Project Number: IQP-MQF 2804 A11

AMBULATORY WORK-RELATED INJURIES AND HEALTH PROBLEMS

by

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An Interactive Qualifying Project

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

in Mechanical Engineering

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Approved:

MAY 2012

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Abstract

Emergency Medical Technicians (EMTs) are integral to the society as they provide immediate medical treatment to those with moderate to severe ailments. Upon arrival to the scene where the ailing person is located, EMTs have to assess the entire situation in order to determine an appropriate method of treatment. Before admitting any treatment, EMTs utilize select pieces of equipment, such as the stretcher and stair chair, to move patients from their original position to the ambulance. With the weight of the equipment and the patient totaling over 200 pounds, EMTs often acquire debilitating injuries that cause them to miss work several days out of the year. Considering the number of injuries that occur to EMS personnel has increased over the years, the Ambulatory Work-Related Injuries and Health Problems focused their efforts to improve the safety of all EMS personnel. To accomplish this goal, the group designed a new device to lessen the strain that EMTs experience while maneuvering these heavy loads. Another method of reducing injuries that the group devised is the inclusion of simulation training to the current EMT training program so candidates obtain practical skills related to lifting and maneuvering patients before certification. The last component of this project incorporated the development of a fitness plan for EMTs to follow post-certification to increase their health and safety.

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Acknowledgements

The Ambulatory Work-Related Injuries and Health Problems group would like to offer their gratitude to UMASS EMS, Boston EMS, Massachusetts General Hospital, Brigham and Women's Hospital, Beth Israel Deaconess Medical Center, and Sheri Bemis for all of their assistance and feedback throughout the duration of our project. Lastly, we would like to thank our advisor Professor Mustapha Fofana for all his support and advice that helped us guide our project in the appropriate direction.

Chapter 1. EMS AND LIFE SAVING PRACTICES

1. Introduction

All around the world, Emergency Medical Services (EMS) provide medical attention to patients with various categories of injuries and complications. Once a call is received at a base, an employee on duty obtains general information regarding the distinctive incident and its location. Ambulatory workers, or emergency medical technicians (EMTs), are required to arrive first at the scene of an emergency to treat the victim as quickly as possible. The typical treatment that EMTs are allowed to administer includes securing an intravenous line (IV) and giving cardiopulmonary resuscitation (CPR). Given that these procedures are executed in a six feet wide by ten feet long patient compartment, the limited space prohibits EMTs from completing procedures efficiently and effectively. Within the small parameters, EMTs have to stabilize themselves using strategically placed rails on the roof of the interior, which are useful while the ambulance is in motion. When extreme vibrations of the ambulance occur, EMTs often lose their balance resulting in several injuries. As well as providing treatment, EMTs have to transport patients from the scene of the accident to the ambulance with the available equipment. Particularly in large cities, most buildings have many levels of stairs, which makes the job of transferring the patient hazardous. In combination with limited space to move the patient, obesity in patients contributes to a multitude of injuries amongst EMTs, specifically to the back, neck, knees, and wrists, due to the strenuous task of lifting. The health and safety of emergency medical technicians should be held at a high priority so they can distribute proper care to those in need.

The previous idea provides the motivation for this project. Consequently, the main objective of the Ambulatory Work-Related Injuries and Health Problems group is to enhance the safety of EMS personnel by reducing the total number of injuries that occur within the field. To achieve this goal, an investigation of the training requirements, curriculum, and fitness of EMTs will be completed. This will promote the team to examine the credibility of the mandatory tests incorporated in the process of becoming an EMT. Future research of human anatomy and physiology will illustrate the capabilities of the human body. With this knowledge, the team can evaluate the amount of force that the spine and other areas of the body can withstand before failure. By comprehending the threshold of weight an average person can transport, an inquiry will be made on the pieces of equipment used on a daily basis. After distinguishing the current issues with the used devices, the team plans to design a piece of equipment that reduces the physical stress on EMTs. After making a model of our design in the computer-aided design program Solidworks, analysis can be completed to demonstrate the capabilities of the device. By doing so, the team will be able to gauge where improvements are crucial and make adjustments accordingly. The comprehension and implementation of biology, physics, and engineering will direct the team towards accomplishing all of the previous objectives.

The remainder of this project includes research, analysis, and discussion of the overall safety of EMTs. Directly following this brief overview of the project is Chapter 2. This chapter addresses the necessary training to become an EMT, the anatomy of the frequently injured areas of the body, and the types of injuries that EMTs endure while on duty. Chapter 3 contains the methodology followed to complete the entire design process from formulating the objectives to the drawing the final design in Solidworks. The termination of this chapter will incorporate detailed information regarding revisions to the current training program along with guidelines for a fitness programs to insure the health and safety of EMTs. Finally, Chapter 4 will summarize all of our findings within our report.

CHAPTER 2. EMS AND PATIENT-CENTRIC QUALITY CARE

2. Introduction

This beginning of this chapter focuses on defining the specific characteristics of the different types of Emergency Medical Technicians (EMTs). Each candidate that desires to become an EMT has to acquire the proper amount of training to administer basic or advanced life support. State-appointed instructors are responsible for demonstrating the appropriate techniques that EMTs use on a daily basis in semester long courses. Successful completion of a state-recognized course allows newly licensed EMTs to provide emergency care legally within the EMS system. Following the definition of each level of practice, the next portion will include a detailed description of the pieces of equipment used regularly by EMTs. In the field, ambulatory workers are expected to maneuver these devices in addition to the weight of patients in diverse environments. The danger associated with this task has increased over the years due to the limited workspace and the obesity in patients. As a result, back injuries among EMTs have become prevalent, causing approximately 10% of emergency responders to miss work at any given time. The conclusion of this chapter will consist of an examination of the anatomy of the back, an explanation of the most common injuries, a discussion of several case studies, and recommendations related to EMT safety.

2.1. Types of EMTs

The National Association of Emergency Medical Technicians states that over 700,000 people work for the Emergency Medical Services in the United States alone [1]. The entire EMS system is comprised of four levels of ambulatory workers, the lowest being certified Emergency Medical Responders, or EMRs. Keeping true to their name, first responders quickly arrive to the scene where the sick or injured patient is located to provide direct care. Potential EMRs are required to complete a training program that includes 40 hours of in-class learning, a practical exam, and a written exam. Once licensure is possessed, responders immediately assess the gravity of situations in order to inform higher-level personnel upon their arrival. Based on the severity of the patient's condition, back-up EMTs will be summoned to the scene to administer advanced treatment with assistance from EMRs.

As a part of their training, EMRs learn a repertoire of skills to aid patients in emergencies using limited equipment. Immediately, EMRs evaluate the medical condition of the patient to determine a method of preliminary treatment. Similar to someone trained in first aid, EMRs become certified in performing CPR, or cardiopulmonary resuscitation, which is used when the heart stops beating and breathing ceases. In the case that blood loss is involved, responders use their medical knowledge to control the bleeding as quickly as possible. Other basic techniques EMRs can execute are recognizing unsafe scenarios, stabilizing patients to prepare for transport, assisting in emergency childbirth, managing the patient's airway and supplying emergency oxygen.

Figure 1 - Automated External Defibrillator [3]

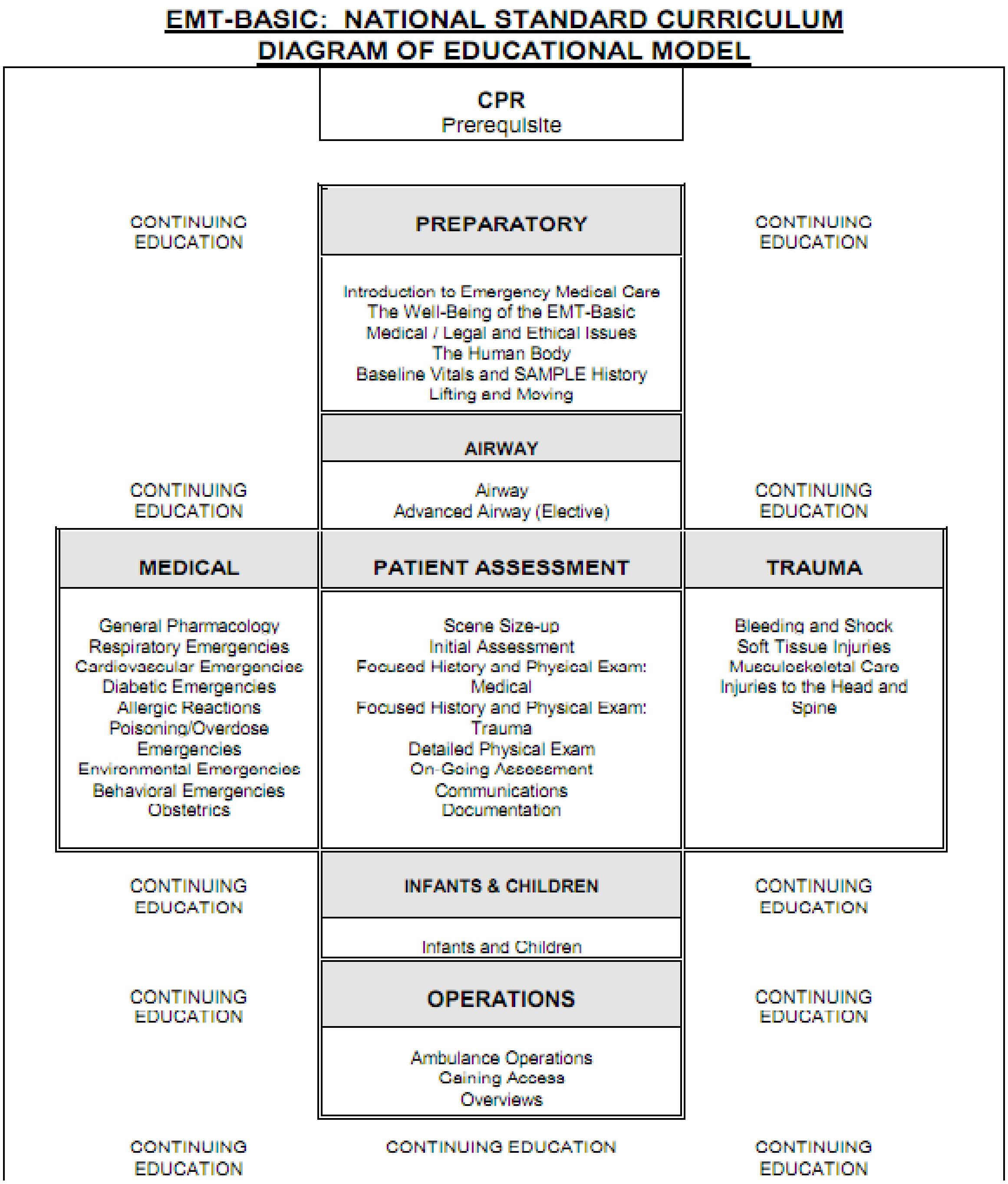
Some EMRs are capable of performing complex tasks, which differentiate them from people solely certified in first aid. Reliant on the specific certification course, EMRs learn to restrict movement of potentially fractured limbs by splinting the injured area until further assessments can be made via x-rays. Responders also acquire the skills to detect a person's vital signs, which include a patient's pulse, blood pressure, respiratory rate, and temperature. In addition, emergency medical responders can use an Automated External Defibrillator, or an AED, to monitor a patient's heart rhythm. In the case that it is irregular, the AED sends an electric shock to restore a normal pattern [17]. A depiction of a common AED is located in Figure 1. Overall, EMRs respond rapidly to provide basic treatment to reduce the risk of future problems until more advanced help arrives at the scene.

The next tier in the Emergency Medical Services system is the first level Emergency Medical Technician, which is an EMT-Basic, or an EMT-B. Those who wish to become an EMT-B have to take a 110 hour-long training course that includes in-class learning and clinical experience. Similar to first responders, EMT-Bs can regularly practice their skills in the field as soon as licensure is admitted. Requiring over double the amount of training as an EMR, basic Emergency Medical Technicians attain knowledge pertaining to intricate techniques [1]. Equipped with more skills, EMT-Bs take more control in emergencies to assist in reducing the mortality associated with traumatic situations.

At the beginning of their training, EMT-Bs learn all of the skills that emergency medical responders learn to establish a basis for techniques involving more complexity. For instance, EMT-Bs are taught how to use specific adjuncts that have the ability to clear an obstructed airway of a patient to restore regular breathing. In addition, basic EMTs are allowed to distribute a few types of medication to patients, such as aspirin for chest pain, glucose tablets for suspected hypoglycemia, and previously prescribed medications specifically for the patient. Under the circumstances, EMTs cannot write prescriptions due to the lack of complete medical knowledge.

Another difference between EMRs and EMT-Bs is that EMT-Bs have more skills regarding the transportation of patients. A portion of their job relates to the decision making process of where the patient should go based on the medical condition. Making only preliminary assessments, EMT-Bs make these decisions alongside more experienced co-workers guaranteeing suitable care for the patients. Lastly, they participate in the lifting and maneuvering of patients from the given location to the stretcher in the ambulance [39]. Table 1 below represents the typical complete curriculum that the qualified instructors use throughout the duration of EMT training courses. Despite the fact that this diagram is specifically for EMT-Basics, the breakdown is similar for all tiers in the EMS system.

Table 1 - National Curriculum of an EMT-Basic [39]



The next tier in the EMS system varies from state to state; specifically in Massachusetts, the more qualified type of Emergency Medical Technician is the EMT-Intermediate, or EMT-I. Within the category of EMT-Intermediate, there are two subtypes: EMT-I/85 and EMT-I/99, the only difference being the types of treatment that they can offer to patients and the amount of training [1].

The training associated with becoming an EMT-I/85, or Emergency Medical Technician – Intermediate 1985, resembles the requirements for any type of EMT. First, they must successfully pass all the courses necessary for a basic EMT to proceed in learning techniques within advanced life support. Subsequently, the candidate must take an additional 120-hour course to obtain additional skills [41]. Their training certifies them to conduct more invasive procedures, such as inputting fluids via an intravenous line, more commonly known as an IV. EMT-I/85s learn different methods of managing a person's airway in attempt to have a higher success rate in pre-hospital care. The 1985 curriculum however does not permit EMTs to distribute more medications than an EMT-B [14].

Emergency Medical Technician – Intermediates based on the 1999 curriculum need to finish an extra 200 to 400 hours of training than an EMT-B to receive an acceptable license. To be able to practice professionally in the field, EMT-I/99s must also have clinical and field internships to confirm they can perform tasks correctly [41]. Within their internships, EMT-I/99s observe and execute invasive procedures that require extensive practice. One of these advanced procedures is the administration of a needle decompression of a pneumothorax, which is when air builds up between the lung and the chest wall. The decompression allows air to escape the interior cavity to reduce the risk of cardiac arrest. Another advanced process that EMT-I/99s can carry out is an endotracheal intubation; by placing a small, flexible tube in the trachea, or the windpipe, the EMT keeps the airway open to ensure that oxygen is being admitted to the body. EMT-I/99s also are trained in using ECGs, or electrocardiograms, which monitors the electrical activity of the heart over a period. The last difference between other EMTs and EMT-I/99s is that EMT-I/99s have the authority to give patients medication to control cardiac arrhythmias along with basic aspirin [14].

The highest level within the pre-hospital care division is the EMT-Paramedic, or more commonly known as a paramedic. Establishing the entire skill set of a paramedic takes the equivalent of an associate's degree, or two years, in training to obtain a nationally recognized license [1]. Acquiring the most skills, paramedics can administer treatment associated with both basic and advanced life support. The supplementary training permits paramedics to dispense 30 to 40 different types of medications to patients in certain circumstances. The other advanced skills they are able to complete include maintaining an infusion of blood, performing a gastric decompression, and accessing indwelling catheters and implanted IV ports for medications in addition to all of the skills of EMT-Bs and EMT-Is [39].

Table 2 - Types, Training, and Skill Sets of EMTs

Type of EMT	Necessary Training	Skills
EMR	40 hours (in-class with practical and written exam)	First aid, CPR, managing airway, restrict movement, detect vital signs, use an AED
EMT-B	110 hours (in-class and clinical experience)	All skills of an EMR, clearing obstructed airways, distribute basic medications
EMT-I/85	230 hours (120 additional hours to obtain advanced skills)	All skills of an EMT-B, inputting fluids via IV, other methods of managing airways
EMT-I/99	~ 310-510 hours (200 – 400 more hours than EMT-B; clinical and field internships)	All skills of an EMT-I/85, needle decompression, endotracheal intubation, ECGs, distribute more medications
EMT-P/Paramedic	2 years (associate's degree)	All skills of EMT-I/99, both basic and advanced life support, allowed to dispense 30 to 40 types of medications, maintaining infusion of blood, accessing indwelling catheters and implanted IV ports

To distinguish the types of EMTs based on their training and capabilities, Table 2 contains this information in a fashion that can be easily understood for comparison.

2.2. Ambulatory Equipment

While on the job, Emergency Medical Technicians utilize a variety of equipment to maneuver patients from the site of their injury to the ambulance. The main pieces of lifting equipment used by these workers are the backboard, the stretcher, and the stair chair. Each is designed to protect patients, whom are either unconscious or incapable of movement, during the transportation to the ambulance. Furthermore, these pieces of equipment are designed to decrease the strain experienced by ambulatory workers in motion.

2.2.1. Stretcher

The ambulatory stretcher is a valuable piece of equipment that allows EMTs to stabilize a patient and quickly move them from the site of injury to safety. The stretcher has been in existence for years, but has evolved to become safer for workers and patients alike. Many mainstream stretchers are the equivalent to hospital gurneys or cots. These structures contain a standard mattress, straps, and handlebars, which surround the patient's head and body to secure them in place. The center of the stretcher is flexible, allowing the patient to be positioned in a way that is comfortable for them, either flat or upright. Wheels, found at the base of the stretcher, are durable and capable of moving the stretcher on different terrains. This basic design was used for many years before being altered, because loading and lifting them into the ambulance placed too much strain on the spine of the EMT. In the past few decades, wheels have been added underneath the cot. The legs of the stretcher also have been modified to allow the stretcher to be rolled into the ambulance from their standing position [23]. Figure 2 depicts a Ferno 93 ES model stretcher, which is similar to what most ambulances in the United States carry today.

Figure 2 - Ferno 93 ES Model Stretcher [23]

This model in particular weighs approximately 77 pounds and has a weight capacity of 500 pounds. Like most stretchers, the Ferno 93 ES Model includes a mounting mechanism that allows the height to be adjusted to a maximum of 32 inches off the ground. Another component of this stretcher is that the top region of the stretcher can be positioned at different angles so that the patient can sit in the upright position if allowed by the EMT. Table 3 contains the specifications of the Ferno 93 ES Model Stretcher.

Table 3 - Specifications of the Ferno 93 ES Model Stretcher

Weight Capacity	500 lbs
Maximum Height	32 in
Minimum Height	9 in
Maximum Length	81 in
Minimum Length	66 in

Stryker and Ferno are the largest manufacturers of stretchers and many other types of medical equipment. Over the years, manufacturers have changed the appearance and materials of these structures in order to create a safer and more effective product. For instance, Stryker's new stretcher design, the Power-PRO XT, incorporates an innovative powered hydraulic lift to raise and lower patients in approximately 2.4 seconds with the touch of a button. The function of the hydraulic lift reduces the risk of back injury significantly and minimizes the strenuous lifting by 250 to 300 fewer pounds per call for each EMT. With the new technology added to the system, the weight of the stretcher has increased to approximately 120 pounds, but its durability has increased to be able to withstand a patient up to 700 pounds [12]. Figure 3 shows the Stryker Power-PRO XT design with the controls for the system on the left.

Figure 3 - Stryker Power-PRO XT [12]

This model of the stretcher includes a X-shaped type frame that can be adjusted to different heights through the use of the hydraulic lift. Table 4 includes various dimensions of the Stryker Power-PRO XT stretcher.

Table 4 - Stryker Power-PRO XT Specifications

Weight	125 lbs
Weight Capacity	700 lbs
Maximum Height	41.5 in
Minimum Height	14 in
Maximum Length	81 in
Minimum Length	63 in

Ferno also generated an elite version of the stretcher involving a similar lift system called the PowerFlexx+ Power Cot. Unlike the PowerPRO XT, this design has an in-the-fastener charging system to keep it powered on every call without having to bring extra batteries.

Figure 4 - PowerFlexx+ Power Cot [16]

The PowerFlexx+ can be used to lift a patient weighing up to 700 pounds due to its all-metal frame providing exceptional strength [16]. The PowerFlexx+ Power Cot and its adaptability can be seen in Figure 4.

Table 5 - PowerFlexx+ Specifications

Weight	132 lbs
Maximum Length	83 in
Minimum Length	61 in
Width	24 in

Table 5 contains information regarding the specifications of the PowerFlex+ Power Cot, including the weight, length, and width.

2.2.2. Stair Chair

The stair chair is another piece of equipment frequently used by EMTs. This modified wheelchair is designed to transport patients down the stairs of multiple story houses and apartment buildings. It has several straps on the seat that stabilize the victim while he or she is being taken down stairs. Handlebars are found at the head and base of the chair, allowing two EMTs to navigate the chair down the stairs safely. Shorter in horizontal length, stair chairs are easier to maneuver down a staircase than a heavy stretcher. Figure 5 shows an original design of stair chair with two sets of handles for EMTs to grasp while maneuvering. According to the online specifications, this design weights about 21.2 pounds [30].

Figure 5 - Basic Version of a Stair Chair [30]

Most recently, tread systems have been added to the bottom of the chair, which allow EMTs to slide the chair down the stairs instead of being carried. Figure 6 below is a photo of the Ferno's EZ glide stair chair with PowerTraxx. This chair, approximately weighing 40 pounds, withstands patient loads up to 500 lbs. The additive PowerTraxx system permits the chair to travel both up and down staircases with the use of an electrically controlled motor, which can run up to 20 flights of stairs per charge [10]. Although the stair chair is a viable method of moving patients, it has been responsible for many injuries among EMTs and paramedics.

Figure 6 - Ferno EZ Glide Stair Chair [10]

This version of the stair chair has a height of 37.5 inches and a width of 20.3 inches. Using these dimensions and specifications, the stair chair is built to sustain the weight of the majority of patients.

2.2.3. Backboards

Backboards are standard pieces of lifting equipment that EMTs may use during an emergency. These thin, slick plastic lifting devices can be used to transport patients in variety of settings. Several holes are located on both sides of the board to assist EMTs while lifting. It also has several attached to stabilize the patient during movement. A depiction of a full length backboard can be seen in Figure 7.

Figure 7 - Full Length EMS Backboard [7]

This backboard in particular weighs about 19 pounds in total and is 72 inches in length and 16 inches in width. Lightweight and easy to maneuver, the majority of EMTs would prefer to use this piece of equipment to transport patients; however, it is not able to withstand weight greater than 400 pounds. This device could potentially reduce the number of injuries in the field, but the reduced weight capacity makes the device less efficient in performance [7].

2.2.4. Safety Assessment of Equipment

Normally, EMTs work in teams of two or more to lift patients using any of these three pieces of equipment. Although all these pieces of equipment are very helpful in the eyes of EMTs and paramedics, they do not always protect these workers from serious injury. Many EMTs in fact sustain multiple injuries while using a piece of equipment intended for patient transportation. The vast majorities of these injuries occur in the spinal region. These injuries can result from a variety of things, but the limitations in the lifting equipment and increase in patient weight have caused most injuries in recent years (Lavender [24]). While using this equipment, EMTs complained of having to overexert themselves in order to carry the weight, because the equipment was not intended to tolerate such a heavy load. The stair chair, an excellent lifting device for moving victims down normal, straight stairs, is not easily used while descending a spiral staircase. The alternatives, more specifically the stretcher and backboard, also presented difficulties, as they cannot be positioned appropriately in small spaces in a household setting. As newly designed lifting equipment has been developed within the past few years, studies are presently being done to investigate the overall efficiency of these devices [33].

2.3. Anatomy, Physiology and Injuries

The job of an Emergency Medical Technician involves a certain level of risk while working in the field. A majority of the risk is directly associated with the little information given during the emergency call. With minimal knowledge of the scenario, EMTs often remain mentally unprepared for an act of duty forcing most to make assumptions regarding the equipment needed. Having to maneuver hundreds of pounds over various terrains, EMTs and paramedics acquire several injuries each year due to overexertion and improper lifting techniques. Studies have shown over the decades that the majority of injuries occur to the back or spine. An investigation of the anatomy and physiology of this area of the body will assist in demonstrating where these injuries transpire exactly.

2.3.1 Anatomy and Physiology of the Back

The human back is the posterior rear area of the body located between the neck and the waist. As a whole, it is a complex structure that serves as a support system for the entire body. The back contains a slightly rigid bony sheath that provides stability in addition to several large muscles that are capable of bearing significant forces. Essentially, this portion of the body allows all EMTs to complete all the tasks required for an entire day's work [4].

