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Designing ergonomic interventions for EMS workers: Concept generation of patient-handling devices

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Abstract

Fire service personnel and private ambulance paramedics suffer musculoskeletal injuries as they lift and carry patients while performing emergency medical services (EMS). Engineering changes, such as the design of new EMS patient-handling devices, offer a potential intervention opportunity for combating this problem. The purpose of this qualitative descriptive study was to generate beginning ideas for the design of new EMS patient-handling devices that were framed within the contextual reality of the end user firefighter/paramedics. Guided by an ecological model of musculoskeletal injuries in the fire service, focus groups were conducted with 25 firefighter/paramedics from 13 suburban fire departments. Based on their availability, participants were assigned to one of three groups with each group focusing on a different EMS patient-handling scenario. Each group participated in two focus group sessions: one session to brainstorm ideas for devices and a second session to validate sketches of their design ideas. The sketches were professionally drawn by an industrial designer who attended all focus group sessions. Sketches, photos, videotapes, and written transcripts were content analyzed to describe the phenomena of interest. The ideas centered on EMS devices for lateral transfers, bed-to-stairchair transfers, and stair descent transport, and served as the starting point for the development of EMS devices in subsequent phases of a mixed method research study. The outcomes of this study were an improved understanding of the contextual issues that need to be considered in designing EMS patient handing devices and a set of industrial design sketches that served as a starting point for subsequent development of the devices. End user acceptance criteria for the devices included: affordability, portability/compactness, durability, operability including being quickly ready for use, and cleanability.

Keywords: Emergency medical services (EMS); Firefighter; Paramedic; EMS patient-handling devices; Concept development; Low back disorder (LBD); Focus group

1. Introduction

Musculoskeletal injuries account for over half of the injuries suffered by firefighters in the United States (US). Many of these injuries occur while performing non-fire emergency tasks, such as emergency medical services (EMS) (Karter and Molis, 2006). This is not unexpected given that today, the majority of fire department calls in the US are for EMS rather than fire suppression. In 2005, 62% of fire department calls were for medical aid, with the numbers increasing steadily over time from about 6 million EMS calls in 1986 to over 14 million in 2005 (National Fire Protection Association (NFPA), 2006). The same injury profile holds true for EMS workers in the private sector, such as paramedics working for ambulance companies where in 2004, of the 5170 injuries reported, 3410 (67%) were sprain/strain injuries (United States Bureau of Labor Statistics, 2006a). These injuries are typically due to overexertion and affect primarily the back (Maguire

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et al., 2005; United States Bureau of Labor Statistics, 2006b; Walton et al., 2003). The consequence of these injuries is high worker compensation costs (Theberge et al., 2006; Walton et al., 2003), permanent disability, and premature retirement (Conrad et al., 1994).

Although EMS workers do a variety of tasks, the most frequently performed strenuous job tasks entail either lifting and carrying patients down the stairs or performing lateral transfers of patients at the emergency scene and at the hospital (Conrad et al., 2000). Very few researchers have described the physical demands associated specifically with EMS worker job tasks (Doormaal et al., 1995; Furber et al., 1997; Lavender et al., 2000a, b; Massad et al., 2000).

In contrast, there is a large body of research addressing the ergonomic risks associated with patient handling among health care workers, almost all of which has been conducted on nursing personnel (see reviews by Bos et al., 2006; Hignett, 2003; Waters et al., 2006). Like EMS workers, nursing personnel in settings such as hospitals, nursing homes, and home health care perform patient transfers from a bed to a stretcher or gurney and seated transfers, such as from a bed to a chair (Lloyd and Baptiste, 2006; McGill and Kavcic, 2005; Nelson et al., 2003a; Parsons et al., 2006). Unlike other healthcare workers, EMS workers must often transport patients down the stairs. Further, mechanical lifts or hoists (Evanoff et al., 2003; Parsons et al., 2006), patient lift teams, or adjustable beds (Trinkoff et al., 2003) used in institutional healthcare settings are not options for EMS workers. There are several unique aspects of patient handling during the provision of EMS that preclude a ready, direct application of these types of devices or administrative controls used in more controlled environments. EMS workers must function with a limited number of personnel in uncontrolled conditions such as tight, confined spaces and in inclement weather. They require portable patient-handling devices of a size and weight that can easily and quickly be brought to the emergency scene. Affordability is an issue, especially in volunteer fire departments with limited equipment budgets. Given these considerations, compact and affordable patient-handling devices, such as transfer boards and gait belts used in the healthcare setting, are two options that could conceivably be adapted for EMS use.

1.1. Theoretical model

This study was guided by a theoretical framework that we developed a number of years ago using focus groups of firefighter/paramedics to elicit their perceptions about the factors that they thought contributed to their musculoskeletal injuries (Conrad et al., 1994). The model posits that *situational factors* (e.g., the EMS scene such as a confined space, presence of stairs, the patient's medical condition and physical characteristics, the EMS job task), *worker factors* (e.g., firefighter/paramedic EMS experience and the number of personnel available), and *workplace factors* (e.g., the EMS patient-handling devices) influence *risk of musculoskeletal injury to firefighter/paramedics.*

1.2. Purpose

The purpose of this qualitative study was to generate initial design ideas for EMS patient-handling devices that were framed within the contextual reality of the end user firefighter/paramedics. This study was the initial phase of a multi-phase mixed methods (Creswell, 2003) research study aimed at creating ergonomic solutions for EMS patient-handling tasks that reduce biomechanical loads and that are viewed by the end users as worthy alternatives to current approaches. More specifically, the information collected in this study was subsequently applied in the following research phases where lab prototype devices were built and biomechanically tested (Lavender et al., 2007a–c). This study builds upon our earlier research that defined and quantified the postural and biomechanical risks related to EMS patient-handling tasks (Conrad et al., 2000; Lavender et al., 2000a, b).

