The Effects of User-Centered Design on the Usability of Patient Handling Equipment

by

Mark Fenzl

June 1, 2012

A thesis submitted to the
Faculty of the Graduate School of the
University at Buffalo
State University of New York
in partial fulfillment of the requirements for the
degree of

Master of Science

Department of Industrial & Systems Engineering

Acknowledgements

This research could not have been completed without the resources (personnel, facilities, funding) of the Department of Industrial & Systems Engineering and the Department of Rehabilitation Science at the University at Buffalo. I would especially like to thank Dr. Andrew Ray for providing expert knowledge, lab space, and unconditional time and effort working with me.

I have greatly benefited from the help, knowledge, and expertise of my advisor and mentor Dr. Victor Paquet. His tremendous amount of passion in the field of Human Factors and Ergonomics motivated me to pursue a thesis. I sincerely appreciate the great amount of time, effort, and suggestions working with me to improve this thesis.

In addition, I would like to thank the support I have received from healthcare professionals such as Robert Guest, Melissa Rowland, and Paula Pless.

I would also like to thank my friends and colleagues Scott and Xinhui for their constant support and advice.

And lastly, I would like to thank my wonderfully loving and kind Mom and Dad, and my terrific brother Michael for always being there for me, and believing and supporting me in everything I do.

Table of Contents

Page

List of Tables

Page

List of Figures

Page

Abstract

Patient transfers are a daily occurrence in numerous hospital and nursing home facilities, as well as homecare settings. Patient transfers require the use of patient handling equipment to reduce the physical loading during patient lifts as compared to when patients are transferred manually by one or two individuals. When used, this equipment is thought to reduce the risk of low back injuries by eliminating the manual lifting requirements otherwise faced by healthcare workers. However, the introduction of patient handling equipment into the workplace has brought about challenges and concerns from a usability perspective, and the usability of the equipment has not been tested in a systematic way. The purpose of the current study is to determine the usability of existing patient handling equipment, including slings, and to test design changes that are hypothesized to make the equipment easier to use. The study first involved a focus group of practicing nurses, certified nursing assistants, and other healthcare professionals to identify challenges in the design of current patient lifting aides and potential design solutions. Then, a usability study was performed to evaluate differences in usability between the current equipment and equipment with design modifications supported by the focus group. Each participant was placed randomly in one of the two conditions (Original or Modified Equipment). Each participant was asked to perform a patient transfer from a bed to a commode. Errors, time, perceived physical exertion (RPE), and a usability survey tool were all used to evaluate both the original and modified equipment. Results suggest that simple improvements to existing patient lifting equipment can be made to improve usability.

Chapter 1: Introduction

The healthcare industry is a high-risk profession when it comes to many musculoskeletal injuries, in particular the low back. Patient transfers are one of the tasks largely associated with the high-risk of producing these types of injuries. The awkward postures and heavy unpredictable distribution of weight load being lifted many times per day by nurses for patient handling tasks, makes these tasks high-risk. Manually lifting patients has been considered a safe practice within the nursing community, even though science proves otherwise.

Previous research strongly supports that these approaches are not effective in reducing caregiver injuries (Nelson et al., 2003). The nursing profession has one of the highest incidence rates of work related back injuries (Bureau of Labor statistics [BLS], 2002), estimated at 12.6/100 full time workers (Bureau of Labor Statistics [BLS], 2003). This number is considered to be a low estimate, since underreporting of injuries in nursing is common (US Department of Health and Human Services (USDHHS), 1999). To combat the high injury rate, the healthcare industry has introduced a wide-range of patient handling equipment into the workplace.

With the introduction of new patient handling equipment into the healthcare industry, one is led not only to the question, is this equipment being used, but also and perhaps more importantly when this equipment is, is it being used in a safe and efficient manor? The current study attempts to systematically analyze the usability of the current patient handling equipment. Having lifts and slings that nurses not only feel comfortable using, but can safely, effectively, and efficiently use these devices increases the likelihood of them wanting to use this equipment and performing the tasks correctly without error.