2.3.1.1 Skeletal Structure of the Back

The major component of the skeletal structure within the back is the spine. It is the flexible bone column that spans from the base of the skull to the tailbone. The main function of the spine is to protect the spinal cord, which is a column of nerves that connects the brain to the rest of the body. Acting as a key element of the skeletal system, the spine is composed of series of attached bones known as vertebrae, which can be seen below in Figure 8.

Figure 8 - One Vertebra [28]

Within the spine, there are a total of 24 vertebrae that create the entire column. Each individual vertebra is described as a hollow ring, called the laminae, with a large segment of bone on the exterior. When all of the vertebrae are stacked accordingly, an elongated tube is formed to act as protection to the spinal cord. Opposite the laminae is the spinous process, which is the part of the bone that sticks out and one can feel it as they rub a hand down one's back. Below the spinous process are two transverse processes, which serve purpose in attaching muscles to the vertebrae [28].

Located in between each vertebra are the intervertebral discs, which are flat, circular sacs that act as shock absorbers. Each disc has a strong outer ring made of fibers called the annulus, and an interior is constructed of a jelly-like material known as the nucleus pulposus.

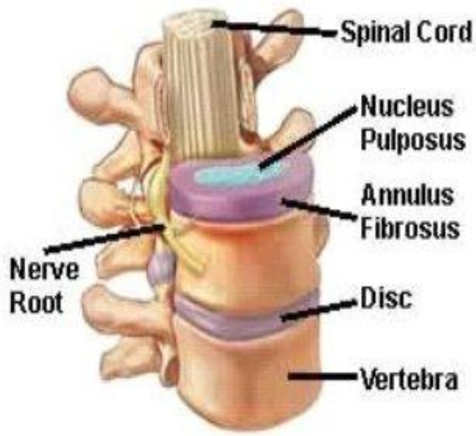


Figure 9 - Diagram of Discs in Between Vertebrae [28]

A diagram of vertebrae with the intervertebral discs in between can be seen above in Figure 9. The function of the annulus is to keep the nucleus pulposus intact and to assist in connecting the vertebrae together [28]. Without the discs, all the vertebrae would rub against each other causing friction and diminishing the ability for fluid movement [4].

The posterior portion of the bone has knobs that connect between consecutive vertebrae to form joints known as the facet joints. With one knob on the left and one knob of the right, the facet joints are a type of synovial joint, a structure that permits movement between two bones such as flexion, extension, and twisting. Figure 10 depicts the location of the facet joints between the vertebrae.

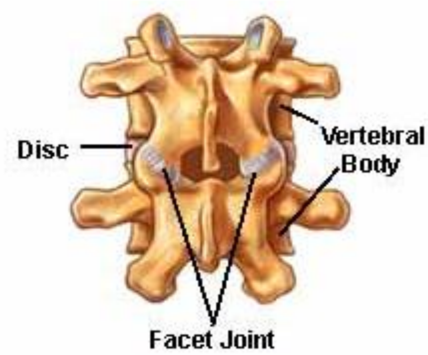


Figure 10 - Facet Joints [28]

To reduce the overall friction of the joint, a material called articular cartilage saturates the ends of the bones allowing them to glide easily to promote a large range of motion. Surrounding the facet joint is a sac made of ligaments and tissue called the joint capsule. Filled with a fluid, the capsule lubricates the joint to decrease the friction and discomfort. The protective cushioning developed in the anatomy allows a wide range of movement without producing severe damage [28].

2.3.1.1.1 Sections of the Spine

The spine is divided into three distinct sections: the cervical spine, the thoracic spine, and the lumbar spine. Where the different parts of the spine are located can be viewed in Figure 11 below.

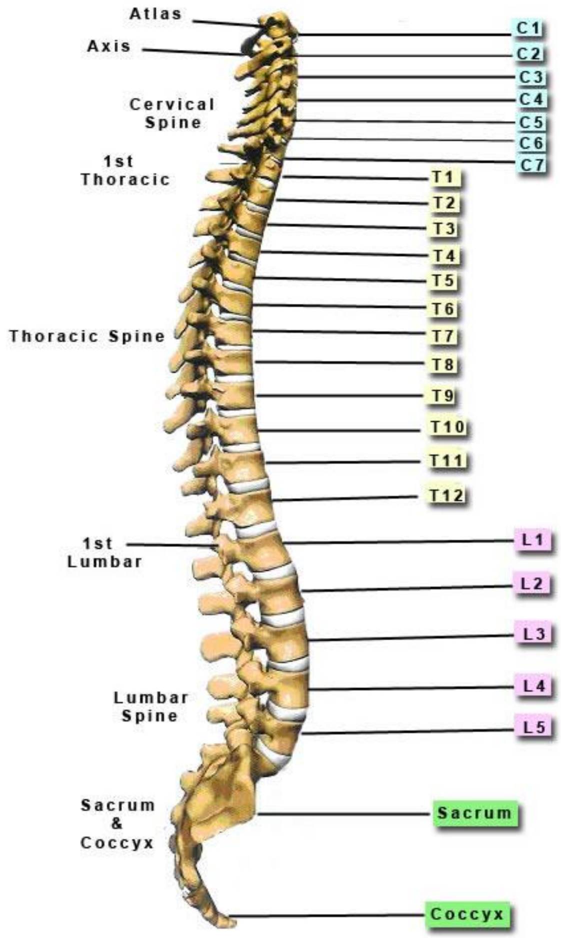


Figure 11 - Sections of the Spine: Cervical [C1-C7], Thoracic [T1-T12], Lumbar [L1-L5], Sacrum, & Coccyx

The topmost part of the spine is the cervical spine, which includes the first seven vertebrae. Starting just below the skull, it has a shape of a lordotic curve, or a backward C-shape. Providing motion to the neck, the cervical spine is significantly more mobile than any other part of the spine and supports the weight of the head [4]. The vertebrae of this section are different in structure as they contain small holes for important arteries to carry blood to the brain. Additionally, there are two specific vertebrae that deal primarily with the rotation of the neck; these are called the atlas and the axis. The atlas is the first vertebra of the spine, and its structure differs from most vertebrae. It has two large arches on the anterior and the posterior of the bone in addition to two prominent masses on the sides. Directly underneath the atlas is the axis, which is secured through the hole of the atlas. This arrangement facilitates the rotation associated with the head and neck [28].

The following section of the spine is the thoracic spine that is shaped like a kyphotic curve, or a C-shape. Containing a total of 12 vertebrae, this fraction of the spine is where the ribs connect to the spine to materialize the back wall of the thorax, or the ribcage area between the neck and the abdomen. With narrow intervertebral discs, the thoracic spine does not have the capability for increased levels of movement and serves mostly as protection for the spinal cord.

The lumbar spine follows the thoracic spine consisting of only five vertebrae. Similar to the cervical spine, the lumbar section is also shaped as a lordotic curve. Located at the base of the back, the individual vertebra are the largest allowing more space for the nerves within the spinal cord. The paramount function of the lumbar spine is to support the torso when stable and in movement. Given the location of this portion of the spine, the lumbar region experiences enormous forces; these forces often exceed the maximum lifting capability of an EMT. As a result, the lumbar spine is most vulnerable for debilitating injuries [28].

2.3.2. Muscular Structure of the Back

Made up of fibrous tissue, muscles provide the driving force behind every movement of the body. Of the three categories of muscle, skeletal muscles are the only type found within the back. The categorical name relates to the fact that these muscles attach to the skeleton via tendons, which are bands of tissue that connect muscle to bone. Although there are over 50 muscles near the spinal cord, the main muscles are the trapezius and the lasstimus dorsi [29]. Figure 12 is a diagram of all the muscles within the back.

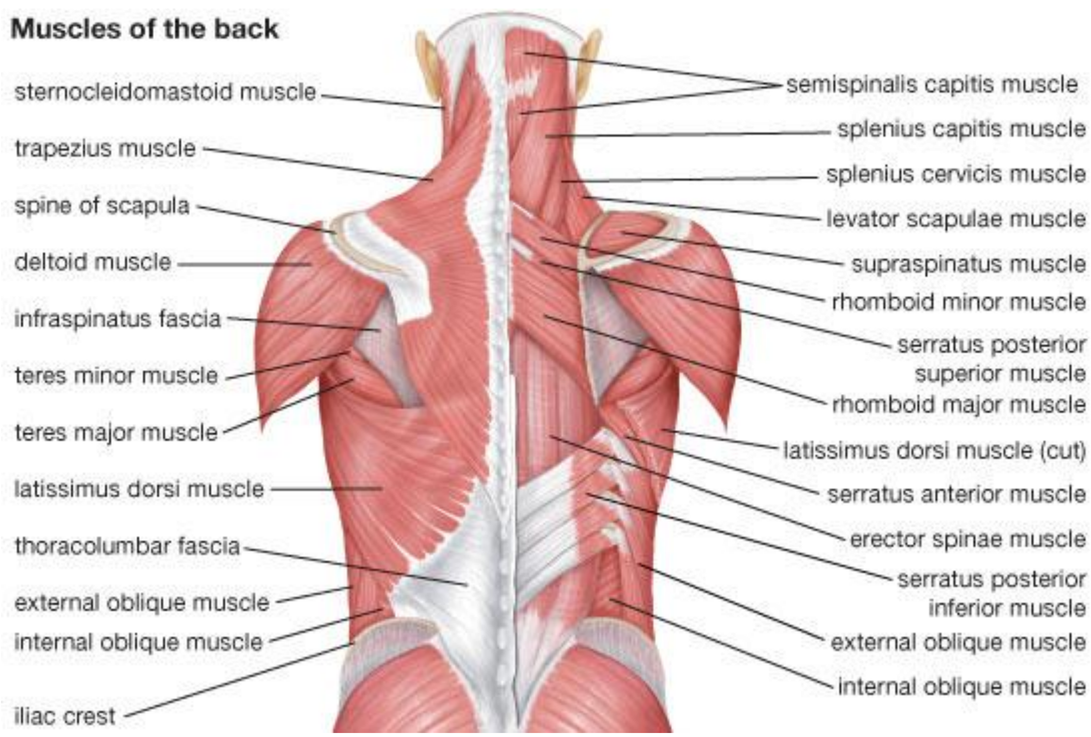


Figure 12 – Diagram of the Muscles within the Back [29]

Muscles located closer to the surface are known as superficial muscles and can easily be seen when making large movements of the body. A superficial muscle in the back, the trapezius muscle, originates at the bottom of the back of the skull and terminates at the bottom of the thoracic spine. Named for its diamond shape, this muscle is responsible for elevating, depressing, rotating, and retracting the scapulae, more commonly known as the shoulder blades. The trapezius participates within the basic roles of neck movement, head support, and arm support [29]. As one can see from Figure 12, the lasstimus dorsi is one of the largest muscles in the body, and it initiates in the middle of the thoracic spine. This muscle extends to the lumbar spine where it fuses with the posterior layer of the lumbar fascia, or the thoracolumbar fascia. This muscle primarily functions in the extension and rotation of the humerus, which is the long bone that runs from the shoulder to the elbow. Controlling various arm movements, the lats, the vernacular name for the muscle, are used vastly during the process of lifting.

2.3.3. Back-Related Injuries

The predominant purpose of the EMS system is to provide immediate, quality emergency care to patients that are in need of medical attention. Many situations that entail EMTs are time sensitive requiring them to move and perform at a rapid pace. Under stressful circumstances, EMTs have to disregard their own safety in order to ensure the safety of the patient. These heroic actions often ensue in back injuries varying in type and severity. Sprains and strains are the most common types of injuries that EMTs procure throughout their tenure. Both localized in lower region of the back, these two categories of injuries differentiate from each other based on the object of the injury. A sprain signifies the tearing or stretching of one or more ligaments, which are the fibrous tissue that connects bones at a joint, near the spine. Forceful, quick movements can cause the ligaments to stretch or tear, because the muscles do not have the capacity to keep the spine within its normal range of motion [40]. At the time of the injury, many have noted that a “pop” or tear can be heard or felt in the spinal region. If that is not the case, sprains can also be detected via the following symptoms: movement induced pain, muscle cramps, and a decreased range of motion [5]. This injury results in acute pain, which is described as sharp or intense. Depending on the seriousness of the injury, inflammation might occur around the sprain to protect the area from further injury. Although inflammation acts as a protection, it also reduces the overall motion of the back and can possibly produce complete immobility. The prognosis for such an injury is contingent on the gravity of the sprain and takes from six to eight weeks to heal; however, extreme back sprains can take several months for a complete recovery. EMTs acquire sprains regularly due to poor lifting strategies and maneuvering heavy patients [40].

Many use the terms sprain and strain interchangeably, but there are in fact distinct differences between the two injuries. Unlike sprains, strains indicate torn or stretched muscle fibers within the back. More commonly referred to as a pulled back, this injury occurs from overloading and overusing muscles along with repetitive twisting and leaning motions. The overexertion of the back muscles causes fatigue generally making muscles weaker and more susceptible to impairment. Similar to those of a sprain, the symptoms of a strain are inflammation and stiffness of the affected area of the back [6]. It can take anywhere from two to eight weeks for the muscle to heal completely. Icing the general area of the inflammation and resting are the only two suggestions for treatment for these two categories of injury [40].

Both sprains and strains can trigger muscle spasms within the lumbar section of the back. Muscle spasms are the unusual and involuntary prolonged contractions of a muscle. Due to the high concentration of nerve endings in the lumbar region, the spasms that occur there are excruciatingly painful, which can induce debilitation for weeks at a time. Despite the fact that they cause significant discomfort, spasms reduce the movement of the back, which lowers the risk of further damage to that area. Doctors advise the patients that experience back spasms to decrease the amount of pressure on the back by either laying down on their side in the fetal position or practicing deep breathing to relax the muscles. In severe cases, chiropractic care may be prescribed for future treatment.

A slightly more severe yet frequent back injury is a disc herniation. The intervertebral discs in the spine generally degenerate with age by losing their elasticity. The jelly-like central region of the disc can rupture through the outer annulus ring or the entire disc can bulge out between the vertebrae; the abnormal rupturing or bulging is what is known as a disc herniation, which can pinch the nerves in the surrounding area of the affected disc [40]. A herniation can occur from activities that range from complete overexertion of the back to general wear and tear over time. Consequently, local pain around the herniated disc and shooting pain in the lower extremities can occur, but some cases might not produce any obvious symptoms. Many medical professionals attempt to treat herniated discs noninvasively through the administration of oral medications and participation in physical therapy. However, if a serious rupture exists, it is necessary to perform a surgical operation [35].

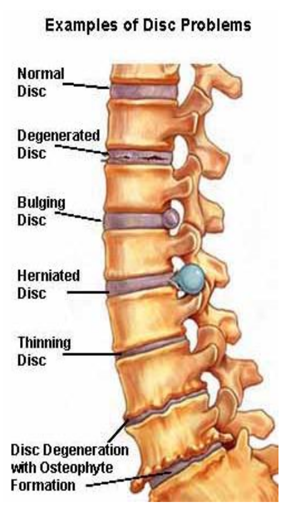


Figure 13 – Diagram of Abnormal Intervertebral Discs [28]

Figure 13 shows the different abnormalities that can occur to the intervertebral discs, including degeneration, bulging, and herniation.

Large compressive forces placed on the spine increase the probability of a single vertebra slipping out of place; this specific condition is known as spondylolisthesis. In the case that a vertebra were to slip forward, the condition is termed anterolisthesis, while the backwards slippage of a vertebra is referred to as retrolisthesis. This injury normally happens to the vertebrae within the lumbar region of the spine and the condition is graded based on the percentage of slip.

Table 6 – Different Grades of Spondylolisthesis and Percentage of Associated Slippage

Grade	Percentage of Slip
I	Up to 25%
II	26% - 50%
III	51% - 75%
IV	76% - 100%
V	Complete disconnection

Table 6 shows the different grades of spondylolisthesis and percentage of slippage associated with each grade. As the grade increases, the patient will experience more pain near the slipped vertebra. For the lower grades of spondylolisthesis, professionals advise periods of resting in order for the affected area to heal and administer oral medications to relieve a percentage of the pain. On the contrary, patients that are prognosed with grades IV and V will most likely need surgery in order to secure the vertebra back into place [9]. Complete recovery can take from a few weeks to several months based on the grade of the condition.

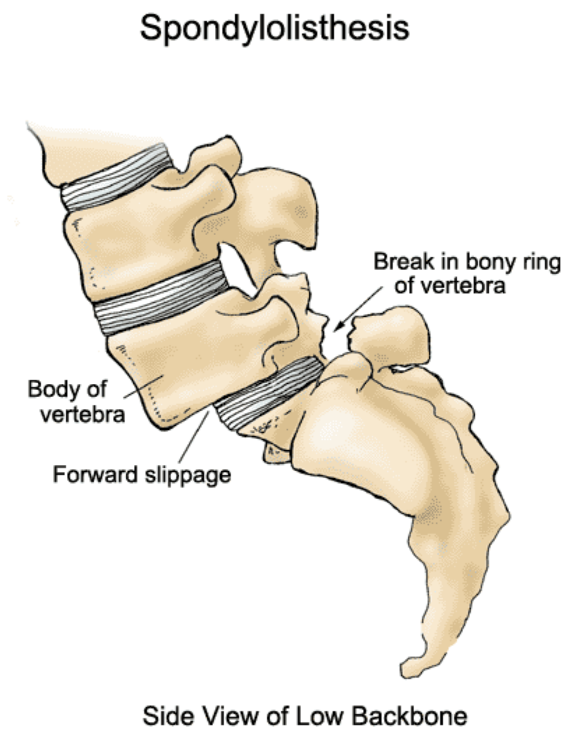


Figure 14 - Diagram of Spondylolisthesis [9]

Figure 15 depicts a diagram of the lower region of the backbone with an example of anterolisthesis, or forward slippage. Despite the fact that there are many types of back injuries, sprains, strains, muscle spasms, and spondylolisthesis are the most common that are inflicted on EMTs due to the exorbitant amounts of force applied to the spinal area.

2.4. Case Studies

Injuries amongst EMTs have become more common as the available workspace decreases and the weight of patients increases. Considering this has not been a substantially noted problem in the past, only few studies have been conducted regarding Emergency Medical Technicians. As a result, within the past few decades, various groups have performed experiments and case studies regarding the injuries that EMTs acquire from strenuous lifting. The motive behind a number of these case studies included the investigation on the stresses and strains placed on the EMS personnel while completing their typical duties. The data collected from these studies show the scope of the problem in its entirety.

2.4.1. Case Study 1 - Ergonomic Evaluation of Ambulatory Cots

In 2004, two German engineers, Karsten Kluth and Helmet Strasser, looked to evaluate the efficiency of ambulatory stretchers, or "roll-in" cots. The team conducted several examinations, each looking to observe the muscular strain that EMS personnel underwent during their routine activities. During these examinations, the team collected information regarding both static and dynamic muscular strain in each of the muscles. Twelve professional ambulatory personnel conducted lifting and transport activities using ambulatory equipment from Ferno, Stryker and Stollenwork, a European manufacturer. Six teams of two carried 78-kilogram dummies, strapped onto the stretchers, to simulate an authentic situation. Throughout the experiment, Kluth and Strasser recorded the weight, design, and the amount of stress the ambulatory cots applied to the personnel as the equipment was maneuvered. An electromyography, or EMG, was used to identify the active muscles while the personnel completed these tasks. Data showed that during the exercise three muscles groups were active:

the M. Flexor Digitorium, which is found in the forearm; the M. Trapeziums pars, which stabilize and abduct the shoulder; and M. Erector Spinae, which is found in the upper back. Using the data collected from the EMG, an analysis was completed to determine percentages related to both the dynamic and static components of the muscle activity. This analysis allowed the muscular activity to be standardized in order to provide the best representation of the data and eliminate any outliers.

In one of the exercises, EMS personnel transported the cots, loaded with the dummy, up and down the stairs twice. While moving the stretcher down the stairs, the study showed that there was a prolonged static strain in all three of the major muscles groups. Dynamic strain was marginal in each case, indicating that EMTs were holding the weight in one position for a long time. Table 7 shows the standardized electromyographic activity values (sEA) from the EMG tests.

Table 7 – Results from EMG Tests

	Forearm (Flexor Digitorium)		**Shoulder** (Trapezius descendens)		**Upper Back** (Erector Spinae)	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Styker	47	5	43	4	34	5
Ferno	46	5	43	5	29	5
Stollenwerk	51	6	42	5	31	4

In another trial, EMS personnel conducted the same experiment at a faster speed. Table 8 displays the sEA values for this experiment below.

Table 8 - Standardized Electromyographic Activity Values

	Forearm (Flexor Digitorium)		**Shoulder** (Trapezius descendens)		**Upper Back** (Erector Spinae)	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Styker	52	6	48	5	42	7
Ferno	52	6	45	6	40	6
Stollenwerk	53	6	48	5	45	7

Table 7 above contains the percentages of muscle contraction involving the three most active muscles mentioned above. According to this study, the muscles in the forearm and wrist area displayed the highest percentage of static muscular contractions. Muscles in the shoulder and upper back were also statically active during these activities. In conclusion, the EMTs did not fully exert their muscles while completing these tasks, but prolonged, repeated exertions of this magnitude can causes injuries to these parts of the body [21].

2.4.2. Case Study 2 - Designing Ergonomic Interventions: Transportation on Stairs

A case study published in 2006 was organized to evaluate four ergonomic interventions designed to decrease the amount of pressure on the lower back of the EMT. These interventions focused on modifying the equipment currently used for lifting and maneuvering patients. The first intervention included altering the Najo backboard with a foot strap designed by Ferno Washington. Originally, the backboard weighed 7.7 kilograms, but the additive strap near the ankle increased the total weight to 8.3 kilograms. These modifications were made to reduce the patient's lateral movement while positioned flat on the board. The second intervention was the 6250 Stair Chair designed by Stryker. Weighing approximately 10.5 kilograms, the chair was equipped with an extendable handle located at the top. The new handle configuration was implemented to give the follower, the EMT closest to the patient's head, better control throughout the descent down the stairs.

Another intervention included within this study was a backboard wheeler, which is a modified backboard with wheels welded to its base and had a total weight of 19.5 kilograms. The wheels were added to reduce the amount of lifting EMTs are required to do on a daily basis. The last intervention evaluated was the full-length ambulatory stretcher with track-like treads at its base. Designed to allow the stretcher to slide down the stairs, these treads facilitated the process of transporting the patients down the stairs using a stretcher. Figure 16 below shows photographs of the backboard foot strap in part a, the backboard wheeler in part b, the modified stretcher in part c, and the stair chair in part d [23].

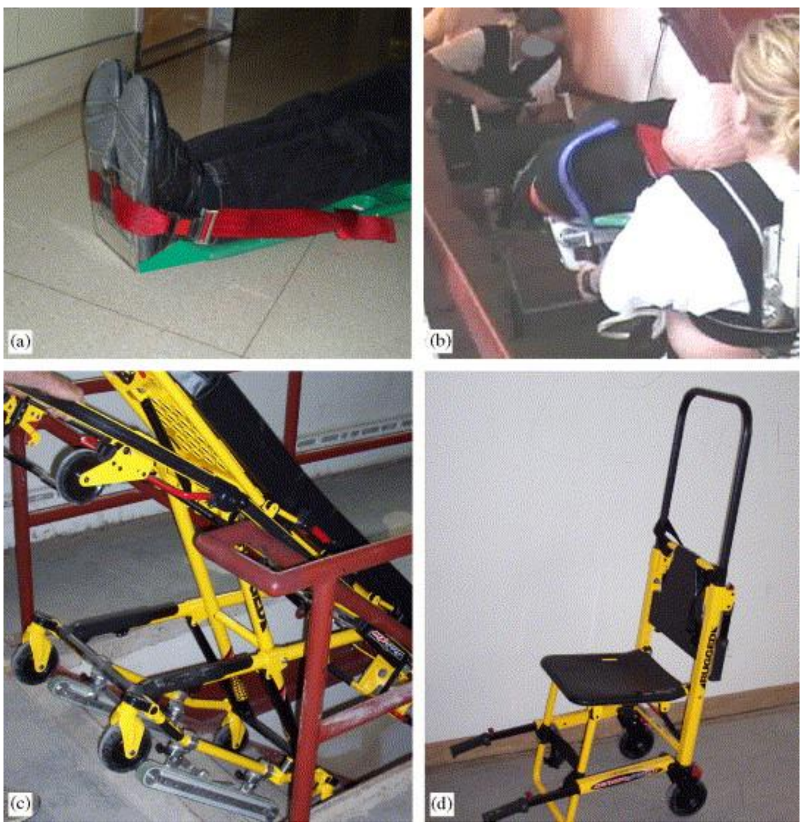


Figure 15 – Ergonomic Interventions [23]

To conduct the test, 11 two-man teams transported a 75-kilogram dummy down a controlled flight of stairs. EMGs were used to monitor eight different trunk muscles within back for observation. The results demonstrated that three of the four interventions proved to be effective. Both backboard modifications demonstrated a reduction in muscle activity of multiple muscle groups during the exercise. Table 4 shows list of acronyms used in the diagrams containing the results from these experiments.

