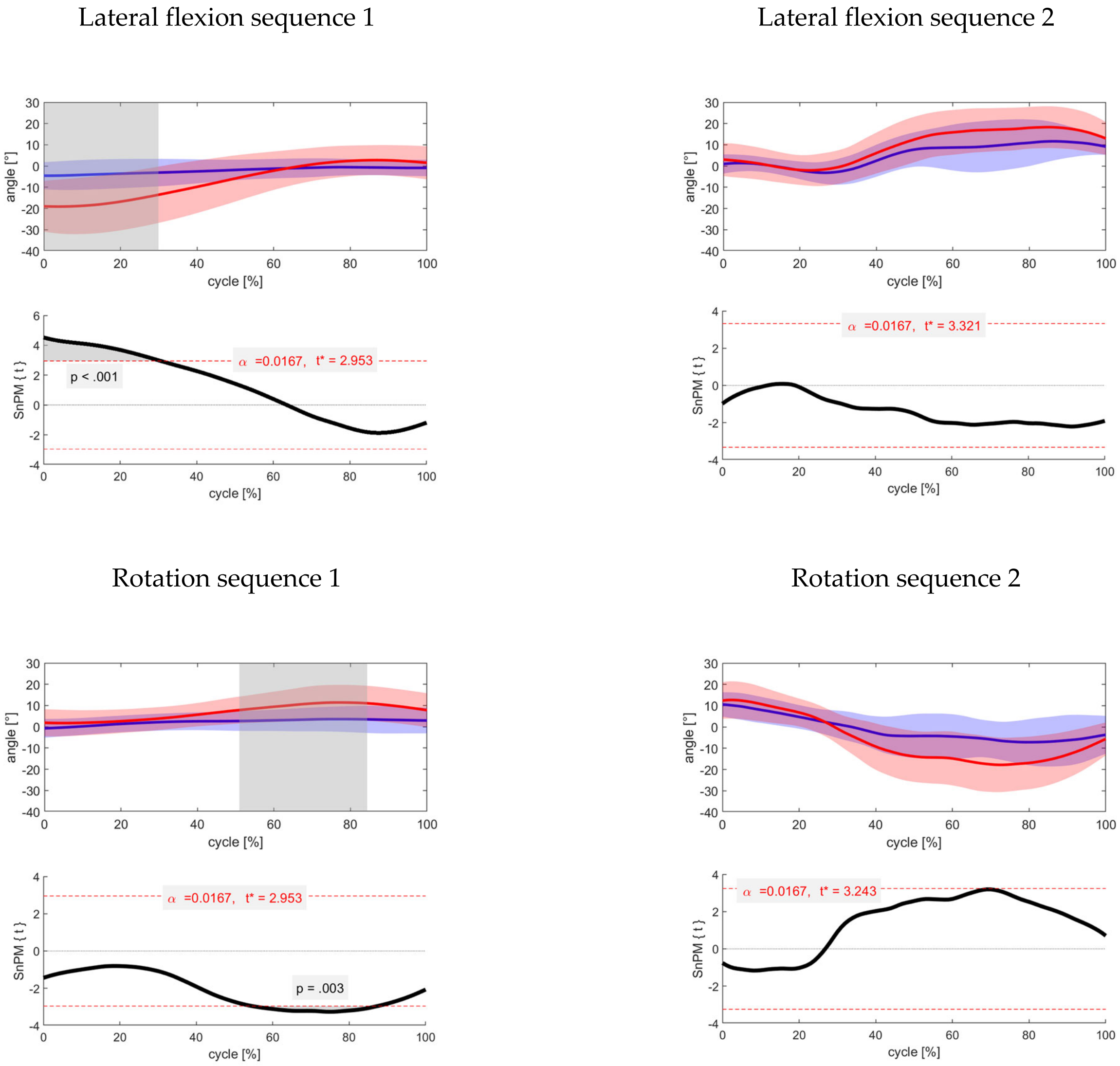


Figure 4. *Cont.*


Lateral flexion sequence 1

Lateral flexion sequence 2

Rotation sequence 1

Rotation sequence 2

Figure 4. SPM analysis of body postures. Blue line = nurse 1; red line = nurse 2; non-parametric t-test.

