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Electric Versus Hydraulic Hospital Beds: Differences in Use During Basic Nursing Tasks

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Biomechanical, postural and ergonomic aspects during real patient-assisting tasks performed by nurses using an electric versus a hydraulic hospital bed were observed. While there were no differences in the flexed postures the nurses adopted, longer performance times were recorded when electric beds were used. Subjective effort, force exertion and lumbar shear forces exceeding safety limits proved electric beds were superior. Patients' dependency level seemed to influence the type of nurses' intervention (duration and force actions), irrespective of the bed used. The nurses greatly appreciated the electric bed. Its use seemed to reduce the level of effort perceived during care giving and the postural load during critical subtasks. Ergonomics and organizational problems related to adopting electric beds in hospital wards should be addressed further to make their use more efficient.

electric hospital bed nursing tasks biomechanical load

1. INTRODUCTION

The hospital bed is a highly functional medical device, whose role is basic for the worker's safety and the patient's quality of care [1]. Its use is absolutely necessary in most nursing and patient care activities, and it is the primary working tool in auxiliary nurses' activities [2]. Its functional and ergonomics properties, therefore, greatly influence the worker's health and safety and potentially affect their exposure to biomechanical overload. However, the use of the hospital bed has been only marginally considered in the literature on ergonomics [3], unlike other devices, such as mobile/ceiling lifters, whose properties have been studied extensively presumably because they were considered to more directly influence the nurses' performance of patient handling tasks. While there are many recommendations on the use of different types of lifters (whole-body, sit-to-stand, mobile, ceiling) and evidence of their biomechanical (spine compression, anterior–posterior and lateral shear forces) and operative (time and human cost, space requirements) implications [4], few indications or guidelines are available on types of hospital beds, apart from a general suggestion to use height-adjustable beds [5].

As device-assisted (with an electric lifter) patient handling accounts for a fraction of the whole shift time (~4%), manually performed patient care represents the greatest part of attending nurses' work [6]. Tasks performed while the patient is in bed (providing hygiene, clothing, mobilizing, posturing, bed making, etc.), often require handling body segments without mechanical or electric devices, and a high postural demand (flexing, reaching, sustaining, holding, moving, bending, etc.). Auxiliary nurses, who show the greatest injury rates among healthcare workers [7], adopt prolonged flexed postures. Those postures involve compressive and shear forces on the spine, together with a cumulative component, which constitutes an independent risk factor for biomechanical overload [8, 9].

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The aim of this study was to prove if using an electric bed instead of a hydraulic one could reduce the time spent by nurses in flexed postures and the force actions associated with patient handling, thus decreasing occupational overload during basic care activities.

2. METHODS

2.1. Tasks and Subjects

Six pairs of volunteer attending nurses (8 females, 4 males) were observed and video recorded while assisting bed-confined patients in the first part of the morning shift in four different hospital wards (palliative care, orthopaedic rehabilitation, neurological rehabilitation, revival unit). Each pair of nurses was observed under two conditions: using a very recently adopted electric bed (A) and using a hydraulic bed (still used in the ward) (B). Earlier, all nurses were given a short demonstration on the new electric bed and were allowed to use it for 10 working days.

The two types of beds require different technical actions: the hydraulic bed involves repetitive pushing with the lower limb on a pedal lever to adjust the height of the bed, and pulling a manual lever behind the bed head section at the same time as pulling/pushing (with the opposite limb) to adjust the bed section (head, waist, foot). In contrast, the electric bed is fully adjustable in height and in sector inclination through an automatic manual keypad or pedal button.

Each pair of nurses performed the same task under two conditions (A and B), assisting two real patients with similar dependence levels defined according to the Health Care Finance Association Patient Assessment System on a 1–5 scale (1 = *independent*, 5 = *totally dependent*) [10]. The 12 patients (males and females) were similar in anthropometric measures (weight 59 ± 4 kg, height 164 ± 5 cm). They were classified as follows: six patients at level 5, four at level 4, two at level 3 (Table 1). The patients or their relatives were asked to sign a formal consent for the video recording, and a privacy statement. The observed tasks included providing hygiene in bed, mobilizing and transferring from bed to wheelchair (with or without aids) in accordance with the patients' condition.