Table 9 - List of Acronyms Used in Figure 16 and 17

ERSL and ERSR-Erector Spinar Muscles
LATL and LATR-Right and Left Latissimus Dorsi
RABL and RABR-Rectus Abdominus
EXOL and EXOR-External Oblique

Figures 16 and 17 display the muscle exertion for the modified backboard and the stretcher with treads.

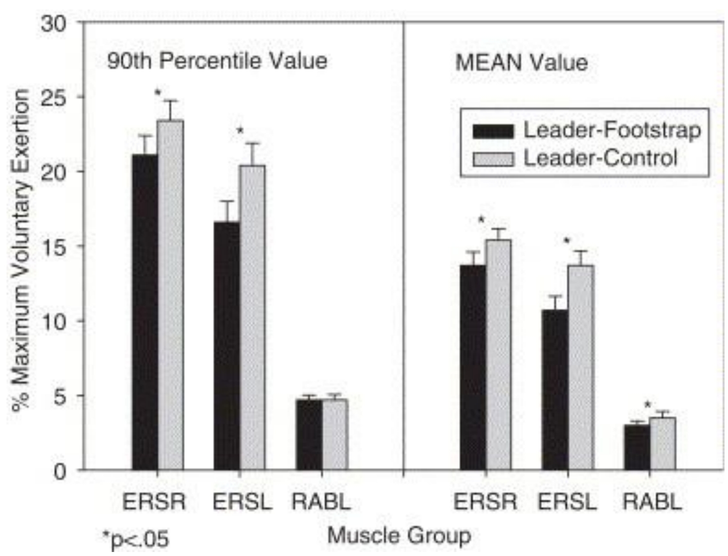


Figure 16 - Maximum Muscle Exertion from Backboard with Foot Strap [23]

The collection of data related to the backboard with the foot strap showed that exertion activity involving the rectus abdominal muscles (RABL) and the erector spinae (ERSR and ERSL) decreased after the intervention occurred; this can be seen above in Figure 16. Similar results were seen in the data collected from the testing using the new tread design for the stretcher, which can be seen below in Figure 17.

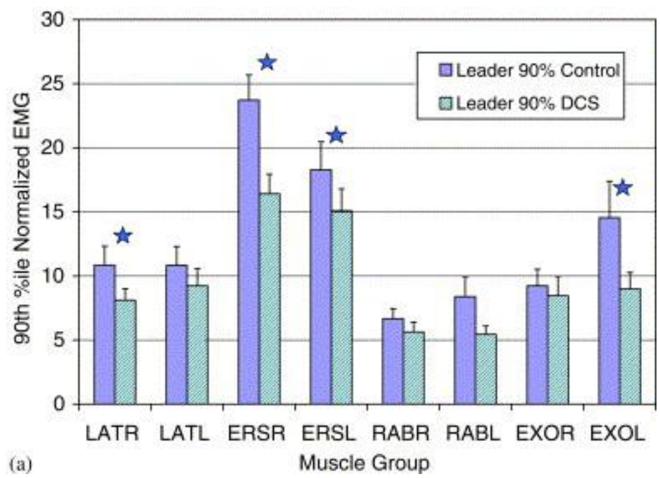


Figure 17 - Muscle Exertions of the Tread Stretcher [23]

In conclusion, the addition of the new components to the existing equipment successfully reduced the overall muscular exertion necessary to perform the tasks required of EMTs [23].

2.4.3. Case Study 3

In 2007, researchers examined the interior of the ambulance to determine the factors that contributed to the overall discomfort EMTs experience while on the job. The study involved an eight-hour observation period of 35 different EMS personnel. Throughout their shifts, the back postures of the EMTs were recorded and analyzed in depth. The tabulation of the results showed that EMS workers spent 53% of their shift in a position involving undesired and uncomfortable back posture [18]. Figure 18 displays the graph of all the collected data from the observational study.

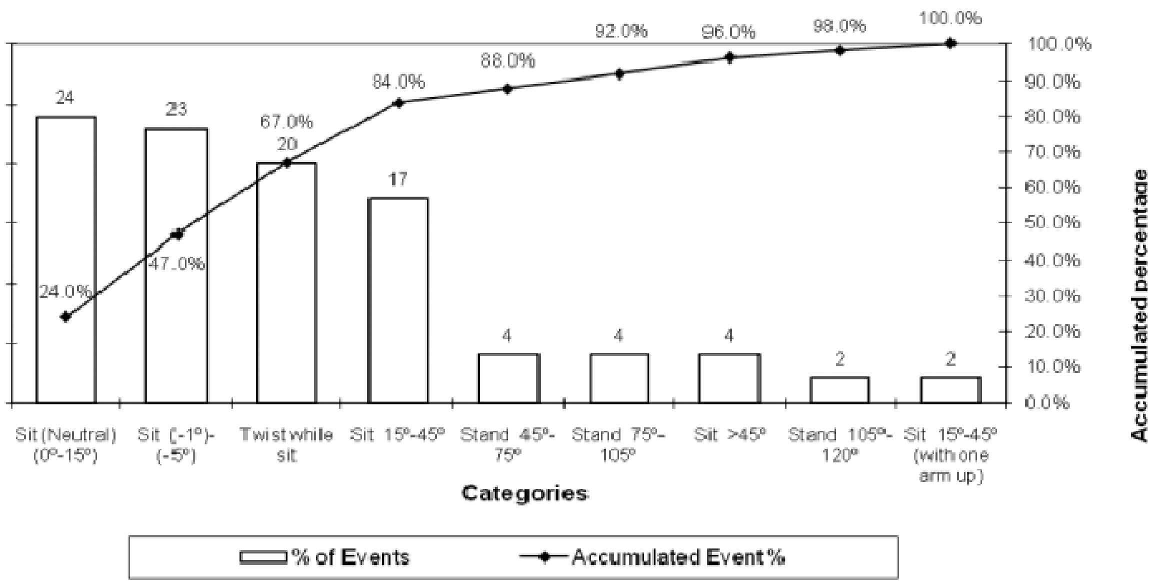


Figure 18 - Recorded Postures of EMTs while Inside the Ambulance [18]

After the observational study, a survey was distributed to assess how often EMTs wore seatbelts. Out of all the participants, 97% noted that they did not use seatbelts while performing clinical procedures, while 40% never wore seatbelts at all while on the job [18]. Although the patient compartment of the ambulance is the main workplace for most EMS personnel, it occasionally provides a somewhat hazardous environment and seatbelts should be worn to ensure safety.

2.4.4. Case Study 4

The perceived risk associated with the work of EMTs lies predominantly in lifting patients of varying weight to a stretcher. Occasionally applied with patient loads of 300 pounds or more, the stretchers have to be maneuvered in order to secure it within the ambulance properly. The original design of stretchers placed a large amount of the strain on the back inflicting many injuries on EMTs. Recent studies indicate that mechanical lift devices reduce the risk of obtaining a back injury on the job.

In 2006, electrically powered stretchers manufactured by Stryker were placed into service in every ambulance within Austin Travis County in Texas. The preliminary hypothesis that the Austin Travis County EMS formulated was that the number of injuries would decrease, because the powered stretcher utilizes a hydraulic system to raise and lower a loaded stretcher. To compare the number of injuries before the institution of the new stretcher to the number after, data were collected and it showed that 1275 injuries were reported before the study. Instituting the new hydraulically powered design reduced the number of reported injuries to only 203. Table 10 shows the numbers regarding the injuries acquired before and after the study was conducted. The table also includes numbers related to different types of injuries, such as sprains and back injuries.

Table 10 - Number of Injuries Pre-Intervention and Post Intervention [37]

Table 1
Overall and subcategory incidence rates and rate ratios for occupational injury.

Population	Interval	Person-years	Total injuries	Injury rate/100 FTE	Injury rate ratio
Total population		2793	1478	52.92	
All injuries	Pre	2087.14	1275	61.09	0.47 (0.41–0.55)
	Post	705.83	203	28.76	
Strain/sprain	Pre	2087.14	471	22.57	0.43 (0.33–0.55)
	Post	705.83	68	9.63	
Back, neck and knees	Pre	2087.14	379	18.16	0.49 (0.38–0.64)
	Post	705.83	63	8.93	
Back injury only	Pre	2087.14	264	12.65	0.40 (0.28–0.57)
	Post	705.83	36	5.10	
Stretcher injury only	Pre	2087.14	137	6.56	0.30 (0.17–0.52)
	Post	705.83	14	1.98	

The results show a significant decrease in injury rate occurred although more systematic studies of occupational interventions are needed [37].

2.4.5. Case Study 5

In 2000, the National Registry of Emergency Medical Technician collected information regarding injuries amongst emergency responders. According to the National Electronic Injury Surveillance System or NEISS, 21,900 EMS personnel were injured and treated while on the job.

Table 11 - Average Annual Number and Rate of Emergency Responder Injuries Treated in 2000 [34]

	Annual average workforce				
Responder group	Data source	Units	Labor estimate	Number of injuries[a] (±95% CI)	Rate per 100 FTE or workers (±95% CI)
EMS					
All EMS	Cert. EMTs	Count[b]	721,400	21,900 (±9,000)	3.0 (±0.9)
All EMS	OES/NHTSA	Count[c]	443,400	21,900 (±9,000)	4.9 (±1.4)
Fire					
Career firefighters	CPS	FTE[d]	355,800	26,500 (±18,100)	7.4 (±3.6)
Career firefighters	CPS	Count[e]	286,700	26,500 (±18,100)	9.2 (±4.5)
Career firefighters	OES	Count[f]	323,700	26,500 (±18,100)	8.2 (±4.0)[g]
Career firefighters	NFPA	Count[i]	290,200	26,500 (±18,100)	9.1 (±4.4)[g]
Volunteer firefighters	NFPA	Count[i]	781,000	10,500 (±6,100)	1.3 (±0.6)[g]
All firefighters	NFPA	Count[i]	1,071,200	37,300 (±18,400)[h]	3.5 (±1.2)[g]
Law Enforcement					
Police/sheriff/transit	CPS	FTE[j]	763,900	64,800 (±25,700)	8.5 (±2.4)
Police/sheriff/transit	CPS	Count[k]	739,000	64,800 (±25,700)	8.8 (±2.5)
Police/sheriff/transit	OES	Count[l]	705,500	64,800 (±25,700)	9.2 (±2.6)[g]

Table 11 above shows the number of injuries amongst EMS personnel along with other types of emergency responders, such as firefighters and police officers. The injuries reported were ranging from mild to moderate severity.

Another part of the case study included an investigation of the specific types of injuries that normally transpire. Out of all the injuries, 41% were from a sprain or strain, while 13% came from a contusion or an abrasion. Of the sprains and strains that EMTs were subjected to, 49% occurred with the lower trunk and 8% results from transportation incidents involving motorized road vehicles. Additionally, the conductors of the study separated the injuries by body part to determine which was injured most frequently. For EMTs and paramedics, the back and neck area was injured 29% of the time.

Table 12 - EMT Related Injuries by Age, Sex, Diagnosis, and Body Part [34]

	EMS (n = 21,900)			Fire (n = 37,300)			Law enforcement (n = 64,800)		
Characteristic	**Number**	**(±95% CI)**	**%**	**Number**	**(±95% CI)**	**%**	**Number**	**(±95% CI)**	**%**
Age group (years)									
<25	5,400	(±2,600)	25	4,800	(±3,900)	13	3,000	(±1,200)	5
25–34	9,400	(±4,500)	43	13,400	(±6,400)	36	34,200	(±14,100)	53
35–44	5,000	(±2,400)	23	12,500	(±7,200)	34	18,100	(±7,800)	28
>44	2,200	(±1,200)	10	6,600	(±4,400)	18	9,500	(±4,600)	15
Sex									
Female	7,000	(±3,200)	32	1,700	(±1,200)	5	8,600	(±3,500)	13
Male	14,900	(±6,400)	68	35,500	(±17,700)	95	56,100	(±23,000)	87
Diagnosis									
Sprain/strain	9,000	(±3,900)	41	12,100	(±6,800)	33	21,900	(±9,300)	34
Contusions/abrasions	2,800	(±1,600)	13	4,800	(±2,700)	13	17,300	(±7,500)	27
Laceration	1,200	(±900)	6	4,100	(±2,000)	11	4,800	(±2,300)	8
Fracture/dislocation	—[a]		—	1,700	(±1,000)	4	2,800	(±1,600)	4
Puncture	1,700	(±1,200)	8	—		—	2,700	(±1,300)	4
Burns	—		—	2,100	(±1,900)	6	—		—
Anoxia	—		—	1,700	(±1,000)	5	1,100	(±1,300)	2
Dermatitis/conjunctivitis	—		—	1,600	(±4,500)	4	—		—
Other[b]	6,300	(±3,400)	29	8,500	(±6,200)	23	12,900	(±7,300)	20
Body part									
Arm	3,400	(±1,700)	16	6,500	(±4,600)	18	11,100	(±4,200)	17
Hand	3,400	(±2,000)	16	5,000	(±2,900)	13	12,200	(±4,700)	19
Leg & foot	3,800	(±1,900)	17	8,900	(±4,400)	24	16,600	(±7,100)	26
Neck & back	6,400	(±3,200)	29	6,800	(±4,500)	18	11,100	(±5,500)	17
Head	—		—	—		—	2,400	(±1,200)	4
Face	1,400	(±600)	6	4,100	(±2,200)	11	5,200	(±2,300)	8
All parts of body	—		—	4,700	(±3,800)	13	4,600	(±3,600)	7
Other/not stated	—		—	—		—	1,600	(±1,400)	2

Table 12 shows the types of injuries emergency responders acquire along with where the injuries are located. The pie chart below offers a better depiction of the distribution of the types of injuries that affect EMTs on the job using the data from Table 12.

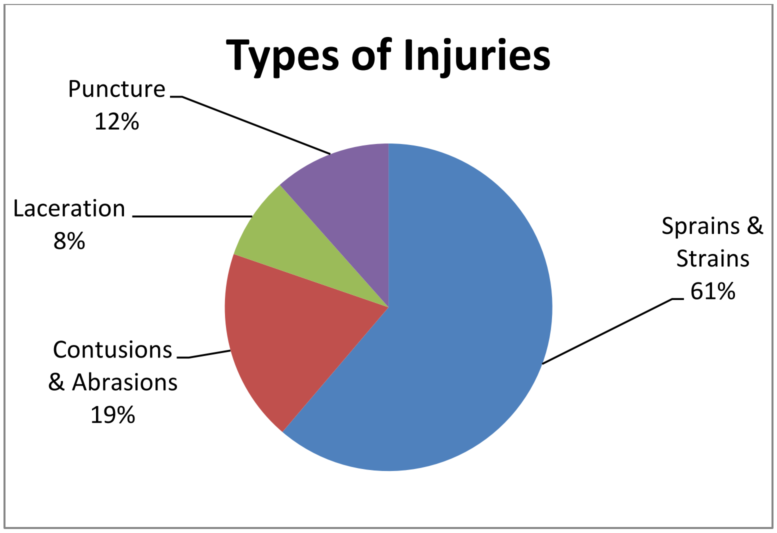


Figure 19 - Types of Injuries EMTs Acquire on the Job

The end portion of this case study included an investigation of the body parts that were often injured in a day's work. Incorporating the data from Table 12, the pie chart below was developed in order to signify what area of the body that EMTs injure the most [34].

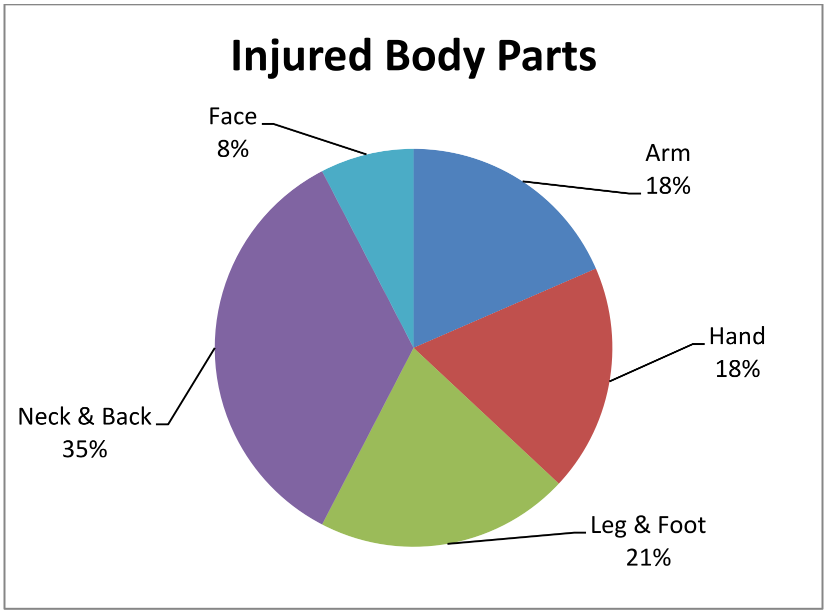


Figure 20 - Most Frequently Injured Body Parts

By briefly looking at both pie charts above, one can easily ascertain that the most frequent injury that EMTs acquire is a sprain or a strain within the neck and back region. These statistics demonstrate the need for engineering practices to be implemented into the EMS system to reduce the number of injuries in total.

2.4.6. Case Study 6

Emergency Medical Technicians were asked to lift patients in a variety of situations that can cause serious damage to various parts of the body, such as the trunk and back region. Though EMTs must perform any number of lifting and transporting tasks, three main lifting activities are essential to an EMT or paramedic to provide proper care. These are: lifting a patient from a bed or floor to a transporting device, transporting victims down the stairs via a stair chair or backboard, and sliding a patient from an ambulatory stretcher to a hospital gurney.

Throughout each of these activities, EMS personnel usually work in teams of two or three if possible to transport patients to safety. Removing a patient from a bed or floor requires two personnel working in complementary roles to lift and slide the patient safely and comfortably onto the transit device. One worker, “the puller,” will stand behind a transportation device and reach across it to pull a patient from the bed. The other worker will assist their partner by assuming the role as “the pusher,” which can be seen below in Figure 21 [24].

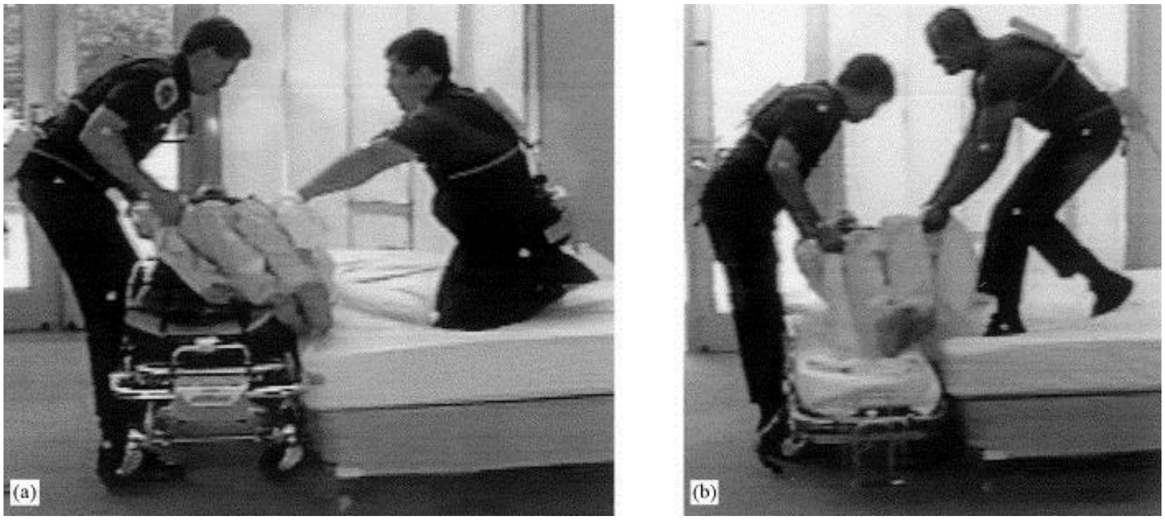


Figure 21 - Two EMTs Performing a Transfer [24]

While standing or kneeling on the bed, the EMT has to lift the patient by the bed sheets and push them towards their partner. Reducing the total friction, this allows for a much easier and efficient transport; however, both personnel during this method of transport are forced to bend forward to reach the patient and exert the necessary force to move the patient from the bed to the transportation device. This puts a significant amount of stress on the lower back and trunk of many personnel.

Transporting the victim down the stairs is also an important duty of an EMT or paramedic. This maneuver requires at least two individuals to lift simultaneously in order to transport the patient down the stairs. One paramedic will take the leader role and hold the patient at the base of the transportation device, whether it is a stair chair or backboard. The other paramedic will perform the follower role, where they must hold the patient from the top handles of the device and prevent it from falling on top of their partner. As a team, the EMTs carry a portion of the force exerted by the patient and lifting equipment down the stairs [24]. This method of transport is commonly conducted with the use of a stair chair and can very effective in emergency situations; however, injuries amongst EMTs have become more commonly associated with the use of a stair chair due to the fact that the majority of people required emergency care is obese. This places a tremendous amount of additive strain to the spine, which increases the risk of injury entirely.

A number of case studies have looked to investigate and place numerical values on the stresses and strains felt by EMS personnel as they complete their duties. Engineers looking to develop ergonomically sound equipment have observed the angular twists and bends in the physique of emergency staff and calculated the physical forces they are asked to carry. In 2005, an evaluation was conducted to assess the biomechanics of each subject while carrying different pieces of equipment down the stairs, including the backboard, stair chair, and stretcher. The leaders of this study asked 20 paramedics to transport a 48-kilogram dummy down several flights of stairs using a stair chair, to slide the dummy from a stretcher to a hospital gurney, and to lift the dummy from the bed to stretcher. A Lumbar Motion Monitor (LMM), a device that analyzes the specification posture of the lumbar and thoracic regions of the spine, was used to record the movements and motions of each paramedic involved in the study.

Figure 22 - Lumbar Motion Monitor

Figure 22 depicts the LMM device that was used throughout this case study. With the assistance of the LMM, the engineers collecting the data could calculate the degree of the angles at which each worker was bending their back in order to life the necessary weight. The force exerted by the equipment and dummy was calculated as well. During the bed to stretcher transfer, the paramedic in the puller role applied 268 Newtons of force in order to pull the 48-kilogram dummy across the bed and into the lifting device. The force was exerted while the paramedic was in the stooped position as his trunk was positioned at a 54^o angle. The assisting partner reduced the friction from the pull by lifting the bed sheets and pushing the patient towards the puller. The partner in this situation only had 49^o of spinal flexion according to the LMM. This type of flexion increases the torque applied on the back during the lift, thus increasing the strain.

As the paramedics transported the dummy down the stairs using the stair chair, the total system exerted a force of 555 N, or Newtons, on the paramedics. The study showed that the distribution of the load was unequal between the two EMTs since the leader carried 38% of the force and the follower carried the other 62% of the force. At the top of the stairs, the leader bends approximately 34^o forward to initiate the carry. The follower begins the next portion of the carry as the stair chair is moved down the stairs [24]. Presently, stair chairs have been equipped with treads at their bases to decrease the amount of weight paramedics have to carry. With these treads, paramedics can slide the patient down the stairs and turn the chair as needed for the next descent. This heavily reduces the weight EMS personnel have to carry on a daily basis. Figure 23 shows the various angles the body is positioned throughout the descent of the stairs using a stair chair.