Nurses are always concerned about not only their safety, but also and probably more so about patient safety. Research by both Bell (1984) and Owen (1988) revealed one reason nurses might not be very willing to use patient handling equipment was because they had the perception that the patients would have a negative response to using the equipment. However, a study performed by Owen et al. (2002) showed that patients actually felt more comfortable and more secure when patient handling equipment was used instead of manual lifting. Similarly, if the patient felt uncomfortable, then that individual experienced a feeling of insecurity.

Another important finding shown in both Bell (1984) and Owen (1988) was that the nurses for the most part did not know how to use the patient handling equipment or they were not available to them on the floor, and therefore would not use the lifts and assistive devices.

In the current study, errors were collected in order to show what parts of the tasks involved with using the patient handling equipment nurses and nursing students have challenges with, and if the modifications made can increase the likelihood of correcting those errors. Making the nurses more comfortable with using the equipment can make it more likely that they may use the equipment. Providing healthcare workers with easy to use equipment is essential for healthcare progressing in the future.

This study attempts to determine the usability of existing patient handling equipment, including slings, in a systematic way, and then see whether a user-centered design approach can improve the usability of the equipment. The purpose of this study is to determine the usability of existing patient handling equipment, including slings, and to determine if there are design changes that can make the equipment easier to use.

Chapter 2: Literature Review

Introduction

Designing around the user is a key component to introducing a successful product. User-Centered Design (UCD) focuses on processing the information provided by the users of the product, and then applying that information into the re-design or modification of that certain product. Fitting the product to the individual, rather than fitting the individual to the product is the goal of user-centered design.

Buurman 1997 suggested involving end-users into the design process, and allowing for better communication between a multidisciplinary design team, especially at the beginning phases. This User-Center Design concept would then consequently create the best opportunities for improving the process of user-centered design and, therefore improving the resulting products by matching the product to the user requirement increasing its practical use. The current study focuses on users at the beginning phases of the design process by involving the users in the focus group, a key to the UCD process.

Kontogiannis and Embrey 1997 discussed a UCD approach to make a computer-based information system easier to operate, increase the user acceptance of the new technologies and working practices. In this study, process information was re-structured in a hierarchical and functional manner that was more accepted by the users, which in turn reduced the number visual display unit (VDU) pages involved with the system, the monitoring process improved, and the training needs for learning the new system could be identified in advance. Therefore, the current study aims to involve the users at the beginning of the design phase in the focus group and then track how this user group (nurses) accepts the new design modifications given to patient handling equipment (lift and slings) and the area where the patient transfer is performed.

Designing patient handling equipment with the user in mind is very important to the success of effective patient transfers. A laboratory study evaluated six patient handling devices, and it was determined that only two of these devices actually resulted in reducing nursing personnel's back stress (Garg et al., 1991). So four out of the six devices tested did not help in reducing back stress. Since the Garg et al. 1991 study, many new patient handling devices have been introduced to the market, which Zhuang et al. 1999 and Zhuang et al. 2000 studied these new technological advances in lifting equipment include battery powered and ceiling mounted devices in both a biomechanical and psychophysical assessment.

Zhuang et al. 2000 performed a psychophysical assessment of nine battery-powered lifts, a sliding board, a walking belt, and a baseline method for transferring nursing home residents from a bed to a chair. It is important to note that not all patient handling devices are the same, or for that matter created equal. Different patient handling devices will produce different results when it comes to injuries.

The objective of the Zhuang et al. 2000 study was to perform a psychophysical assessment in order to: (1) investigate the effects of resident-transferring methods on the psychophysical stress to nursing assistants performing the bed-to-chair transferring task, (2) collect patient comfort and security data, and (3) identify transfer methods that could reduce the psychophysical stress perceived by nursing assistants and residents.

The walking belt and stand-up lifts were viewed by the nursing assistants as not being complicated devices to use, and just as easy to use these as performing the baseline manual transfer method. The other lifting devices that included the four basket-sling lifts and the ceiling lift received higher stress ratings. The higher stress ratings among the basket-sling lifts possibly could have been caused by postural stresses consequently resulting from using slings, and maneuvering and steering the lift to the chair. Also, the use of transfer devices increases the complexity of the transfer task. The manual transfer method only requires a few steps, while the patient handling equipment transfers require a number of sub-tasks.