3.3. *Turning Acceleration*

The following results of the turning acceleration are divided into the analysis of the maximum data and the analysis of the time course.

3.3.1. Maximum Turning Acceleration

Tables 5 and 6 show the results of the left- and right-sided turning maneuver with the maximum acceleration in X (transverse), Y (sagittal), and Z (longitudinal) directions (cf. Figure 2) for participants' shoulder and hip, separated for both sequences as well as for both nurses.

Table 5. Comparison of maximum turning acceleration in left-sided positioning between nurses and sequences; two-way ANOVA, main effects (ME), interaction of nurse x sequence (IA), and between-subject effect (BE) (N = 12) *†.

X, Y, Z	**Seq**	**Nurse 1 (m/s^2)**	**Nurse 2 (m/s^2)**	**ME**		**IA**	**BE (n)**	**BE (Seq)**
				p	η_p^2	p	η_p^2	η_p^2
Hand on shoulder X	1	1.17 ± 0.35 (0.75–1.92)	1.91 ± 1.79 (0.68–7.19)	**<0.001**	**0.710**	0.666	0.065	0.704
	2	4.80 ± 0.75 (3.33–5.75)	5.25 ± 1.31 (3.05–6.86)					

Table 5. *Cont.*

X, Y, Z	Seq	Nurse 1 (m/s^2)	Nurse 2 (m/s^2)	ME		IA	BE (n)	BE (Seq)
Hand on shoulder Y	1	1.19 ± 0.50 (0.66–2.50)	1.83 ± 0.86 (0.72–3.38)	**<0.001**	**0.651**	0.143	0.174	0.616
	2	4.04 ± 1.41 (2.50–7.82)	5.91 ± 2.28 (2.87–9.09)					
Hand on shoulder Z	1	1.19 ± 0.50 (0.94–2.67)	2.18 ± 0.54 (1.42–3.41)	**<0.001**	**0.661**	0.064	0.216	0.615
	2	3.08 ± 0.85 (1.98–4.38)	4.07 ± 0.60 (3.43–5.16)					
Hand on hip X	1	5.08 ± 1.64 (2.83–7.36)	3.21 ± 1.66 (0.99–5.90)	**0015**	**0.210**	0.118	0.166	0.008
	2	4.67 ± 0.94 (3.02–6.43)	4.10 ± 1.33 (2.19–6.01)					
Hand on hip Y	1	6.23 ± 2.07 (2.14–9.73)	4.82 ± 3.39 (1.18–12.36)	**0.016**	**0.208**	0.358	0.038	0.169
	2	3.77 ± 1.39 (2.35–6.24)	3.53 ± 1.14 (1.53–5.55)					
Hand on hip Z	1	5.12 ± 2.00 (2.68–8.53)	2.50 ± 1.35 (0.93–5.91)	**<0.001**	**0.354**	**<0.001**	0.044	0.031
	2	3.64 ± 0.93 (2.19–5.41)	5.02 ± 1.60 (3.23–8.87)					

* seq = sequence; n = nurse; m/s^2 = meter per square second; † = values are mean ± SD (range); results in bold type indicate significance at the $\alpha \leq 0.05$ level.

Table 6. Comparison of maximum turning acceleration in right-sided positioning between nurses and sequences; two-way ANOVA, main effects (ME), interaction of nurse x sequence (IA), and between-subject effect (BE) (N = 7) *†.

