Transdisciplinary Collaboration in Developing and Designing Patient Handling/Transfer Assistive Devices: Current & Future Designs

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Many health care facilities deal with challenges associated with safe patient handling and movement. Back injuries are a serious problem for nursing personnel who perform frequent patient handling activities. The main objectives of this study are to demonstrate the necessity of patient handling/transfer assistive devices, explore the economic benefits of them, review current assistive patient transfer devices, and investigate design parameters of an ideal patient handling/transfer assistive device. This paper also focuses on the importance of the transdisciplinary collaboration in developing and designing patient handling/transfer assistive devices.
Keywords*:* transdisciplinary research, patient transfer/handling, assistive devices.

1 Introduction

Health care workers have higher rates of work-related musculoskeletal injuries when compared to the general population. These musculoskeletal injuries can occur due to mechanical stress placed on the ligaments, bones, muscles or supportive tissues of the body. The comparison between health care staff and other industries shows that between 1980 and 1992, the injury and illness rate for nursing home workers increased from 10.7% to 18.2% among the nation's 1,506,000 nursing aides, orderlies, and attendants (US Department of Labor, Bureau of Labor Statistics, 1994). Due to 1994 Bureau of Labor Statistics data, nursing home workers face the third highest rate of occupational injury and illness (221,000 cases in 1994) among all US industries. The biggest portion of back injuries can be related to events that occur during the handling and lifting of residents. The injury rate for the health care sector was higher than the average for all other industries combined between 1996 and 2000 years in Canada (Workers Compensation Board of British Columbia). Approximately 5000 nurses were surveyed in 2001 and results indicate that 85% of the nurses experienced back pain at work (The American Nurses Association, NursingWorld.org Health and Safety Survey, September 2001). Another example, the injury rate per 100 Full Time Equivalent (FTE) workers for the Acute and Long term care sectors in British Columbia were 6.4 and 10.7, respectively, while the injury rate for all other industries in BC was 3.7 in 2001(Workers Compensation Board of British Columbia, 2002).

A study called NEXT (nurses early exit study)

[1] is also investigated in European Union in 2003. The aim of this study was to identify why nurses are leaving their profession earlier than members of other professions. The study indicates that almost all European Union countries have a lack of active nurses and the situation is expected to be worse in the next 20-30 years. Several reasons contribute to this situation: the population of young people in the working age will decrease, while the older people in the working age will increase and also the number of people who need care (over 64 years) will increase.

The procedures which involve repositioning, transferring and lifting patients are considered the most painful for care giving personnel. The main and hardest patient handling tasks can be listed as: bed to chair transfer, chair to bed transfer and patient repositioning task in the bed. These tasks can have more or less risk on the musculoskeletal system with respect to patient weight, capability of patient, frequency and duration of the lifting, workplace geometry and environment, stability of the patient, and the horizontal and vertical position of the patient relative to the health care worker [2-6].

Definition and solution of the patient transfer/handling problem with respect to different discipline approaches is surveyed from the literature. Different discipline approaches, such as business and administration, health care personnel education, engineering, and social sciences, have been found [4, 7, 8, 9-15].

Traditional prevention to this problem based on teaching workers proper body mechanics while manual lifting, has not yielded widespread success in reducing injury rates. A possible reason to why safe patient handling/transfer trainings did not work in practice is the job of the health care workers can be very hard and stressful. Thus, they cannot apply the required movements for safe lifting [17-24].

The stressfulness of patient handling and transferring tasks can be overcome by using today's common assistive devices like overhead (ceiling) lifts, floor lifts or stand-up lifts. However, there are still weak points to be developed in these devices. For example, mobility of ceiling lifts is limited by rail tracks, and installation of rail tracks is not only expensive but also troublesome. Stand-up or standing lifts are limited by their functionality on the tasks, because they are designed to be used in only from a seated to standing position lifting task for patients who can put weight on their feet. Mobility of floor lifts is limited because of size of their base due to concerns of stability and also in the literature, they are defined as difficult to use and time consuming with respect to overhead lifts.

The purpose of this study was to identify and evaluate not only the different disciplinary approaches to define the problem but also different approaches for the solutions to the problem. In the light of this variety of definitions and solutions to the problem, a transdisciplinary collaboration for the solution of the problem is proposed. Different discipline standpoints such as economical, biomechanical, psychological, cultural, and educational are investigated, to find a convenient solution for musculoskeletal injuries related to patient handling/transfer tasks.