The current study aims to evaluate these sub-tasks involved with using the patient handling equipment (both the lift and sling) during a patient transfer from a bed to a commode. Assessing where nurses and nursing students make these errors, and what sub-tasks in particular give these young professionals challenges will help give designers key areas to focus on when designing future equipment. The nursing assistants also suggested that some minor design problems associated with the equipment could cause a high level of stress (Zhuang et al., 2000). Decreasing the stress associated with these tasks can be accomplished by making the design of the equipment more intuitive and easier to use.

The transferring task used by Zhuang et al. 2000 is similar to the transferring task performed in the present study. Zhuang et al. 2000 required the nursing assistants to transfer a resident from a supine position (resident lying on their back) to an upright-seated position in a chair. A main difference being that in the present study the participant’s are transferring them to a commode instead of a chair. Both require nurses and nursing assistants to put the patient or resident in an upright posture in order to place them on the chair or commode.

Zhuang et al. 1999 also completed a biomechanical assessment of nine battery-powered lifts, a sliding board, a walking belt, and a baseline method for transferring nursing home residents from a bed to a chair. The study showed that the transfer method and resident weight are both factors in determining low back loading on the nursing assistant. The floor-based lift reduced exposure to low back stress during lifting activities while performing a transfer by two-thirds compared to baseline manual lift. The use of these lifts has been shown to reduce the biomechanical stress, which in turn will reduce the number of low back injuries related to patient handling.

Another interesting finding of the study suggests that nursing assistants consider rolling the resident away from themselves using a pushing motion instead of rolling the resident toward themselves before placing the sling under the resident. In the current study, the researchers tested this suggestion by keeping track of this action as an error, which was taught as being an error during the safe patient handling class.

Ergonomic Intervention Programs

Patient transfers are a high-risk task associated with many musculoskeletal injuries, and therefore hospitals, nursing homes, and other healthcare facilities have introduced numerous patient handling devices into the workplace, and have implemented ergonomic intervention programs.

A study by Garg et al. 1992 suggests that the most viable solution for reducing low-back pain to nursing personnel is a comprehensive ergonomics approach. This comprehensive ergonomics approach should not only be geared towards the physical stresses experienced by nurses, but also attributed to the safety and comfort during patient transfers. Therefore, Garg et al. 1992 suggests that the design and layout of patient rooms, toilets and bath areas, bed selection, wheelchairs and patient transferring devices should be safe and comfortable, easily accessible, and easy to operate. These transferring devices should not require excessive time to make the transfer either. In this regard, making these design changes to both the equipment and room have the ability to produce a positive impact implementing an ergonomic intervention program.

Ergonomic intervention programs have the goal to change the work environment to meet the needs of the worker, and not to have the worker adapt to the environment. This is a challenging task in any workplace, but the healthcare industry has proved to be especially challenging to implement these changes. For instance in a manufacturing setting, it would seem highly likely for a worker to lift a 100 pound box or widget without the assistance of a machine or lift. However, the manual lifting of a 100-pound patient is often viewed as part of the job in the nursing profession. The current push for zero-lift policies in hospitals and healthcare organizations, along with legislation at the state level is an attempt for the healthcare industry to catch up with the rest of the workforce.

Ergonomic intervention programs in hospitals and nursing facilities have been shown to be highly effective in reducing the risk of injury in healthcare workers, especially nurses. A study performed by Nelson et al. 2006 studied the implementation of a multifaceted ergonomics program. This study assessed 23 high-risk healthcare units, which experienced the highest incidence and severity of job-related musculoskeletal injuries. The implementation of the multifaceted ergonomic program in these high-risk units would therefore be able to show the greatest amount of improvement.

The multifaceted ergonomics program resulted in an 18% decrease in lost workdays post-intervention. The program was well accepted by patients, nursing staff, and administrators. The results of the study showed positive outcomes associated with injury rates, modified duty days, job satisfaction, self-reported safety in performing patient handling tasks, and cost. Technology was indicated to have the most potential in improving and creating a safe work environment for nurses and other healthcare professionals. There is still a significant room to make improvements to the patient handling equipment, and to do so ergonomic specialists will need to work closely with direct patient care providers who use this equipment.

