INTRODUCTION

A quick response to medical emergency incidents demands the prompt arrival of an ambulance with a medical team able to provide rapid treatment and safe transportation of patients to a hospital without delay. Medical emergencies occur irregularly 24 hr a day, 7 days a week, 52 weeks a year. Their settings present a wide range of working conditions and unpredictable physical demands. The working area for ambulatory first aid is the ambulance interior; in this “working cell” the patient, medical staff, and medical aids are located. In this defined space, efficiency and safety measures should be near optimal. The operational doctrine for medical emergency services, in general, requires rapid evacuation of a patient from the scene to a hospital, except for immediate lifesaving treatment procedures that must be administered in situ.

The ambulance attendant has to perform clinical procedures inside the ambulance, in a prolonged sedentary posture, fighting the vehicle’s vibration. Attendants worldwide report health issues resulting from their working conditions. Shook and Spelt (1985) stated that ambulance design does not take into consideration the human factor. Noise levels need to be attenuated by soundproofing; siren controls should be altered and moved for easy access; front seats should be redesigned; and the upholstery should be made of cloth.

Smith (1986) indicated six possible sources of inefficiency in the interior of the ambulance that must be given priority in redesigning. Design modifications of restraints aids were suggested to allow for better cardiopulmonary resuscitation (CPR) performance and to prevent injuries caused by flying objects. Moreover, the proposed enhanced designs improved controls on equipment for error-free manipulation, as well as for better overall

Objective: This study aims to evaluate safety and accessibility of an advanced life support (ALS) ambulance interior. Background: The standard ambulance’s interior design is unsatisfactory based on perceived discomfort and postures that constrain paramedics and medical staff, resulting in unsafe treatment of patients, mainly when being transported. Methods: Two procedures were used to evaluate performance during a wide range of rescue tasks: a survey, based on questionnaires, interviews, and observation of paramedics performing routine tasks; and upper body and back posture analysis, based on postural considerations. Results: Findings revealed that 74% of the paramedics stated that the location of the paramedic’s seat is inefficient while they perform clinical procedures; 94% found the bench uncomfortable; 77% felt that the vertical distance between the bench and the stretcher is too far; and 86% needed to steady themselves when the vehicle was moving. Posture analysis showed that paramedics undergo several nonneutral back postures, including twisted back (>20°) and sitting with back flexion between 20° and 45°. Conclusion: Because the interior of the ALS ambulance was found to be unsatisfactory both to paramedics and patients, alternative design issues are proposed. Application: The suggested practical layout contains four main modifications: (a) replacing the bench with two adjustable paramedic seats, (b) redesigning the medical cabinet for easy access, (c) adding an adjustable folding seat opposite the two new seats, and (d) adding a swiveling base and lifting apparatus that will accommodate the stretcher and enable better accessibility to patients by the paramedic personnel.

Ergonomic Evaluation of the Ambulance Interior to Reduce Paramedic Discomfort and Posture Stress

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comfort and habitability concerning siren noise, lights, and climate.

An analysis of tasks and exposure to dangerous body exertions performed by Doormaal, Driessen, Landeweerd, and Drost (1995) showed that during 16% to 29% of an average shift, personnel riding in the moving ambulance maintained extreme postures. Most strenuous tasks were found to be lifting and moving the patient, in addition to medical actions and care. The researchers’ conclusions included the need for attendants to pay more attention to their own postures and for the development of an improved, ergonomically-based working environment. The same results were presented by Landeweerd and Kant (1996), who investigated the tasks performed by ambulance nurses. They also found that transporting patients to and from the ambulance, in addition to patient care, was considered strenuous. No design modifications were suggested.

Letendre and Robinson (2000) found that Canadian paramedics considered performing CPR, accessing a patient and equipment, loading a stretcher in and out of the ambulance, and intubating a patient as the most physically demanding activities. Ferreira and Hignett (2005) reviewed the layout of the patient compartment in a British ambulance in terms of the paramedic efficiency and safety using link analysis and postural analysis. Their conclusion was that future patient compartment design should be improved with health, comfort, and performance considerations in mind.