2 Identification of the Patient Handling/Lifting Tasks

The definition of the problem starts with identifying physically demanding patient handling and lifting tasks that the health care personnel encounter almost every work day. The risky tasks in terms of overexposure of ergonomic stress on health care staff can differ in acute care and long term care facilities. Thus, both need to be investigated. Table 1 shows the list of physically demanding tasks identified by different studies.

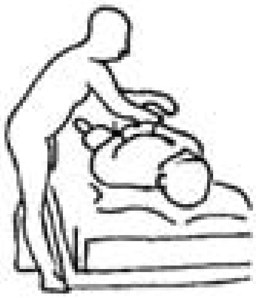
Physically demanding tasks have been identified in long term care facilities in order to understand which tasks expose nurses to ergonomic stresses. Patients in this type of facility need less assistance from health care personnel than the patients in acute care facilities.

Skotte et al. [2] used a dynamic three dimensional biomechanical evaluation technique to investigate the low back loading during common patient handling tasks which are shown in Figure 1. Ten female health care workers participated in the study and performed nine common patient handling tasks on male stroke patients. Patient handling tasks were classified into three groups: lifting, repositioning, and turning. The maximum compression on low back in two lifting tasks (lifting the patient from bed to standing on the floor and repositioning the patient in the wheelchair) was found to be significantly higher than all other tasks.

Hye-Knudsen et al. [3] examined the kinematics of thoracolumbar spine during common patient handling tasks. The aim of the study was to find the

Table 1: Physically Demanding Tasks Identified by Different Studies.

Skotte et al. [2]	lifting from bed to standing on the floor	repositioning on wheelchair
Hye-Knudsen et al. [3]	from lying to sitting on bedside or vice versa	repositioning on wheelchair
Garg et al. [5]	transferring patient from toilet to wheelchair or vice versa	wheelchair to bed or vice versa
Callison et al. [6]	bed to chair or vice versa	bedside commode to bed or vice versa



(a) Turning Patient in the Bed from Back to Left Side.

(b) Moving the Patient from Sitting on the Bed to Supine Position.

(c) Repositioning the Patient in the Bed.

(d) Transferring Patient from Sitting on the Bed to Sitting in a Wheelchair.

(e) Turning Patient in the Bed from Back to Right Side.

(f) Repositioning the Patient Posteriorly in the Seat of the Wheelchair.

(g) Elevate the Patient from a Supine Position in the Bed to Sitting Position on the Edge of the Bed.

(h) Repositioning of the Supine Patient Towards the Head of the Bed.

(i) Lifting the Patient from Sitting on the Edge of the Bed to Standing on the Floor.

Figure 1: Common Patient Handling Tasks, [2].

relationship between musculoskeletal injuries and asymmetric working postures which are seen more frequently than industrial material handling operations. Ten female health care personnel participated in study by applying nine different tasks. A lumbar motion monitor was used to obtain kinematic data and also muscle activity was recorded by surface electrodes. Displacements and deflections were found significantly higher on the following tasks: from lying to sitting on bedside, from sitting to lying on bed, and repositioning on wheelchair.

Patient handling/lifting tasks which include usage of assistive devices are also investigated in the literature. Dutta et al. [4] measured the peak external hand forces and external moments on the lower back while using loaded overhead and floor lifts (see Figure 2) which are operated by one or two caregivers. Forces and moments are estimated from the ground reaction forces and motion capture data. Use of overhead lifts caused significantly less back loads than use of floor lifts. However, two caregivers working together did not reduce the loads in the use of floor lifts, when they used overhead lifts the loads in the operation reduced. Because overhead lifts generated lower loads on caregivers, they are predicted to reduce the risk of back injury to caregivers. In a preference survey conducted among the caregivers, majority of caregivers preferred overhead lifts to floor lifts. However, overhead lifts require installed tracks to operate which makes them highly restricted in terms of mobility and availability. Thus, there is still a need for a better floor lift.

Another nursing home ergonomic evaluation study was conducted by Garg et al. [5] among 38 nursing assistants who performed 16 different patient handling tasks related to low back pain. The data is collected by videotaping and surveying nursing assistants. Garg et al. [5] found hardest tasks to be transferring patient from toilet to wheelchair, wheelchair to toilet, wheelchair to bed, bed to wheelchair, bathtub to wheelchair, chairlift to wheelchair, weighing patients, and lifting patients up in bed. Transfer times, lack of accessibility, patient safety and comfort, physical stresses associated with the devices, and lack of skill were some of the reasons for not using the assistive devices. Also, environmental barriers like confined spaces and stationary railings are observed. Additionally, frequency of patient handling tasks is examined. The five most frequent tasks were toilet to wheelchair, wheelchair to toilet, wheelchair to bed, bed to wheelchair, and bathtub to wheelchair. It is noticed that the list of hardness and frequency of tasks follow each other.

