# Human-Centered Design in the Care of Immobile Patients

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**Abstract.** Nurses frequently suffer from low back pain, but oppose against using mechanical lifting devices. It was found that the nurses' reluctance to use technical aids may be due to several drawbacks of currently used lifting devices in patient care: 1) the lifting maneuver is controlled through a control device located at a distant position form the patient (e.g. fixed to the supporting structure). 2) Conventional lifting devices are position controlled and operate at a low velocity. 3) The lifting device holds the entire weight of the patient, while the nurse performs translational movements. Therefore existing technological solutions were studied and novel ways were explored of achieving intuitive interaction, e.g. through the use of force and position sensors and shared control strategies. The initial results of our task analysis suggest that both the handicapped/ immobile person and the nurse may be supported by intelligent assistive lifting devices.

**Keywords:** nurses, lifting device, intuitive interaction.

## 1 Introduction

Musculoskeletal injuries comprise the largest proportion of total injuries in all types of nursing activities. Musculoskeletal injuries occur in both acute care and nursing homes, with care aids presenting twice the risk of registered nurses [1]. Several countries use a so-called no lifting policy to improve the care of immobile patients and limit excessive physical loads of nurses [2]. Nurses frequently suffer from low back pain, but strongly oppose against using mechanical lifting devices. It is hypothesized that enhancing such devices by ergonomically designed interaction control modalities would result in more intuitive use and help to overcome the nurses' reluctance. Similar "lifting and balancing" devices have been proposed for automotive production environments to minimize operator strain and are seeing increasing application in body unweighting systems.

## 2 Aim

To perform a user-oriented analysis of typical lifting and bed to wheelchair transfer tasks, to explore and develop potentially useful solutions that better fit the control of patient lifting devices to the needs of nurses and patients, e.g. by an intelligent assistive device which partially unweights the patient while the nurse initiates and controls the lifting and/or transfer movement in a collaborative manner while holding and guiding the patient in a natural manner.

M. Kurosu (Ed.): Human Centered Design, HCII 2011, LNCS 6776, pp. 321–326, 2011.

## 3 Methods

Two computer-based questionnaire studies were used to analyze the origin of back pain at work. The principal provider of occupational health services for Swiss hospitals carried out a questionnaire study among supervisors as well as among hospital nurses to identify the perceived physical strain during work, especially during patient care tasks. A similar study was started among Japanese hospital nurses.

A representative study among Swiss employees, the Swiss data from the Fourth European Working Conditions Survey (847 employees, response rate 32%) [3], was used to gain more insight into the complex relationships between musculoskeletal disorders and physical loads at work, organizational factors, work satisfaction, as well as lack of recovery [4] [5]. The answers to questions on risk factors for work-related musculoskeletal disorders (n=67) were dichotomized in such a way that for each variable, the twenty percent with the most unfavorable working conditions were considered to be at risk. Of these variables, 29 showed significant bivariate relationships with work-related musculoskeletal disorders and were entered into a logistic regression model with backward elimination.

In a limited number of hospital nurses recordings of heart rate, arm accelerations (by actimeter), and electromyography (EMG) of the trapezius muscle are underway and will help to discriminate between static and dynamic musculoskeletal strain at work. Further, a task analysis was performed based on expert ratings, video-analysis and nurses' comments.

With the aim of alleviating musculoskeletal strain during patient transfer and overcoming nurses' reluctance to use technical aids, existing technological solutions were studied and novel ways of achieving intuitive interaction, e.g. through the use of force and position sensors and shared control strategies, are being explored.

## 4 Results

532 nurses answered the emailed questionnaire. Nurses showed an increased risk (relative risk=1.4; $p<0.01$) to suffer from low back pain compared to a random sample of Swiss women (n=4505). Lifting/ transferring immobile patients indeed are the most strenuous tasks for nurses (fig 1).