This study looks at current interior compartments, with the objective of producing feasible suggestions for an improved overall design. The propositions are intended to make the ambulance working cell ergonomically suitable as a mobile working environment unit for use by the medical personnel treating a patient during emergency runs. The new design takes into consideration functionality, geometrical factors, and emergency vehicle constraints.

In Israel, where this study was performed, ambulance design follows the American Federal Specification for the Star-of-Life, KKK-A-1822E (General Services Administration [GSA] Federal Supply Service, 2002; Type II). Two classes of ambulance are in use in Israel: (a) the emergency medical technician (EMT) ambulance, which responds to a wide range of calls (mostly nonemergency patient transfers); and (b) the advanced life support (ALS) ambulance, which responds to emergency, life-threatening calls. This investigation discusses the latter because of its complex equipment and the clinical procedures that are carried out within the compartment. The study was conducted in a mostly urban area, with some hilly topography.

METHODS

The Working Cell

The ambulances on which this investigation was performed (Chevrolet Savannas) are widely used in Israel. The vehicles are built, prepared, and equipped in the United States according to Israel’s medical life support organization directives. The main components of the interior cell are (a) the medicine cabinet (attached to the left wall of the vehicle, as seen from the rear), which stores all the necessary medicines, drugs, and equipment; (b) a stretcher, located on the side and foot of the bench, fastened to the floor of the vehicle; (c) the paramedic’s seat, located at the head of the stretcher and close to the monitor/defibrillator; (d) a four-passenger bench (a wooden box functioning as a storage space) attached to the right wall opposite the medicine cabinet; and (d) a monitor/defibrillator located on a shelf in the cabinet, near the paramedic’s seat, to his or her right. At the head of the bench is a side door for easy entry by attendants on duty.

Participants

Thirty-five experienced emergency medical staff members (paramedics, paramedics who act as shift managers, and medical doctors) from five different public ambulance stations in northern Israel, assigned to eight ALS ambulances, were eligible to participate in this study. These paramedics are fully trained and paid on a monthly basis. Four persons refused to participate, leaving 31 participants (4 medical doctors and 27 paramedics), or 88% of the original 35, who consented to be part of the study. The participants work in three 8-hr shifts, schedules according to a monthly work roster: morning (07:00–15:00), evening (15:00–23:00), and night (23:00–07:00 on the next day). Each staff member has at least four shifts per week plus a weekend shift every 3 weeks.

Personal information regarding gender, age, height, weight, body mass index, and seniority was gathered for the 31 eligible participants and appears in Table 1. The intensive care service serves
a population of almost 450,000 and responds to an average of 350 emergency calls per month. Two hundred of these calls require the ambulance crew to take a patient to hospital; other calls are either cancelled (mild) and/or end in the patient being transferred to EMT ambulances for treatment (semiserious).

**Clinical Procedures**

In order to gather preliminary findings on the staff’s procedures and work routines around the clock, we studied observations from one morning, one evening, and one night shift. Postural behavior of the paramedics was observed when repetitive manual work duties were performed, according to guidelines presented by Gilad (2001). Accordingly, the “profile” of major working postures has been figured and analyzed. Because two types of ALS teams operate during the morning and evening shifts, they were both observed equally. One team consists of a pair of paramedics (a senior paramedic who is in charge and a freshman who drives). Another team consists of a medical doctor who is in charge, a senior paramedic, and a freshman paramedic who drives the vehicle. At night, only a 2-person ALS team is on call.

The observations were selected randomly from the work roster, with the limitation that participants change every shift. In total, 2 doctors and 10 paramedics were observed. All the teams were observed for the same length of time (8 hr). The observer accompanied the teams, sitting on the seat next to the driver and recording all activities that were performed by the staff inside the ambulance: work routines, sitting habits, clinical procedures and tools used, and so forth. Based on the data that were observed and recorded, a questionnaire, interviews, and focused observations were carried out.