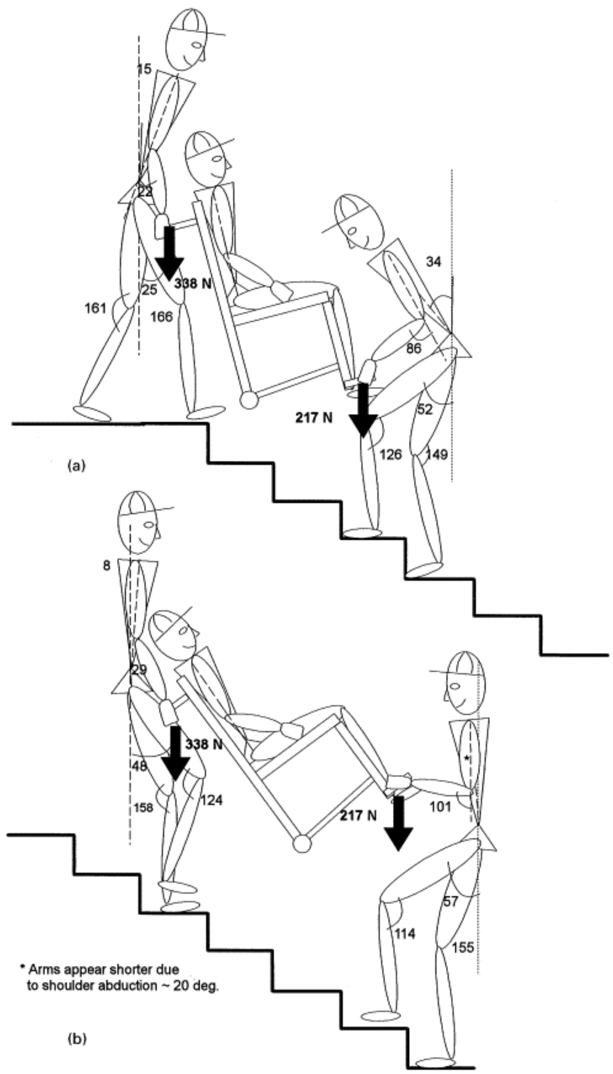


Figure 23 - Forces Placed on Different Parts of the Body while Lifting [24]

The two parts of this figure, A and B, demonstrate the effect of angling the back forward 34 degrees on all of the other angles associated with other body parts. By keeping the back in the upright position, less strain will be placed on the back, which will reduce the number of back injuries among EMTs.

2.5. Lifting and Safety Procedures

A large portion of the injuries that Emergency Medical Technicians acquire results from lifting a heavy piece of equipment. Exposed to large forces in the posterior region of the body, EMTs have to be cautious in terms of the technique used to maneuver patients. The reason for this is that one small adjustment in movement can result in a debilitating injury causing EMTs to miss several days of work. As a precautionary step, several guidelines and methods should be followed to ensure one's safety.

2.5.1. Lifting and Maneuvering Techniques

During their training, EMTs are taught specific lifting techniques in order to transport patients safely to the appropriate destination. Appendix A shows a complete outline of the EMS curriculum associated with lifting and carrying patients. EMTs are first advised to consider the total weight of the system that is being lifted along with the weight of the patient before lifting actually occurs. If the total weight is greater than an EMT is capable of lifting, they should refrain from overexerting themselves by requesting additional help. For most pieces of equipment, a minimum of two people should be lifting it at once in order to distribute the load equally. In the situation that more EMTs are required to transport a patient, an even number of EMTs should be involved to maintain relative balance during the lift [27].

EMTs should be in the appropriate starting position to perform an efficient lift. Planting their feet about shoulder width apart, EMTs should be able to obtain a sturdy base to increase their overall balance. Instead of bending at the waist, it is accurate to bend at the knee to grasp the loaded piece of equipment [26]. Once in the squatted position, EMTs should grasp the stretcher, stair chair, or backboard with their hands about 10 inches apart and their palms facing upward to incorporate the maximum force from the hands and arms. Keeping the back completely straight without twisting, EMTs should solely lift using their legs, which contain more powerful muscles. During exertion, it is important to exhale deeply, because holding one's breath and/or grunting causes additional strain that can be easily avoided; exhaling also has shown to add power during a lift [11]. EMTs should attempt to keep their arms and the patient as close to their body as possible to create appropriate leverage and to maintain their balance [26].

Figure 24 - Demonstration of Improper and Proper Lifting Techniques [26]

Figure 24 depicts two EMTs preparing to lift a stretcher. The one of the left is bending via the waist, which can result in a severe injury, while the one of the right is demonstrating the proper techniques that should be utilized in the field.

Guidelines have been made for carrying patients as well. Whenever possible, patients should be placed on devices that can roll so that EMTs do not experience as much strain on the body in one day of work. This also minimizes the total distance needed to carry the patients. Simple instructions, like flexing at the hips and refraining from hyperextension of the back, save several EMTs each year from injuries related to lifting. When EMTs have to carry patients down flights of stairs, they are required to carry the patient so that they are traveling feet first. For the safety of the EMT, a stair chair should be used if the patient's condition allows it. If the piece of equipment is absent, a sturdy kitchen chair can be used as a replacement if need be [26].

2.5.2. Types of Lifts

Emergency Medical Technicians learn how to lift patients using different methods given the circumstances. The basic lift EMTs use is the power lift, or the direct ground lift. For this lift, two to three EMTs line up on the same side of the patient. While kneeling on one knee, the EMT near the patient's head places one arm under his or her shoulders to cradle their head and one arm under the patient's lower back. The second EMT places their arm directly below the first EMTs arm on the small of the patient's back and the other underneath the knees of the patient. If a third EMT is necessary, they slide both arms under the patient's waist. Figure 25 shows two EMTs performing a direct ground lift below.

Figure 25 - Direct Ground Lift [26]

Subsequently, the EMTs lift the patient to their knee level and stand up straight while rolling the patient in towards their chests. A similar type of lift is known as the extremity lift. To perform this lift, an EMT kneels behind the patient's head and reaches under their arms to grasp their wrists. To perform this lift successfully, another EMT is needed to hold the lower region of the patient. Figure 26 demonstrates what an extremity lift looks like [26].

Figure 26 - Extremity Lift [26]

The types of lifts mentioned previously were nonemergency lifts, which signifies the patient was not in grave danger when the EMTs arrived. Occasionally, there are situations that

EMTs have to retrieve patients extremely quickly so further harm is not done to them. Within their training, EMTs learn a series of emergency moves in the case when a “life over limb” decision is necessary. The first emergency move is the clothing drag technique, which is when the EMT holds the collar of the patient’s shirt and pulls him or her to safety. Figure 27 shows an EMT using the clothing drag technique.

Figure 27 - Clothing Drag[26]

In the figure, the EMT is required to lean forward during this lift in order to generate enough momentum to pull the incapacitated victim to safety. Another emergency move is called the blanket drag technique. To perform this procedure, an EMT places a blanket alongside the long axis of the patient’s body leaving about a foot of material at the head. The patient is then log rolled onto the blanket where he or she is wrapped entirely for protection. Gathering up the extra material of the blanket, the EMT pulls the blanket with the patient inside to a safe location. Figure 28 below shows an EMT preparing the patient in a blanket so that she can perform the proper technique.

Figure 28 - Blanket Drag Technique [26]

The last type of emergency move EMTs use is the arm drag technique. This technique is similar to the extremity lift, but it can be performed with only one EMT. By grabbing the patient's wrists from under their arms, the EMT pulls the patient out of the dangerous area. Figure 29 depicts an EMT performing the arm drag technique.

Figure 29 - Arm Drag Technique [26]

Based on the nature of these lifts, the majority of EMTs should be able to position their back in an appropriate manner so that they can avoid injuries. However, as the situations that require EMTs become more severe, the responders normally disregard using proper body mechanics so that they can bring the victims to safety as quick as possible. As a result, EMTs could potentially curve their backs during the maneuver, escalating the possibility of obtaining a harmful injury.

2.5.3. Injury Prevention

Once an EMT injures their back, they are three to five times more likely to reinjure it. Considering that most EMS systems do not have a physical fitness requirement, most candidates interested in becoming EMTs do not know their maximum lifting limit, which could result in various problems since they are unable to maneuver heavy loads. Physical fitness testing would demonstrate which candidates are able to fulfill the duties of an EMT based on the results. Although this would be helpful, the integration of a test would limit the number of EMTs if the candidates had to meet a certain health standard to work as an EMT legally; also, this would isolate those who are not as physically fit from becoming an EMT, which is undesirable since EMTs are needed around the world. To eradicate the possibility of segregation within the emergency health care field, EMS systems should institute programs obliging EMTs to exercise daily so that they can increase their strength and agility. Through the institution of a program like this one, all of the EMTs would be healthier and less likely to become injured while on the job [11].

CHAPTER 3. IMPROVING SAFETY FOR EMS PERSONNEL

3. Introduction

The project goal that we formulated during the first term of the project was to enhance the overall safety of EMS personnel by reducing the number of injuries that occur within the field. Based off the project statement, our original idea was to modify the stair chair to lessen the amount of stress applied to EMTs back. To receive input from EMTs about our project, we had the opportunity to visit UMASS Memorial Hospital's Ambulance Headquarters located in Worcester, Massachusetts. This visit allowed us to ask the paramedics various questions regarding the equipment and safety precautions used both inside and outside the ambulance. At the site, we were able to take pictures of the stretchers, stair chairs, and the interior of the ambulance to stimulate our minds to create the best product possible that will achieve our overall goal. This chapter contains the methodology we followed throughout the duration of this year in addition to the final product of the project.

3.1. Visit to UMASS

To get a better scope of the problem, we were fortunate enough to meet with the UMASS Memorial EMS personnel at the Worcester depot to interview several of their paramedics. Through these interviews, we hoped to learn the types of injuries these workers are subject to on a day-to-day basis. Another objective of our interview was to determine how paramedics felt about their working environment and the curriculum they were required to learn before being hired. Using the information the group received from the EMTs would help to devise a possible and realistic solution. Below are the interview questions we asked EMS during our stay at the depot.

Table 13 - Interview Questions for EMS Personnel

Question
1. Do you have an injury awareness program instituted into the EMS system?
2. When treating the patients, are you normally standing or sitting?
3. What are the types of injuries EMTs typical sustain? a. How many of these injuries occur? b. How often do they occur? c. Are back injuries very prevalent?
4. How often are restraints used while in the patient compartment? a. Are they readily available? b. What types are available? c. Are they used while attending to the patient?
5. Is there a protocol for the way injuries are treated amongst EMT workers?
6. What is incorporated within EMT training?
7. Do you experience a considerable amount of involuntary movement? 8. How many EMTs/paramedics are in the ambulance at any given time?

Overall, the group gained valuable firsthand information during this enlightening experience regarding the injuries that EMS personnel endure while in the field. The injuries that they acquired affected the following body parts: the knees, wrists, elbows, and most commonly, the spine and neck. EMS personnel elaborated on how these injuries transpire, and most signified that maneuvering patients of varying weight in awkward and dangerous positions cause the most injuries. When space is limited, they have to twist their necks and torso in order to move the patient to a safe area. Repeating this motion places a large amount of strain on the body causing them to be more prone to injuries. These injuries also occur from the consistent lifting EMS personnel perform on a daily basis. Depending on the situation, paramedics and technicians lift the patient from their current position to a piece of ambulatory equipment in order to move them effectively. Constant lifting puts a significant amount of force on the lower back, which could result in multiple back injuries in one's career as an EMT if one does not take the necessary precautions.

Another piece of information we wanted to ascertain through interviewing EMTs was about their perception of the lifting equipment used while on duty. Several of the individuals expressed a discomfort using the stair chair given the danger associated with transporting patients down sets of stairs. Figure 30 depicts an earlier version of the stair chair that UMASS EMS personnel still use today.

Figure 30 – Earlier Version of the Stair Chair

Since this version of the stair chair has a low weight capacity, UMASS EMS have employed the use of a newer version made of stronger materials and includes a tread system which enables personnel to slide patients down the stairs.

Figure 31 – New Version of the Stair Chair Used at UMASS Memorial

Figure 31 is a picture of the sturdier version of the stair chair used at UMASS. Even with the added tread systems, EMTs remained uncomfortable using them in certain situations. Most stated that problems often arose when a larger patient needed to be moved down the stairs. The current stair chair could not accommodate the weight of obese patients, which puts additional physical stress on the paramedics. In regards to the question the group proposed about fitness, the paramedics did not believe that was an issue for them while performing daily activities; they mentioned that including a physical fitness program would not improve their safety, even though they though it was a feasible idea. From all of the input from the EMTs at UMASS Memorial, we wanted to generate a design for a new piece of equipment that could resolve some of the problems that EMTs encounter without taking away from the effectiveness of the current equipment used.

3.1.1. Survey

Visiting UMASS provided us with insight on where improvements are necessary to ensure better safety for EMTs while on the job. Having only conversed with a few at the UMASS headquarters, we decided to develop a survey to collect EMS personnel's views on injuries, safety, and training. After making a few drafts, we were finally ready to distribute it among various groups of EMS. A complete version of the survey can be seen in Appendix B. Fortunately, the group obtained a few contacts in addition to our external mentor Stephen Haynes, the EMS Chief at UMASS. The first contact we received was Ricci Hall, who is a registered nurse, firefighter, member of the Central Massachusetts EMS region board, an EMT instructor and EMT certification test proctor. The other contact was Sheri Bemis, who is the Oxford Fire Chief and a member of the Central Massachusetts EMS region board. With their long list of credentials and experience, we thought it would be worth attempting to contact them to see if they would take the time to fill out our brief survey. Eventually, Sheri responded to our email and distributed the electronic version of the survey to a small group. Overall, the sample size was only 12 EMTs/paramedics, which is lower than we had anticipated. Despite the low sample size, we analyzed the available responses to determine if there was a consensus.

Of the 12 respondents, 75% noted that they acquired an injury while maneuvering a piece of equipment while in the field. Based on the data found in numerous case studies, this statistic is not very surprising given the dynamic environment associated with being an EMT. Of the nine EMTs that were injured, the majority mentioned that they were using a stretcher or a stair chair when the injury occurred. The other question related to injuries queried which body part was most frequently injured. Similar to the data included in Chapter 2, the majority, more specifically seven out of the nine that answered that particular question, indicated that they injured their backs the most frequently. From these questions of the survey, we wanted to focus our project on reducing back injuries of EMTs through the alteration of a piece of equipment to make it more ergonomically sound.

An additional question on the survey emphasized the effectiveness of training for EMTs and if they felt prepared for the physical demands of the job. With full participation on this question, two-thirds revealed that they felt unprepared for the work in the field. There was also an open-ended question at the end of the survey requesting the participants note any changes they would make to the EMS system to increase the overall safety of EMTs. Out of the 12, only two signified that they did not have changes with an additional respondent noting that avoiding injuries is not possible when overweight patients need to be maneuvered down narrow stairwells. Others mentioned that changes should be made within the ambulance guaranteeing EMT safety while it is in motion. Another stated that more training and education is required on proper lifting and other techniques, while another thought a physical fitness requirement would be useful. From the results of the survey, we collectively noticed a common theme relating to the inefficient amount of training.

As a result, we thought it would be advantageous to enhance the present training program to include more education on proper techniques and strategies to facilitate them in performing the necessary tasks daily. Originally, we intended to integrate a physical fitness test prior to certification to confirm that each candidate is capable of completing certain tasks, but refrained from doing so. The reason for this is that if a test were implemented prejudice would be involved, which would essentially diminish the number of certified EMTs across the country. To avoid this, we concurred to enrich the EMS system by requiring EMTs to maintain a weekly fitness routine as a means of increasing their strength and fitness level, which ultimately will reduce the chances of acquiring a serious injury. Through designing and/or altering a piece of equipment in addition to the augmentations of the training program, the total output of this project will provide an exceptional solution to the problem at hand.

3.2. Methodology

The section of the chapter contains all of the processes used to reach the final product of this Interactive Qualifying Project, starting from the objectives and ending with the detailed drawings of our proposed design.

3.2.1. Design Objectives

Towards the beginning of this project, we formulated a list of objectives that needed to be fulfilled by the design portion of this project. This list includes that the device should be:

- Safe for patient
- Safe for EMT
- Minimal Cost
- Relatively lightweight
- Made of available materials
- Used by EMTs of varying heights
- Easy to use
- Durable/Reliable

Using the objectives mentioned above, we used pairwise comparison chart to rank them accordingly. This chart involves listing each of the objectives in a table in the first column and top row. Starting at the first objective in the first column, we compared each objective to the others and assigning a value of zero, one-half, or one to signify which objective was more important. Assigning the value of one demonstrates that the objective on the left of the chart carries greater importance. When comparing two objectives and the difference was inconclusive, a value of one-half was given, meaning that both objectives had equal significance. The completed chart can be seen below in Table 14.

Table 14 - Pairwise Comparison Chart

	Safe for Patient	Safe for EMT	Minimal Cost	Lightweight	Materials	Heights	Easy to Use	Durable	Sum
Safe for Patient		0.5	1	1	1	1	1	1	6.5
Safe for EMT	0.5		1	1	1	1	1	1	6.5
Minimal Cost	0	0		0	0	0	0	0	0
Lightweight	0	0	1		0.5	1	0.5	0	3
Materials	0	0	0	0.5		0	0	0	0.5
Heights	0	0	1	0	1		0.5	0	2.5
Easy to Use	0	0	1	0.5	1	0.5		0.5	3.5
Durable	0	0	1	1	1	1	0.5		4.5

Using the table above, the objectives were put in order to determine the relative rankings. Table 15 below shows the totals from the pairwise comparison chart and the relative rankings.

Table 15 - Objective Rankings

Objective	Score	Rank
Safe for Patient	6.5	1
Safe for EMT	6.5	1
Durable	4.5	3
Easy to Use	3.5	4
Lightweight	3	5
Height	2.5	6
Materials	0.5	7
Minimal Cost	0	8

Considering the essence of the problem statement, we were not surprised that safety for both the EMT and the patient received the highest scores. To certify that the product is safe, this objective will be placed at the utmost important throughout the entire design process. In the case that we do not believe the design does not fulfill this objective, alterations will be made until we are completely satisfied with the design. The objective dealing with the total cost of the product was ranked the lowest. Although the cost objective received a score of zero, that does not entail that the objective is insignificant, but it does exemplify that the other objectives are superior to it.

3.2.2. Design Constraints

There are certain aspects related to the design that if are not met it ultimately fails as a project; these are known as the design constraints, which are restrictions or limitations to the product. The constraints related to this project include the following:

- Safe
- High Weight Capacity ($\geq$ 800 pounds)
- Easy to use
- Able to descend stairs easily with guidance
- Manageable weight

If these constraints are not met fully, the design will not reduce the strain that EMTs encounter while maneuvering heavy equipment and patients. As a result, these were greatly considered during the entire designing process.

3.2.3. Objectives and Constraints Tree

The following diagram organizes all of the objectives/constraints and associates each with a possible method or solution.

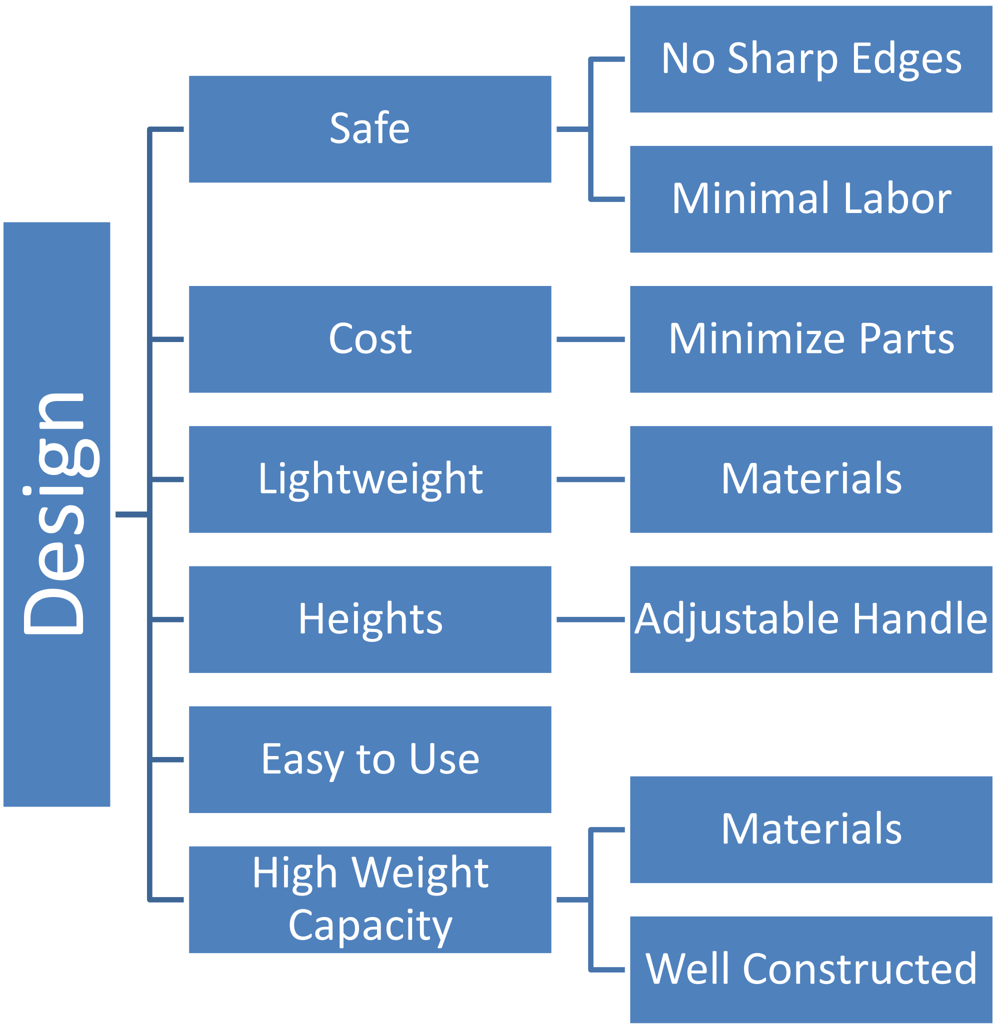


Figure 32 - Objectives and Constraints Tree

This objectives and constraints tree was utilized to brainstorm feasible options that could be used in generating various design alternatives in the later stages of the project.

3.2.4. Ambulances

During the visit to UMASS Memorial, we had the opportunity to see the interior of their Type I ambulances, which have a square patient compartment mounted onto a truck-like chassis. Figure 33 is a picture of the exterior of the ambulance at UMASS.

Figure 33 - UMASS Memorial Type 1 Ambulance

In the beginning of the third term of the project, Professor Fofana requested that our group make a drawing of this type of ambulance using the computer-aided design software SolidWorks. Prior to using SolidWorks, we utilized the engineering drawings from the Vehicle Product Number 12862 pamphlet, which included the various dimensions related to the ambulance. In addition, the pictures taken at the UMass Memorial headquarters were helpful in gauging the amount of storage within the ambulance and the appropriate positioning of each compartment.

3.2.4.1. Descriptions and Depictions

Working in tight spaces, EMTs do not have ample amount of space to admit treatment comfortably. This causes EMTs to position themselves in a way that allows the most access to the patient depending on the category of injury or ailment. In the depiction below, there are two seating options for the EMT to select, one on the right side of the patient and one at the head. The seat on the side of the patient is meant for the EMT to perform various tasks on the patient centralized at their core, such as administering CPR and starting an IV line. If an EMT is sitting at the head of the patient that normally entails the injury involved the head or the neck. Figure 34 also reveals the amount of space for EMTs to move about the ambulance. Positioning the stretcher at an equidistant position from either side of the ambulance provides the EMT with equal space to reach necessary equipment on both the left and right sides.

Figure 34 - Interior of Type I Ambulance

The compartments on the same side as the additional chair all include sliding cabinet doors to prevent any items from escaping while in motion. With the EMT most likely sitting on that side, the majority of the supplies and materials are stowed within those compartments.

Figure 35 shows the various locations of these cabinets and compartments. In addition, there is a counter for the EMT to station materials to be used on the patient in the near future and to stabilize themselves in case of unintended motion; this is located directly to the right of the EMT if they are seated at the head of the patient.

Figure 35 – Right Side of the Ambulance (view from chair at head of the patient)

The other side of the ambulance includes more space for seating, mainly for the family and friends of the victim for consolation purposes. Based on the type of injury, EMTs prefer additional passengers not to ride in the patient compartment so there is more space to work on the patient. Above the bench on the opposite side is a few more storage compartments that are utilized to store items less frequently used, but become less accessible when members of the victim's family are sitting there. Figure 36 displays this side of the ambulance described previously.

Figure 36 - Side of the Ambulance with Seating for Additional Passengers

The last part of the interior of the ambulance that is vital to the EMT is the ceiling. Like any vehicle, the ambulance has a tendency to vibrate which affects the EMTs work and stability. Located on the ceiling are three bars for the EMT to brace in the case of turbulence. Although the ambulance is equipped with restraints at every seat, EMTs usually do not use them as they inhibit proper care. Without these handles, EMTs would most likely injure themselves or further injure the patient. A depiction of these bars can be seen below in Figure 37.

Figure 37 - Grips on the Ceiling of the Interior of the Ambulance

There are compartments on the exterior of the ambulance used to store other pieces of equipment to lift and transport patients excluding the stretcher. Including these into the design of the ambulance maximizes the amount of space within the interior by reducing the amount equipment stored inside. Looking at the figure showing the exterior of the Type I ambulance (Figure 33), one can see the locations of the various compartments. All of the depictions of the ambulance assisted us in determining all of the components necessary to incorporate in our CAD model so there is space to store all of the materials for the EMTs to provide proper care.