2. Methods

2.1. Research design

This was a qualitative descriptive study using focus groups with content analysis as the analytic approach. As described by Sandelowski (2000), a qualitative descriptive design is a method of choice when straight descriptions of phenomena are desired. The qualitative descriptive study is not highly interpretive but rather "entails the presentation of the facts of the case in everyday language" (Sandelowski, 2000, p. 336). This qualitative approach was appropriate for this study given that our goal was to describe end users' design ideas from their perspective. The objective was to generate a breadth of ideas rather than reach consensus. The flow diagram shown in Fig. 1 summarizes the research methods.

2.2. Sample

The accessible population was suburban fire departments that perform emergency medical operations and employ firefighters who are crossed trained as paramedics or emergency medical technicians (EMTs). The fire departments included both union and non-union work environments.

A convenience sample of firefighter/paramedics who had experience handling EMS calls was recruited. Eligible participants were those who were employed as firefighter/paramedics or firefighter/EMTs (the term firefighter/paramedics is used in this paper), performed EMS tasks as part of their assigned duties, and were between the ages of 18 and 55 years old. Special effort was made to include females and members of racial minority groups, who compose a small percentage of this occupational group.

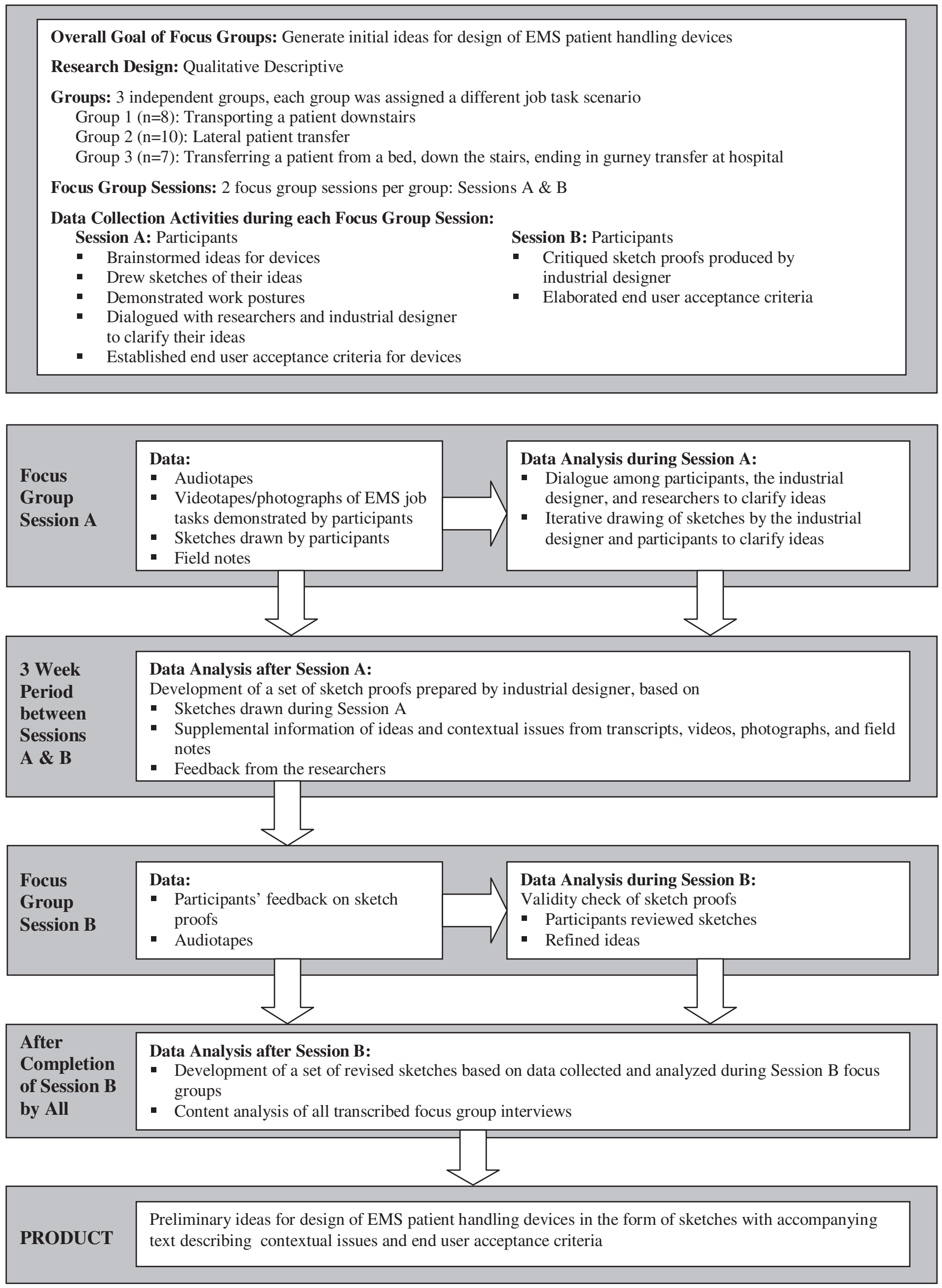

Fig. 1. Flow diagram of focus group process.