On arrival at an incident, the senior paramedic (and the medical doctor, if present) focuses on treating the patient (checking pulse, blood oxygen saturation, blood pressure, etc.). The freshman typically assists by retrieving and storing equipment and by helping the senior paramedic with procedures. Because our interest was primarily concerned with the work being performed inside the interior cell of the ambulance, the driver was observed only when he or she was not driving.

Call time (the time between the sounding of the alarm and the moment the ALS ambulance returns to the station) was divided and defined into four stages: (a) driving to the scene, (b) treating a patient on the scene (outside the ambulance), (c) treating while transporting to hospital (inside the ambulance whether stationary or in motion), and (d) returning to the station. However, only the time spent inside the ambulance (stage c) was of interest to us.

**Interviews and Observations**

A questionnaire was distributed to the 31 emergency medical staff. They were allotted 1 week to fill it in and return it. The questionnaire was meant to allow us to identify associations between subjective discomfort perceptions and variables inside the ambulance interior. It contained 32 questions and was divided into three sections: (a) general information: age, gender, weight, height, physical condition, and athletic activities (6 questions); (b) professional data: seniority and number and type of shifts (5 questions); and (c) work conditions: sitting habits, sitting comfort, and body postures struck when using the equipment during patient treatment (21 questions).

Free-flow one-on-one interviews were held with 10 staff chosen at random out of the 31 participants (3 freshman paramedics, 4 senior paramedics, 1 shift manager, and 2 medical doctors). The interviews were based on 20 questions and lasted for half an hour; they were used to better understand staff work habits, routines and procedures, type of activities, behavioral patterns, comfort perception, and health complaints. Analysis of the

### TABLE 1: Characteristics of Ambulance Personnel

<table>
<thead>
<tr>
<th>Variable</th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td>32.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Under 32</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 33</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td></td>
<td>1.75</td>
<td>0.3</td>
</tr>
<tr>
<td>Below 1.75</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above 1.76</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
<td>77.0</td>
<td>10.1</td>
</tr>
<tr>
<td>Below 77</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above 78</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index</td>
<td></td>
<td>25.3</td>
<td>2.1</td>
</tr>
<tr>
<td>(kg/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seniority (years)</td>
<td></td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Above 8</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below 8</td>
<td>22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
qualitative data was carried out by coding the speech into meaningful categories, enabling the researcher to organize the text and discover patterns. Coding is a process of simultaneously reducing the data by dividing them into units of analysis and coding each unit.

**Work Postures**

Back postures were analyzed by observations inside the ambulance over 40 shifts of 8 hr each (day, evening, and night), which were chosen at random over a 5-month period. The observations were distributed over the 31 participants, but because of the random nature, some participants were observed more than once. All observations were made by an experienced analyst, who accompanied the teams on their calls, sitting on the seat next to the driver. The observations followed the leading paramedic (not the driver) during his or her time inside the ambulance.

The postural analysis was based on posture categories that were sampled in periods lasting approximately 20 s. Following the approach suggested by Gilad, Chaffin, and Woolley (1989) for determining torso kinesiology, the analysis revealed back postures as they were occurring through the various clinical procedures performed. For each observation the analyst recorded categorical scales as introduced by Neumann et al. (2001) in their back pain study. These observations contained trunk postures (14 categories): 8 standing postures and 6 sitting postures. Simultaneously, these categories were recorded by a single mark on a worksheet. The analyst observed the participant and selected the posture which, in his judgment, best represented the back posture at that instant.

In order to determine the accuracy of the trunk angle data recorded during observation, during two randomly selected calls each day, back postures were digitally recorded from the lateral side using a camera mounted inside the vehicle. While the analyst was marking his observation on the worksheet, a photograph was taken. Later the photographs were inserted into an AutoCAD program for an angle measurement match with the angles observed.