3.2.4.2. Dimensions

Using the Vehicle Product Number 12862 pamphlet, we were able to determine a majority of the proper dimensions for the Type I Ambulance. Table 16 below consists of all of the dimensions found in the handout.

Table 16 - Dimensions of an Ambulance

Specification	Dimension (inches)
Floor to Ceiling	72
Complete Width	96
Cabinet #1	47.75w x 24h x16dp
Cabinet #2	28h x 16dp
Recessed Cabinet	26w x 12h x 8dp
Cabinet #3 & #4	30w x 16h x 18dp

With the height of the ambulance at roughly six feet, some of the EMTs, predominantly female, will be able to walk throughout the patient compartment without having to stoop; however, the male EMTs might be taller than six feet, which escalates the possibility that they have to duck their head. Increasing the height may be beneficial, but the vehicle would be more likely to roll over, resulting in more injuries. The width of the vehicle is 96 inches, providing a sufficient amount of space for movement about the ambulance and storage. All four cabinets mentioned in the table above could vary in size depending on the wants and needs of the specific branch of Emergency Medical Services.

3.2.4.3. Existing Ambulance Model

Based on the dimensions and the visual displays of the interior of the ambulance, we utilized SolidWorks to make a basic yet complete engineering drawing of the existing model using inch-based dimensioning. The construction of such a model assists in demonstrating where improvements are necessary so that we can build off it. Below is the model of the patient compartment as a whole.

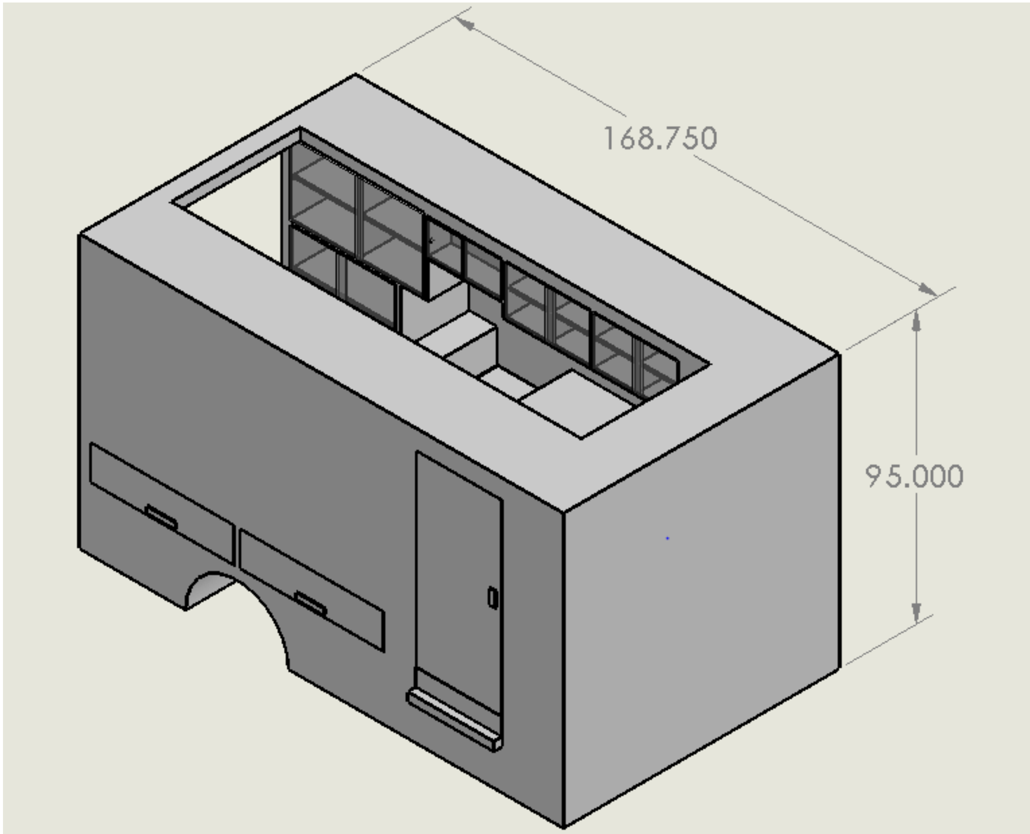


Figure 38 - Complete SolidWorks Drawing of Ambulance in Isometric View

Figure 38 shows a basic SolidWorks model of the patient compartment of the ambulance. This depiction of the model is oriented in isometric view to observe the projections related to the x-, y-, and z-axis. Additionally, the roof of ambulance was not included to allow the viewer to see a fraction of the interior of the ambulance. The purpose of the door depicted is for the EMTs to enter and exit the vehicle without having to deal with the obstruction of the stretcher in the back. Also, EMTs use the exterior compartments for the larger pieces of equipment. These are easily accessible and permits more supplies to be stowed inside the ambulance.

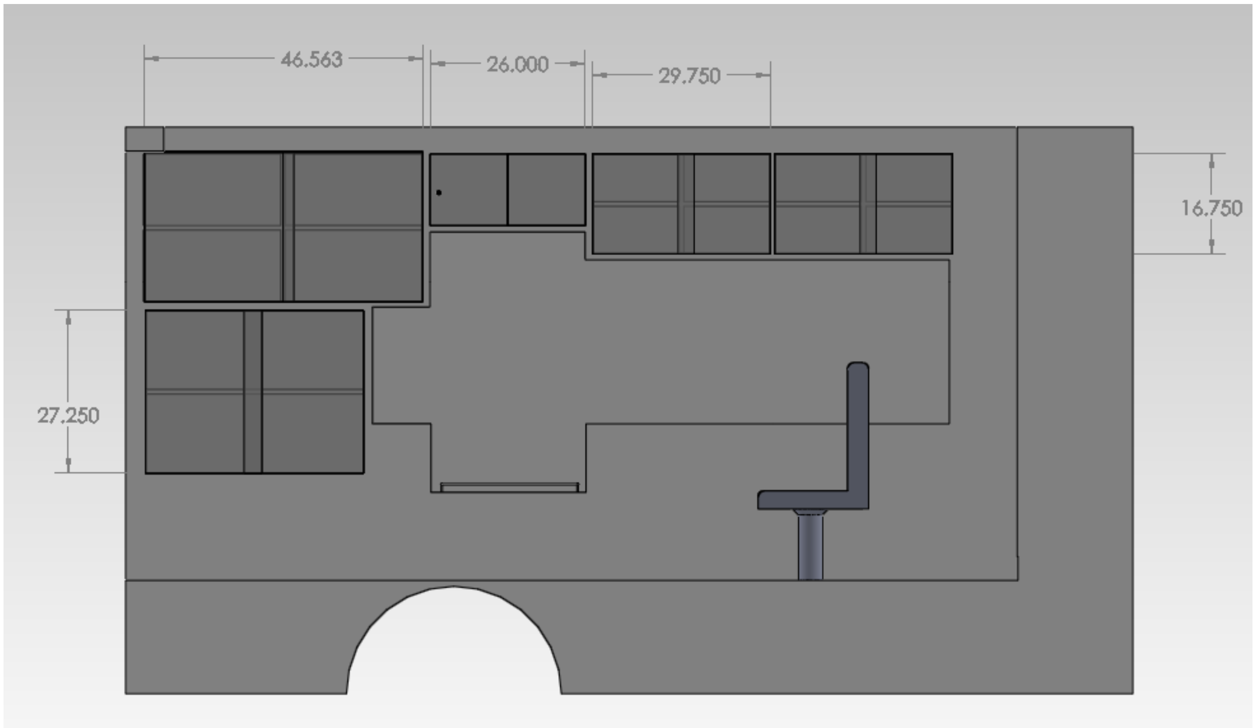


Figure 39 - Interior of the Ambulance - Right Side

This screenshot shows the right side of the ambulance from the perspective of the EMT seated in the freestanding chair. Ambulatory workers store the majority of their supplies within the cabinets located on this side. With the stretcher located in the middle of the ambulance, the EMT does not have to reach over the patient for supplies in this type of configuration. The view also displays two seating options and the counter, which can be seen in Figure 39.

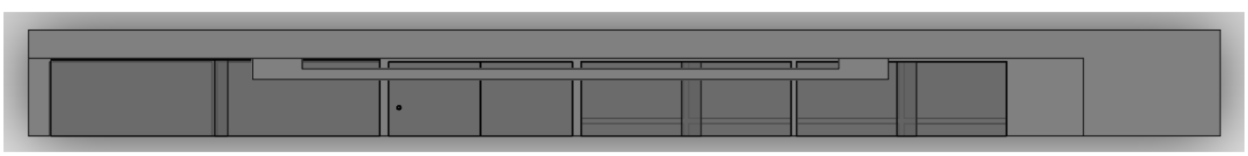


Figure 40 - Top Region of Ambulance Equipped with Handles

The figure above is a section view of the top portion of the ambulance showing the handles to ensure stability during motion. The location of these handles forces the EMT to be angled over the patient slightly, which increases the probability of further injury to both the patient and the EMT. Having drawn the basic existing model, we analyzed the different components and noted the obligatory changes to improve the overall safety inside the ambulance.

3.2.4.4. Alterations to Current Ambulance

From various discussions with EMTs and the chance to view the interior of the ambulance, we formulated a document of potential alterations of the interior and exterior of the ambulance to benefit the EMT and the patient in terms of safety. Most current ambulances include sharp, pointed edges on all of the cabinets and counters. Unintended motion occasionally results in EMTs losing their balance and falling into these edges causing injuries. The first alteration is to make the edges within the ambulance rounded to reduce the injuries associated with unintended motion.

During our visit to UMASS, one of the EMTs emphasized the positioning of the side chair. At its current positioning, the EMT is unable to administer treatment properly as they cannot access the patient’s extremities at the proper angle. By shifting the seat about a foot towards the back of the ambulance, EMTs will be able to start an intravenous line easily since the appropriate portion of the patient’s arm would be positioned directly in front of the EMT. This alteration facilitates the EMT in attending to the patient in need of treatment localized at their core.

Seen in the previous section, the ambulance is equipped with few handles for bracing or stabilization while it is in motion. The vibrations within the patient compartment become quite noticeable causing EMTs to grab onto the handles located on the ceiling of the ambulance. Given that they are directly above the patient, the EMT leans over the patient, which is extremely unsafe. Including another handle near both EMT chairs would solve this problem if and only if they do not protrude in a way that could inflict other injuries.

Another issue inside the ambulance is the disposal of hazardous materials. Unlike hospitals and doctor's offices, ambulances are not equipped with appropriate biohazard containers. Instead of a plastic container, EMTs use plain plastic bags to dispose of all materials. This method is inefficient, because plastic bags can easily puncture from either a needle or sharp object. Not only can this result in injuries, but diseases can be spread from patient to EMT. In order to resolve this problem, a proper disposal container will be inserted into an allotted section of the ambulance so that it is concealed in a compartment level with the counter. To diminish the amount of equipment located in the interior of the ambulance, we plan to incorporate a large closet-like compartment accessible from the exterior part of the ambulance. The current ambulance is equipped with various storage locations on the exterior, but most have shelves dividing the space, which limits the size of the objects that can be placed within it. Removing the shelves grants us the ability to develop a new piece of equipment that is not confined to the size of the shelves.

3.2.4.5. Updated Ambulance Model

The minor changes described above should reduce the number of the injuries to EMTs that occur within the ambulance while transporting a patient to the nearest hospital. To visualize the changes, we included them into a refurbished version of the computer-aided design model of the existing ambulance.

From the posterior view, there does not seem to be any drastic alterations with the exception of one of the exterior storage cabinet, which is below in Figure 41.

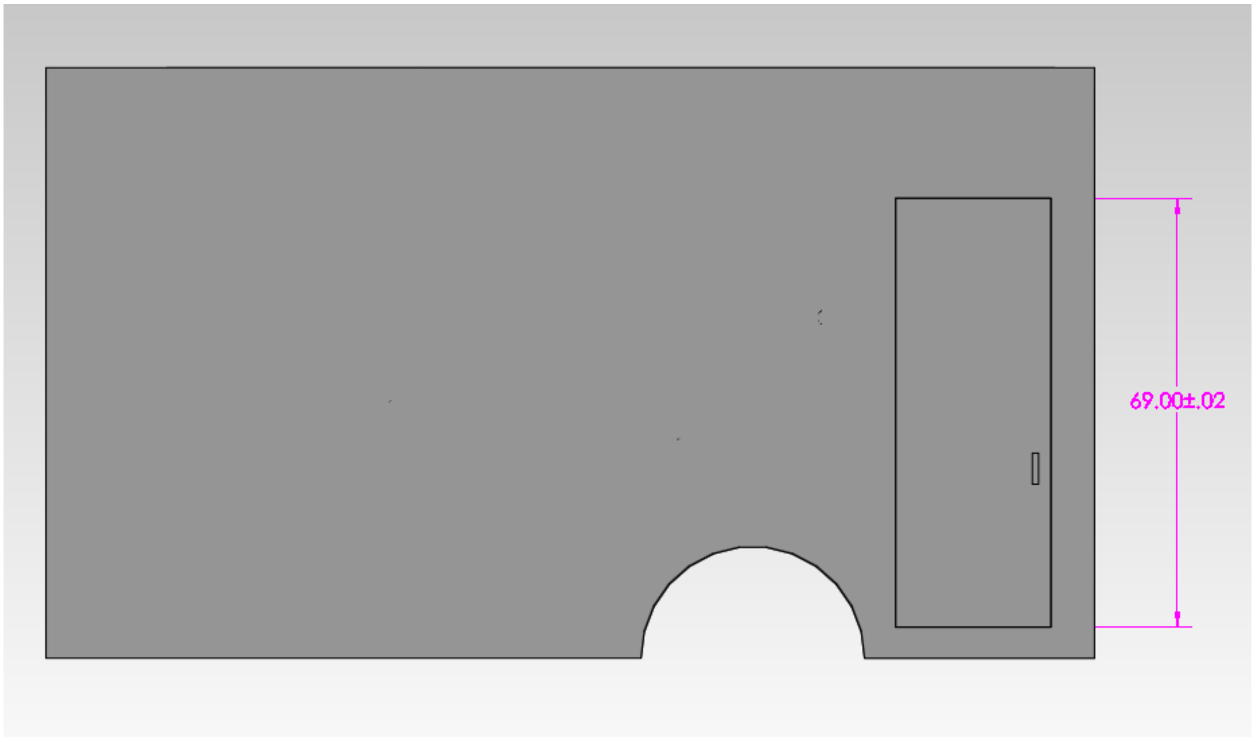


Figure 41 - Altered Exterior Storage Compartment

The dimensions of this compartment are larger than the cabinet of the original model to provide more space for larger pieces of equipment, such as our design. To reduce the height pieces of equipment need to be lifted for stowing, the distance from the bottom of the compartment to the bottom of the ambulance is only five inches making it closer to the ground. The depth of this cabinet depends greatly on the width of the ambulance and the depth of the cabinets on that side. Due to this confinement, the cabinet currently has a depth of eight inches, but it can be altered easily by rearranging the interior slightly.

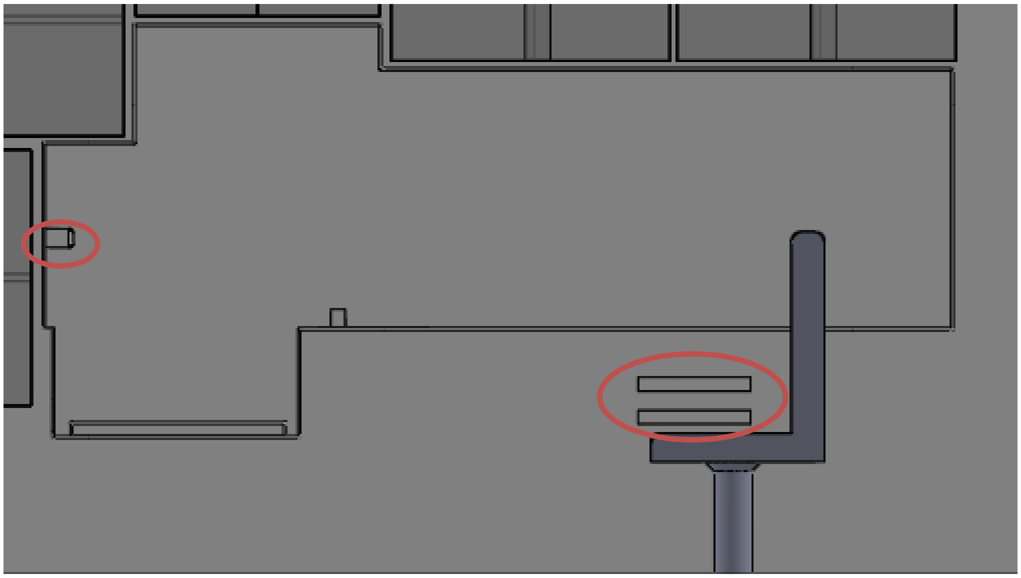


Figure 42 - Depiction of Shifted Chair and Addition of Handles

The picture above displays the chair located to the side of the stretcher. To accommodate the EMT, the position is now nine inches to the left [in this view] to gain better access to the patient's arm and core. The red circles indicate the locations of the added handles; one is by the freestanding chair below the counter and the other is by the side chair on the wall. These will help with stabilization during motion. Although it is not completely obvious from this view, a one-half inch fillet was applied to all of the edges inside the ambulance.

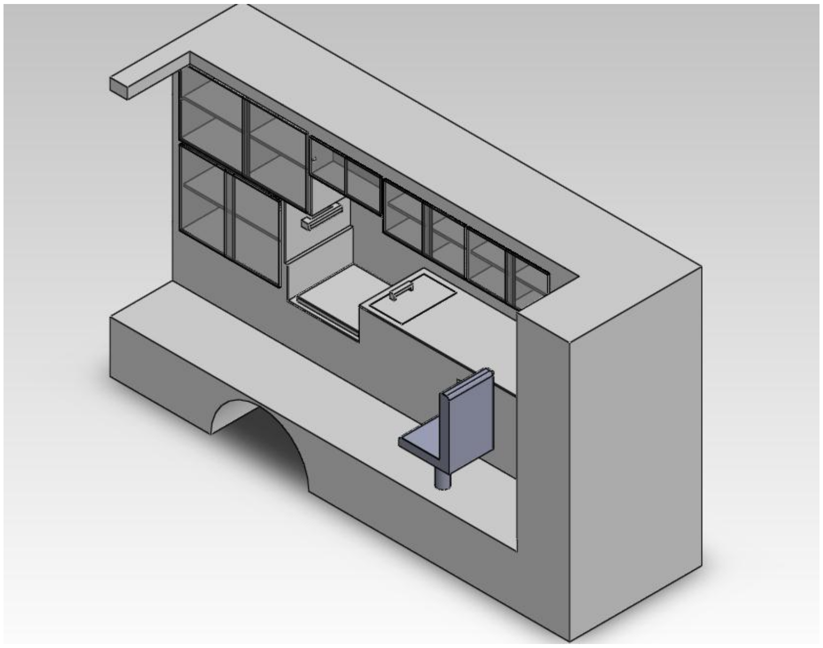


Figure 43 - Isometric Section View of Interior of the Ambulance

The isometric view of right side of the ambulance (viewed from the freestanding chair) shows a better angle the handle located by the side chair. On the other side of that chair is a lid for a compartment to hold a biohazard container, which can be seen in Figure 44 below. The compartment is 20 inches wide, 12 inches long, and 18 inches deep, which allows a container similar to the one below to fit inside it.

Figure 44 - Biohazard Container [8]

By integrating all of the mentioned renovations, the ambulance will become a safer environment for both EMTs and patients alike.

3.2.5. Preliminary Design

The main goal for our design is for it to be able to descend flights of stairs without placing an elevated amount of strain on the back of the EMT. Through our literature review, interviews with EMTs, and general group discussion, we collectively examined features of both stretchers and stair chairs to generate a feasible and effective design. When in a stretcher, the patient is most likely strapped into the device while lying on their back. In this position, their weight is distributed over a larger area, making them more stable. With the stair chair, the patient is in the seated position, which distributes their weight quite differently. Depending on their physical and mental state, the patient might shift their weight while in the chair, which could affect the balance of the pair of EMTs that are transporting the patient down the stairs. The weight of both devices in addition to the weight of the patient applies large forces to the EMT. Considering weight of a stair chair is approximately 25 pounds, more EMTs use the device to maneuver patients from their original location most frequently since it is about 100 pounds less than a standard stretcher. Although the stretcher is significantly heavier, the adjustable height feature is desirable as it can be adapted within other designs. Based on our complete assessment of these pieces of lifting equipment, we developed a preliminary design, which can be seen below in Figure 45.

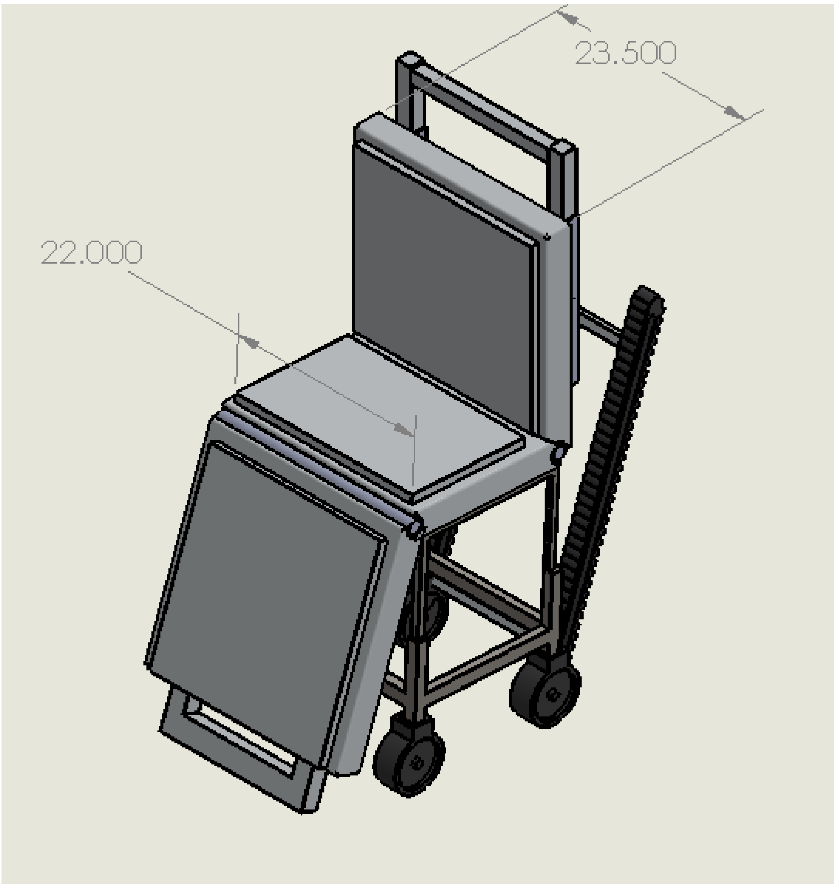


Figure 45 - Preliminary Design - Isometric View

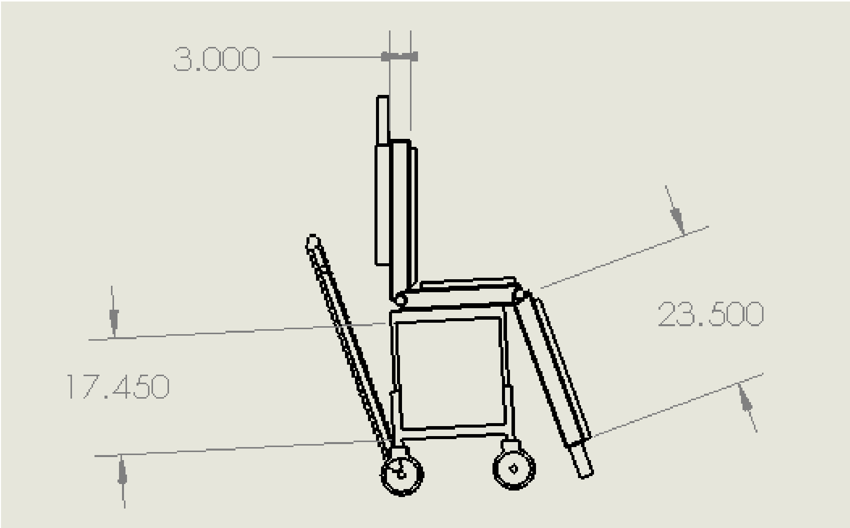


Figure 46 - Preliminary Design - Side View with Hidden Lines Removed

Our preliminary design seen above merges features of the stair chair and the stretcher to alleviate the strain EMTs experience in the lower region of their back. Equipped with four wheels, this device will be able to be wheeled around on flat surfaces similar to a wheelchair prior to the descent down the stairs. To operate the device correctly and effectively, the patient is to be in the seated position for the entire time it is in use. At the top of the staircase, the frame on which the seat rests is height adjustable so it can be lowered to a point where it is relatively close to the ground but does not obstruct the path of the treads located on the back. By adjusting the height, the patient's center of mass will be closer to the ground, which would lessen the chance of further injury in the case that the device capsizes due to an imbalance. With an EMT at either end, the device should be tilted backwards so that the treads are parallel with the edges of the stairs. Unlike the original stair chair, the portions of the chair where the patient lies on can extend out like a stretcher to distribute their weight in a better orientation. Throughout the transportation down the stairs, the EMT at the top of the chair can use the extendable handle to hold the majority of the weight; this feature allows the EMT to keep his or her back straight permitting the correct posture while carrying patients down the steps. The EMT located at the bottom of the device simply guides it in the correct direction so it does not collide with any railings or walls.