X, Y, Z	Seq	Nurse 1 (m/s^2)	Nurse 2 (m/s^2)	ME		IA	BE (n)	BE (Seq)
				p	ηp^2	p	ηp^2	ηp^2
Hand on shoulder X	1	1.00 ± 0.40 (0.60–1.68)	1.19 ± 0.52 (0.55–2.07)	**<0.001**	**0.828**	0.982	0.012	0.828
	2	5.10 ± 1.58 (2.97–7.56)	5.32 ± 1.08 (3.27–6.66)					
Hand on shoulder Y	1	0.94 ± 0.18 (0.68–1.23)	1.55 ± 0.58 (0.74–2.66)	**<0.001**	**0.718**	0.463	0.136	0.703
	2	4.41 ± 2.48 (1.71–7.79)	5.80 ± 0.91 (5.12–7.69)					
Hand on shoulder Z	1	1.51 ± 0.49 (0.80–2.13)	1.80 ± 0.74 (1.01–3.28)	**<0.001**	**0.755**	0.602	0.127	0.745
	2	3.23 ± 0.53 (2.27–3.90)	3.75 ± 0.53 (3.10–4.47)					
Hand on hip X	1	1.00 ± 0.40 (0.60–1.68)	1.19 ± 0.52 (0.55–2.07)	**0.038**	**0.291**	0.088	0.199	0.030
	2	5.10 ± 1.58 (2.97–7.56)	5.32 ± 1.08 (3.27–6.66)					
Hand on hip Y	1	0.94 ± 0.18 (0.68–1.23)	1.55 ± 0.58 (0.74–2.66)	0.085	0.237	0.766	0.168	0.095
	2	4.41 ± 2.48 (1.71–7.79)	5.80 ± 0.91 (5.12–7.69)					
Hand on hip Z	1	1.51 ± 0.49 (0.80–2.13)	1.80 ± 0.74 (1.01–3.28)	**0.018**	**0.339**	**0.013**	0.171	0.002
	2	3.23 ± 0.53 (2.27–3.90)	3.75 ± 0.53 (3.10–4.47)					

* seq = sequence; n = nurse; m/s^2 = meter per square second; † = values are mean ± SD (range). Results in bold type indicate significance at the $\alpha \leq 0.05$ level.

Participants' Shoulder Acceleration

For left-sided positioning, we found higher shoulder accelerations for turning participants' shoulders in all three directions in nurse 2 compared to nurse 1. The statistical analysis showed a significant between-subject effect of nurses in participants' shoulder sagittal plane ($p = 0.004$, $\eta p^2 = 0.174$) and in the shoulder longitudinal plane ($p = 0.001$, $\eta p^2 = 0.216$). Both nurses showed higher overall shoulder accelerations for participants' shoulders in all three directions in sequence 2. The statistical analysis showed significant between-subject effects for sequences in participants' shoulder transverse plane ($p < 0.001$, $\eta p^2 = 0.704$), sagittal plane ($p < 0.001$, $\eta p^2 = 0.616$), and longitudinal plane ($p < 0.001$, $\eta p^2 = 0.615$).

For right-sided positioning, we found higher shoulder accelerations for turning participants' shoulders in all three directions in nurse 2 compared to nurse 1. Both nurses showed higher overall shoulder accelerations for participants' shoulders in all three directions in sequence 2. The statistical analysis showed significant between-subject effects for sequences in participants' shoulders in the transverse plane ($p < 0.001$, $\eta p^2 = 0.828$), sagittal plane ($p < 0.001$, $\eta p^2 = 0.703$), and longitudinal plane ($p < 0.001$, $\eta p^2 = 0.745$).

Participants' Hip Acceleration

For left-sided positioning, we found higher hip accelerations in the transverse and sagittal plane for nurse 1 in both sequences compared to nurse 2. In the longitudinal plane, nurse 1 produced higher participant hip accelerations in sequence 1, and nurse 2 produced higher participant hip accelerations in sequence 2. Statistical analysis showed significant between-subject effects for nurses in the transverse plane ($p = 0.005$, $\eta p^2 = 0.166$) and for sequences in the sagittal plane ($p = 0.004$, $\eta p^2 = 0.169$).

For right-sided positioning, we found higher participant hip accelerations in all three directions in nurse 2 compared to nurse 1. Statistical analysis showed significant between-subject effects for nurses in the transverse plane ($p = 0.022$, $\eta p^2 = 0.199$), sagittal plane ($p = 0.038$, $\eta p^2 = 0.168$), and longitudinal plane ($p = 0.036$, $\eta p^2 = 0.171$). Furthermore, both nurses produced higher participant hip accelerations in sequence 2 compared to sequence 1 but without any statistically significant between-subject effects.