TABLE 1. Scheme of the Subjects and Tasks Investigated: 6 Coupled Nurses Observed During Tasks With Real Patients

Coupled Nurses	Gender	Age (years)	Weight (kg)	Height (cm)	Ward	Patients' Classification	Task
1	F	44	58	166	palliative care	5	hygiene on supine patient
	F	38	64	168			
2	F	32	54	164	palliative care	5	hygiene on supine patient
	M	42	91	199			
3	F	38	63	170	functional recovery and rehabilitation	4	manual bed-to-wheelchair transfer
	M	37	59	166			
4	F	39	68	172	functional recovery and rehabilitation	4	hoist-assisted bed-to-wheelchair transfer
	M	46	72	166			
5	F	47	55	167	neurological rehabilitation	3	manual bed-to-wheelchair transfer
	M	34	63	168			
6	F	42	47	157	revival unit	5	hygiene on supine patient
	F	38	59	169			
	total (n = 12)	39 ± 4	62 ± 11	169 ± 10			
	F (n = 8)	39 ± 4	58 ± 6	166 ± 4			
	M (n = 4)	39 ± 5	71 ± 14	174 ± 16			

Notes. Patients' classification and tasks were the same in conditions A (electric bed) and B (hydraulic bed); 5 = totally dependent; requires total transfer; 4 = extensive assistance; can perform part of activity, usually can follow simple directions, may require tactile cueing, can bear some weight, can sit up with assistance, has some upper body strength, may be able to pivot transfer, may require total transfer; 3 = limited assistance; highly involved in activity, able to pivot transfer and has considerable upper body strength and bears some weight on legs, can sit up well, but may need some assistance. F = female, M = male.

2.2. Data Collection

Filming was done with a single camera (Sony DCR-SR57, Japan) operating at 50 Hz with a shutter setting of 1/500th of a second. The camera was located perpendicular to a line placed on the floor 2 m from the patient's bed, whilst two markers were positioned 0.60 m apart and were used to facilitate the scaling of the calculated kinematic data. Filming was continuous during the whole duration of the task; it focused on both nurses at the bedside, to address the postural and kinematic faces, and to capture the patient's positions.

At the end of the task, each nurse was asked to produce on a grip dynamometer (Baseline, Fabrication Enterprises, USA) a force subjectively comparable to that exerted in the most challenging phase of the just performed task (in accordance with the psychophysical cross-modality matching technique) [11], which was then expressed as a percentage of maximal voluntary contraction (MVC). This maximal measure was taken before the trial as the individual reference point.

Each nurse also provided a subjective assessment on Borg's CR-10 scale [11] of the effort perceived when completing the task, especially related to bed control and adjustment. Finally, all nurses on duty in the wards who were acquainted with both types of beds used a 0–10 scale (0 = *very bad*, 10 = *very good*) to assess five ergonomics and usability aspects (comfort, ease of use, safety, efficacy in reducing musculoskeletal disorders, efficiency related to time) of the electric bed. They also compared six ergonomics aspects (comfort, ease of use, stability, solidity, safety, maneuverability) of the two beds on a 1–5 scale (1 = *worst*, 5 = *best*).

2.3. Data Analysis

The video recorded tasks were analyzed relative to the biomechanical and postural requirements. The analysis was carried out with the 4D WATBAK (University of Waterloo, Canada) software package, an advanced two-dimensional modeling program designed to predict both the acute and cumulative loads on the lumbar spine during occupational activities [12]. The program is equipped with a quasi-static two-dimensional linked-segment model; it comprises nine individual segments and is used to assess force activities performed in work settings. Although 4D WATBAK provided estimates that were considerably lower than the inverse dynamics model, it was considered to be the only suitable tool for an easy estimation of spinal loading during tasks performed in an industrial setting [13].

The biomechanical model generated, on the basis of anthropometric data (gender, age, height, weight) and of features of the task (type, duration, frequency, posture, force, asymmetry), the load estimates for the major body joints and especially the low back, including moment (torque), compression and shear forces. The peak loads for each parameter and the cumulative load were shown for the duration of the whole activity. Those data were compared with epidemiological evidence to determine statistical probability of case-classification of low back pain (LBP) for individual and combined risk factors.