To record the staff member’s spine contour, a line, tangent to the thoracic segment and the sacral segment, was drawn connecting these two segments of the spine contour. This allowed us to use the pictures to make another estimate of the back angle. The postures were then divided into normal and nonneutral ranges, based on the forms used extensively in earlier studies of cumulative trauma disorder, which include axes of rotation divided into ranges according to the overall range of motion, as reviewed by Corlett, Wilson and Manenica (1985).

**RESULTS**

During an 8-hr shift, the average number of incidents responded to by the ALS ambulance team was 4.4, with a range of 2 to 12 incidents and call times of 34 to 78 min. On average, 46% of call time (31 min) was spent traveling to and from a scene. An average of 18% of this time (12 min) was spent providing medical treatment inside the ambulance: 7 min (56%) when the ambulance was stationary and 5 min (44%) attending the patient while traveling to the hospital.

**Observation Findings**

Preliminary observations made on working routines revealed that paramedics and doctors perform the same duties and, therefore, choose to sit in the same locations. Because of this insight, the resulting data are presented over the job title (activity) and are not linked to the person carrying out the treatment (paramedic or doctor).

Mainly, participants sat on the paramedic’s seat during emergency runs. A plan of the interior showing paramedics in relation to a patient lying on the stretcher is presented in Figure 1 (hand accessibility, for the male population in the 5th to 95th percentile, is drawn for each sitting location). Nine major frequent action categories were observed in the “treating while transporting to hospital” stage, as shown in Figure 2. Based upon the frequency of their occurrence, four action categories were identified as our primary concerns: sitting on the bench (sitting in a neutral back posture), providing treatment to the patient on the stretcher, reaching for the medicine cabinet, and using the monitor.

The following contents of the ambulance were chosen for further detailed investigation: (a) the dimensions and orientation of the bench, and its suitability as a seat in a moving vehicle; (b) the stretcher’s position and height vis-à-vis treating a patient; (c) the medical cabinet’s location and its accessibility (hand reach/grasp distance); and (d) the accessibility and location of the monitor/defibrillator (reach/grasp and handling distance). Because no Israeli anthropometric estimates exist, the

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Figure 1. Plan scheme of the ambulance. Circles represent hand reach range for the 5th–95th percentile of the male population.
Figure 2. Pareto chart for tasks observed in treating a patient during call time inside the ALS ambulance.
dimensions were compared with anthropometric estimates for U.S. adults, as discussed in Pheasant (1986). The American population was selected because of its similarity to the Israeli population and the availability of data on it.

The height of the bench from the floor, which was 50 cm, matches the 95th percentile of men, with no provision made for shorter people. The height of the stretcher from the floor, with a patient lying on it, was found to be below the attendant’s elbow level. The horizontal distance between the medicine cabinet and the bench was 78 cm, beyond easy reach of the 95th percentile of men.

Survey Results

Several questions in the questionnaire dealt with the paramedic’s sitting location. To the “yes” or “no” question “Does the location of the paramedic’s seat contribute to comfort and efficient performance of clinical procedures?” 74% of the participants marked “no.” To the question “Is there any eye contact between the paramedic sitting on the paramedic’s seat and the patient lying on the stretcher?” participants were given four possible answers: “good eye contact” (14%), “eye contact only when the patient lies flat” (61%), “eye contact only when patient lies in an inclined position” (0%), and “no eye contact” (25%). (Numbers in parentheses refer to the percentage of participants choosing that answer.)

To the “yes” or “no” question “Do you feel comfortable sitting on the bench?” 94% of the participants answered “no.” Participants were given four possible answers to the question “What in your opinion should be improved in the bench’s design?” The first three choices were preset, and the fourth (“other”) allowed free text: “the bench’s width and height” (39%), “backrest dimensions and location” (38%), “lack of armrests for each sitting place” (21%), and “other” (2%). Here, respondents mentioned the bench’s upholstery and the lack of cushions to absorb shocks and bumps.