Since most existing studies on patient handling have been conducted in long term care facilities, Callison et al. [6] investigated musculoskeletal injuries due to patient handling/lifting in an acute care facility. Different from long term care facilities, the main goal in an acute care hospital is to stabilize the patient, treat the illness or condition, and discharge the patient home or to another type of facility, such as long term care. Thus, generally in acute care facilities, patients are unstable, unpredictable and their mobility can be limited by the medical condition. Therefore, it's important to identify patient handling tasks in acute care facilities. Survey and work sampling methods are used to achieve this goal. The nurses ranked the most physically demanding patient transfer tasks as follows: bed to chair, chair to bed, bedside commode to bed, and bed to bedside commode. On the other hand, the least physically demanding task was side to side transfer. Also, it is observed that the majority of transfers were handled without using assistive lifting devices.

3 Different Discipline Standpoints to the Problem

According to the literature survey of patient transfer/handling related papers, solution of musculoskeletal injuries related to patient handling/transfer tasks includes not only an engineering perspective, but also social sciences, business and administration, medical sciences (biomechanics, physiotherapy etc.), and statistics (surveys, interview etc.) point of view.

3.1 Business and Administration Standpoint

Reducing patient handling injuries can result in considerable economic benefits to employers, as well as prevention of significant pain and suffering for workers.

Analysis by Chhokar et al. [7] about musculoskeletal injury trends in the interval of three years pre-intervention and three years post-intervention of implementing use of patient handling/transfer assistive devices revealed a significant and sustained decrease in days lost, workers compensation claims, and direct costs associated with patient handling injuries

(a) Overhead (Ceiling) Lift.

(b) Floor Lift.

Figure 2: Overhead and Floor Lifts with Quick Fit Slings, [4].

(see Figure 3). The payback period was estimated assuming that pre-intervention injury costs would either continue to increase (0.82 years) or plateau (2.50 years) in the year immediately preceding intervention. The rapid economic gains and sustained reduction in the frequency and cost of patient handling injuries beyond the first year strongly advocate for ceiling lift programs as an intervention strategy. Figure 3 shows the economic benefits of assistive patient transfer devices in three years after installation of ceiling lifts. Based on this rate of savings, a payback period of 2.50 years is required to recover the initial investment of $344,323 for the intervention. Assuming that the claims costs would have continued to increase through the post-intervention period, the extrapolated direct costs for the three years post-intervention would have reached $1,559,349. Using this approach of economic estimation, a total of $1,257,605 was saved during the three years post-intervention, with payback of the initial investment occurring within 0.82 years.

In another study by Randall et al. [8], the cost of related injuries can be staggering, having a direct impact on the afflicted persons and the institution. After evaluation of alternative means of reducing the risk of caregiver injury in conjunction with the need for more frequent patient handling, a commitment was made to invest in ceiling lifts as a means to an end.