The video recorded tasks were decomposed in single subtasks, each taking into account duration and repetition, to obtain an inventory of relevant actions to be assessed. The subtasks were divided into (a) direct force actions applied on patients (lifting, pushing, pulling, reaching, sustaining, handling) to move, transfer, wash, change them; (b) indirect force actions applied on the bed, linen, device to fix and adjust the bed; and (c) secondary tasks (standing, moving around, picking light material) irrelevant with respect to biomechanical load (Table 2). The video recorded postures were reproduced manipulating the human mannequin. Directions of the hand applied forces were derived from the video (nurse pulling/pushing upwards/downwards), whereas load amplitudes were derived from different methods: direct measurement (dynamometer), where it was possible to mimic the single action inserting the instrument between the nurse and the patient/bed; normative data, when the patient's body segment was moved or lifted (considering partial weight according to the weight of the whole body) [14]; or subjective estimation of the applied force, expressed by the nurse on a CR-10 scale and related to a percentage of MVC [11].

TABLE 2. Chronometric Composition of 12 Tasks According to Biomechanical Analysis

	Condition A											
Nurse Code	**11 (F)**	**12 (F)**	**21 (M)**	**22 (F)**	**31 (M)**	**32 (F)**	**41 (M)**	**42 (F)**	**51 (F)**	**52 (M)**	**61 (F)**	**62 (F)**
Task	hygiene in bed		hygiene in bed		bed-to-wheelchair manual		bed-to-wheelchair hoisted		bed-to-wheelchair manual		hygiene in bed	
Patient Classification	5		5		4		4		3		5	
Total Duration (min)	19.0		22.0		1.9		4.0		1.0		16.0	
Direct action (%)												
inspecting	8.5	26.8	1.8	20.4	—	—	—	—	—	—	—	—
handling	12.6	11.0	10.6	21.2	—	—	—	—	—	—	12.5	32.3
keeping lifted	0.5	0.5	—	—	—	—	—	—	—	—	—	—
moving limbs	—	—	5.3	1.5	4.0	4.0	2.2	—	—	—	—	—
pushing patient	0.8	3.3	0.2	1.1	—	—	—	—	—	—	—	—
fixing position	—	—	6.8	9.0	—	4.0	26.6	27.0	46.6	33.3	18.7	12.5
leaning	0.4	3.7	—	—	—	—	—	—	—	—	12.5	6.2
various	13.5	—	3.2	15.9	27.7	—	44.4	37.0	—	—	—	—
Indirect action (%)												
pulling linen	0.6	1.4	0.3	2.1	—	—	—	—	—	—	0.4	0.4
pushing linen	2.5	—	5.0	13.6	—	—	2.2	—	—	—	3.1	11.2
lifting bedrails	3.0	0.6	—	—	—	—	—	—	—	—	—	—
lifting linen	—	1.6	1.1	1.5	—	—	3.3	—	—	—	—	—
operating bed	—	—	6.0	4.5	—	—	—	2.2	—	—	—	—
operating device	—	—	—	—	—	—	3.0	—	—	—	—	—
No action (%)	57.6	51.1	59.7	9.2	68.3	92	18.3	33.8	53.4	66.7	52.8	37.4

Notes. F = female, M = male; direct action = action involving patients; indirect action = action involving bed, linen, device.

TABLE 2. (*continued*)

	Condition B											
Nurse Code	**11 (F)**	**12 (F)**	**21 (M)**	**22 (F)**	**31 (M)**	**32 (F)**	**41 (M)**	**42 (F)**	**51 (F)**	**52 (M)**	**61 (F)**	**62 (F)**
Task	hygiene in bed		hygiene in bed		bed-to-wheelchair manual		bed-to-wheelchair hoisted		bed-to-wheelchair manual		hygiene in bed	
Patient Classification	5		5		4		4		3		5	
Total Duration (min)	13.5		17.0		1.5		3.0		1.0		15.0	
Direct action (%)												
inspecting	29.7	23.0	11.8	17.6	—	—	—	—	—	—	9.6	—
handling	20.0	25.0	21.7	13.7	—	—	—	—	38.4	—	14.6	27.7
keeping lifted	17.3	4.2	—	—	—	—	—	—	—	—	—	—
moving limbs	—	—	6.8	4.8	8.8	4.4	3.3	—	—	—	—	—
pushing patient	0.5	0.5	11.8	3.0	—	—	—	—	—	—	—	—
fixing position	—	—	10.7	20.6	6.6	8.8	42.2	40.5	61.5	100	5.3	13.3
leaning	2.0	5.1	—	—	—	—	—	—	—	—	4.2	—
various	—	—	17.6	24	48.8	66.6	33.3	33.3	—	—	12.8	15.9
Indirect action (%)												
pulling linen	1.5	1.2	—	1.1	—	—	—	—	—	—	0.9	0.4
pushing linen	2.0	0.4	3.5	4.7	—	—	—	—	—	—	5.3	4.1
lifting bedrails	—	—	—	—	—	—	—	—	—	—	—	—
lifting linen	0.6	—	2.4	1.5	—	—	—	—	—	—	—	0.9
operating bed	3.0	1.8	0.5	3.9	—	—	2.2	1.6	—	—	—	—
operating device	—	—	—	—	—	—	2.2	—	—	—	—	—
No action (%)	23.4	38.8	13.2	5.1	35.8	20.2	16.8	24.6	0.1	—	47.3	37.7