Another field study by Jang et al. 2007 required the researchers to study a variety of nursing tasks, including lifting a patient, and assessed which tasks were of high-risk to the low back. The researchers identified a total of two hundred fifty four (254) nursing activities. Fifty four (54) of them either were either incomplete or could not be grouped properly. The other two hundred (200) activities were organized into eighteen (18) specific task categories. The study assessed that RN's performed thirteen (13) tasks, eleven (11) were performed by NA's, and five tasks (5) specifically that involved lifting patients were performed by both RN's and NA's.

These specific tasks are shown in Figure 1, a table taken out of the Jang et al. 2007 study. There are a large number of tasks that nurses are required to do as part of their daily duties. This places a great deal of stress on these professionals. Time is valuable to nurses along with ensuring quality of care to the patients. Making the lifts and slings easier to use could help alleviate some of the stress involved in lifting patients by increasing efficiency.

Task category	Description of the activity	Movement category*	Task performers	No. of observ.	Risk category
Assist patient to move	Help patient move to bathroom	Mixed	Both	9	Low
Bathe patient	1) Bathe patient on bed; roll patient side to side for access 2) Bathe patient in chair; kneeling down when washing feet	Dynamic	NAs	14	Low
Check blood glucose	Put lancet in spring loaded holder; prick finger with lancet; place blood drop on test strip; insert strip in glucometer; check reading	Static	RNs	20	Low
Check blood pressure	Wrap cuff snugly and uniformly around arm circumference; palpate brachial artery; check gauge reading	Static	RNs	13	Low
Dangling	Lift patient from lying to sitting on bed	Mixed	Both	7	Low
Draw blood	Draw blood	Static	RNs	3	Low
Make bed	Collect bed sheets and pillow cases; make bed (including organizing bed area for access)	Dynamic	NAs	20	Low
Medical wound care	Cleanse wound; apply new gauze dressing to cover wound	Dynamic	RNs	11	Low
Medicine injection	Inject medicine into patient's arm	Static	RNs	7	Low
Partial lift	Move patient up in bed using draw sheet under patient's back while patient bends knees to aid the movement	Dynamic	Both	4	High
Physical assessment	Check blood pressure, temperature, heart rate, and listen to lungs	Mixed	RNs	15	Low
Prepare medicine	Enter data in computerized medicine distribution machine; pick up medicine	Mixed	RNs	15	Low
Putting on stockings	Put on stockings (antiembolism knee-high elastic stockings)	Dynamic	Both	3	Low
Take temperature	Put probe of electronic thermometer into patient's mouth, hold its position for 1 minute, check reading	Static	NAs	24	Low
Total lift	Move patient up in bed using draw sheet under the patient's back without patient's aid	Dynamic	Both	6	High
Transport patient	Move patient from chair to bed, or bed to chair	Mixed	Both	8	High
Walk patient	Accompany patient while walking with or without equipment	Dynamic	NAs	7	Low
Weigh patient	Assist patient to stand up and walk to scale	Mixed	NAs	14	Low

Note: *Static means this activity involves performing static postures and maintaining postures for a period of time; dynamic means the activity involves performing continuous movement; mixed means the activity involves performing static postures and continuous movement.

Figure 1: This table from Jang et al. 2007 displays the specific tasks of both RN's and nursing assistants (NAs), along with a description of those tasks.

The manually lifting of a patient was assessed to be high-risk. One of the measurements taken during the study was ratings of perceived exertion (RPE). The study showed that nurses perceived patient handling tasks as the most stressful activity. Therefore, the study supports self-reported perceived exertion as an acceptable tool to be used to identify nursing tasks that have a high risk of injury to both the low and high back.