The analysis of the Swiss data set on working conditions and work-related disorders revealed for musculoskeletal disorders that eight variables had a significant predictive effect in the logistic regression model (Odds Ratios and 95 confidence intervals):

- Poor fit of working hours with family or social commitments 3.4 (2.0–5.6)
- Carrying or moving heavy loads or persons 2.9 (1.7–4.9)
- Exposed to vibrations from hand tools, machinery, etc 2.8 (1.8–4.5)
- Frequent, disruptive, unforeseen tasks 2.3 (1.5–3.4)
- Not very / not at all satisfied with working conditions 2.0 (1.2–3.5)
- Rare / no assistance from superiors 1.7 (1.1–2.7)
- Pace of work dependent on numerical performance targets 1.7 (1.1–2.5)
- Not free to decide when to take holidays or days off 1.6 (1.1–2.3)

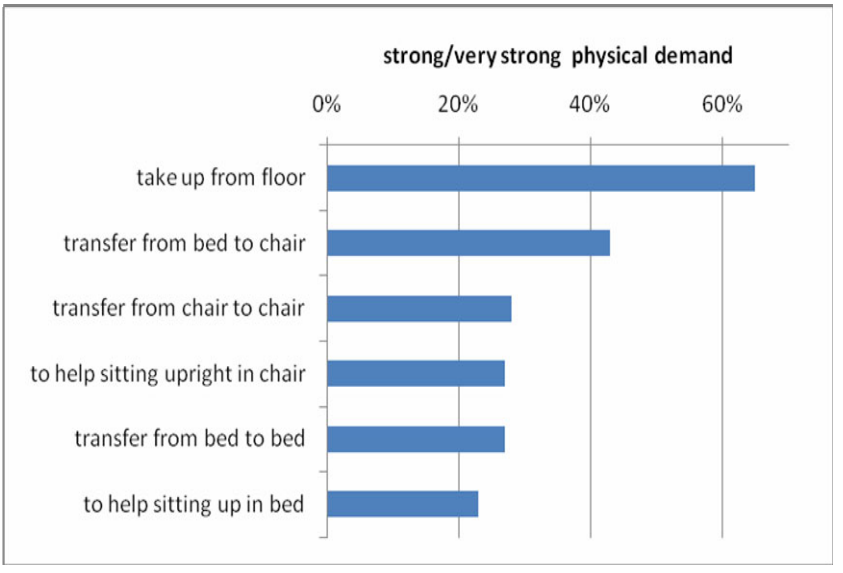


**Fig. 1.** The physically most demanding tasks in handling immobile patients. Percentage of nurses indicating strong or very strong exertion (n=532).

The analysis of the activity (based on accelerator data) from Japanese hospital nurses showed that a high incidence of continuous high activity was observed especially during night shifts. An example is shown in Fig. 2.

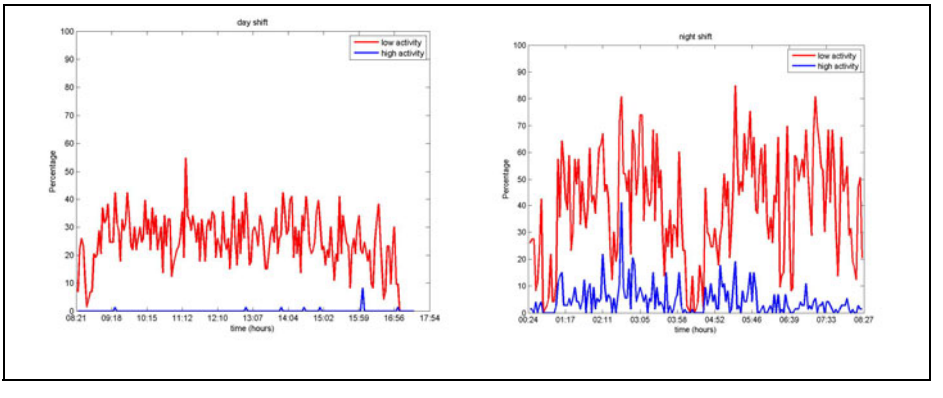


**Fig. 2.** Registration of work activities (illustrative example) during two 8-hour work shifts in a Japanese hospital nurse. Legend: percentage of low (upper, red curve) and high physical activity (lower, blue curve) during a day (left) and night shift (right).

Often nurses use the so-called kinesthetic approach to optimally activate a patient with every maneuver needed. The kinesthetic approach tries to activate patients as much as feasible, nurses are supposed to give the needed advice but not more physical support than is necessary. Such a close collaboration between nurse and patient is well illustrated in Fig. 3.