3.2.5.1. Design Assessment

Analyzing this design as a whole, we deemed that it was inefficient in reducing the amount of labor needed to operate the device properly. The only feasible way to adjust the height of the chair was manually since the addition of a motor would increase the overall weight significantly. The issue related to this being manual labor is that the patient would already be on the chair when it needs to be lowered. At that point, the EMTs would have two options. The first option is that they remove the patient and place them in a safe location. Once the patient is safe, the height is adjusted as necessary and the patient is then replaced on the device again. This essentially causes more work for the EMT and delays the treatment that the patient needs for survival. The other option is for the EMTs to adjust the height while the patient is on the device. This requires a great amount of strength and restraint to complete this procedure as the weight of the patient plus the weight of the top region of the device has to be lowered very slowly. Proceeding with this method would result in the most injuries, which would ultimately make the design an overall failure. Due to this issue, we decided to continue brainstorming to generate a feasible alternative design.

3.2.6. Final Design

After deciding to go in a different direction with our project, we researched additional equipment used for lifting and maneuvering patients. In time, we discovered a device used by several EMTs to carry a patient down the stairs. Known as the MegaMover 1500, the device is a soft stretcher made of a spun-bound polypropylene material. The stretcher-like device is 40 inches by 80 inches in size, can withstand up to 1500 pounds, and weighs less than one pound. To reduce the weight each EMT has to carry, there are 14 handles on the device for easy lifting and maneuvering in tight spaces [19]. The MegaMover 1500 is below in Figure 47.

Figure 47 - MegaMover 1500 [19]

With its high weight capacity and its lightweight material, the MegaMover 1500 would be an advantageous product that could be incorporated into a mechanical system to carry patients down the stairs. To receive input on our findings, we met with our advisor Professor Fofana to determine whether progress was made or not. Once we discussed our views and recent findings, Professor Fofana brought up the idea of designing a dolly-like device. Taking a trip to the Washburn Laboratories, we were able to see a dolly and visualize how we could alter it to be able to transport a patient down the stairs. Before drawing our design on paper, we completed more background research regarding dollies to gather more information on their structural qualities and capabilities. Considering these dollies, or hand trucks, are used to move refrigerators and other large appliances, developing a structurally sound dolly-like device could potentially resolve the problem related to the weight capacity. Below is a picture of one of the dollies we examined that is purchasable at Home Depot.

Figure 48 - Milwaukee Dual Handle Hand Truck [36]

The Milwaukee Dual Handle Hand Truck is able to maneuver up to 1000 pounds. The device itself weighs 43 pounds, which is slightly higher than the weight of the average stair chair. The two vertical bars with handles attached to them support the majority of the load, which provides a sturdy base for the entire device. The two curved bars linked to the axle function as structural enforcement while transferring heavy loads to a given destination [36].

The other type of dolly we looked at was the Industrial Strength Steel Hand Truck Curved Handle with Stair Climbers, which is depicted below in Figure 49. This design includes a similar base structure with the two vertical bars, but can only carry up to 600 pounds. Visually, this device looks like it would weigh more than the previous design due to its additional components, however it only weighs 32 pounds. Unlike the first design, this one includes a 24-inch folding nose extension to assist in lifting and stabilizing heavy objects [20]. The stair climbers on this hand truck involve continuous friction reducing belts for easy transportation.

Figure 49 - Industrial Strength Steel Hand Truck Curved Handle with Stair Climbers [20]

Having looked at the various hand trucks, we gained a better understanding of the device's capabilities and used the products as benchmarks throughout the later stages of the design process.

3.2.6.1. Conceptual Design

With the information gathered regarding the present lifting equipment and the hand trucks, we started drafting a conceptual design using pen and paper. Starting with the base design, we drew a basic dolly equipped with a solid, curved sheet of metal between the two vertical poles. The purpose of this addition is to serve as a base support for the weight of the patient to be transported; without it, the patient would have to be secured tightly onto the device to prohibit them from falling through the open spaces of the hand truck. During this phase, we designed a seat cushion with springs to distribute the patient's weight properly and to concentrate their center of mass directly downward. Since the height of patients vary, we had to design our device in a way that taller individuals can lie on comfortably. To resolve this problem, our design included a lounge chair-like design with an angled section for the legs. This essentially shortens the patient in relation to the device as it is in use. Instead of angling a portion of the base system, a wedge-like structure was drawn below the seat to act as a leg rest. Keeping the comfort of the patient in mind, we integrated sections of cushioning surrounding the head and back regions for support. Given that the device will be descending the stairs at approximately a 45° angle, a seatbelt type mechanism is obligatory so the patient can be secured to the device without having fear of sliding or falling off it. To ease the job of the EMT, extendable handles are located at both ends of the device so that the users can descend the stairs without having to curve their spines. The last addition we devised was a larger tread system located on the posterior portion of the device so it can be slid down the stairs in a similar fashion as the current stair chair. Using the hand drawn sketch of the design, we generated detailed sketches in SolidWorks in order to analyze various aspects of it, such as the weight and structural capabilities.

3.2.6.2. Original Design

For better visualization, this section includes all of the computer-aided design drawings of the constructed parts and assemblies merged to create the design mentioned previously. Commencing at the foundation of the design, the base was modeled after the Milwaukee Dual Handle Hand Truck seen in Figure 48. The part of design mimics certain aspects of the hand truck to increase the overall weight capacity of the device allowing overweight patients to be maneuvered by this device.

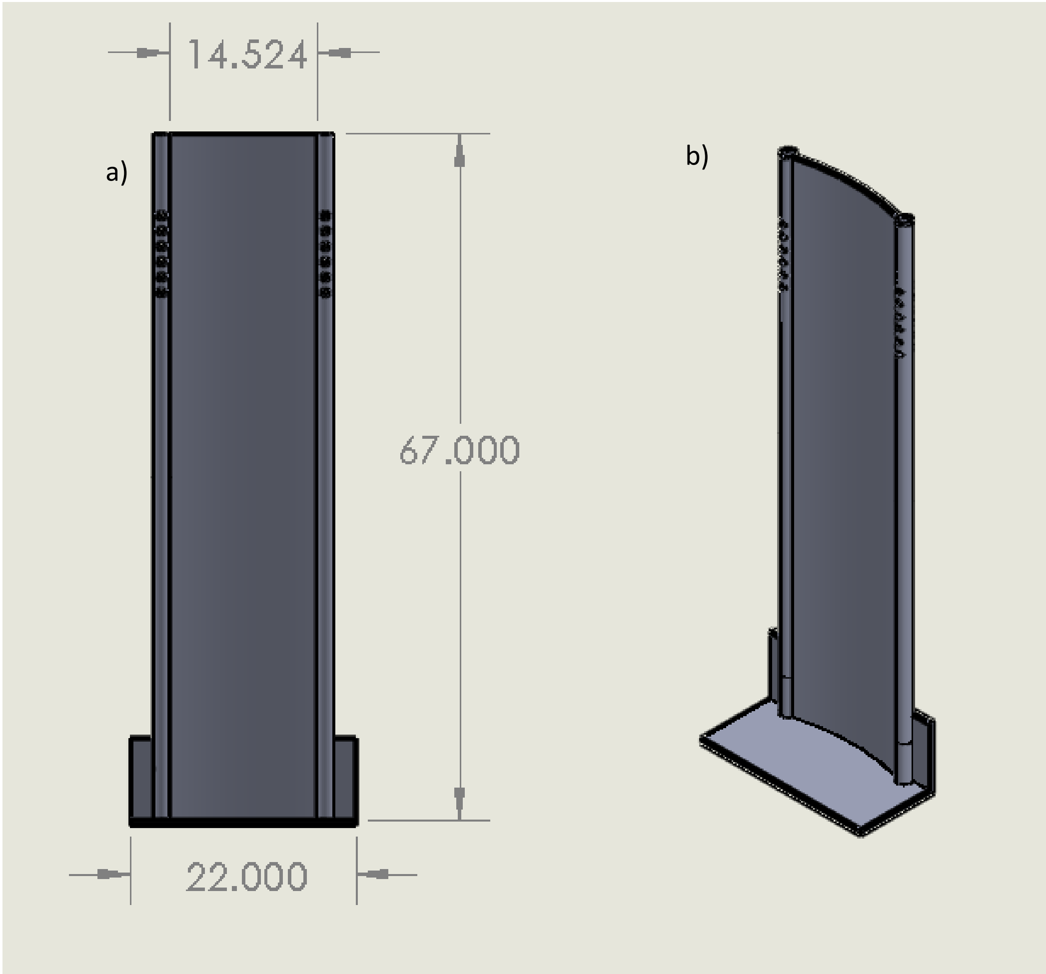


Figure 50 - Base Part of the Design

Figure 50 shows both a front view and an isometric three-dimensional view of the base structure of our design. Similar to the hand truck, this includes two 67-inch long columns acting as the main support system for the applied load. To reduce the overall weight of this device, these columns are hollow and include a set of six holes on each pole. These holes are meant for the incorporation of a locking system associated with an extendable handle. The flat bottom part in the depiction functions as part of the support system as well as a footrest for the patient lying on the device. The curved material between the two columns is where padding will be added for cushioning and back support of the patient. Since this part of the design will experience the largest forces, the material would have to be either steel or a steel alloy given that its yield strength is approximately $2 * 10^9$ Pascals. Ideally, this metal would serve well in this application, but the density of steel is 7800 $^{kg}/_{m^3}$. With a high density, the weight of the system is bound to increase, especially if more material were to be used to manufacture the device. As a result, a lighter material has to be included as means of keeping the overall weight as low as possible.

The next part of the design that is vital for transporting the patient down the stairs is the handle located at the top of the device. Inserted into the two poles of the base design, the handle fastens into place via a peg-type locking system. This locking system allows the user to adjust the height by sliding the handle up or down to a new hole on the base design. Designed for the user, the handle is adjustable so that EMTs of varying heights can move the device while keeping their backs straight. Unlike the Milwaukee Hand Truck, our idea for the handle was inspired by a shopping cart handle in the sense that it contains a long bar that is rests at an angle of 150° from the poles, which can be seen in figure below.

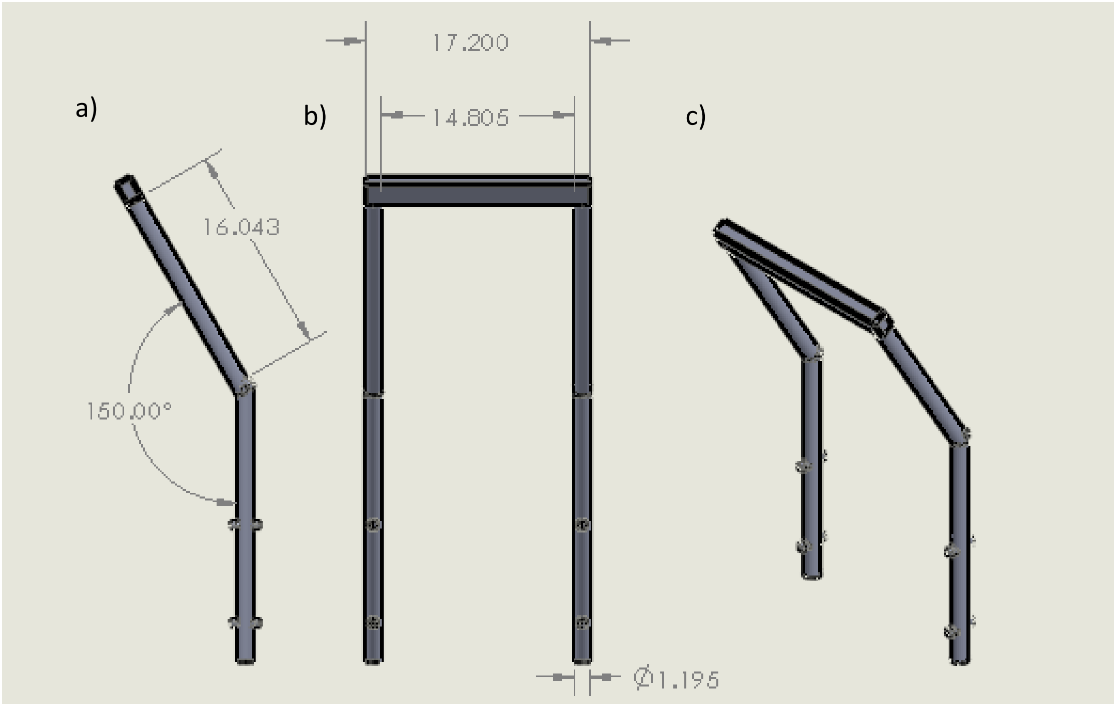


Figure 51 - Top Handle

Figure 51 depicts the handle configuration in its right, front, and isometric views. Located at the bottom of each view is the peg-like portion used in the locking system. The complete orientation of the handle provides ample space for the EMT to grasp when it is descending the stairs. If the two separate hand design had been implemented, it would be more difficult for the EMT to grip since his or her hands could easily slip off the device. Designing the handle with an angle and making it one continuous bar eases the accessibility and gripping for the EMT.

Attached to the base design is a wedge-like structure for the patient's legs to rest while they are being transported from their location to the ambulance. As one can see from Figure 52, the structure is designed as a support for an overlaying MegaMover 1500-type fabric.

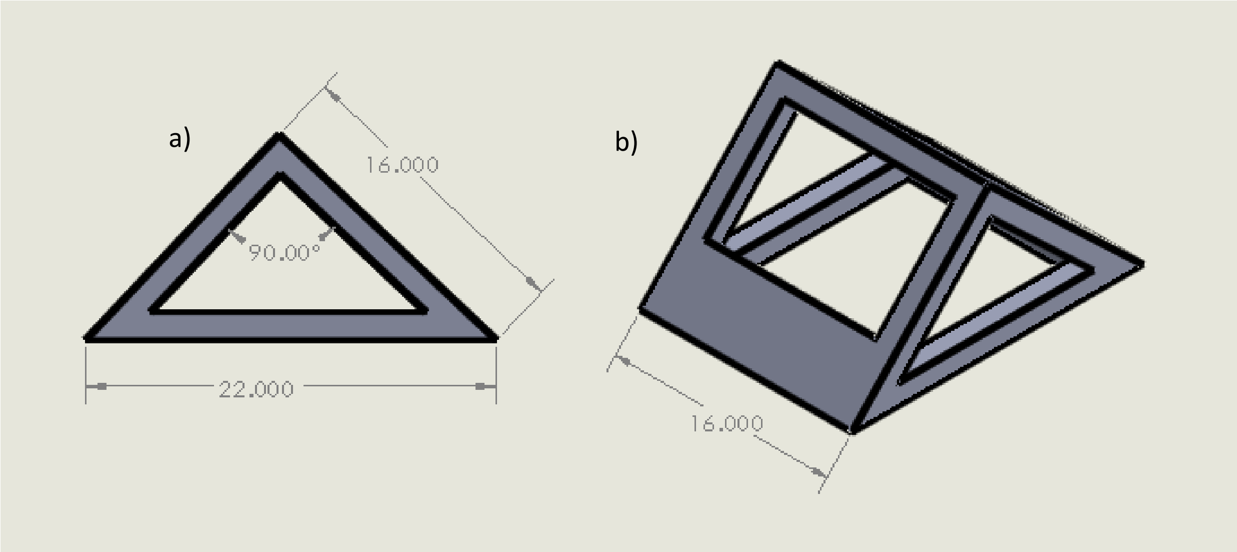


Figure 52 - Leg Portion of Design

This depiction includes two perspectives of the device: part A on the left shows the right view and part B on the right is the isometric view. The component will be attached to the base structure of the "dolly" at a location that is between five and six inches from the bottom of the device. The structure creates the lounge, or beach, chair-like characteristic to the design. Integrating this permits the patient's weight to be distributed more evenly across the device without height being an issue.

Directly above the additive leg piece is the seat section that is comprised of a cushion with four separate springs attached to the bottom. Generally, a person's center of mass is around the waist area, which would apply the most pressure to the seat region of the device. The springs function in the design to assist in distributing the weight of the patient evenly across the area where the cushion is attached.

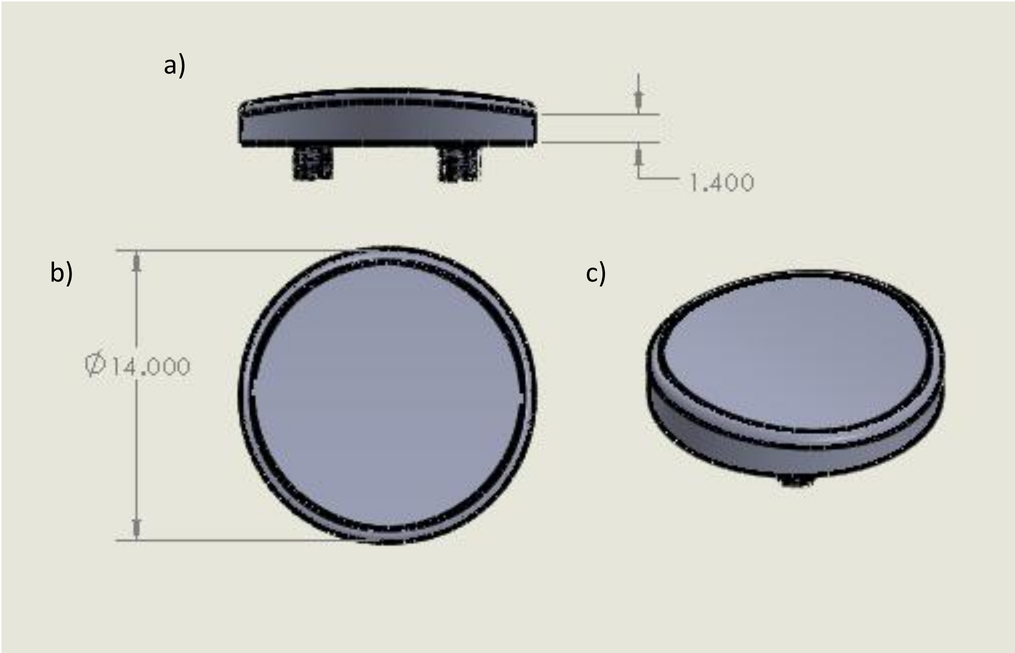


Figure 53 - Seat of the Design

Figure 53 shows the seat in the front, top, and isometric views to see both the cushion and the springs. If this were to be manufactured, the springs should have a high spring constant *k* as they have to endure weights of patients over 300 pounds. However, they cannot be too stiff that no visible displacement occurs from its unloaded position to its loaded position. Experiments and tests are needed to determine the appropriate type of spring for this application.

The last main component of the design is the tread system that is to be attached to back of the design. The system consists of two separate treads that are attached to bar with an extended piece to be secured to the base structure of the design.

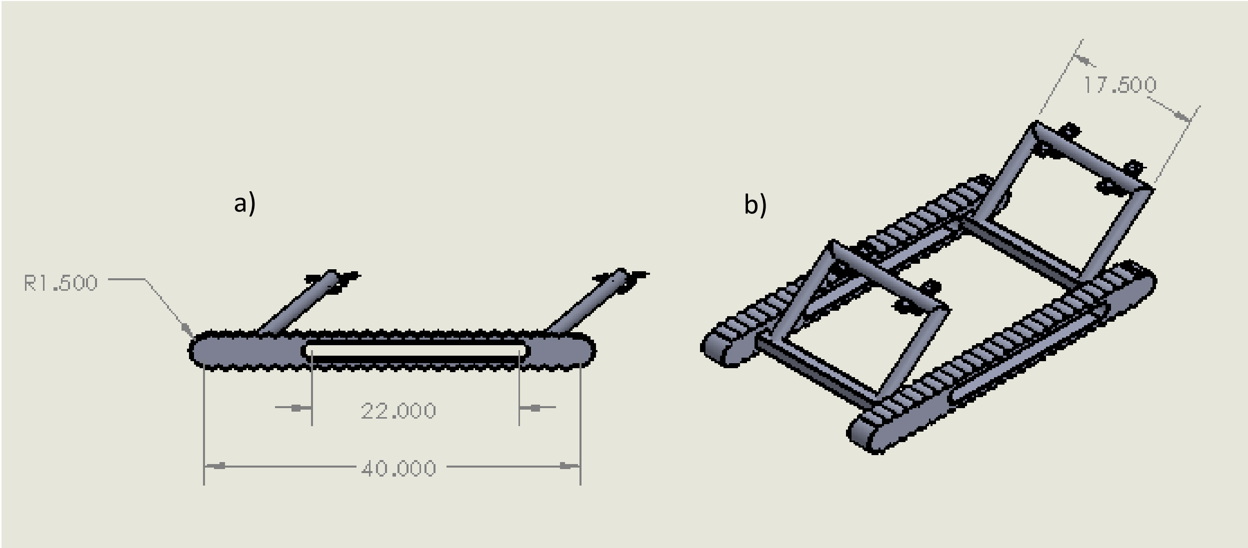


Figure 54 - Tread System of Design

Figure 54 depicts the right and isometric view of the tread system. To reduce the weight of the entire device, both treads have an extruded cut through the entire three inch width. The extended pieces of the bars, which are angled in the depiction, are to be clamped to the support structure in a configuration where the treads are parallel to it. The clamps shown in the depiction allow motion of the treads in the y-direction, which means the extended piece rotates about its central axis. With this degree of freedom, the treads can be in one of two positions. The first position would be similar to the one depicted above; if the extended pieces of the bar are angled the same way, this would entail that the treads would be stowed and not in use. In the second position, the extended piece is pivoted about its central axis, which permits approximately 120° of rotation arranging the system in its extended limit. When a patient is to be transported down a flight of stairs, the treads will be pivoted to the upward position so that they will not collapse during the descent. Keeping the tread system parallel to the edges of the stairs, the user can slide the device down the stairs in a way that insures the straightness of their back. In total, the addition of the tread facilitates the EMT's job considering it permits the device to be guided down the stairs rather than lifted.

Having described and drawn the major portions of the design in SolidWorks, we compiled all of the parts to form the dolly-like device. Figure 55 shows the design in its entirety.

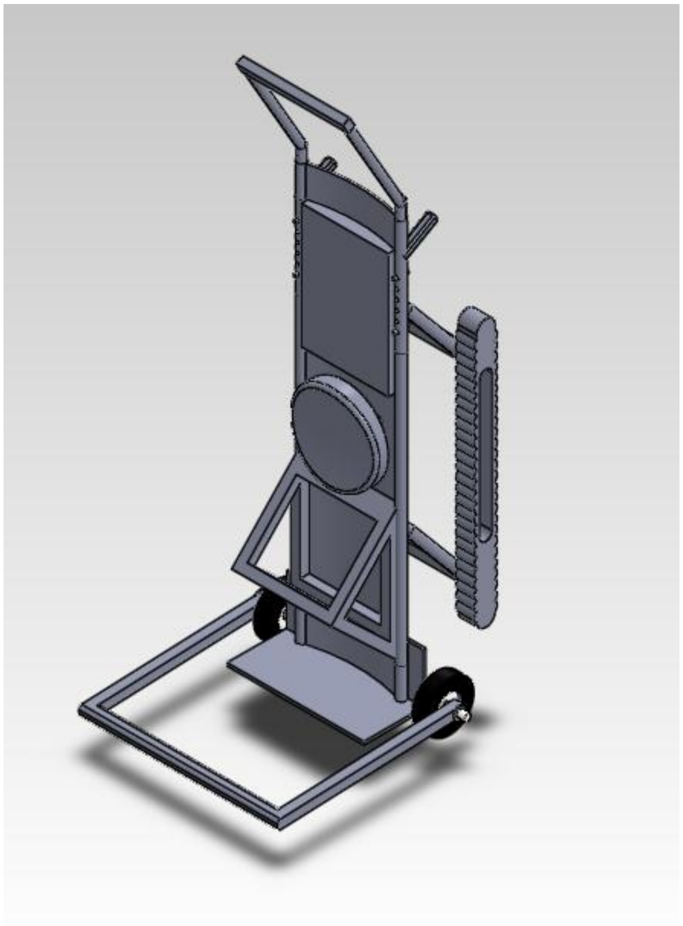


Figure 55 - Assembled Dolly-Like Device

There are a few additional components of our design not mentioned previously. Since this piece of equipment is intended to be used by two EMTs, the U-shaped portion on the bottom of the device is another handle to be used by the second EMT. This handle had to be designed ergonomically so that the user will be able to maintain the appropriate posture while transporting patients. To assure this, the handle has a length of 30 inches from the point that it is attached to the axle to the portion that is held by the EMT. Figure 55 depicts the handle in its extended position; however, when the device is being guided down the stairs, the handle can be rotated to a higher degree about the axle making it accessible to the EMT in different positions. If an EMT is wheeling a patient around and the tread system is not in use, the bottom handle can be pivoted up and act as a restraint to stabilize the patient. In addition to the bottom handle, a set of handles are located below the extendable handle towards the top of the device. Emergency Medical Technicians could use these when moving the patient on flat surfaces to ensure that the system remains close to the body for easy operation and manipulation.