Notes. F = female, M = male; direct action = action involving patients; indirect action = action involving bed, linen, device.

The duration of three trunk flexed postures (mild <20°, moderate 20°–60°, sharp >60°), considered in this range according to REBA [15], were analyzed for each nurse by a postural module of the software. The duration of patients' induced positions (supine, lateral lying, semiseated, seated, shifted from supine to seated, lifted) was counted. It was also observed if the patients moved their limbs or body segments by themselves, if they were vocally stimulated (about movements) or if the nurses handled them.

Statistical analysis was performed with Primer (McGraw Hill 2002), using analysis of variance (ANOVA) to test differences (between conditions A and B, among 12 nurses and six tasks), and with Pearson and Spearman rank to test correlation.

3. RESULTS

3.1. Time and Postural Analysis of Nurses' Tasks

There were significant differences between condition A (electric bed) and B (hydraulic bed) in the total duration of tasks (10.6 ± 8.9 versus 8.5 ± 7.0 min, respectively; $p = .008$) and in the time the nurses devoted to bed adjustment (height, section inclination and lateral inclination where available) (6.9 ± 7.4 versus 3.2 ± 2.5, as a percentage of task duration, respectively; $p = .05$) (Table 3).

There were no differences between condition A and B in the duration of trunk flexed postures (<20°, 20°–60°, >60°) or in the time the nurses spent close to beds. With regard to upper limbs activities, there was no difference between A and B in the frequency of total technical actions and direct/indirect force actions.

Subjective effort relative to using the electric bed (A) was assessed as significantly lower than that relative to using the hydraulic bed (B) (1.3 ± 0.8 versus 5.5 ± 1.4, $p < .001$; with 1.5 = *very light–light*, 5 = *hard* on the CR-10 scale); the same was true for grip force (cross modality) (34.3 ± 19.0 versus 72.8 ± 26.1, as a percentage of MVC; $p = .002$), which expressed the most demanding phase in bed adjustment.

Under both conditions, the patient's level of dependency (1–5 scale) directly influenced total task duration ($r = .92$, $p < .05$ in A and B) and total technical upper limbs actions ($r = .56$, $p = .05$ in A; $r = .68$, $p = .017$ in B), whereas only in B did it account for direct force actions ($r = .87$, $p = .001$). Moreover, the patient's level of dependency did not account for differences in bed adjusting time.

3.2. Patients' Postural Analysis

The timed distribution of patients' positions (supine lying, lateral lying, semiseated, seated, shifting from supine to seated, lifted) did not yield significant differences between condition A and B, with

TABLE 3. Overall Results of Videographic Postural Analysis of Nurses

Condition	Total Duration (min)	Trunk Flexion[a] Mild	Trunk Flexion[a] Moderate	Trunk Flexion[a] Sharp	Bed Adjustment[a]	Close to Bed[a]
A	10.6 ± 8.9	18.7 ± 11.1	11.3 ± 9.6	1.8 ± 3.0	6.9 ± 7.4	74.3 ± 22.4
B	8.5 ± 7.0	25.7 ± 16.2	17.1 ± 12.6	2.2 ± 3.8	3.2 ± 2.5	86.0 ± 11.6
ANOVA	$F = 10.28$				$F = 4.60$	
	$p = .008$				$p = .050$	