3.3.2. SPM Analysis for Turning Acceleration

To check for differences in acceleration in all three directions of the nurses' hands at participants' hips and shoulders over time during the sequences between nurses, a secondary analysis (SPM analysis) was conducted. The SPM–Hotelling's T2 test revealed a significant difference for the nurses' hands at participants' shoulders in sequence 1 between 7% and 25% as well as between 26% and 27% of the cycle (Figure 5). No other differences occurred for nurses' hands at participants' shoulders nor at participants' hips in both sequences.

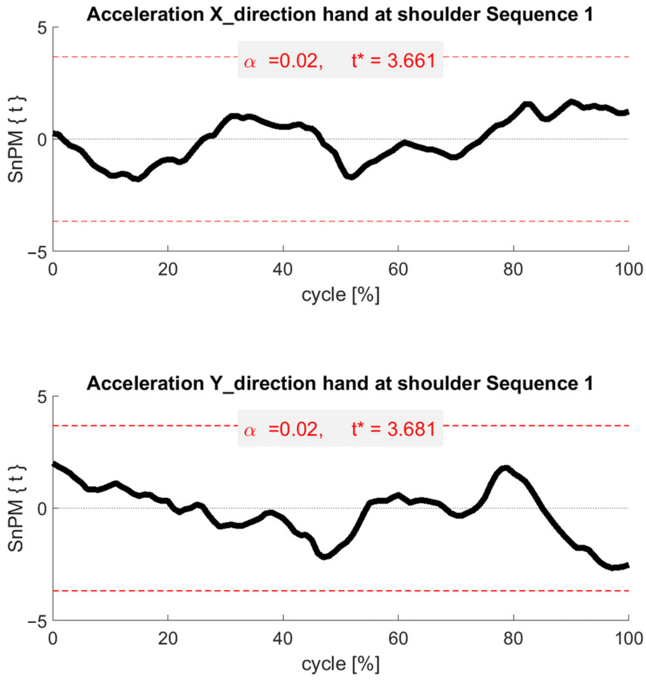


Figure 5. *Cont.*

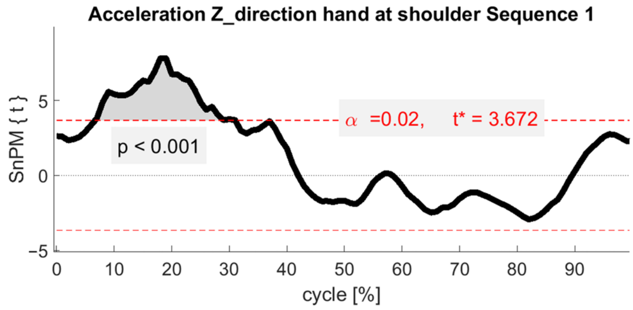


Figure 5. Acceleration of the hand on the shoulder in sequence 1.

Similar to the analysis of the angles, a Shapiro–Wilk test revealed a non-normal distribution for the accelerations, therefore a non-parametric SnPM {t} post-hoc analysis with a Bonferroni correction for nurses' hands at participants' shoulders in sequence 1 was conducted. The analysis showed a significant difference in the acceleration in the longitudinal plane between 7% and 27% of sequence 1.

3.4. Perceived Exertion

Table 7 shows the results of the left-sided positioning for the perceived exertion, separated for both nurses. Overall, nurse 2 showed lower mean values in perceived exertion. Statistical analysis revealed significant differences between both nurses for left-sided overall perceived exertion ($p = 0.033$) with lower mean values of 1.25 (95% CI: 0–2) for nurse 2, perceived exertion of the shoulders ($p = 0.006$) with lower mean values of 1.53 (95% CI: 1–2) for nurse 2, perceived exertion of the arms ($p = 0.014$) with lower mean values of 1.33 (95% CI: 0–2) for nurse 2, as well as perceived exertion of the legs ($p < 0.001$) with lower mean values of 4.00 (95% CI: 3–5) for nurse 2. For right-sided positioning, both nurses showed comparable values, except for perceived exertion of the legs. Nurse 2 showed significantly lower mean values of 3.62 ($p < 0.001$, 95% CI: 2–5).