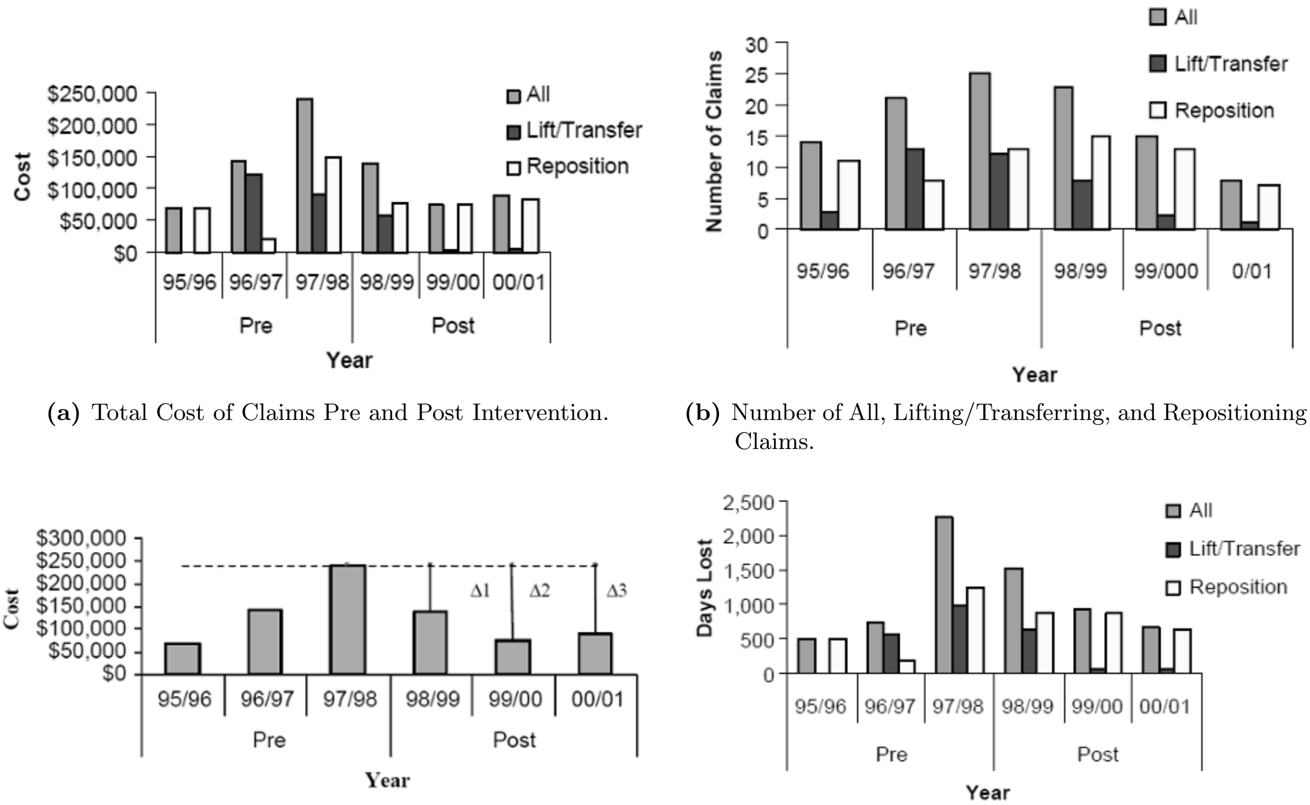
Miller et al. [9] state that there was a 70% decrease in claims cost related to health care staff injuries at the intervention facility using assistive devices, accounting for a decrease of 18 days lost. In comparison, there was a 241% increase in total claims costs at the comparison facility, with an associated increase of 499 days lost during this same time period.

3.2 Biomechanical Standpoint

The study of approaching the structure and function of biological systems (generally humans) with the methods of mechanics is called biomechanics. Biomechanics is closely related to engineering because regular approach in biomechanics is to use traditional engineering methods of mechanics to analyze biological systems.

Loads on back of health care personnel are analyzed in two different biomechanical analysis papers [10, 11]. In both studies, obtained back loads are compared with the back-compression criterion limit (3,400 N) recommended by the National Institute for Occupational Safety and Health (NIOSH, 1981 and 1994). Movement analysis methods were used to obtain the kinematic data, and they used force sensors on hands and feet to obtain the external forces. NIOSH also suggests a maximum permissible limit of spinal compression of 6,400 N.

Daynard et al. [10] measured data entered to a biomechanical model by using movement analysis methods, and biomechanical model was used for calculation of the compressive and shear forces on



(a) Total Cost of Claims Pre and Post Intervention.

(b) Number of All, Lifting/Transferring, and Repositioning Claims.

(c) Claims Cost for All, Lifting/Transferring, and Repositioning Claims.

(d) Days Lost for All, Lifting/Transferring, and Repositioning Claims.

Figure 3: Economical Benefit Graphs, [7].

the spine (L4-L5) by taking into account the subject's height, weight, and gender. This study was more comprehensive than the study conducted by Zhuang et al. [11], because the cumulative spinal load was considered by multiplying the duration of the task with the spinal load. Additionally, the study involved a control group, five different tasks, and two different patients. Results revealed that both education/technique training and new assistive handling equipment reduced spinal loading in several tasks. Lack of training for bed to chair transfer and chair boosts of patients resulted in spinal loading which was risky according to NIOSH. However the examination of cumulative spinal loads showed that the use of assistive equipment increases exposure to risky spinal loads, as more actions are required to complete the transfers.

Zhuang et al. [11] aimed to evaluate the effects of resident transfer method and resident weight on the biomechanical stress to nursing assistants while performing a bed to chair transferring task. In the light of this evaluation, re-identifying the methods could reduce the biomechanical stress to the nursing assistants. Twelve transfer methods (nine battery-powered lifts, a sliding board, a walking belt, and a manual transfer) were evaluated. A three dimensional biomechanical model was used to estimate the L5/S1 compressive force with the inputs of body posture, hand-force magnitude and direction, and the anthropomorphic data. In the results, it is clearly mentioned that nursing personnel were exposed to excessive biomechanical stress when performing resident transfers without using any assistive device (avg. 3487 N). Average back-compressive forces associated with using ceiling and floor lifts were smaller than NIOSH criteria. Thus, the spine loads were reduced in use of ceiling and floor lifts, unlike the other assistive devices and manual transfer methods.