Condition	Force Actions[b] Indirect	Force Actions[b] Direct	Total Upper Limbs Actions[b]	Subjective Estimate of Force CR-10 [11]	Subjective Estimate of Force Grip Force (%MVC)
A	4.5 ± 8.3	7.0 ± 8.5	172 ± 168	1.3 ± 0.8	34.3 ± 19.0
B	8.9 ± 10.4	10.3 ± 11.9	229 ± 228	5.5 ± 1.4	72.8 ± 26.1
ANOVA				$F = 83.80$	$F = 17.42$
				$p < .001$	$p = .002$

Notes. a = duration (%), b = number, A = electric bed, B = hydraulic bed; mild = <20°, moderate = 20°–60°, sharp = >60°; %MVC = percentage of maximal voluntary contraction.

the patients most of the time in supine lying (40%–53%), seated (16%–22%) and lateral lying (~15%) positions (Figure 1). The postural pattern was very similar (r = .75–1) between class 5 and 4 patients, while it was not between the more collaborative class 3 patients. A and B patients did not differ in the frequency of active movements performed by themselves, nor in vocal stimulation or passive handling yielded by the nurses.

The patient's dependency level correlated significantly ($p < .001$) under each condition, both with total task duration ($r = .90$) and with frequency of repetitive upper limb actions performed by nurses ($r = .80$). In condition B, the patient's dependency level directly correlated with their time of lateral lying ($r = .9$, $p < .05$) and with the frequency of direct force actions applied by the nurse ($r = .91$, $p < .05$).

3.3. Peak and Cumulative Biomechanical Analysis of Nursing Tasks

The WATBAK analysis showed a higher level of biomechanical exposure of the nurses in condition B compared with A, both relative to the LBP combined index (0.16 ± 0.04 versus 0.14 ± 0.03; $F = 7.4$, $p = .02$) and to the shear L4–L5 component (0.31 ± 0.07 versus 0.27 ± 0.06; $F = 6.67$, $p = .02$) (Figure 2).

Under both conditions, some subtasks characterized by high postural demand (lifting or holding patients' body segments, reaching, adjusting the bed, etc.) revealed shear forces exceeding safety limits (NIOSH action limits) [16] by an overall value of 31% (B) and 13% (A), and an overall duration of 15% (B) and 10% (A). Computing the weighted outmatched shear force value (obtained by multiplying each action limit by its duration) for each task revealed a significant difference in the LBP combined index between condition B and A (322 ± 274 versus 233 ± 192, respectively; $F = 15.2$, $p = .04$).

3.4. Nurses' Subjective Assessment

In total, 63 nurses from all wards were surveyed. The nurses used a 0–10 scale (0 = *very bad*, 10 = *very good*) to express appreciation of the ergonomics and usability features of the electric bed (comfort 8.6 ± 1.5; ease of use 8.9 ± 1.4; safety 9.1 ± 1.5; efficacy 9.2 ± 1.5; efficiency 9.0 ± 1.5). They expressed significantly different assessments when comparing the electric and the hydraulic bed on a 1–5 scale (1 = *worst*, 5 = *best*) for any of the rated features: comfort (4.5 versus 1.4), ease of use (4.6 versus 1.5), stability (4.1 versus 1.9), solidity (4.4 versus 2.0), safety (3.9 versus 1.9), maneuverability (4.5 versus 1.3),