Recruitment letters and accompanying fliers were sent to a total of 23 fire departments who were members of a mutual aid consortium with whom we previously worked, or were members of an intergovernmental risk management agency that expressed interest in our study. Institutional Review Board approval for the study was obtained from the university and written informed consent was obtained from each participant. Participants were compensated for time spent in the focus groups.

Participants included 25 individuals representing 13 different fire departments. In all, 92% ($n = 23$) of the participants were male, 96% ($n = 24$) were white and the remaining one participant was African American. The mean age of the group was 37 years (range 25–52 years). The mean number of years of experience performing EMS operations was 13 years (range 2–28 years).

2.3. Data collection

The data were collected using focus groups, a method often used in qualitative descriptive studies to capture a broad range of information about events (Sandelowski, 2000). Focus group methods can help inform the product design process (Bruseberg and McDonagh, 2002). Industrial designers, Langford and McDonagh (2003), noted that focus groups are a useful method for identifying the features that users value or enjoy, as well as those that they dislike and can be used to elicit user needs and aspirations for the product, to contribute to potential design solutions, to express acceptance criteria, and to evaluate prototypes.

Three separate groups of firefighter/paramedics (termed Groups 1–3) participated. Each group concentrated on a different EMS patient-handling scenario and was asked to imagine an improved EMS patient-handling device that could reduce the physical demands of the tasks involved. The scenarios presented to the groups were as follows:

- Group 1: the sub-task of transporting a patient down the stairs;
- Group 2: the sub-task of a lateral patient transfer; and
- Group 3: a sequence of sub-tasks from transferring a patient from a bed onto a backboard, then down the stairs, onto a stretcher and into an ambulance, and finally from a stretcher to a hospital gurney at the end of the run.

As described, Groups 1 and 2 were asked to address single sub-tasks whereas Group 3 considered a series of sub-tasks that included the sub-tasks addressed in the other two groups. The tasks were drawn from our earlier research that identified and quantified the biomechanical risk of the most frequently performed, physically strenuous EMS patient transfer/transport tasks (Conrad et al., 2000).

Each of the three groups participated in two rounds of focus group sessions (termed Focus Group Sessions A and B). Guided by our theoretical framework, separate discussion guides with probes were created for Sessions A and B. The probes allowed us to clarify and expand on ideas presented, thus reducing interviewer bias. The order of focus groups was as follows:

- Group 1 Focus Group Session A, Group 1 Focus Group Session B;
- Group 2 Focus Group Session A, Group 2 Focus Group Session B;
- Group 3 Focus Group Session A, Group 3 Focus Group Session B.

We chose to run the three groups in sequential order so that we could refine the discussion guides as needed to optimize the information we collected. Only minor refinements were made. The focus groups ranged from seven to 10 participants and lasted 2 hours. There was a 100% retention rate between Sessions A and B for all three groups. At the end of the session, participants completed a brief demographic questionnaire and received their compensation.

The sessions were very lively, utilizing a variety of participatory methods that engaged the participants as well as the researchers and an industrial designer who were present for all sessions. While the first author moderated the sessions, all the authors engaged in dialogue with the participants.

In Focus Group Session A, participants brainstormed ideas for new EMS devices that they thought could reduce musculoskeletal problems. To help the participants understand the kinds of information we sought and the thought processes we envisioned, the ergonomist (SL) gave a brief introduction of the kinds of body movement and postures that pose injury risk. The moderator then gave an everyday example, describing the biomechanical challenges of a manual pull-type golf cart. The participants easily envisioned a push-type golf cart with ergonomically designed features to reduce awkward body movement. Our criterion that their ideas for equipment redesign needed to address the current physical demands of the scenario/tasks presented to them guided the generation of ideas. In generating ideas, we asked participants to address issues of perceived effort, feasibility, adoption, and economic impact.

To start the discussion flowing, the participants were asked to describe situational factors they would likely encounter in the scenario presented to them. Next, the participants were asked to describe a typical piece of equipment or method they currently use in that particular situation. They brought up the conditions that posed injury risk given the task, the situation, and the selected piece of equipment. Once this preliminary contextual scenario was elaborated, the group started brainstorming about potential solutions. They were asked to talk about the problems experienced with currently used devices and to offer ideas for what their ideal device would look like. Participants were encouraged to offer varying views and perspectives when suggesting possible ergonomic solutions. As solutions were suggested, they were discussed, debated, and further developed by the group. We were looking for a wide range of viable ideas rather than consensus.

In Session A, three common patient transport devices (a stretcher, a stairchair, and a backboard) were available to be used as props for the participants to demonstrate work postures and to refer to features of the devices that posed problems and could potentially be improved. In addition, participants were invited to sketch their ideas using overhead transparencies that were projected on a screen for all to view. The industrial designer also produced sketches as the conversation progressed, which were displayed on an overhead projector for the participants to critique, modify, and expand upon. The groups easily generated many potentially worthy ideas.