Table 7. Comparison of perceived exertion in left- and right-sided positioning between nurses; Mann–Whitney U test, main effects (ME) *†.

Borg Score	Nurse 1	Nurse 2	*ME*				
			U	*p*	*MD*	*SE*	*95% CI*
Left-sided (N = 12)							
overall	10 ± 1 (8–12)	9 ± 1 (7–10)	**35.00**	**0.033**	**1.25**	**0.50**	**0–2**
neck	8 ± 1 (7–10)	8 ± 1 (7–9)	66.00	0.755	0.22	0.35	−1–1
shoulder	9 ± 1 (7–11)	8 ± 1 (6–9)	**25.00**	**0.006**	**1.53**	**0.45**	**1–2**
arms	11 ± 1 (8–12)	9 ± 1 (7–11)	**30.50**	**0.014**	**1.33**	**0.52**	**0–2**
upper back	9 ± 1 (7–11)	9 ± 1 (7–11)	63.00	0.630	0.28	0.52	−1–1
lower back	11 ± 1 (8–12)	10 ± 1 (8–12)	68.00	0.843	0.14	0.54	−1–1
legs	10 ± 1 (8–12)	6 ± 0 (6–6)	**0.00**	**< 0.001**	**4.00**	**0.37**	**3–5**
Right-sided (N = 7)							
overall	9 ± 1 (7–11)	9 ± 2 (7–10)	21.50	0.710	0.29	0.64	−1–2
neck	8 ± 1 (6–9)	8 ± 0 (7–9)	23.50	0.902	−0.19	0.44	−1–1
shoulder	9 ± 1 (7–10)	8 ± 1 (7–10)	15.50	0.259	0.62	0.57	−1–2
arms	10 ± 2 (7–12)	10 ± 1 (8–11)	18.00	0.456	0.48	0.69	−1–2
upper back	9 ± 2 (6–11)	9 ± 1 (8–11)	21.50	0.710	−0.43	0.67	−2–1
lower back	10 ± 1 (8–12)	10 ± 1 (10–11)	22.00	0.805	−0.29	0.57	−2–1
legs	10 ± 2 (7–11)	6 ± 0 (6–6)	**0.00**	**0.001**	**3.62**	**0.55**	**2–5**

* MD = mean difference; SE = standard error; 95% CI = 95% confidence interval. † = Values are mean ± SD (range). Results in bold type indicate significance at the $\alpha \leq 0.05$ level.

4. Discussion and Conclusions

This case study aimed to assess the impact of nurses' upper body posture during manual patient handling techniques, particularly while executing a standardized 30° repositioning maneuver. The study sought to uncover potential variations in posture between the two participating nurses while conducting the positioning maneuvers and correlate these findings with the acceleration experienced by the repositioned patient participants. In the context of patient participant repositioning, differences in the duration of positioning emerged, notably during left-sided repositioning. This variability indicated nuanced differences in the techniques employed by the nurses, despite both being instructed to adhere to ergonomic principles aimed at minimizing physical strain [37,39]. Typically, patient repositioning techniques are tailored to individual patient needs, often within the constraints of nurses' time availability [12]. It was noteworthy that nurse 1 exhibited shorter positioning times compared to nurse 2, potentially leading to reduced stress on body regions due to shorter exposure to challenging postures [5]. However, the study highlighted the fine balance required to avoid rapid movements during repositioning, which can contribute to musculoskeletal discomfort [48].

The subsequent analysis of upper body posture revealed that both nurses' upper-body flexion, lateral flexion, and rotation fell within ergonomic limits if these postures were sustained for short durations. Prolonged maintenance of extreme postures, as highlighted by ergonomic standards [16,17], can result in musculoskeletal overload. It became evident that nurse 2 adopted more pronounced and potentially discomforting postures in all dimensions, implying an increased risk of overloading. Variations in maximum flexion, lateral flexion, and rotation between the two nurses underscored the divergent techniques they employed. The examination of sequence effects and acceleration further illuminated the intricacies of the repositioning process. Sequence 2 emerged as more physically demanding, attributed to the extended duration of sustained extreme upper body postures. Acceleration analysis demonstrated that nurse 2 initiated higher accelerations in both shoulder and hip regions, aligning with her more pronounced upper body postures. This finding was consistent with nurse 1 showcasing a more economical and less physically demanding technique.