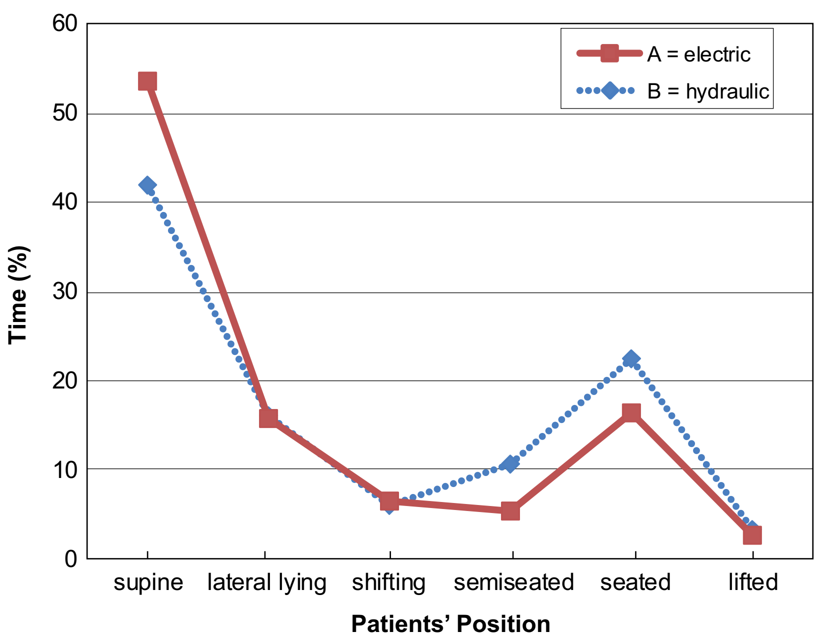

Figure 1. Patients' positions. *Notes.* shifted = shifted from supine to seated.

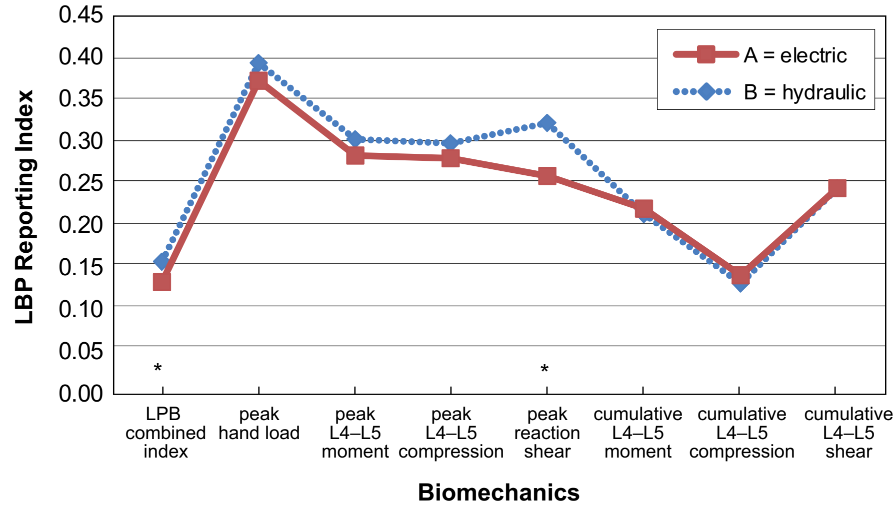

Figure 2 . Results of WATBAK [12] analysis. *Notes.* * $p \leq .05$; LBP = low back pain.

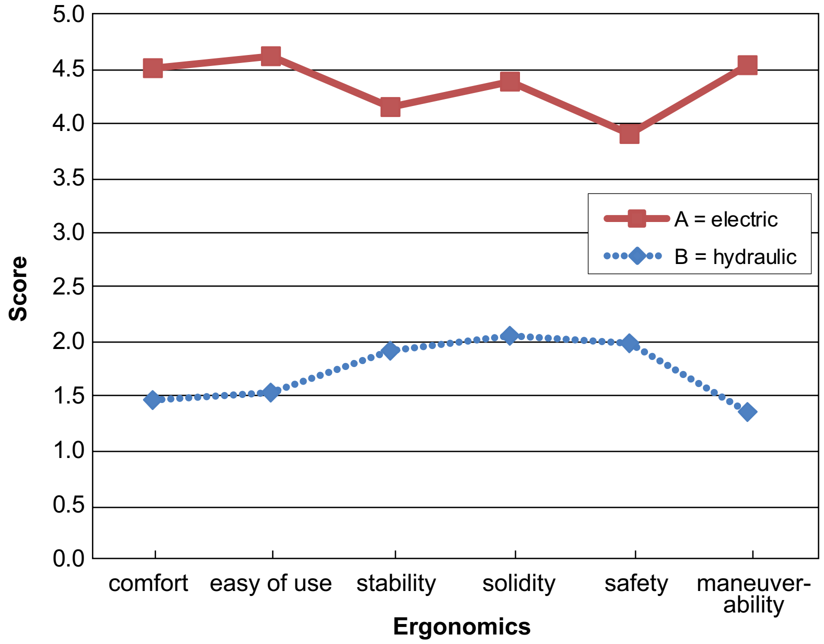

Figure 3. Nurses' comparative assessment.

showing also in this case a definite preference of the electric bed (Figure 3).