The question “How do you find the bench’s height in relation to the stretcher?” offered two answers: “too high, so one is forced to bend” and “suitable”; 77% of the participants answered that the bench was too high.

The question “Do you use any restraints or seatbelts when sitting on the bench during emergency runs?” had four options: “always use seat belts” (3%), “only on administrative rides (no patient in vehicle)” (40%), “never use seat belts” (40%), and “always use seat belts but not when performing clinical procedures” (17%). To the “yes” or “no” question “Do you feel the need to steady yourself inside the vehicle when it is moving?” 86% answered “yes.”

For the question “Have you ever been injured on duty during emergency runs?” four options were suggested; the first three were preset and the fourth (“other”) allowed free text: “injury caused by bashing against the ambulance wall during sharp turns” (40%), “injury caused by unwieldy objects” (31%), “no injury” (21%), and “other” (8%); here, respondents mentioned injuries caused by road accidents. The question “Have you injured or nearly injured a patient during emergency runs?” had four options: “more than once” (10%), “injured once” (13%), “almost injured” (23%), and “never injured” (54%).

Work behavior and motion patterns were studied and clarified through the interviews. There were three major findings:

1. All participants preferred to sit on the bench at the side of the stretcher when performing clinical procedures, with the exception of switching places between the bench and the paramedic’s seat when it made more sense (e.g., when needing to read data from the monitor or when performing an intubation or defibrillation procedures).

Attendants’ main reasons for preferring the bench over the paramedic’s seat for treating a patient were (a) difficulty in accessing a patient’s head from the paramedic’s seat without the constant need for deep back flexion (as seen in Figure 1 and Figure 3, bottom panel); (b) difficulty in accessing a patient’s upper limbs in order to perform clinical procedures (such as checking a pulse); (c) partial or no eye contact between the patient and the paramedic sitting on the seat (as seen in Figure 3, bottom panel), which is extremely important when performing any procedure; and (d) the difficulty in reaching medication stored in the cabinet, which was not accessible from the paramedic’s seat (Figure 3, bottom panel). However, participants also admitted failing to reach the medicine cabinet from the bench. In order to access the cabinet they are forced to stand up and bend, as seen in Figure 3, bottom panel (whether the vehicle was stationary or moving); nevertheless, access was regarded as much easier from the bench.

2. Ninety percent of the participants complained of the difficulty and need to bend forward in great back flexion to operate on a patient lying on the
Figure 3. Latitudinal section (left) and longitudinal section (right) of the ambulance’s interior showing a paramedic and a patient. Dotted circle represents hand reach range for the 5th and 95th percentiles of the participants.
stretcher, as seen in Figure 3, top panel. The vertical distance between the stretcher (20 cm [7.8 inches] above the vehicle floor) and the bench’s top surface (50 cm [19.6 inches] above the vehicle floor) forces the paramedics to stay in strenuous postures for prolonged periods during clinical procedures.

3. Sixty percent of the participants commented about the difficulty in reaching a patient from both sides (because of the placement of the stretcher, accessibility is possible only from the side of the bench), resulting in the need to stand up and bend forward at times for better accessibility.

**Posture Analysis**

The number and type of incidents treated during the 8-hr shifts over a period of 5 months were documented. Special attention was given to incidents during the “treating while transporting to hospital” stage. The type, time, and back posture for each activity (a sum of 13,200 recordings) were documented during morning, evening, and night shifts and revealed nine typical back postures inside the ambulance: three standing postures (45°–75°, 75°–105°, and 105°–120°) and six sitting postures (–5°––1°, 0°–15°, 15°–45°, 15°–45° with one arm up, >45°, and twisted >20°), as shown in Table 2. The digital camera recordings confirmed the good accuracy of the trunk angle observed. All back angles measured and calculated from the pictures matched the back posture observed.