A study performed by Owen et al. 2002 examined perceived level of exertion among nurses at two hospitals, the one being an experimental hospital where an ergonomic program was instituted, and the other being a control hospital where the staff's typical methods of lifting and transferring patients were unchanged. Many lifting devices were brought into the hospital and made available for the nurses to use in the experimental group where the ergonomic program was instituted. The number of back and shoulder injuries, lost workdays, and restricted workdays was collected an annual basis in a five-year follow-up study.

The Owen et al. 2002 study showed that perceived physical stress to the back was significantly reduced for all tasks at the experimental hospital. The number of back injuries, lost work, and restricted days was also reduced with the implementation of the ergonomic program. There was a 40% decrease in injuries comparing 18 months pre-intervention to 18 months post-intervention.

The current study will focus on taking the current equipment being used, and modifying this same equipment to adapt to the users needs. The nurses are the users and need to be involved in the design of this equipment. Understanding the challenges associated with using this equipment, and then producing solutions to these problems can help reduce the risk of injury and could potentially be used by manufacturers in the future.

Floor-Based Lifting System

Marras et al. 2009 compared a floor-based system to a ceiling lift system. A patient handling course tested 4 conditions, which were: 1) a straight section; 2) sharp turn section; 3) gradual turn section; 4) confined turn. The floor-based system resulted in high spine loading when turning maneuvers were performed, and showed that A/P shear loading and the A/P shear levels often exceeded the threshold limit for disc tolerance. In comparison with gradual turns, the sharper the turns were, the greater the A/P shear was expected.

However, the results produced showed that any type of turn, both confined and unconfined, increased A/P shear to approximately the same level. The modifications of placing the commode label next to the bed would therefore be expected to decrease the A/P shear and be found in the RPE values. The current study studies whether a design modification may help participants decide to place the commode next to the bed, which would theoretically reduce the turning required consequently reducing A/P shear and potentially be shown in the RPE values. The Borg (2001) study scale will be used in the current study to measure RPE values for pushing/pulling the lift.

Inexperienced Nurses

The healthcare environment has been determined to have LBP point prevalence rates of 17%, as well as annual prevalence rates that have reached 40 to 50%, and lifetime prevalence at an alarming rate of 80% (Hignett 1996). This has been shown to potentially produce significant lost time from work (Smedley et al., 1997). The current study's focus on recruiting young, healthy, inexperienced nurses and nursing students to evaluate how these individuals will use the product is important for future development of products. Understanding how this user group interacts with the equipment can help manufacturers better understand how to design more intuitive equipment in the future.

It has been shown that LBP rates among young and healthy nursing students is approximately 12 to 13% with a cumulative incidence of more than 22% estimated based off two year prospective studies (Baldasseroni et al., 1998). These rates are exceedingly greater than what is expected for young and healthy individuals. These numbers should raise concern and assessing the habits of these young individuals, and helping design their environment and equipment to meet their needs can potentially reduce the risk of these injuries and pain from occurring.

The current study specifically recruited inexperienced nurses and nursing students for the usability study for this reason. If researchers can understand where novice users struggle, and try to reduce these areas where they do find challenges, then this could potentially help these young nurses transition into their profession easier as it relates to patient handling and the equipment involved. The thought process is that as the equipment becomes more user friendly and easier to use, then the greater the likelihood of these nurses will be more comfortable with and consequently wanting to use the equipment more.

Chapter 3: Methodology

Introduction

In order to systematically analyze the patient transfer task, a task analysis was done to layout the tasks and sub-tasks involved with performing an ideal patient transfer for a 69” in height, 150 lb. patient without error. Table 1 displays the task analysis for the three tasks involved with performing the patient transfer, along with the sub-tasks that fall under each of the three tasks.

Table 1: This table shows a task description of performing an ideal patient transfer.