3.3 Social Sciences Standpoint

Influence of culture, experience, and psychology on decision making plays an important role in the solution of patient the handling/transfer problem. In this section, papers in the literature related to these effects are discussed.

Effects of training and experience on patient handling/transfer tasks were investigated by Hodder et al. [12]. Three different tasks (patient reposition from side of the bed, head of bed, and patient transfer from bed to wheelchair) were performed by health care personnel both experienced and not experienced on training. Data was collected in terms of trunk kinematics and muscle activities. Results indicated that experienced staff use up to 18.1% (maximum voluntary excitations) less muscle activity. Furthermore, the study revealed that mechanical lifts are still not practical in all hospitals and home care.

Another study on the effects of caregiver experience on patient handling/transfer tasks was conducted by Dutta et al. [4]. Peak external forces and moments, which are generated on low back, were measured when the caregivers used floor and overhead lifts. Twenty caregivers were categorized as experienced and less experienced and performed five different maneuvering tasks with assistive devices. Motion capture and ground force measurement techniques were used for collecting the data. Findings showed that experience significantly affects the difficulty of use of floor lifts, while it does not play a significant role on overhead lifts.

Myers et al. [13] introduced the cultural effects on adaptation of the health care workers to patient lifting devices. A sociological and anthropological view of culture explored specifically how work culture or safety culture might be involved in workplace safety. Cultural facilitators and barriers of nurses and physical/occupational therapists in two acute care hospitals were examined by using audio recordings and text data. Data revealed that both adopted a "patient first" approach which includes usage of lift devices highly dependent on patients' benefit and not necessarily for staff safety. Another finding was that the implied purpose of patient lifting devices clashes with the nurses' cultural emphasis on compassion, and with physical/occupational therapists' cultural emphasis on independence except when use increases patients' independence. The study also discussed that cultural expressions involving the nature of care giving in between health care professionals may affect the tendency to adopt safety measures in complex ways. In this matter, the authors suggest that workers' understanding of the purpose of their work, and acceptable means of conducting it, should be understood before implementing safety interventions.

Furthermore, Chany et al. [14] explored how staffs personalities can be linked to load on the spine during repetitive lifting of patients. Twenty four participants were divided into two groups: novice and experienced. Spine compression, anterior – posterior shear, and lateral shear were measured to define the spine loading. Participants were categorized into personalities with respect to Myers-Briggs personality type indicator and performed repetitive, asymmetric lifts. Sensing versus intuition is one of four dichotomies in Myers-Briggs personality type indicator, and they are the information-gathering functions. They describe how new information is understood and interpreted. Individuals who prefer sensing are more likely to trust information that is in the present, tangible, and concrete. On the other hand, those who prefer intuition tend to trust information that is more abstract or theoretical, that can be associated with other information (either remembered or discovered by seeking a wider context or pattern). The results indicated that intuitors are exposed to higher spinal loads than sensor personality type. Novice lifters typically encountered greater spinal load. Moreover, perceiver personality group received greater spinal load than judgers' personality group.

The psychophysical evaluation of nine battery-powered lifts, a sliding board, a walking belt, and a baseline manual method for transferring nursing home patients/residents from a bed to a chair was targeted in the study of Zhuang et al. [15].The psychophysical evaluation included investigation of the effects of resident transferring methods on the psychophysical stress to nursing assistants performing the transferring task. Evaluation also aimed at identifying transfer methods that could reduce the psychophysical stress reported by nine nursing assistants. The results showed that the psychophysical stresses on nursing assistants were significantly reduced with the use of the assistive devices on resident transfers with respect to transfers with the baseline manual transfer method. Moreover, the basket-sling lift and stand-up lift were preferred methods, and the assistive devices' resident comfort and security ratings were greater than or equal to the baseline manual method.

4 Current Designs and Solutions to the Problem

4.1 Current Patient Transfer Devices

In all of the referenced papers of this section, floor and ceiling lifts are found as the most helpful assistive patient transferring devices. A ceiling lift consists of a ceiling mounted track, an electric motor, and a patient sling used to lift, transfer, and reposition patients/residents (see Figure 4). One or more staff members are capable of placing a sling on a patient/resident and hooking it onto the ceiling lift. Ceiling tracks can be configured in numerous arrangements to accommodate many beds within a single room and possibly multiple rooms. In general, there are two different types of ceiling lift motors: portable and fixed. Portable motors are favorable than fixed motors because of their following features: ease attachment and detachment from the ceiling lift tracks. Floor lifts require much more space than ceiling lifts to operate while ceiling lifts require significant structural modifications in patients room. Thus, ceiling lifts are preferable for newly constructed facilities.