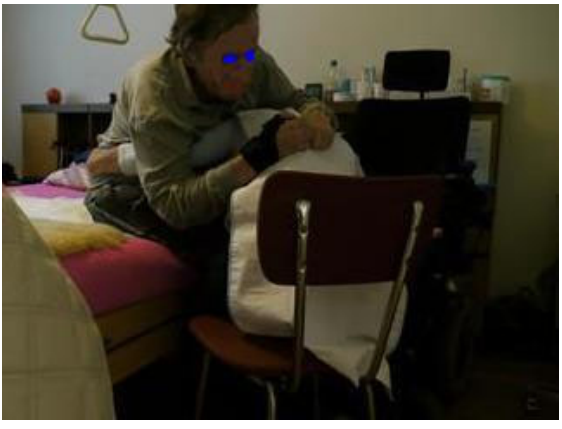

**Fig. 3.** By using kinesthetic techniques (as can be seen on fig 3) the nurse partly protects her back and activates the patient by giving him precise indications on how to contribute as much as possible with his own force

If patient and nurse have a good personal relationship, such a physical and mental collaboration between patient and nurse can help to improve the patient's capacities and supports the healing process. In contrast to this situation, the use of a traditional lifting device tends to impede the physical contact between patient and nurse. The nurse may perceive such a situation as an artificial or emotional barrier between patient and nurse, and therefore avoids such technical aids.

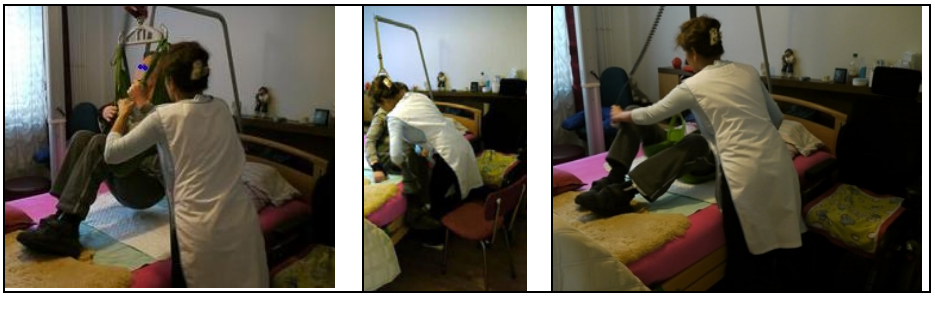

**Fig. 4.** Use of a traditional electric lifting device in the patient's bedroom. Note the difficulty to simultaneously control the lifting machine and provide support/contact to the patient.

Figure 4 shows several limitations of lifting devices currently used in patient care which motivate the development of more intuitive, collaborative systems: 1) the lifting maneuver is controlled through a control device located at a distant position form the patient (e.g. fixed to the supporting structure, or hanging on a cable attached to the frame). 2) Conventional lifting devices are position controlled (i.e. stiff) and operate at a low velocity. 3) The lifting device holds the entire weight of the patient, while the nurse performs translational movements. These factors result in inconvenient and non-intuitive use and unnecessarily high cognitive load. This interaction could be improved

by employing principles of intelligent assist devices that are already finding increasing application in industrial environments [6]. The user interface could be simplified by achieving an interaction in which touching/pushing the patient directly activates the mechanical assistance with appropriate speed and direction. This could be achieved using passive, spring-balanced, patient unweighting systems, or active, force-controlled systems that unweigh the patient based on the input from force sensors placed close to the patient's body (e.g. integrated into the harness). This would make the interaction more intuitive and result in true collaboration between nurse and lifting mechanism.

## 5 Discussion

Swiss and Japanese nurses showed an increased prevalence of low back pain, as it is well-known in other countries [2]. Since the risk factors of work-related musculoskeletal disorders include both physical and work-organizational factors and since multiplicative models are highly predictive, all different aspects of the workload must be taken into account when developing preventive measures. Especially time pressure and work organizational factors must be accounted for when designing lifting devices for nurses. Societal and legal aspects, but also intuitive use with short learning curve strongly influence the provision and actual use of lifting devices in hospitals as well as in the home care setting. The initial results of our task analysis suggest that both the handicapped/ immobile person and the nurse may be supported by intelligent assistive lifting devices.

## 6 Conclusions

Transfer tasks of immobile patients represent a high physical load for nurses, and are a major source for musculoskeletal disorders. As existing lifting devices provide a non-intuitive operator interface, nurses are often reluctant to use them. The human-machine interaction should therefore be designed in such a way that sensors which can register the intention of the nurse can be attached near the body of the patient, so that they can be used to intuitively guide direction and speed of movement trajectories imposed by the nurse while the assistive device unweights the patient, resulting in an ergonomic, collaborative approach.

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