4. DISCUSSION

While we expected the use of the electric bed to be more time efficient, our results showed that the nurses spent more time using the electric than the hydraulic bed, both in whole tasks and in the bed adjustment phase. However, the nurses in the study had had very short training time (for organizational reasons, the study was carried out 10 days after the first electric beds were provided) and the uncertainty in their use (e.g., locating and activating commands) could have caused longer performance times. In addition using electric devices, such as mechanical hoists in manual handling of patients, could effectively require longer performance times [6] because of the irreducible technical time required to activate the automatic system. Perhaps a longer familiarization phase could enhance the nurses' confidence in using the electric bed and reduce performance time.

Our study showed that using electric beds compared with hydraulic ones, reduced both perceived subjective effort (CR-10 rating of 1.3 ± 0.8 = *very light* versus 5.3 ± 1.4 = *heavy*) and estimated force exertion (34% versus 72% MCV). This is due to electric beds completely eliminating heavy interventions with the upper (adjusting the bed head by pulling) and lower (height adjustment by pushing a pedal) limbs [17].

A less flexed posture the nurses adopted with the electric beds was a result we expected. However, this study revealed no difference under the two conditions, with an overall 19%–26% of time duration spent in mild (<20°), 11–17% in moderate (20°–60°) and ~2% in sharp (>60°) trunk flexion.

Also, even if the height of the bed could be adjusted, the nurses often worked with the level of the bed lower than the level of their hips. In particular, during the on-site observation, it was noted that the nurses maintained moderate flexion for 2 min, e.g., during the patient's hygiene or medication. Both the difference in stature between the coupled nurses and the insufficient training received about bed control could have led to this result.

According to Hodder, Holmes and Keir, auxiliary nurses spend ~50% of the work shift in >10° flexed postures and 25% of the work shift with >30° flexed trunk, and they perform many tasks with >75° flexed postures especially if working alone [6]. In this study, coupled nurses had moderate postures (≤60°) in 29% (electric bed) and 42% (hydraulic bed) of the duration of a task, and sharp postures (>60°) in 2%.

The patient's level of dependency correlated significantly under each condition, both with the total task duration and the frequency of repetitive upper limbs actions. The more the patient was dependent, the more time and assistance the nurse required, independently of the type of bed used.

The type of bed did not affect the patients' positions during the analyzed phases, and their position (supine, lateral lying, semiseated, seated, lifted) seemed comparable under both conditions, especially in highly dependent patients (levels 5–4). It is possible that the handling technique the nurses adopted with dependent patients could not vary much, even if an electric bed was used, therefore producing similar positions in the patient; while with collaborative patients, the handling technique could be more flexible in accordance with the patient's functional capabilities.

When a hydraulic bed was used, the frequency of direct force actions (applied by the nurses to move the patient) correlated with the patient's level of dependency: this signifies that this type of bed did not help to reduce the nurses' manual interventions. This fact was confirmed by the higher values in condition B than in A, relative to the LBP combined index (0.16 versus 0.14), to the shear L4–L5 component (0.31 versus 0.27) and to the weighted outmatched shear force value (322 versus 233) representing exceeded biomechanical safety limits in critical subtasks.

The administered questionnaires showed an excellent subjective appreciation of the electric bed, both absolutely and in comparison with the hydraulic one.

This study presents intrinsic limits due to the real setting considered (no systematic control over the concomitant variables), organizational aspects (few observations, short period of training allowed, coupled nurses of different stature and anthropometry, similar but not identical pairs of assisted patients, possible spatial incongruence) and observational method (simple videographic system, bidimensional mathematical model). However, the study highlights some important ergonomics (choice, training, features of beds) and organizational (duration of performance, distribution of charges, single or coupled unrolling) aspects related to the use of a hospital bed. Reducing postural and biomechanical risk factors (both in intensity and frequency) is a primary issue in preventing musculoskeletal disorders in attending nurses, especially when they assist highly dependent patients.Using the electric bed could reduce the level of effort and force applied by nurses during care giving, without affecting the duration of the total task or flexed postures, which seem to be more related to the level of patients' dependency.

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