Hasanat et al. [16] evaluated ceiling lifts in comparison to floor lifts based on transfer time, patient comfort, and staff perceptions in three long term care facilities with varying ceiling lift coverage. The time required for transferring or repositioning patients along with patient comfort levels were recorded for 119 transfers. In the three facilities, 143 health care workers completed the survey on their perceptions of patient handling tasks and equipment. For both transferring and repositioning tasks, staff preferred to use ceiling lifts and also found them to be less physically demanding. Duration of bed to chair transfer tasks in ceiling lifts was found to be less than floor lifts with 156.9 seconds and 273.6 seconds on average.

Also, Miller et al. [9] indicated that staff perceived that using ceiling lifts compared to manual methods put them at significantly ($p<0.05$) less risk of injury. Seventy five percent of staff preferred to use the ceiling lifts over any other method for lifting and transferring residents. This study demonstrated that incorporating ceiling lifts into the design of a new multi-level care facility reduced patient handling injuries and decreased perceived risk of injury among health care staff.

4.2 Training Programs

Training programs play an important role in prevention of possible musculoskeletal injury due to patient handling/transfer tasks, if the training program can be successfully implemented by health care personnel. The studies in the literature [17-24] defining and evaluating patient handling/transfer training programs are surveyed in this section.

A method based training approach has traditionally been used to solve the problem of back pain related with patient handling. A study was conducted by Hignet et al. [17] to examine if the competency-based training changes the behavior (physical and cognitive) for patient handling tasks. Sixteen health care organizations in the UK participated from the acute and primary health care sectors. Behavioral data was collected by observations and interviews during two patient handling tasks (sitting to standing and repositioning in sitting). The results designated that more positive safety principles of organizations make the tasks more complex, and thus influence the decision making about the patient handling tasks.

Creating safer working environments for nursing staff was the aim of the study of Nelson et al. [18]. On this matter, a multifaceted program was designed and evaluated for the effect of the program on injury rate, lost work days, job satisfaction, self-reported unsafe patient handling acts, level of support for program, staff and patient acceptance, program effectiveness, costs, and return on investment. Twenty-three high risk units in seven facilities participated in the study over two nine month periods, and data was gathered through surveys, weekly process logs, injury logs, and cost logs. The rate of musculoskeletal injuries was significantly decreased, while the total number of lost workdays was decreased 18% which is not statistically significant. Significant cost saving was also achieved in this study. In addition, the study states that "over the past 30 years, efforts to reduce work-related musculoskeletal disorders in nurses have been largely unsuccessful." [18].

A patient handling training program was evaluated in the study of Cornish et al. [19] by surveying student nurses. A survey was completed by 106 students which was 34% of overall students. This participation rate can be considered as an evidence of the perceived low importance of patient transferring and handling. Most completed responses were gathered from child branch students, while mental health students responded to this study by a low percentage of 9%. Students observed if the patient handling techniques are applied in practice, and 60% of the

(a) Manual Transfer Method.

(b) Walking Belt.

(c) Sliding Board.

(d) Floor Lift.

(e) Ceiling Lift.

(f) Stand-up Lift.

Figure 4: Types of Current Patient Handling/Transfer Assistive Devices, [7]

students observed assistive device use where needed in practice. The students were asked if there is a difference between training scenarios and practice, and two key findings were revealed: poor practice and constraints on practice. Poor practice includes poor posture of staff, use of inappropriate techniques, use of incorrect equipment for the task, and a lack of safety checks. On the other hand, constraints on practice issue includes a lack of appropriate equipment, lack of time, lack of staff and perception of the situation as an emergency. The need of better equipment for patient handling and transferring was exposed by the reported results of students about use of equipment in practice: it was sometimes (43%), most of the time (36%) or always used (6%) rather than never used (1%) or hardly ever used (14%).

5 Transdisciplinary Collaboration in Assistive Device Design and Development

Effective research activities in an inclusive setting require intensive and continuing collaboration of all members of a research team. There is a movement away from the traditional multi and interdisciplinary models, in which researchers work jointly but from each of their respective disciplinary perspectives to address a common research problem. Within many fields, such as medicine, biosciences, and cognitive science, there is growing awareness of the need for transdisciplinary approaches [25-27].