Focus Group Session B served as a validity check as participants reconvened with their original group. Here, the participants reviewed professionally prepared sketches of their ideas and offered further input. The sketches served as a representation of their ideas as filtered through the interpretation of the industrial designer and research team. After Session B, a few minor edits were made to the drawings.

2.4. Data analysis

''Qualitative content analysis is the analysis strategy of choice in qualitative descriptive studies …and is a dynamic form of analysis of verbal and visual data''(Sandelowski, 2000, p. 338). Data consisted of multiple media: videotapes and photos taken of participants as they demonstrated work postures, sketches drawn by the participants and by the industrial designer during the sessions, audiotapes, transcripts, and handwritten field notes. After Focus Group Session A, the researchers and industrial designer met to debrief. The industrial designer refined her sketches based on the debriefing meeting and review of the various data. The research team and the industrial designer then reviewed her sketch proofs, again referring to the transcript, field notes, photos, and videotape. In this way, data triangulation was used to minimize bias. The industrial designer revised the sketches one more time based on research team feedback, and these revised sketches were presented for review by the participants when they reconvened with their original group members for Focus Group Session B (see Fig. 2 for sample sketches). This latter session was, in essence, a validity check to confirm that the industrial designer's sketches accurately reflected the participants' ideas. Again, participant feedback was solicited resulting in minor refinements to the sketches.

In addition to the visual analysis of videotapes, photos, and sketches, we conducted a qualitative content analysis of the transcribed focus groups to obtain a narrative description of the devices and contextual issues. We analyzed six transcripts (i.e., 1A, 1B, 2A, 2B, 3A, 3B), treating the A and B session for each group as a set. We analyzed transcripts across groups only when a similar device was suggested by multiple groups. A *Microsoft Word* document of each transcript was prepared by a professional transcriptionist. Three of the authors (K.M.C., P.A.R., and J.G.S.) each took primary responsibility for reviewing the set of transcripts from one of the three groups of participants. Our aim was to identify ''notable quotes'' in the transcripts that captured the participants' main ideas and views. A provisional name was assigned by the authors to each of the devices depicted in the sketches and these names were used as labels for the devices described in the transcripts. Each author identified passages in the transcripts based on the following *a priori* categories developed from the discussion guides: the current device or method used to perform the task, the ergonomic problems considered to be related to the current devices or method, situational factors that contribute to the problem, and the design features of the ideal device. The authors labeled the passages that illustrated the *a priori* categories with the device name, focus group number/ session, and the line number. The authors reviewed each other's analysis and notable quotes.

2.5. Qualitative rigor

Like Kidd and Parshall (2000), we discuss qualitative rigor using the conventional terminology of reliability and validity in order to facilitate communication with different disciplines and with our funder. This approach is particularly appealing to us because our research uses mixed methods (i.e., quantitative and qualitative methods).

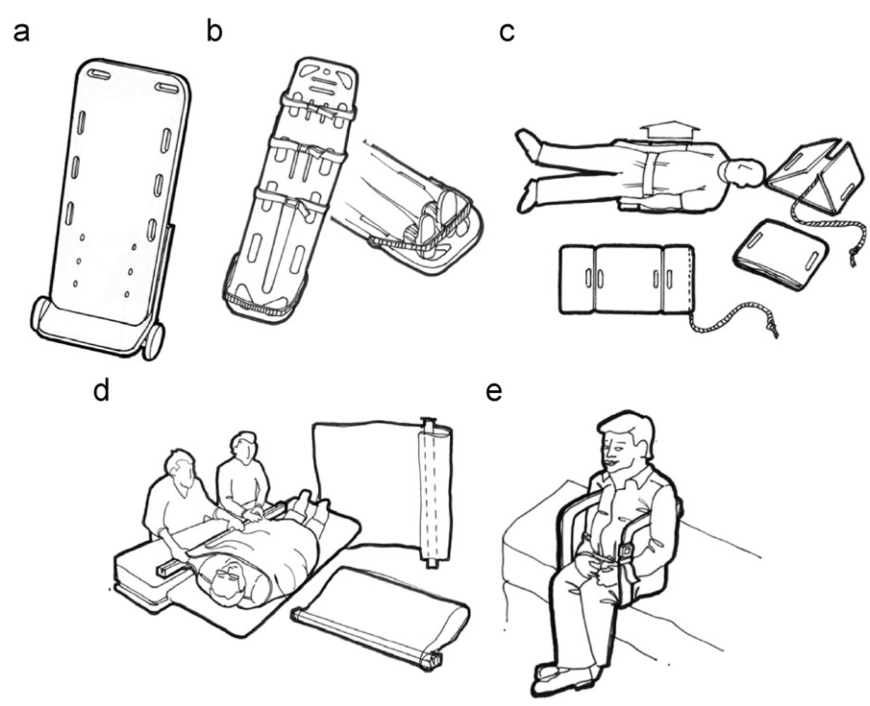

Fig. 2. Sketches of design ideas for EMS patient-handling devices: (a) backboard wheeler, (b) backboard footstrap, (c) bridgeboard, (d) transfer rod, (e) transfer sling.