Overall, we assessed that our design successfully fulfilled the objectives for safety of the EMT given the orientation of the patient on the device and the adaptable handles. With the orientation of the leg portion and the position of the seat, the device would apply added pressure to the back of the patient causing discomfort. Since safety was ranked first for both the patient and the EMT, alterations had to be made to the design in order for the objectives to be fulfilled deeming it a success. Through brief discussion with Professor Fofana, we devised a feasible alteration that would provide more comfort the patient. This alteration entailed solidifying the top section of the leg portion of the design and shifting the chair so that it could be mounted on that. This would make the device more chair-like, but it would essentially reduce the amount of force the patient experiences in their back while strapped onto the device. After this assessment, the changes were made to the SolidWorks model, which can be seen below in Figure 56.

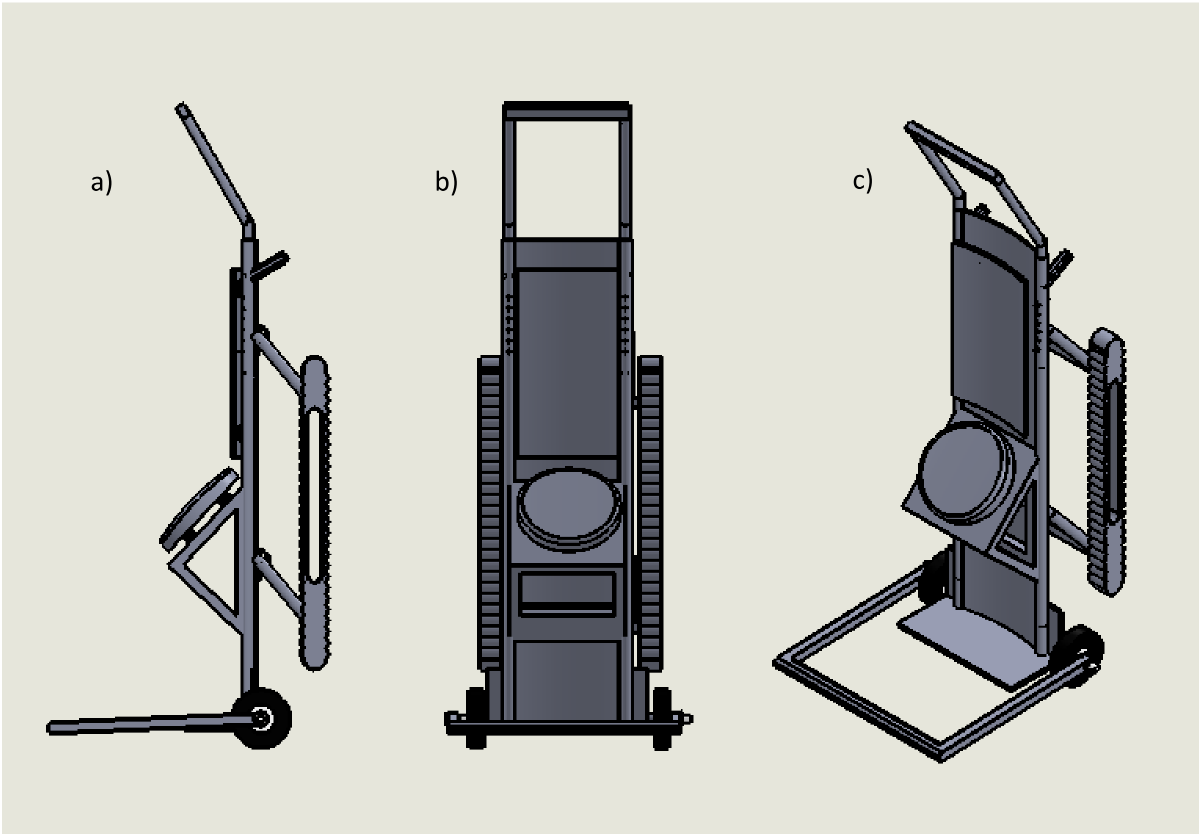


Figure 56 - Right, Front, and Isometric View of Altered Dolly-Based Design

These three views are shown to display the computer-aided design model at different angles to gain a better understanding of the positioning of the various components. Above the seating system, there is a sufficient amount of cushioning to provide support and comfort. Given that our designed piece of equipment serves as a base, additional elements, such as the spun-bound polypropylene material and securing straps, are to be incorporated so that the patient can be secured to the device while being transported. Figure 57 is a simple depiction that demonstrates the concept of how our design would work with the overlay material used in the MegaMover 1500.

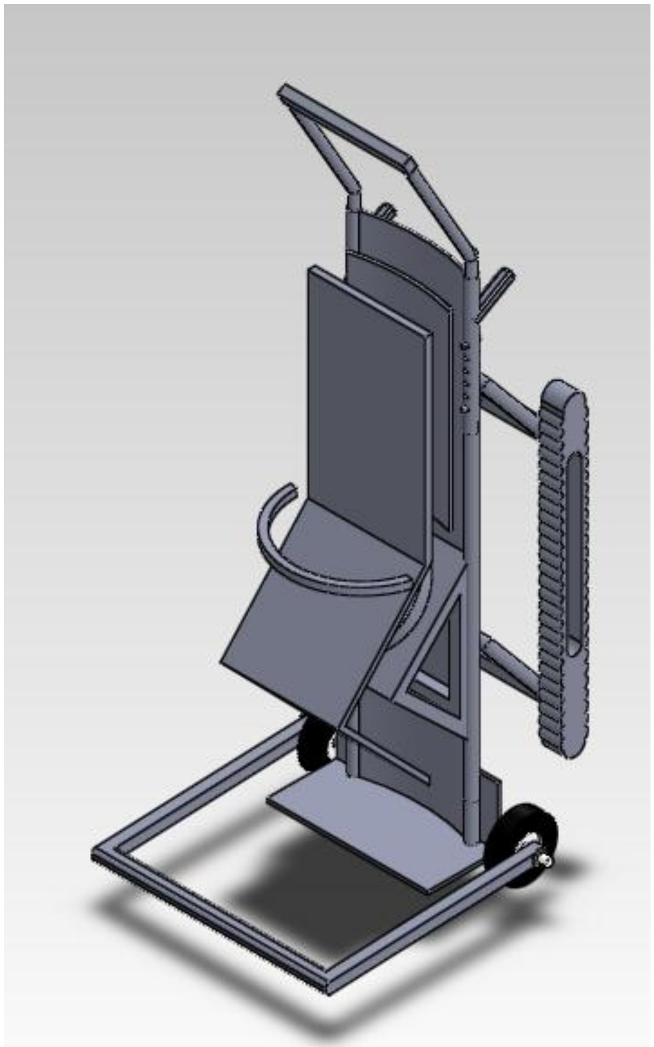


Figure 57 - Dolly-Based Design with Overlay Material

With limited experience and a time constraint, we developed the additive components to demonstrate the proof-of-concept simply. Although not displayed, the polypropylene material could be attached via hook-locking system, where hooks would be located around the perimeter of the material. For this attachment system to be successful, holes need to be drilled into the two vertical columns of the base design so the material can be fixed to the device appropriately.

3.2.7. Analysis of Final Design

To analyze the capabilities of the structural base component of the final design, the SimulationXpress Analysis Wizard, a built-in utility within SolidWorks, was utilized. Using the Analysis Wizard, various forces and pressures can be applied to individual components of models to verify that they can withstand substantial loads. To perform this analysis properly, at least one fixture, or a standard geometry that will remain static when a force is applied, should be designated on the individual component. After the fixtures are set as needed, the material of the individual part needs to be selected to determine the yield strength. The final part of the procedure entails applying the signified force to the appropriate surface to commence the analysis.

Based on the fact that this simulation utility deals solely with part analysis, we decided to assess the base part of the design seen in Figure 50. Considering the patient would be laying on the curved, central portion of the device, both of the vertical columns and the bottom footrest serve as the fixtures for this analysis. Four separate analyses were completed using two different alloys and two different applied forces. Since we did not verify the materials to be used for our design, the two materials tested were an aluminum alloy, alloy 6061, and a stainless steel, AISI 316. Once a specified force was applied to the base structure, SolidWorks generated an animation of the associated deformation, which demonstrated the locations that experienced the greatest amount. The application of this force also permits the software to document the stress that the device underwent throughout the test.

The first test entailed applying a force of 1000 Newtons (N) to the structure, which is the equivalent of having a 220-pound patient be secured to the device. Applying this force to the structure constructed of the aluminum alloy 6061 demonstrated that the maximum stress was about 85.2 pounds per square inch (psi), which is equal to 587.5 kilopascals (kPa). To access whether the device could be used to maneuver a 220-pound patient, the maximum stress, 587.5 kPa, was compared to the ultimate tensile strength (UTS) of the material, which is the maximum stress a material can experience before necking or deformation occurs. The UTS for Alloy 6061 is about 124100 kPa, which is significantly greater than the maximum stress the structure experienced. With the maximum stress of the structure less than the UTS of Alloy 6061, the structure could successfully be used to carry patient of 220 pounds, only deforming the base about .003 millimeters (mm). Applying the same load to the device made of AISI 316 Stainless Steel Sheet with a UTS of 580000 kPa, the maximum stress of the device experienced under the 1000 N force was 78.3 psi, or 539.9 kPa. The deformation under this load was only .001 mm, which can be explained by the fact that stainless steel is a much stronger material since its UTS is almost five times as high. Figure 58 shows a still depiction of the base structure and the stress experienced at different locations.

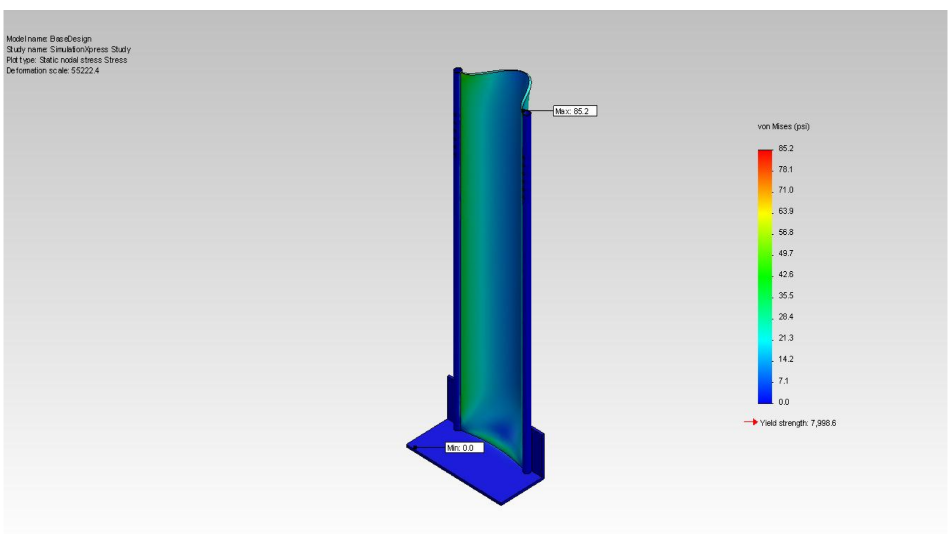


Figure 58 - Stress Experienced Under 1000 N Load (6061 Alloy)

For the other set of tests, a 4500-Newton force was used, which is similar to securing a 1000-pound patient to the device. For the aluminum alloy 6061, the maximum stress was 2644 kPa, which is still less than the UTS of the material. The deformation of the structure was about .01 mm, which is much greater than the resulting deformation under the 1000-N force. The last test was performed on the device using the stainless steel. The maximum stress under this load was about 2431 kPa and the greatest deformation of the material was .005 mm.

The results of these tests reveal that this device can be used to maneuver overweight and bariatric patients by using either Alloy 6061 or the AISI 316. To ensure that the device would be able to carry obese patients, AISI 316 or other forms of stainless steel should be used to manufacture the device due to its higher UTS and yield strength. Although it is a stronger material, stainless steel has a higher density than aluminum, which would increase the overall weight of the device. For instance, the weight of the base component using the aluminum alloy is approximately 48 pounds while the weight of the same component using the stainless steel material is about 141 pounds. Considering using stainless steel would elevate the overall weight of the device considerably, it would be advisable to use the aluminum alloy 6061; however, investigation of other materials could be done in future work related to this project.

3.3. Enhanced EMT Training

Based on the information gathered from various journal sources and the results from the survey we distributed to EMTs, there is a clarified need for an enhanced training program. Although EMTs learn how to perform various skills necessary to treat ailing patients, they often do not acquire the appropriate techniques related to lifting and transferring patients. This lack of attention within the training program itself causes injuries within the field forcing many EMTs to miss work throughout the year. As a result, the Ambulatory Work-Related Injuries and Health Problems group developed detailed components that would be beneficial to incorporate them into the current training program. By doing so, EMTs would have an increased knowledge of what to expect while in the field and the number of injuries in total would be reduced.

Mentioned within the literature review, Appendix A includes an excerpt of the current curriculum related to the lifting and moving patients. Through a brief examination, the National Standard Curriculum of EMT-Bs only requires instructors to relay information about lifting verbally without any hands-on experience. Within in-class training, EMTs learn basic techniques, such as lifting with the legs and refraining from twisting while performing a lift. Another advisable technique within the current curriculum is to keep the weight to be maneuvered close to the body. Figure 59 is shown to demonstrate the importance of this act.

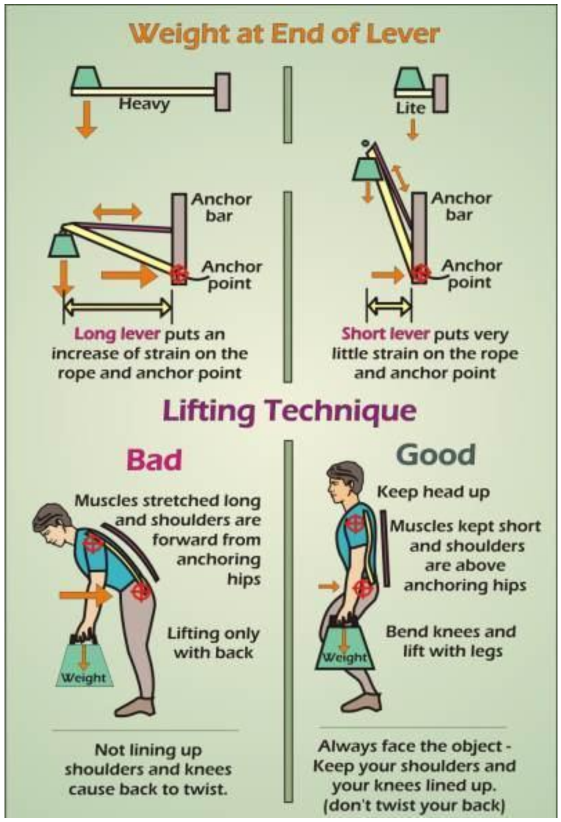


Figure 59 - Schematic of Proper Lifting Techniques [32]

The schematic correlates lifting a weight to placing a load on the end of a lever. By keeping the lever arm short, significantly less strain is experienced in the on the rope and the anchor point. Applying this idea to the human body, if the EMT holds the weight only a few inches away from the body, the top and bottom regions of the back will experience less strain. Utilizing this tactic will greatly reduce the possibility of acquiring a back injury [32].

Many people often "learn by doing," meaning performing experiments and gaining hands-on experience is a helpful part of the learning process. Based on that fact, simulation training should be incorporated into the current training program so candidates in hopes of becoming EMTs can execute lifts correctly. Before having candidates go through simulation training and testing, the group thought it would be beneficial for all of them to comprehend their limits. A proposed requirement to be added to the current training system is have each candidate, if healthy enough, to perform repetition maximum testing. Mostly used by personal trainers, repetition maximum testing can be used to determine the maximum strength. This can be done by requesting each candidate to perform one repetition of a bench press of a specified weight until they cannot lift a higher weight. The maximum weight that each candidate can lift should be recorded for later use. With the knowledge of one's personal lifting limit, each EMT will be able to access each situation where lifting is involved carefully as they will know when additional help is needed given the weight of the patient.

Once the instructor grants permission after maximum testing, each candidate will have to perform all of the lifts and maneuvers discussed in the previous chapter. These lifts are the direct ground lift, the extremity lift, the clothing drag, the blanket drag technique, and the arm drag technique. Since most of these have to be completed using at least two people, this requirement includes performing each lift using a dummy with a partner. After successfully implementing the proper tactics and techniques, each pair has to perform the same test, but with an actual person rather than a test dummy. These lifts are meant to remove a patient from a dangerous situation as quickly as possible. As a result, injuries often occur from emergency moves, but including the simulation training described previously EMTs will know the proper body mechanics to lower the risk of acquiring such debilitations.

Although the emergency moves become difficult as the patient's weight increases, other procedures produce a larger risk of injury due to the dynamic environment and the presence of lifting equipment. The other requirements the team thought would be valuable to integrate into the current training system all revolved around the two most commonly used pieces of lifting equipment: the stretcher and the stair chair. For stretcher simulation training, each candidate will have to perform tests four times: twice with a certified EMT, or instructor, and twice with another candidate. During the first test, the candidate will receive instructions from the EMT or instructor to perform the lift of the stretcher as smoothly as possible. Considering the EMT will be giving the candidate directions, the EMT will be the person walking forwards during the maneuver. After the candidate successfully carried out this test, the EMT and the candidate have to switch positions, so the candidate can acquire a sense of the responsibility necessary to give directions to the other EMT or person assisting him or her. During the testing phase where two candidates lift the stretch, each has to carry the stretcher once at both ends so each individual can play each role. Throughout the duration of this test, the instructor will evaluate both of the candidates' techniques. Another task should be implemented into the training program for EMTs is to have the candidates lift and secure the stretcher in the ambulance. Based on each individual's lifting maximum, the person in the back of the stretcher will have to assess whether extra assistance is needed to move the stretcher into place.

Implementing simulation training for the stair chair presents a greater challenge taking into consideration that at least two sets of stairs with a landing is involved. Since not all EMS depots are built alike, the instructors and other certified EMTs will be in control of finding a safe location with a set of stairs with at least one landing for training and additional practice. After the set of stairs is reserved, each candidate is obligated to perform a set procedure with a certified EMT and a fellow candidate two times with each partner. This test inquires the trainees to lift a stair chair and carry it down a flight of stairs to the landing position. When the landing is reached, the pair has to devise a proper method of altering the orientation of the stair chair with the dummy patient on it so the second set of stairs can be descended in the appropriate manner. Each candidate will practice this task twice with each partner so he or she can gain appearance being the EMT in the front and back of the patient. Once the techniques have been mastered, all of the candidates will be critiqued on their abilities in order to determine if they receive certification or not [22]. The main purpose of these additions to the training program is to teach EMTs how to evaluate given situations properly to ensure the safety of themselves and the patient. A detailed outline of these alterations is located in Appendix D.

3.4. EMT Fitness Program

As mentioned previously, Emergency Medical Technicians are not required to go through any form of physical fitness testing to receive certification from the government. Though the group originally thought it would be beneficial to integrate such a program into the current EMS system, segregation and discrimination would be prevalent as not every candidate would be able to become an EMT based on the set standard for one's fitness level. To avoid this from occurring, we framed a basic fitness program that EMTs are asked to follow throughout the duration of their career to increase their strength, endurance, and health. Prior to formalizing a set of requisites for a potential program, we researched existing programs that other organizations utilize.

In general, most organizations specify that each member should exercise a certain number of minutes or hours per week. Within the weekly workouts, various areas needed to targeted, such as cardio respiratory endurance, muscular strength, muscular endurance, and flexibility. The United States Coast Guard (USCG) publishes a document for candidates to record their weekly goals and achievements related to the four mentioned areas of fitness. A part of this document includes recommendations each area in terms of the frequency. For instance, cardio respiratory endurance exercises like running, cycling, and swimming should be completed between three and five times a week for about 20 to 60 minutes per session. This component of the program serves to increase the strength of one's heart and lungs while under strenuous activity. The muscular strength and endurance aspects of the program should be completed either two or three times a week to increase amount of force a muscle can produce in a single effort heighten and one's ability to resist fatigue. Lastly, the focus on flexibility involved in the

USCG program mentions that each member should perform yoga-like activities three times a week. Appendix E shows the United States Coast Guard's Personal Fitness Plan document.

Through examination of the USCG Fitness Plan, we began the process of generating an EMT fitness plan by setting up the frequency that exercises should be done. Many doctors and specialist advise patients to get at least a half hour of exercise per day to live a healthy lifestyle. From this general advice, the fitness plan insists that each EMT exercises a minimum of 150 minutes a week, which is roughly 30 minutes per day excluding the weekend. Like any fitness program, our plan incorporates a general goal, which is to increase one's muscle strength and endurance permitting each EMT to lift heavy loads for longer periods. Although the main goal for this program deals strictly with increasing one's strength, we thought at least two thirty minute sessions per week should be devoted strictly to cardiovascular training to ensure that the heart and lungs remain in a healthy condition. The following activities are examples of those that fulfill the cardio requirement: running, swimming, cycling, jump roping, and rowing. For the muscular endurance and strength constituent of the workout plan, we decided to focus on strengthening the areas that are most frequently injured rather than encapsulate all muscle groups; according to the case studies, the areas of the body that need to be strengthened are the back, legs, and arms. A few of the suggested exercises the group used to develop the EMT fitness plan are discussed below in the subsequent sections and Appendix F contains information regarding the entire fitness plan [31].

3.4.1. Back and Core Exercises

Given that the muscles within the back and oblique regions are predominantly used to facilitate the movement of the spine and upper body, strengthening these areas is quite important especially for EMTs as they are required to lift heavy loads throughout their shifts. There are many different exercises that function to the strengthen muscles within the back with and without using lifting machines. Of the several existing exercises, we decided to highlight a few that would provide the EMTs with the most benefit in the future within the fitness plan. A few of the selected exercises targeting the back and core are standing rows, standing flies, lat pulldowns, lower back extensions, planks, and crunches.

Standing rows and standing flies are two very similar exercises. Both exercises require the individuals to stand with their feet hip width apart to establish a strong, sturdy base. After the feet are properly positioned, the individual has to bend slightly at the knees and waist keeping the back perfectly straight. For the standing row, a set of dumbbells of a manageable weight are held by the individual's sides and drawn towards the waist. After a short pause, the individuals should return to the starting position. The standing fly exercises encompass the same positioning of the lower body and the back and the use of a set of dumbbells. Starting with the arms extended in front of the body just below shoulder height, individuals are to raise their hands out to the sides as seen in Figure 60.

Figure 60 - Standing Fly Exercise [15]

Upon holding the arms out in that position for a few seconds, the arms should be returned to their original position.

Lat pulldowns are performed using a specific workout machine equipped with a cable attached to a bar. Sitting on the available bench facing the bar, individuals are to grab the two ends of the bar keeping their upper arm parallel to the floor. This exercise entails pulling down on the bar so that the elbows move towards the ribcage. An important component to this and all exercises is exhaling during exertion as it assists in preventing internal injuries. Returning to the original position after exertion signifies the completion of one repetition. An exercise where dumbbells or weights are not included is the lower back extension. The correct position to perform this exercise is lying face down on the floor with the hands tucked behind the head keeping the elbows bent. After situating oneself in this position, the shoulders should be lifted a few inches off the ground and held in the extended position for a few seconds upon returning to the starting position.

To strengthen the abdominal region, we suggested a series of planks and crunches to target the upper and lower abs. The two types of planks to be included into the EMT plan are the traditional plank and the side plank. For the traditional plank, the EMT has to lay face down on the ground. Pushing off the ground, the individual rests on his or her toes and forearms keeping the back as flat as possible. This position should be held for 30 to 60 seconds and repeated two or three times. A side plank is executed in a similar fashion; however, the individual first lies on his or her side and hoists their weight up balancing on only one forearm and foot. The last part of the program focusing on the oblique region is a series of various crunches. To target both the upper and lowers abs, we included traditional crunches, where individuals lie on their back and lift their upper body towards their knees, and reverse crunches, where individuals bring their legs bring their legs up towards their core. Figure 61 is a schematic demonstrating the direction of the motion for both types of crunches.