As the complexity of new patient assistive device development processes increases, the design process must include transdisciplinary collaborative knowledge synthesis provided by a large number of experts (actors) for integrated solution. Transdisciplinary research teams (patients, nurses, medical doctors, engineers, medical technicians, clinical psychologists, physical therapists, and architects) confer a distinct advantage and play an important role in developing a good design that complies with human factors and ergonomic principles [28]. In this model, actors work collaboratively for the common goals (designing an assistive device), using shared methods and techniques, sharing responsibility for planning, sharing of information for problem solving and decision-making, and assessment. The design that does not consider collaborative efforts of actors along with the use of poor technology may result in poor quality, and unsafe, inefficient, and high cost design. Approximately, 5,000 types of medical devices that are used by patients around the world have device-related problems [29].

Although new technologies are an essential part of our global information society and they play an important role in our daily lives, the values of a specific technology may not be realized due to four general drawbacks [29-32]:

- poor technology design that does not adhere to human factors and ergonomic principles,
- poor technology interface with the patient or environment,
- inadequate plan for implementing a new technology into practice, and
- inadequate maintenance plan.

User (patients, nurses, physical therapists, and others) involvement that incorporates human factors within the assistive device design and development, offers many possibilities that allow the development of safer and more usable medical devices that are better fit to users' needs. User involvement of assistive device design and development at different stages of the design process such as design concept development, testing and verification and deployment stages are the key elements for successful design. This process is crucial for capturing users' perspectives and their inputs during the development stages. Assistive device users are dissimilar in several characteristics, such as needs, skills and working environments. This is also an important consideration for incorporating users' perspectives in the design and development process.

Medical doctors, as part of the collaborating team, also play an important role in the transdisciplinary effort to provide appropriate assistive technology or prescribe a particular device for different patients.

Figure 5 shows transdisciplinary collaboration to design new assistive device between designers (design team, architects, and medical technicians), service providers (medical doctors, occupational therapist, nurses, rehabilitation specialists, social support professionals "clinical psychologists"), and users (patients). As shown in Figure 5, the design process begins with an identified need that can be satisfied by assistive device as a result of collaborative effort. Considering alternative solutions at beginning of the design process, during the concept stage is the most