The construct of interest is "design ideas for new EMS patient-handling devices to reduce musculoskeletal injury among EMS workers."

2.5.1. Reliability

We assessed reliability in terms of stability and equivalence. With focus groups, stability refers to the same group being convened on more than one occasion; in our case we reconvened the same group on two occasions (Sessions A and B). Equivalence can be a concern when multiple moderators or coders are used (Kidd and Parshall, 2000). The same moderator (K.M.C.) facilitated all sessions, and she received focus group training from Krueger (Krueger and Casey, 2000), an expert in the field. We had three coders who reviewed each other's analysis and found near-perfect agreement. We did not calculate inter-rater reliability with a statistical test. Our coding rules involved applying the *a priori* categories and labeling passages by device name, focus group session, and line number.

2.5.2. Validity

Kidd and Parshall (2000) recommend that the background of the focus group members be considered in assessing content validity. Our participants were experienced in EMS and, thus, may be considered a panel of experts. In this way, we believe content validity was demonstrated. Participants' review of sketches of their design ideas drawn by the industrial designer during Session A and their later review of refined sketches in Session B served as validity checks. We collected multiple data (e.g., photos, videotapes, transcripts, and sketches) and in this way used data triangulation to enhance construct validity of our conclusions. Theoretically, the ultimate test of construct validity would be a reduction in musculoskeletal injury that could be attributed to the use of new EMS patient-handling devices that incorporate the ideas offered in the focus groups.

3. Results

3.1. End user acceptance criteria for the new devices

The ideas for new devices often included some evaluative comments beyond the goal of making the firefighter/paramedic's job safer and easier while not adversely impacting the patient. Content analysis of "the design features of the ideal device" quickly revealed a set of commonly held end user acceptance criteria that if attained would make the device desirable and likely to be adopted by EMS workers. The criteria were echoed across groups and were continually referred back to when evaluating potential ideas.

The criteria established by our end users were:

- Affordability: "That's the first thing my chief says to me—'how much does it cost?'"
- Portability: compact, and easily stowed on the ambulance. "Can you make small stuff that we can stick with us and we've got all the time?"
- Operability: quickly ready for use, including any necessary assembly. "Not a lot of buttons and garbage to do all the time."
- Cleanability: easily cleaned and disinfected. "My only concern with that is decontamination."
- Durability: no easily broken or lost parts. "You would be surprised how worn out something gets from just sitting there or being taken in and out of a building all day long."

3.2. Design ideas

Twenty ideas were generated that clustered around the following types of EMS patient-handling devices: backboard accessory devices, stairchairs, lateral assistive devices, bed-to-stairchair assistive devices, and jump-kit (i.e., medical supply bag) accessories. This section of the paper highlights the five devices that were later built for this study by the university scientific instrument shop and that demonstrated statistical and practical advantage in subsequent lab tests.

3.2.1. Bridgeboard

Participants discussed issues related to lateral patient transfers such as from the patient's bed to the ambulance stretcher and from the ambulance stretcher to the hospital gurney. Initially, the patient may be found at home in bed and need to be transferred from the bed to a stretcher. Most calls end at a hospital with a stretcher to hospital gurney transfer. Participants remarked that a typical method for doing these lateral transfers is to position one firefighter/paramedic on each side of the patient and to use the bed sheet to slightly lift the patient to accomplish the move from one surface to the other. There are several negatives to this approach, particularly when the patient is being moved from a bed. With an adult patient, the bed is likely to be a double size or larger. This means that one firefighter/paramedic may need to get on the bed rather than stand on the floor when moving the patient to the ambulance stretcher. Participants commented that if the bed surface is soiled, this forces them to stand, rather than kneel, and bend forward while lifting the patient. And if the bed is worn out or not appropriately supported, the firefighter/paramedic is left to work in an awkward posture while standing on an unstable surface. Whether standing or kneeling, the position of the firefighter/paramedic on the bed while lifting the patient is one that is biomechanically challenging.

Additional problems were noted in the performance of lateral transfers. One problem is that, although the stretcher can be positioned at approximately the same height as any bed or hospital gurney, there is always some gap between the bed and stretcher or stretcher and gurney that hinders sliding movements as the patient is moved from one surface to the other. Another is that the patient needs to be lifted sufficiently to reduce the friction of pulling the patient from one surface to the other. In order not to bear the weight of the patient any longer than necessary (as one worker noted, "a lot of our patients are larger size") and to coordinate the actions of the two firefighter/paramedics, this can result in a "1, 2, 3 heave" type of maneuver, which places significant dynamic loads on the firefighter/paramedic and is uncomfortable for the patient.

Firefighter/paramedics commented that they had sometimes used a slide board device that could deal with these last two issues when transferring a patient in a nursing home or a hospital, but that the device they were familiar with was too large and unwieldy for use outside of those institutional settings where storage was not an issue.

The discussion quickly turned to how that device could be adapted to be useful in responding to calls in a patient's home or institutional setting where a large board was not available. At this point, the issue was raised of whether a long institutional-type board was actually necessary to perform the task. As someone noted, surfboards used to be long until people realized that one could maintain (and even improve) the functionality with a shorter board. It was suggested that the board needed only be long enough to "get the bulk of the person" that is, to cover the length of a patient's torso, thus supporting the majority of the bodyweight. Additional design features suggested were to make the board foldable for easy storage, that there are no sharp edges, and that there be an easy-to-grip handhold for carrying and placing the board.