The analysis shows that during 53% of the stage of performing clinical procedures, the staff underwent seven undesirable and uncomfortable back postures, three in standing postures (45°–75°, 75°–105°, and 105°–120°) and four in sitting postures (15°–45°, 15°–45° with one arm up, >45°, and twisted >20°), deviating from the normal. Figure 4 summarizes the back postures of the paramedic personnel and emphasizes the four most frequent upper body postures during the performance of clinical procedures. Two of these postures are regarded as extreme: sitting with a twisted back (>20°) and sitting with back flexion between 20° and 45°.

Based on the data collected from the observations, we created a posture angle profile for the four major actions observed during patient treatment (see the four tallest bars of Figure 4). The posture angle profile of a body segment consists of the four actions on the vertical axis, along with angular deviation of the motion concerned on the horizontal axis. The graphical projection of an

<table>
<thead>
<tr>
<th>Activity</th>
<th>Back Posture</th>
<th>% Time</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance Is Stationary</td>
<td>Sit/stoop Totals</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Sit and bend (30°–45°)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sit and bend (&gt;45°)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sit bend (15°–45°) arm up</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sit twisted (&gt;20°)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Stand/bend Totals</td>
<td>Stand and bend (45°–75°)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stand and bend (75°–105°)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stand and bend (105°–120°)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ambulance Is Moving</td>
<td>Sit/stoop Totals</td>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sit neutral (–10°–30°)</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sit and bend (30°–45°)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total time</td>
<td></td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

= 18% of total call time
Figure 4. Pareto chart for back postures observed during the “treating while transporting to hospital” stage.
angular deviation for a movement as related to a body segment is a kinesiological presentation of the joint’s main movements in the act.

Figure 5 presents a posture profile scheme of the back, in flexion movements, while standing (on the left of the figure) and sitting during patient transport to the hospital. The figure clearly shows the angular range and angular deviations of the torso while standing and sitting for those four major working stages. Posture angle analysis of the motion patterns, as obtained, indicate that most of the movements are performed by flexion deviation along a wide range (up to 45° and beyond and twisted). Based on the results of the posture profile that includes the maneuvers and the motion pattern, the workstation can be redesigned in order to achieve a more limited angular interval.

DISCUSSION

The interior of an ambulance must be designed to provide safety and meet ergonomic requirements. It must permit male and female personnel to perform their jobs in a secure working environment. The results of this study found a clear association between subjective discomfort perceptions and variables inside the ambulance interior. Kinesiological presentation of the back’s main movements revealed a large angular range, which impairs both personnel functioning and patient treatment and which could be alleviated by better design.

The location of the paramedic’s seat was found by most participants to be unsuitable for performing most regular clinical procedures. Moreover, eye contact between the patient and the paramedic seated in the designated seat was found to be problematic. As a result, for better accessibility to the patient, the paramedics (and the doctors) prefer to sit on the bench alongside the stretcher. These findings are consistent with those of Ferreira and Hignett (2005). Nevertheless, the bench, though better for some tasks than the paramedic’s seat, was found to be uncomfortable and much higher than the stretcher alongside it. Sitting on the bench meant the staff underwent deep back flexions for most of the treating time.

The distance between the bench and the medicine cabinet was found to be beyond a reasonable distance, forcing the study participants to stand up or to bend forward while rising on their feet in order to reach it or to operate the monitor/defibrillator located on a shelf in the cabinet; this made it difficult to use seat belts. In some cases, because of the inconvenience of buckling and unbuckling over and over, the attendants chose not to use them at all, despite the risk of self-injury or concern for patient injury. The stretcher’s location allowed access to the patient from one side only (the bench’s side). These findings are consistent with those of Letendre and Robinson (2000), who concluded that some of the most physically demanding activities were accessing the patient and the equipment.