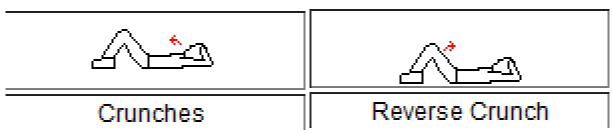


Figure 61 - Schematic of a Crunch and Reverse Crunch [2]

The last type of abdominal exercise is the double crunch, which is completed by performing the motions of the crunch and the reverse crunch simultaneously.

3.4.2. Leg Exercises

As it is recommended by health professionals and EMS personnel alike, the legs should generate the majority of the power to conduct the appropriate lifts to move patients and equipment to a given position. Given that these muscles are heavily relied upon in lifting, the EMT fitness plan includes several exercises to strengthen them to make lifting patients easier. One strengthening exercise that can be completed with or without dumbbells is the lunge. The stationary lunge is completed by originally standing with the feet shoulder width apart and stepping forward while stabilizing the front foot and while pressing the back knee towards the floor. Returning to a standing position, the same maneuver should be performed using the opposite leg. Similarly, the exercise known as the squat does not require the use of additional weights; however, they can be used to increase the level of difficulty of the exercise. To perform a squat, the individual has to stand with his or her feet shoulder width apart and bend at the knees as if he or she were going to sit in a chair. At the point of bending where the legs are at a 90° angle, the individual should return to the standing position.

Some of the workout machines in gyms across the country are designed to strengthen the various muscles in the legs. One of which is called the leg press. As seen in Figure 62 below, the individual sits and straightens his or her legs to maneuver a given weight. During this exercise, the only precaution that should be taken is to make sure the one does not lock his or her knees, because doing so can result in serious injuries.

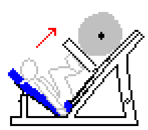


Figure 62 - Leg Press Exercise [2]

Another machine that is to be used if following this fitness plan is the quad extension machine. To use this device, the individual has to sit in the allotted area and position the ankles behind the knobs at the bottom; once properly positioned, he or she should try to move the weight by straightening the legs. After holding the weight for a few seconds, the individual is to bend his or her legs to return to the normal sitting position. Figure 63 shows a depiction of an individual using this machine.

Figure 63 - Quad Extension Exercise [15]

The last of the machine related exercises related to strengthening the muscles within the legs is the hamstring curls machine. This exercise entails the individual to lie down on the workout bench and tucking his or her ankles behind the padded portion. While in this position, he or she should lift the weight by bending the knees and bringing the ankles towards the core. Holding the weight for a few seconds, the legs should be extended once again to the original position. Figure 64 shows the depiction of this machine [15], [2].

Figure 64 - Hamstring Curl Exercise [15]

Appendix F includes an outline of all the exercises within the EMT Fitness Program in addition to the ones mentioned previously.

Chapter 4. CONCLUDING REMARKS

During the beginning stages of this project, the group experienced difficulty in defining the objectives due to the entire scope of the category of safety. Through discussions and extensive brainstorming sessions, the basis of this project was developed, and it consisted of four separate components. The first of these components was altering the interior of the ambulance to ensure improved safety of both the patients and EMTs. The implemented modifications were only of the smaller scale as the group did not alter any of the existing storage compartments; however, redesigning the entire cabin including the compartments and seating areas would be the best method to reduce the total number of injuries that occur within the ambulance.

Given the number of injuries EMTs acquire from lifting patients and equipment, the second portion of the project involved designing a new device to be used to transport patients down the stairs. The goal of this device was to lessen the strain within the users' back when moving it down the stairs. With the shopping cart arrangement of the upper handle, EMTs can maintain proper posture while maneuvering patients. Another objective for the design was to increase the weight capacity to be used with obese or bariatric patients. An analysis was performed on the device using the SimulationXpress in SolidWorks, which showed that the device did withstand large forces equivalent to those patients would apply to it. If provided more time, the group would perform a more detailed analysis on the device in addition to assess which materials should be used to reduce the overall weight of it.

The third part of the project entailed enhancing the training program with simulation training. Through research and interviews with paramedics, the group realized that EMT candidates did not have to perform any of the requested lifts to receive certification. Based on that fact, the group formulated an outline of basic guidelines to be added to the current program that will guarantee EMTs attain the proper skills to perform the necessary lifts. The addition of simulation training will help EMTs comprehend the expectations of them before going out into the field. In addition to the simulation training, the final section of this project comprised of creating a fitness plan for EMTs to follow after becoming certified. The purpose of this program is to have EMTs workout on a daily basis to increase their strength and health throughout their careers. If this were to be integrated into EMS systems, all personnel would be at a better fitness level allowing them to perform the necessary lifts with more efficiency. Overall, the four components of this project, if utilized, would effectively improve the safety of EMS personnel, but there is still room to improve each aspect of the project in the future.

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Appendix A – EMT Curriculum for Lifting Patients

PERSONNEL

Primary Instructor: One EMT-Basic instructor knowledgeable in this area.

Assistant Instructor: The instructor-to-student ratio should be 1:6 for psychomotor skills practice. Individuals used as assistant instructors should be knowledgeable about lifting and moving patients.

Recommended Minimum
Time to Complete: Three hours

PRESENTATION

Declarative (What)

I. Body Mechanics
   A. Lifting techniques
      1. Safety precautions
         a. Use legs, not back, to lift.
         b. Keep weight as close to body as possible.
      2. Guidelines for lifting
         a. Consider weight of patient and need for additional help.
         b. Know physical ability and limitations.
         c. Lift without twisting.
         d. Have feet positioned properly.
         e. Communicate clearly and frequently with partner.
      3. Safe lifting of cots and stretchers. When possible use a stair chair instead of a stretcher if medically appropriate.
         a. Know or find out the weight to be lifted.
         b. Use at least two people.
         c. Ensure enough help available. Use an even number of people to lift so that balance is maintained.
            (1) Know or find out the weight limitations of equipment being used.
            (2) Know what to do with patients who exceed weight limitations of equipment.

5. Correct carrying procedure on stairs
   a. When possible, use a stair chair instead of a stretcher.
   b. Keep back in locked-in position.
   c. Flex at the hips, not the waist; bend at the knees.
   d. Keep weight and arms as close to the body as possible.

C. Reaching
1. Guidelines for reaching
   a. Keep back in locked-in position.
   b. When reaching overhead, avoid hyperextended position.
   c. Avoid twisting the back while reaching.
2. Application of reaching techniques
   a. Avoid reaching more than 15 - 20 inches in front of the body.
   b. Avoid situations where prolonged (more than a minute) strenuous effort is needed in order to avoid injury.
3. Correct reaching for log rolls
   a. Keep back straight while leaning over patient.
   b. Lean from the hips.
   c. Use shoulder muscles to help with roll.

D. Pushing and pulling guidelines
1. Push, rather than pull, whenever possible.
2. Keep back locked-in.
3. Keep line of pull through center of body by bending knees.
4. Keep weight close to the body.
5. Push from the area between the waist and shoulder.
6. If weight is below waist level, use kneeling position.
7. Avoid pushing or pulling from an overhead position if possible.
8. Keep elbows bent with arms close to the sides.

II. Principles of Moving Patients

A. General considerations
1. In general, a patient should be moved <u>immediately</u> (emergency move) only when:
   a. There is an immediate danger to the patient if not moved.
      (1) Fire or danger of fire.
      (2) Explosives or other hazardous materials.
      (3) Inability to protect the patient from other hazards at the scene.
      (4) Inability to gain access to other patients in a vehicle who need life-saving care.

b. Life-saving care cannot be given because of the patient's location or position, e.g., a cardiac arrest patient sitting in a chair or lying on a bed.

2. A patient should be moved quickly (urgent move) when there is immediate threat to life.
   a. Altered mental status
   b. Inadequate breathing
   c. Shock (hypoperfusion)
3. If there is no threat to life, the patient should be moved when ready for transportation (non-urgent move).

B. Emergency moves
   1. The greatest danger in moving a patient quickly is the possibility of aggravating a spine injury.
   2. In an emergency, every effort should be made to pull the patient in the direction of the long axis of the body to provide as much protection to the spine as possible.
   3. It is impossible to remove a patient from a vehicle quickly and at the same time provide as much protection to the spine as can be accomplished with an interim immobilization device.
   4. If the patient is on the floor or ground, he can be moved by:
      a. Pulling on the patient's clothing in the neck and shoulder area.
      b. Putting the patient on a blanket and dragging the blanket.
      c. Putting the EMT-Basic's hands under the patient's armpits (from the back), grasping the patient's forearms and dragging the patient.

C. Urgent moves
   1. Rapid extrication of patient sitting in vehicle
      a. One EMT-Basic gets behind patient and brings cervical spine into neutral in-line position and provides manual immobilization.
      b. A second EMT-Basic applies cervical immobilization device as the third EMT-Basic first places long backboard near the door and then moves to the passenger seat.
      c. The second EMT-Basic supports the thorax as the third EMT-Basic frees the patient's legs from the pedals.
      d. At the direction of the second EMT-Basic, he and the third EMT-Basic rotate the patient in several short, coordinated moves until the patient's back is in the open doorway and his feet are on the passenger seat.

e. Since the first EMT-Basic usually cannot support the patient's head any longer, another available EMT-Basic or a bystander supports the patient's head as the first EMT-Basic gets out of the vehicle and takes support of the head outside of the vehicle.
f. The end of the long backboard is placed on the seat next to the patient's buttocks. Assistants support the other end of the board as the first EMT-Basic and the second EMT-Basic lower the patient onto it.
g. The second EMT-Basic and the third EMT-Basic slide the patient into the proper position on the board in short, coordinated moves.
h. Several variations of the technique are possible, including assistance from bystanders. Must be accomplished without compromise to the spine.

D. Non-urgent moves
1. Direct ground lift (no suspected spine injury)
    a. Two or three rescuers line up on one side of the patient.
    b. Rescuers kneel on one knee (preferably the same for all rescuers).
    c. The patient's arms are placed on his chest if possible.
    d. The rescuer at the head places one arm under the patient's neck and shoulder and cradles the patient's head. He places his other arm under the patient's lower back.
    e. The second rescuer places one arm under the patient's knees and one arm above the buttocks.
    f. If a third rescuer is available, he should place both arms under the waist and the other two rescuers slide their arms either up to the mid-back or down to the buttocks as appropriate.
    g. On signal, the rescuers lift the patient to their knees and roll the patient in toward their chests.
    h. On signal, the rescuers stand and move the patient to the stretcher.
    i. To lower the patient, the steps are reversed.
2. Extremity lift (no suspected extremity injuries)
    a. One rescuer kneels at the patient's head and one kneels at the patient's side by his knees.

b. The rescuer at the head places one hand under each of the patient's shoulders while the rescuer at the foot grasps the patient's wrists.
c. The rescuer at the head slips his hands under the patient's arms and grasps the patient's wrists.
d. The rescuer at the patient's foot slips his hands under the patient's knees.
e. Both rescuers move up to a crouching position.
f. The rescuers stand up simultaneously and move with the patient to a stretcher.

3. Transfer of supine patient from bed to stretcher
   a. Direct carry
      (1) Position cot perpendicular to bed with head end of cot at foot of bed.
      (2) Prepare cot by unbuckling straps and removing other items.
      (3) Both rescuers stand between bed and stretcher, facing patient.
      (4) First rescuer slides arm under patient's neck and cups patient's shoulder.
      (5) Second rescuer slides hand under hip and lifts slightly.
      (6) First rescuer slides other arm under patient's back.
      (7) Second rescuer places arms underneath hips and calves.
      (8) Rescuers slide patient to edge of bed.
      (9) Patient is lifted/curled toward the rescuers' chests.
      (10) Rescuers rotate and place patient gently onto cot.
   b. Draw sheet method
      (1) Loosen bottom sheet of bed.
      (2) Position cot next to bed.
      (3) Prepare cot: Adjust height, lower rails, unbuckle straps.
      (4) Reach across cot and grasp sheet firmly at patient's head, chest, hips and knees.
      (5) Slide patient gently onto cot.

Appendix B – EMT/Paramedic Safety Survey

Please circle the answers that apply.

1. Have you been injured while maneuvering a piece of equipment in the field?
    a. Yes b. No

2. If so, what piece of equipment has caused the most injuries?
    a. Stretcher b. Stair Chair c. Backboard d. Other _______________

3. Do you see any flaws in the equipment used?
    a. Does not support the weight of heavier patients
    b. Puts too much pressure on the EMT/paramedic
    c. Too cumbersome while maneuvering down stairs
    d. Other ________________

4. What area of the body have you injured the most?
    a. Back b. Neck c. Wrist d. Knees e. Other ______

5. Do you feel the training required to become an EMT properly prepares you for the physical demands of the job?
    a. Yes b. No

6. Do you think there is enough safety equipment within the ambulance to prevent injuries during motion?
    a. Yes b. No

7. Is there anything you would change about the EMS system to increase the overall safety of EMTs/paramedics?

Appendix C – Survey Results

Table 17 - Results from EMT Safety Survey (n=12)

Question Number	Answers	Percentages
1	Yes No	75% 25%
2	Stretcher Stair Chair Backboard Other	44.4% 33.3% 11.1% 11.1%
3	Does not support the weight of heavier patients Puts too much pressure on the EMT Too cumbersome while maneuvering downstairs Other	36.4% 45.5% 36.4% 36.4%
4	Back Neck Wrist Knees	87.5% 12.5% 0% 0%
5	Yes No	33.3% 66.7%
6	Yes No	58.3% 41.7%

“Other” Responses to Question 3

- Difficult to bring up stairs
- Center of gravity issue
- Places are too small
- Requires lifting of very heavy patients

Question 7 Responses

- No
- No
- More training and education on proper lifting, carrying, reaching, techniques
- Have a physical fitness requirement
- Net at top of bench, near side door
- Powered cots, safety nets in every rig
- More personal help when moving large individuals
- Better communication systems
- Ambulances should be designed for the safety of the EMTs and paramedics
- Automatic lifts, airbags in patient compartment

Appendix D – Alterations to the Current EMT Training Program

Alteration 1 – Repetition Maximum Testing

a. Acquire regulation 45 pound bar and additional weights as necessary
b. Perform one repetition of a bench press with just the bar
c. Add weight onto the bar gradually
d. Perform one repetition of the total weight
e. Record the highest weight that each individual can lift safely

Alteration 2 – Lifting and Maneuvering the Stretcher (with EMT/Instructor)

a. Assess the given situation with the assistance of a certified EMT and/or instructor
b. Listen to the instructions and advice of the EMT while performing the maneuver
c. Lift the appropriate end of the stretcher at the same time as the EMT
d. Once the stretcher is off of the ground, walk a distance of twenty feet at the same pace
e. At a safe location, lower the stretcher back to the ground
f. Switch ends to gain experience in both positions

Alteration 3 – Lifting and Maneuvering the Stretcher (with other candidate/partner)

a. Assess the given situation with a partner
b. Communicate with the partner to determine how to maneuver the stretcher in the given environment
c. Lift the appropriate end of the stretcher at the same time as the partner
d. Once the stretcher is off of the ground, walk a distance of twenty feet at the same pace
e. At a safe location, lower the stretcher back to the ground
f. Switch ends to gain experience in both positions

Alteration 4 – Lifting and Securing the Stretcher in the Ambulance

a. With the stretcher about five feet away from the back of the ambulance, lift the stretcher off the ground
b. The EMT/candidate closest to the ambulance should set the pace while maneuvering the stretcher closer to the ambulance
c. Once the stretcher can touch the back of the ambulance, the other EMT should ask for assistance if necessary
d. Place the stretcher align with the securing mechanism located on the floor of the interior of the ambulance
e. The other person (with help if needed) should propel the device forward to ensure the device is completely secured in place before any movement of the ambulance
f. Repeat task in the other position

Alteration 5 – Lifting and Maneuvering the Stair Chair (with EMT/Instructor)

a. Assess the situation in all of its aspects
b. Ensure that the patient or dummy patient is correctly strapped into the device
c. With the EMT in the front position, he or she should give the appropriate advice to the candidate throughout the procedure to ensure safety
d. Guide the stair chair down the first flight of stairs until landing area is reached

e. When ready, both have to lift the chair to alter the orientation of it to descend the next flight of stairs
f. At the bottom of the stairs, lower the device to the ground properly
g. Repeat procedure in the opposite positions

Alteration 6 – Lifting and Maneuvering the Stair Chair (with candidate/partner)

a. Assess the situation in all of its aspects
b. Ensure that the patient or dummy patient is correctly strapped into the device
c. With one candidate in the front position, he or she should give the appropriate advice to the other throughout the procedure to ensure safety
d. Guide the stair chair down the first flight of stairs until landing area is reached
e. When ready, both have to lift the chair to alter the orientation of it to descend the next flight of stairs
f. At the bottom of the stairs, lower the device to the ground properly
g. Repeat procedure in the opposite positions

Appendix E – Coast Guard Fitness Plan Document

U.S. Department of Homeland Security
U.S. Coast Guard
CG-6049 Rev. (06-07)

Personal Fitness Plan

All Coast Guard military personnel shall complete sections 1, 2, 6, and 8.
All Coast Guard military personnel on weight probation shall complete all sections.

1.

Last Name _______________ First Name _______________ Middle Initial ____

2. My program plan is as follows:

Activity	Components (X)					Intensity (RPE)	Duration	Frequency (X)						
	CRE	MS	ME	F	BC			M	T	W	T	F	S	S

3. My probationary period will begin on ____________ and conclude on ____________. During this probationary period I understand it is mandatory for me to engage in fitness activities, monitored by my UHPC, that will promote body fat and weight loss, for a minimum of one hour, three times per week. I understand that I am required to complete a monthly physical fitness test to assess my adherence to this fitness plan.

Initials: ____________

4. General or Long Term Goals

A. ______________________________ ____________ (Target date)

B. ______________________________ ____________ (Target date)

C. ______________________________ ____________ (Target date)

5. Specific or Short Term Goals

A. ______________________________ ____________ (Target date)

B. ______________________________ ____________ (Target date)

C. ______________________________ ____________ (Target date)

6. Member Acknowledgement

(Member Signature) ____________ (Date) ____________

7. Unit Health Promotion Coordinator: *(only for members on probation)*

(Signature) ____________ (Date) ____________

8. Supervisor

(Signature) ____________ (Date) ____________

PRIVACY ACT STATEMENT

Authority: 10 USC 8012 and Executive Order 9397
Principle Purpose: To complete a Personal Fitness Plan as part of the Health and Fitness Program and the Coast Guard Weight and Body Fat Standards Program.
Routine Uses: Used to assist military members with developing a Personal Fitness Plan in accordance with the Coast Guard Weight and Body Fat Standards Program COMDTINST M1020.8 (series). Information will be released to authorized personnel involved in health assessment.
Disclosure: Voluntary; however, failure to furnish the requested information will impede on determining the health and fitness process.

U.S. DEPT. OF HOMELAND SECURITY, USCG, CG-6049 (Rev. 06-07)

Reset

INSTRUCTIONS FOR COMPLETING PERSONAL FITNESS PLAN FORM

Sections 1, 2, 6, and 8 should be completed by military members in compliance with Coast Guard Maximum Allowable Weight (MAW) Standards in accordance with COMDTINST M1020.8 (series) for the basic fitness plan.

All sections shall be completed by military members not in compliance with MAW standards for the detailed fitness plan.

1. Self-explanatory.
2. Program plan. Those in compliance with MAW standards should use this section to develop a basic fitness plan to include cardio respiratory endurance training (CRE), muscular strength (MS) and muscular endurance (ME) training. Those not in compliance with MAW standards should use this section to develop their detailed fitness plan which should address the five health-related components of fitness including cardio respiratory endurance (CRE), muscular strength (MS), muscular endurance (ME), flexibility (F) and body composition (BC). Members should select activities, mark which components of health-related fitness each activity addresses, and fill in intensity, frequency, and duration based on guidelines below and in Appendix C of COMTINST M1020.8 (series).

   Cardio Respiratory Endurance (CRE) is the ability to perform prolonged, large-muscle, dynamic exercise at moderate-to-high intensities. Examples of activities in this area include, but are not limited to running, cycling, and swimming. **Muscular Strength** (MS) is the amount of force a muscle can produce with a single maximum effort while **muscular endurance** (ME) is the ability of a muscle to resist fatigue and sustain a given level of muscle tension. Weight training and resistance bands would be examples of activities in these areas. **Flexibility** (F) is the ability to move the joints through their full ranges of motion and is accomplished with stretching exercises or yoga type activities. **Body Composition** (BC) refers to the proportion of fat and fat-free mass (muscle, bone, and water) in the body. Cardio respiratory training to lose fat and weight training to add muscle mass both address body composition.

	Frequency	Intensity	Duration
CRE	3-5 days/week	55-64% of max heart rate (unfit); 70-85% of max heart rate (average)*; 12-17 RPE**	20-60 minutes (one session or multiple sessions lasting 10 or more mins)
MS/ME	2-3 days/week	Resistance heavy enough to cause muscle fatigue in number of recommended set/reps.	8-12 reps of each exercise; one set of each exercise
F	2-3 days/week or more	Stretch to the point of mild discomfort, not pain.	Each stretch should be held for 10-30 seconds.

Intensity

* Estimated Maximum Heart Rate = 220-age

** Rating of perceived exertion (RPE) is a method used to determine intensity of exercise. It is basically a subjective measure of how hard we think or feel we are exercising.

How does the exercise feel?	RPE
Very, very light	6-7
Very light	8-10
Fairly light	11-12
Somewhat hard	13-14
Hard	15-16
Very hard	17-18
Very, very hard	19-20

3. Military members on Weight Probation should initial to indicate understanding of personal accountability for their individual physical fitness and weight management progress.
4. General or long term goals. Here the member should enter their overall or ultimate goals related to fitness and weight management. In general, one of those long-term goals should be to be in compliance with Coast Guard MAW standards. The member should list target dates for goal attainment.
5. Specific or short term goals. Here the member should enter milestones to assist them on their way to their final goals. Goals should be fitness or weight management related, meaningful, measurable, and realistic. For example if your long-term goal is to lose 20 pounds, a short-term goal might be to successfully complete two weeks of your fitness plan. The member should list target dates for goal attainment.
6. Self-explanatory.
7. This section shall be signed by Unit Health Promotion Coordinator (UHPC) if the member is on weight probation.
8. Self-explanatory. Member's supervisor should sign to acknowledge existence of a plan and upon end of marking period should look for adherence to plan.

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Appendix F – EMT Fitness Plan

This is the EMT Fitness Plan that the Ambulatory Work-Related Injuries and Health Problems generated for EMTs to follow to increase their strength to ensure a high level of physical fitness.

It is advised that each EMT exercise a minimum of 30 minutes per day; however, the amount of time can increase based on the individual's original level of fitness. The groupings of exercises are broken up into categories based on the targeted set of muscles.

Biceps:

Exercise	Sets	Reps
Traditional Bicep Curl	4	12
Reverse Bicep Curl	4	12
Hammer Curl	4	12

Triceps:

Exercise	Sets	Reps
Traditional Triceps Extension	4	12
Overhead Triceps Extension	4	12
Skull Crushers	4	12
Push Ups	2	25
Push Downs on Lat Pulldown Machine	4	12
Dips or Bench Dips	2	15

Chest:

Exercise	Sets	Reps
Bench Press (flat bench)	3	12
Chest Press (machine)	3	12
Pec Fly	3	12

Shoulders:

Exercise	Sets	Reps
Front Raise	3	12
Side Raise	4	12
Shoulder Shrugs	4	12
Shoulder Press	3	12

Back:

Exercise	Sets	Reps
Back Extension	4	12
Deadlifts	4	12
Standing Fly	4	12
Standing Row/Fly	4	12
Lat Pulldowns	4	12

Abdominals:

Exercise	Sets	Reps
Crunches	2	25
Oblique Crunches	2	25
Planks	2-3	30 sec
Side Planks	2-3	30 sec
Flutter/Scissors Kicks	2	25
Twisting Crunches	2	25
Reverse Crunches	2	25
Double Crunches	2	25

Legs:

Exercise	Sets	Reps
Lunges	4	25
Step Ups	4	25
Quad Extensions	4	12
Hamstring Curl	4	12
Leg Press	4	12
Hip Adduction	4	12
Hip Abduction	4	12

All of the listed exercises should not all be done during the same session. These should be used to formulate different workouts to target different areas that need strengthening. The number of sets and reps are displayed as only a suggestion and can be altered for different results.