Interest in making this device small in size deals with the common problem of inertia encountered when introducing new equipment. "If it's not right in front of your face you don't think about it" and "we tend to look at the same equipment all the time…so we tend to use the same pieces of equipment all the time…if it's stuff that is light enough that we can bring with us almost all the time that would be nice."

3.2.2. *Transfer rod*

The difficulties encountered when transferring patients laterally from a bed to a stretcher at the EMS scene were discussed in several focus group sessions. Participants explained how they often use the bed sheet on which the patient is resting to do the transfer. "A lot of times you take the fitted sheets off the bed and move the patient" and "take the sheet off and just… everybody just grabs the sheet and just pulls him." In talking about ideas for facilitating such a transfer, the participants brought up concepts such as tarpaulins and vinyl sheets with handles that could be used with or instead of the bed sheet. This discussion led to the idea of a pole or rod that could be used with a slippery sheet. Later, the concept evolved into a rod device that could be used with the existing bed sheet by wrapping the sheet around the rod along the side of the patient to facilitate the transfer. The idea was that the transfer rod would lessen the strain on the firefighter/paramedics by distributing the patient's weight along the rod instead of having the load unevenly distributed, potentially leading to injury for the firefighter/paramedics. The discussion then turned to considering the use of a single rod with both firefighter/paramedics positioned on the stretcher side of the patient or the use of dual rods with one firefighter/paramedic positioned on the stretcher side of patient and the other firefighter/paramedic positioned on the bed. In addition, it was suggested that the transfer rod be designed to be collapsible so that it could be easily stored on the stretcher.

3.2.3. *Transfer sling*

Patients are sometimes transferred from a bed to a stairchair at the EMS scene when their condition allows for it. The participants demonstrated how this process generally entails getting the patient into a sitting position on the edge of the bed at which point the firefighter/paramedic hooks his/her arms underneath the patient's armpits using an under axilla lift technique to lift and pivot the patient to the chair. Focus group participants described situations in which overweight patients were difficult to grasp during transfers. In addition, participants discussed the need to respect patients' modesty and personal space when making such transfers, especially for female patients and/or those wearing light sleeping wear. Participants also mentioned the need for an alternative place to grasp patients who have soiled garments. During these transfers, firefighter/paramedics often find themselves in awkward postures in an effort to accommodate patients' needs.

The concept of adding "handles" to the patient to aid in patient transfers came out of the focus groups. Two existing devices, the "gait belt" and the "rescue seat," were discussed and this led to the idea of a sling-type device that uses elements of both. Similar to the gait belt, the sling puts handles on the patient, but it also incorporates aspects of the rescue seat, such as the patient's sitting posture during transfers and the capability of lifting the patient's entire weight. Although the gait belt is commonly used in nursing homes, the firefighter/paramedics were not familiar with its use in the fire service. In addition to bed-to-stairchair transfers, the sling device can be used to move patients out of confined spaces. One firefighter/paramedic remarked, "You know where this would be something that you could use is in those difficult situations we were talking about. In a bathroom and someplace where you can't get a hold of your patient. Because you're grabbing arms and we all know what it's like trying to move dead weight around."

3.2.4. *Backboard wheeler*

Participants brainstormed about solutions to carrying a patient down stairs using a backboard. The backboard, also termed a spine board, is a 6 ft long board with handholds used to transport patients who need to be lying flat in a supine position. Sold by a number of manufacturers, today's backboards are typically plastic and X-ray translucent. Participants expressed the physical demands posed by carrying an increasingly heavy patient population on the backboard and the awkward postures the firefighter/paramedics often assume because of confined space on staircases, especially as they carry patients through a landing. Similarly, transporting a patient in a small elevator requires awkward twisting and lifting motions as many elevators will not accommodate a backboard when carried horizontally. In detailing the difficulties of providing medical care to a patient who is being transported in a small elevator, one participant noted, "if you ever do CPR on somebody on a backboard at a forty-five degree angle … that's an experience to remember."

In coming up with ergonomic solutions, the idea of rolling the backboard rather than carrying it down the stairs was expressed by many participants. "I've got an idea. . . Are we our own worst enemies insisting on carrying the complete load? What if we had something like a backboard that actually had like … bicycle tires at the bottom and you just wheeled them around like a sack of potatoes. Just right down the stairs."

The idea of an upright wheeled backboard device that could easily pivot around tight corners made one participant think, "Because then you get the tight elevators and tight stair landings. The backboard (device)… you can stand it straight up and just turn them any way you want. You've gotten around that "oh geez, we can't make this corner … lift it up over the handrails."

Once the idea was introduced of a detachable backboard wheeling device that permitted patients to be rolled in an upright position, the participants began adding other features. These included telescoping and adjustable handles to accommodate firefighter/paramedics of varying heights as well as the material composition of the handles to provide for easy grip. Various kinds of braking mechanisms were discussed with the idea that brakes would control the descent of the wheeling device, thus reducing the force felt by the worker at the bottom of the board and safeguarding against the device rolling away down the stairs. Various types of strapping to secure the patient to the backboard were discussed.