Observations on participants sitting on the bench show some nonneutral back flexions while performing clinical procedures. The “treating while transporting to hospital” stage lasted 18% of total call time (12 min), on average. For 53% of this time (6.4 min, 9.5% of call time), on average, the staff held extreme back postures. This could represent substantial dynamic loading while in the working postures (i.e., paramedics attempting to perform tasks while in a moving vehicle). Our figures are smaller than those found by Doormaal et al. (1995) because the present study did not include investigations on back postures during the “treating a patient on the scene” stage or during the typical types of lifts used when carrying a patient to and from the ambulance and, later, to the hospital bed.

Such tasks generate loads on the lumbar joints that exceed the National Institute of Occupational Safety and Health (NIOSH) maximal permissible limit, as was found by McGill, Potvin, and Norman (1990). According to Punnet, Fine, Keyserling, Herrin, and Chaffin (1991), exposure to trunk flexion (the degree of flexion and exposure to more than one nonneutral posture, for more than 10% of a work cycle) was found to increase the risk of musculoskeletal disorders. The combination of strenuous occupational demands, plus the working conditions described previously, may lead to fatigue, to lower cognitive performance, and, possibly, to human errors and accidents. This reality, compounded by the difficulty involved in using the seat belts while treating patients, poses a risk of injuries both to staff and patients.

This study has focused only on back flexion during medical procedures, ignoring the neck, shoulders, and wrist joints. Also, although the study provides a frequency count of the observed back postures, there are no data showing the duration of the back postures. Additional observations on all joints, with duration data, might give a more complete understanding of nonneutral postures.
Figure 5. A posture profile scheme of the back in flexion movements during the “treating while transporting to hospital” stage.
during procedures. Imprecise posture analysis may have occurred because the crowded conditions made it difficult to perform observations inside the moving vehicle. Nonetheless, the importance of the posture analysis carried out here is that it suggests that uncomfortable postures do exist when clinical procedures are executed. In order to obtain unbiased results, it is desirable to record the staff performing the clinical procedures on a digital video from the lateral and frontal sides. Later, the footage could be analyzed at intervals of approximately 20 to 30 s so that upper extremity postures can be analyzed.

Our alternative work area layout design suggests the following modifications, which address the implications for ambulance design discussed in this study. If implemented, these suggestions may reduce attendants’ discomfort when treating patients and performing clinical procedures in the ambulance cell and may increase the attendants’ usage of seat belts and the use of safety restraints for patients:

1. Replace the bench with two adjustable paramedic seats suitable both for men and women, placed alongside the stretcher. One chair might have the option of folding and/or rotating on its swiveling base apparatus.

2. Redesign the medical cabinet for easy access to medical aids in most compartments (by the 95th percentile of women). Even if nothing else is changed in the ambulance cell, these should be relocated for easy access by the men and women sitting on the currently used seats. Such a design should consider head clearances for the 95th percentile of men.

3. Add an adjustable folding seat on the opposite side of the bench to allow the insertion of the stretcher into the ambulance when folded and the option of treating a patient from both sides when unfolded, as shown in Figure 6.

4. Add a swiveling base and lifting apparatus to serve as a base, which will accommodate the stretcher lying on it. This will enable the stretcher to be rotated and lifted and, with the patient lying on it, will allow better accessibility to the paramedic personnel, with no need for uncomfortable back flexion, as shown in Figure 6.

These practical modifications to the current design can be implemented without remodeling the physical structure of the ambulances in use. Such suggestions, if carried out, may reduce physical discomfort, which can lead to human error and accidents, and the risk of injury to staff and patients.

Figure 6. Plan scheme of the new rotating stretcher design. Circles represent hand reaching range for the 5th and 95th percentiles of the participants.
CONCLUSIONS

Observations of a wide range of life-threatening events indicate an interior design that is problematic for the tasks being performed inside the vehicle. It seems that the interior design is based primarily on spatial utilization, with little concern for ergonomics. Based on the data derived and observations of how work is actually performed in the ambulance interior working cell by the variety of personnel who participated in this study, we suggest a few guidelines to enhance the interior design. We believe that these suggestions, some of which are detailed in Figure 6, can reduce the uncomfortable and extreme postures indicated in this study.

REFERENCES


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