Patient Transfer Task Description
Task 1: Sling Selection
1. Select Medium sized sling (2 Choices: Medium or Large)
Task 2: Sling Positioning
1. Fold/Roll up sling to place under patient
2. Have patient lift knee to chest
3. Pull patient towards the nurse
4. Place sling next/under back of patient
5. Roll patient other direction back on back
6. Pull sling under patient
7. Adjust sling properly to center patient
8. Bring lift over to bed and position the lift on angle over patient
9. Place bar horizontally over chest of patient
10. Loop Straps under legs
a. Right Leg
b. Left Leg
11. Attach hooks to lift for 90 degree sit-up or slightly leaned back position
a. Upper right arm strap (Sit-up-Black, Slightly leaned back-Grey)
b. Upper left arm strap (Sit-up-Black, Slightly leaned back-Grey)
c. Lower right leg strap (Sit-up-Blue, Slightly leaned back-Blue)
d. Lower left leg strap (Sit-up-Blue, Slightly leaned back-Blue)
Task 3: Lifting the Patient
1. Place commode next to bed
2. Use either the remote or the button on lift to lift patient
3. Lower patient onto commode
4. Unstrap sling
5. Remove Sling

Sling Selection requires the user to decide what sling is most appropriate to use for the patient transfer. Sling Positioning then requires the user to place the sling under the patient and attach the sling to the lift in one of two positions (sit-up or slightly leaned back). Sub-tasks 1-7 for Sling Positioning involve placing the sling under the patient. Having the patient lift their knee to their chest requires the patient to lift their leg furthest away from the nurse so that their knee goes to their chest. The nurse can then pull the patient towards their body using the leverage of the patient's knee, adjust the sling under the patient, and then have the patient roll back onto their back. The nurse must then pull the sling under the patient and adjust the sling so that the patient is centered on top of the sling. Bringing the lift over to the bed and positioning the lift on an angle over the patient requires the nurse to move the lift on an approximately 45 degree angle over the bed with the horizontal bar of the lift over the patient's chest. The horizontal bar must be placed horizontally over the patient's chest. There are two ways to position the horizontal bar, both horizontally, with the bar going from shoulder to shoulder across the patient's chest, and longitudinally, with the bar going from the sternum to pelvis. Figure 2 shows the horizontal and longitudinal positions the horizontal bar could be placed.

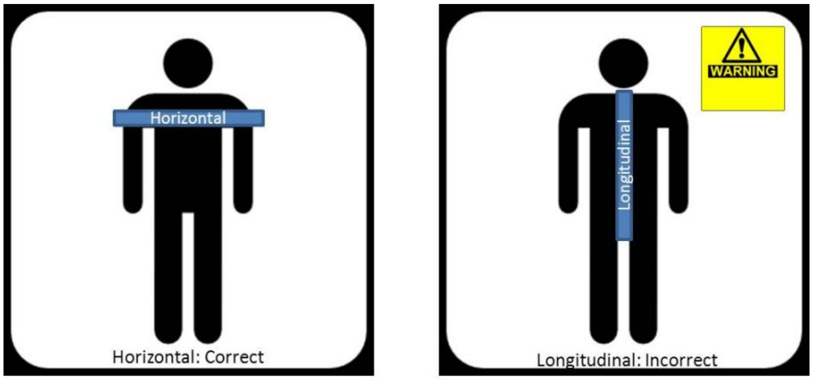


Figure 2: The correct horizontally positioning the horizontal bar over the patient's chest (left) and the incorrect longitudinal positioning of the horizontal bar over the patient's chest are shown here.

Looping the straps under the patient's legs involves the nurse looping the longer leg strap through the shorter leg strap so that the straps loop around the patient's leg. The order in which each leg is secured does not matter. Figure 3 displays the longer strap labeled as strap "1" with an arrow then showing the way it is supposed to be looped through the shorter strap labeled as strap "2".

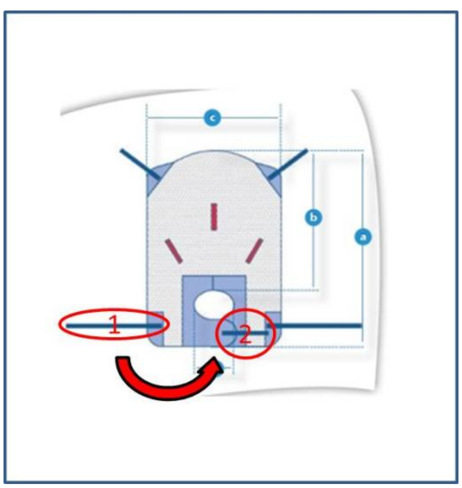


Figure 3: This shows the longer strap (1) should be looped through the shorter strap (2) in order to have the sling straps looped around the patient's leg.