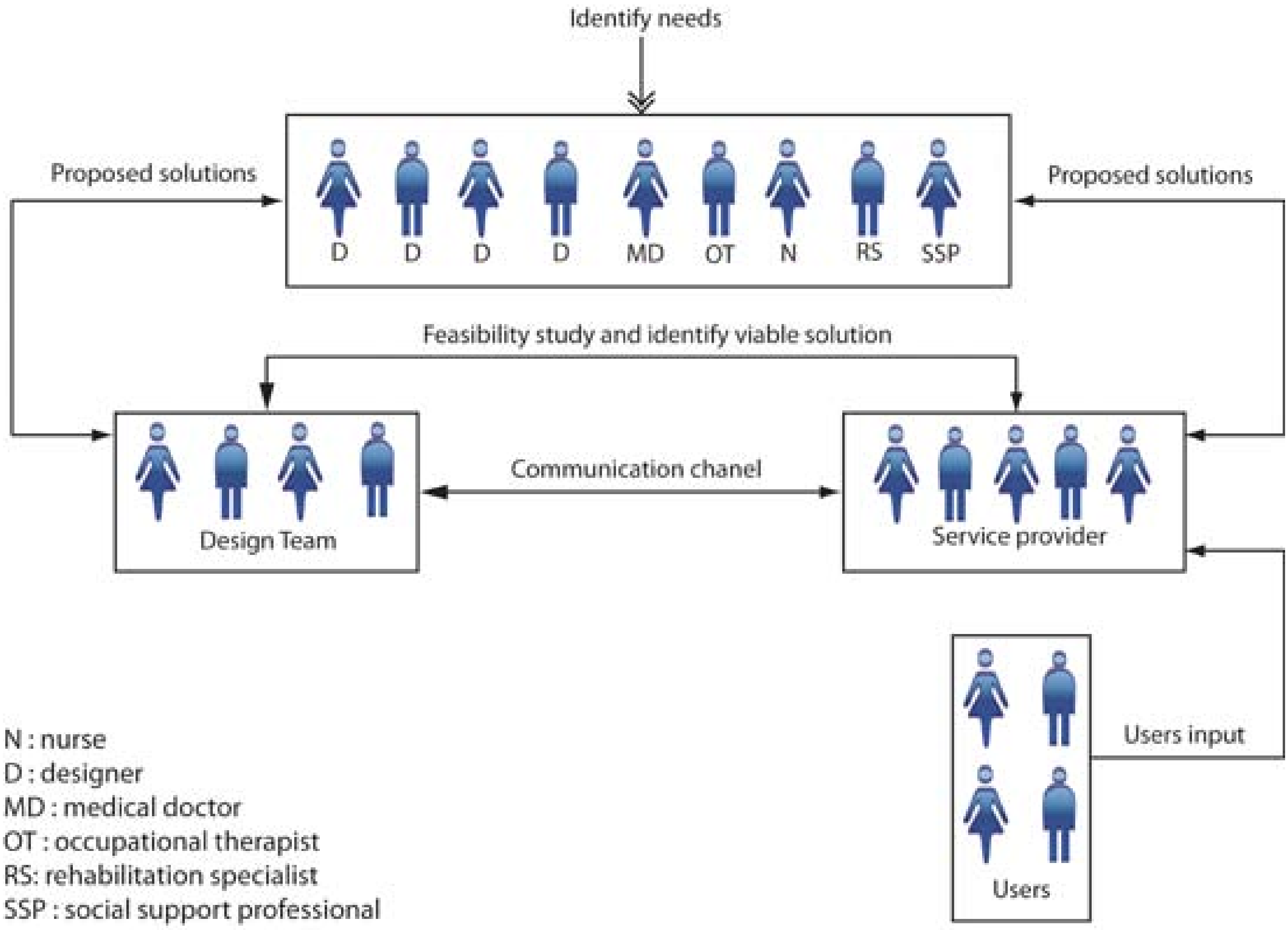


Figure 5: Transdisciplinary Collaborative Design Process.

important. In the transdisciplinary collaboration process, service providers serve as a communication channel between designers and users. Designers and service providers make initial contact with users to create ideas. After feasibility study and a thorough selection, these ideas go into research development by designers [33, 34].

As with any design project, the design of an appropriate assistive device benefits from a cross-disciplinary collaboration. This transdisciplinary collaboration may even include social, cultural and religious considerations during the design process.

6 Design Parameters of an Ideal Patient Transfer Device

Besides the features of the current designs, the new design of assistive device for patient handling/transfer should be retrofit-able to a conventional patient's bed. It should be user friendly for ease of use and should require less training than current designs. It should be capable of multi tasks like toilet to wheelchair transfers and transferring to patient cleaning facilities, and to utilize the device for more cases, portability and mobility must be increased. Moreover, abortion of process in case of emergency should be included for safety reasons. The durations of the tasks should be reduced, because the duration of the tasks is directly related to risk of being exposed to excessive spinal loads and duration is pretty high in floor and ceiling lifts [16]. The assistive devices can be made more time efficient by replacing the sling with grips or handles since preparing patient for sling is one of the most time consuming parts of the process. Installation costs should be reduced. For example, installation cost in ceiling lifts was estimated by OHSAH (2003) as $3,500 per bed [9].

Randall et al. [8] describes the process that was used for the selection of a ceiling lift manufacturer to be partner in reducing the risk of caregiver injuries and to fulfill the need of more frequent patient handling. The important design parameter outputs of the ceiling lift selection process can be summarized as: Lift weight capacity, vertical lifting distance, simple and smooth operation, the battery charging system, scale features, lift utilization diagnostics, easily disinfected surfaces, sling variety, staff education and training and ease of maintenance.

Eight design parameters were found for assistive devices in the study of Radovanovic et al. [35] as follows: weight, height, level of consciousness, mobility in bed, transfers from bed/stretcher or bed/chair and vice versa, walking, catheters and equipment, and patient environment. The assistive device validity was established based on content and construct validity. Surveys were used to validate the product. The results of the study showed that the assistive device seems to be reliable and valid for patient handling assessment.

7 Conclusion

The National Institute of Standards and Technology estimates that 20.6 percent of Americans have some sort of disability. For disabled people, assistive devices are essential to help them perform everyday tasks. Many simple devices were used to create superior independence for people with disabilities. Assistive devices range from something as simple as a bar attached to a bathroom wall to assist disabled people getting on and off a toilet.

In this paper, the importance of patient transfer assistive devices is demonstrated. Then the importance is supported by two biomechanical analysis papers from literature. Also, economic benefits of patient transfer assistive devices are shown by related papers in literature. Moreover, social sciences standpoints are examined. Limitations of current designs are found and design criteria of new devices are determined. Finally, the distinct advantages of transdisciplinary collaboration in assistive design and development are discussed.

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