3.2.5. Backboard footstrap

Also raised was the idea of incorporating a footrest on the backboard to lessen the likelihood of the patient slipping and making the carrying task more difficult for the firefighter/paramedic. The backboard footrest was conceived as an adjustable, detachable device that could be used with existing backboards. Focus group participants discussed the issue of overweight and tall patients slipping or not fitting properly on the backboard during transport. In emphasizing the problem of taller patients, one participant commented, "Well nowadays, everybody you put on a backboard is six-foot-four and their feet hang off the board anyways." Having a patient slip down the board and then thrust their feet into the firefighter/paramedic places the firefighter/paramedic at risk for injury. "You end up with a lot of feet in your chest by the time you're at the bottom of the stairs."

Through further discussion, participants came up with a potential solution that involved an attachment for existing backboards rather than backboard modification or the development of a new backboard. Design ideas included, "just have a piece of adjustable webbing at the bottom and that way if their feet hang over the bottom you can still make it long enough that… you can wrap it around their feet "and "It could even be as simple as a seatbelt attached to the bottom handholds of the board."

4. Discussion

4.1. End user acceptance criteria

The end user acceptance criteria, except for *affordability*, reflect an emphasis on ease of use. The first criterion arises from the fire chief's need to consider cost as well as utility when evaluating a firefighter/paramedic's request to purchase equipment. Participants at all levels frequently complained that items marketed to the fire service are priced significantly higher than similar items marketed to other industries, in part perhaps due to manufacturers' liability concerns when marketing to what is seen as a high-risk industry.

Equipment cost obviously has a differential impact on departments depending on their financial situation. Cost is a particular issue in communities with fire and EMS services based on the donated services of volunteers. However, both professional and volunteer fire/EMS services realize the value of investing in equipment that has the potential to reduce the injury-production impact of the work being performed.

Although a modern truck-based ambulance may appear large compared to early generations of car-based vehicles that were little more than a station wagon fitted to carry a stretcher, they are filled with medical equipment and have little available room for storing additional devices. Participants' definition of easily stowed meant that the device must be securely stored so that it is not dislodged even during extreme vehicle movements while still being quickly accessible for use and quickly returned to storage so that no time is lost that might compromise patient care quality.

This concern for time also extends to the device being quickly ready to use. Any preparatory work beyond unfolding a device or assembly that is more than snap-locking a couple of pieces together was viewed negatively. Parts that can easily break or come off and be lost make a device susceptible to prolonged periods of nonuse and "early retirement." And finally, given the concern for blood borne pathogens, all equipment must be easily and quickly cleaned of contamination by bodily fluids and dirt. Smooth shapes and materials were viewed positively.

Although applied to a different consumer group, the criteria established by our participants are largely consistent with those volunteered by end users of assistive technology devices (Lane et al., 1997).

4.2. EMS devices for lateral transfers

Two of the five design ideas suggested were for EMS lateral transfer devices (i.e., the *bridgeboard* and the *transfer rod*). The *bridgeboard* was conceived as a friction-reducing device that would ease the transfer and bridge the gap between a bed and a stretcher or a stretcher and gurney when laterally moving a supine patient. A variety of friction-reducing devices, such as transfer boards and sheets, are used for lateral transfers in healthcare facilities. Results from a number of studies suggest that such devices can reduce the risk of musculoskeletal disorders (Baptiste et al., 2006; Lloyd and Baptiste, 2006; McGill and Kavcic, 2005; Nelson et al., 2003a, b). However, the devices available in healthcare facilities either did not meet all the end user criteria stipulated by our participants, they required log rolling the patient, or they did not effectively bridge the gap between the bed and stretcher. Thus, commercially available devices were not viewed as an option and further development of the *bridgeboard* was pursued in future phases of our research.

The second idea for a lateral transfer device, the *transfer rod*, was envisioned to facilitate the grasp of the bed sheet during a lateral transfer of a supine patient. The usual method of simply rolling up a bed sheet in one's hands for use in a patient transfer is similar to the use of draw sheets in health care facilities. However, by rolling a bed sheet around a rod, the sheet could be grasped, such that the patient could be wholly lifted from head to toe and the load more evenly distributed. The rod was suggested as an alternative to the bridgeboard or as an adjunct for use with the bridgeboard for lateral transfers. The rod would need to be collapsible to make it compact and easily stowed and, of course, easily cleaned. No such device was found to exist on the market; thus, this idea was further pursued and ultimately a prototype produced.