Interestingly, nurse 2, despite demonstrating more extreme angular positions, reported lower subjective perceived exertion across various body regions. This seemingly contradictory finding could be attributed to differences in perceived exertion between novice and experienced individuals although both participants were trained nurses, but with different years of experience, as suggested by existing literature [49].

Addressing these challenges in patient repositioning, the study highlighted the limitations of existing assistive aids, such as pillows and blankets, which offer only partial relief to nurses' discomfort and may not consistently improve patient comfort. Specialized systems catering to patient support are often one-sided in their functionality, underscoring the need for comprehensive, innovative solutions that prioritize ergonomic care for both nurses and patients [50,51].

Considering these findings, recommendations for future studies include a more extensive investigation into the physical burdens that nurses face while handling bed-bound patients, especially in cases of higher patient weights. Adhering to upper-body posture guidelines outlined by ISO and DIN EN standards could potentially alleviate the risk of musculoskeletal strain [16,17]. Moreover, technical training and ergonomic supervision have shown promising results in reducing work-related injuries and discomfort among nurses [32,33,37,39].

To conclude, this study illuminated the intricate interplay between repositioning techniques, nurses' upper body postures, and the resulting acceleration experienced by patient participants, as well as nurses' perceived exertion. By adhering to ergonomic guidelines and embracing technical training, the nursing community can work toward safer and more effective patient-handling practices. Innovative tools and ongoing research stand to contribute significantly to enhancing patient care and alleviating the physical strain faced by nurses in their vital roles.

Limitations

The interpretation of the study's outcomes should consider its inherent limitations. Chiefly, a noteworthy technical restriction pertains to the constrained number of participating nurses—a mere two trained individuals. This restricted representation potentially curtails the findings' applicability to a broader healthcare professional population. However, according to the actual situation in care settings, explorative feasibility studies like ours should give first insights into potential requirements for future studies. Augmented generalizability and more robust conclusions mandate an expanded, more heterogeneous sample size. Nevertheless, it has to be noted that the results were derived by a total of six positioning trials per person (both sides triple; N = 114 trials). The study's outcomes, while aligned with extant literature concerning the challenges nurses face in manual patient handling, might be somewhat circumscribed due to the diminutive sample size, affecting comparative analyses and correlations with previous research endeavors. Furthermore, the exclusive focus on bilateral 30° turning maneuvers might not comprehensively encompass the array of techniques nurses encounter in practical settings. This selected scope limits the spectrum of scenarios under scrutiny.

Another noteworthy limitation pertains to the reliance on self-reported perceived exertion data garnered from nurses during the manual repositioning procedures. The integration of subjective measurements introduces inherent biases and reporting disparities. Objective measurements, such as electromyography or force sensors, would proffer more precise and reliable data regarding the physical demands placed on nurses. Employing these objective metrics would enhance the fidelity of the collected data. Furthermore, the external validity of the study is restricted by the study's specific context and sample composition. Healthy individuals serving as representatives for bed-bound patients might not comprehensively replicate the multifaceted challenges nurses encounter when dealing with a diverse array of patient conditions. Thus, careful consideration is requisite when extrapolating the results to different healthcare scenarios.

Nevertheless, acknowledging these limitations, the study provides invaluable insights into the challenges confronted by nurses in the realm of manual patient handling, especially in manual patient repositioning processes, underscoring the importance of patient-centered and ergonomic practices. Subsequent research endeavors, enriched by larger and more diverse participant samples, enhanced methodological frameworks, and the incorporation of objective measurements, stand to build upon these insights. Such future investigations hold the potential to propel our understanding of nurse well-being and the quality of patient care in the context of manual handling, especially in the repositioning process, to new heights.

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