4.3. EMS device for bed-to-stairchair transfers

The idea of a *transfer sling* for lifting non-weight bearing patients quickly from a bed to a stairchair at the EMS scene was offered as an alternative to the typical under arm axilla lift. While the elimination of manual lifting of patients in favor of mechanical aides for seated transfers has been recommended for healthcare facilities (Elford et al., 2000; Garg and Owen, 1994; Nelson et al., 2003a; Waters et al., 2006; Zhuang et al., 1999), Elford et al. (2000) pointed out that in uncontrolled environments, such as among ambulance personnel, manual lifting may be unavoidable. In such situations, manual aids such as slings that in effect provide "handles" to improve the quality of the coupling between the patient and handler can be effective. In testing a polymer sling with cutouts at both ends for gripping around a patient's lower abdomen/hips, Garg and Owen (1994) concluded that this type of sling was not suitable for non-weight bearing patients although biomechanical analysis showed it be superior to manual lifting; it was rated as comfortable by patients; and required little time to complete the transfer. The weight capacity of the polymer sling was not listed. The focus group participants' idea of using a two-strap sling made of strong webbing that could be easily positioned both under the patient's legs and behind their back could be used to lift non-weight bearing patients and make for a quick transfer that would not require log rolling the patient as in the case of transfer seats on the market. The idea of using two straps to secure the patient both under the thighs and behind the back is similar to the two-sling method used in the Elford (Elford et al., 2000) study where two slings equipped with handles posed less risk of back injury than the under arm axilla lift when used by a two-person team. The *transfer sling* concept was refined over time starting with a device that resembled a seat belt loop with a secure buckle developed as a lab prototype.

4.4. EMS devices for transport down stairs

Two of the five devices (i.e., the *backboard wheeler* and the *footstrap*) were accessory devices that were envisioned for use with existing backboards. The job task of transporting patients down stairs is not described in the healthcare industry literature. In actuality, the original idea for the *backboard wheeler* generated in the focus group came from a participant who made the analogy between the wheeler concept and a two-wheel hand truck. A recent review by Jung et al. (2005) identified 34 ergonomic studies on the use of manual vehicles, including hand trucks, to reduce the physical stress associated with manual material handling of heavy loads. In Jung et al.'s (2005) review paper, many of the design features discussed were similar to the ones considered in our focus group (e.g., wheels, brakes, handles, material composition, and methods for securing the load). Unlike the typical hand truck, however, the ideal *backboard wheeler* described by our participants was intended not as a standalone device, but rather one that attaches to any standard backboard for transporting humans (not furniture and such) and it needs to be collapsible for easy storage on an ambulance. Although the lab prototype, looking much like a hand truck, showed positive results, further design work is needed due to its complex requirements.

The second accessory device for down-the-stairs transport on a backboard was the *footstrap*. Just as hand trucks have shelves to hold the load, the intention here was to help prevent the patient from slipping down the board creating injury risk for the EMS worker. Unlike a shelf on a hand truck, however, the foot strap needs to be detachable. The lab prototype of the footstrap was a detachable acrylic plate with straps that wrapped through the handholds on a backboard.

4.5. Product

The product of the focus groups was a rich, detailed description of ideas for new EMS patient-handling devices expressed in the voices of firefighter/paramedics. The focus groups provided an opportunity to learn about the contextual issues that affect patient transfer/transport and that need to be considered in developing design solutions. While there was variability among the fire departments represented in terms of which EMS device may be preferred in a given job task scenario, there was considerable consistency in what constituted desirable design features for the EMS devices. The end user acceptance criteria developed in the focus groups continued to serve as a guidepost for product development in future research phases.

Upon completion of the focus groups, the research team reviewed all 20 ideas and reduced the number to 16 based on ergonomic considerations, current product availability, and the end user criteria. These concepts were presented at a subsequent stakeholders' meeting where participants again offered input and voted for their top choices. Eight lab prototypes were ultimately tested, five of which were built at the university and were highlighted in this paper. We later contracted with an engineering firm that, with continued input from our end users, further refined the devices. Presently, four of the devices are being commercialized. The engineering firm recently received federal research funding for further development of the fifth device, the backboard wheeler.

4.6. Strengths and limitations of the study

Engaging participation of the end users in designing ergonomic solutions was a critical first step to creating viable alternatives that are responsive to firefighter/paramedics' unique working conditions. Throughout all phases of this study and in our earlier work, firefighter/paramedics, as the experts of their job experiences, have been viewed as critical research partners. This approach allowed us to efficiently access both the task knowledge and job skills of the firefighter/paramedics to create design ideas for practical and inexpensive solutions to reduce the musculoskeletal injury potential of the EMS patient-handling tasks under consideration.

Another study strength was the use of sketches that provided an opportunity for the participants to review and make corrections to the representation of their ideas as filtered through the interpretation of the industrial designer and research team. We were fortunate to capture an opportunity to engage with an engineering firm to license the technology for the five devices. With continued input from our end users, the devices were further refined. As previously noted, four of the devices are being commercialized. Finally, the qualitative rigor of the study enhanced our confidence in the rich and insightful opinions and thoughtful perspectives collected from our participants.

In terms of limitations, by using *a priori* categories in analyzing the data, we became less open to new categories that may have emerged from the data. Resources limited the number of focus groups conducted. Even with the limited number of focus groups, a considerable number of design ideas was generated. While the inclusion of only suburban fire departments may be viewed as a study limitation, there was considerable variability in community size and the nature and age of housing stock, such as single unit ranch and multi-level housing, multi-unit high rises, nursing homes, and industrial complexes. The inclusion of EMS personnel from private ambulance companies would have been an asset.

5. Conclusion

Together, firefighter/paramedics, an industrial designer, and university researchers developed a worthy set of initial design ideas for EMS patient-handling devices. The participants articulated clear end user acceptance criteria that should be considered when designing devices if we are to increase the likelihood of their future adoption. The design ideas generated in this focus group study were further developed in subsequent phases of a mixed methods research study.

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