Attaching the hooks to the lift to position the patient in the sling requires the nurse to attach the hooks of the sling straps to the lift in order to position the patient in one of 4 positions (sit-up, slightly leaned back, leaned back, and fully laid back). The current study only has the nurse put the patient in either the sit-up or slightly leaned back position. There are three colored hooks on the arm straps (blue, grey, and black) and two colored hooks on the longer leg strap (blue and grey). The nurse must correctly attach the correct colored hooks to the horizontal bar to position the patient in the sling. Figure 4 displays the label on the lift that shows the nurse how to put the patient in one of the 4 positions.

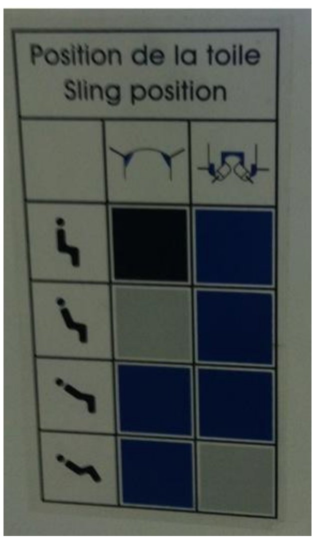


Figure 4: This shows the label on the lift that instructs the nurses how to position the patient in one of 4 positions.

Lifting the Patient first has the nurse place the commode next to the bed. Figure 5 shows how the commode is expected to be placed next to the bed. The nurse must then lift the patient using the remote or control panel on the lift and place them on the commode. The nurse is then expected to unstrap the sling from the lift and remove the sling from the patient on the commode.

Figure 5: This shows the commode being placed correctly next to the bed.

Focus Group

The study first involved a focus group of 6 healthcare professionals. All six of the individuals in the focus group were practicing nurses, both certified nursing assistants (CNAs) and registered nurses (RNs). Of the nurses, 5 were female and 1 was a male.

Before the focus group, all nurses read and signed the UB Informed Consent Form (See Appendix A). Each then completed a short questionnaire that inquired about their training and experience. It also contained several items related to demographics. (See Appendix B). All of the nurses had completed a safe patient handling training class. Five out of the six had attended the training class taught at Safe Patient Handling Training Center at UB. The 3-hour long training class stresses the importance of using the patient handling equipment by explaining the musculoskeletal injuries that can result from performing manual lifts, along with giving them exposure to the lifts, slings, and other assistive devices used in the field.

The training class teaches the students how to use the equipment by allowing students the hands-on experience of practicing using the equipment. The lift and sling used in this study were used in the training class. One of them had received the same training at a different location. Two out of the six were currently experiencing back pain. The nurses ranged in age from 21 to48 years. Two questions on the demographic information questionnaire asked the participants to describe their experience as is related to patient handling equipment and the slings.

Four out of the six reported to be an "expert" experiencing the use of patient handling equipment. Those same four individuals also considered themselves as "experts" in the use of slings. Two out of the six considered themselves novice users of lifts and slings. as being. The "Novice" users report they attended the safe patient handling training class, but still do not feel comfortable using the sling or patient handling equipment without supervision. The questions asked during the focus group attempted to explore into why these nurses may not feel comfortable using this equipment.

One of the goals of the focus group was to identify challenges in the design of current patient lifting aides and possibly come out with potential solutions to these problems. The following questions were developed and asked at the focus group:

Questions:

1. When/why would you perform a manual lift?
2. When/why would you perform a lift using lifting equipment?
3. What lifting equipment do you use? Why?
4. What lifting equipment do you prefer? Why?
5. What tasks are the most difficult to perform with the lifting equipment and why?

6. What tasks are easy to perform with current lifts? Why?
7. How do you select the appropriate sling for an assisted lift?
8. Are there any challenges associated with selecting or using the slings?
9. Are the labels/directions on the current equipment (slings/lifts) easily understood? If so, do they provide useful instructions?
10. Have you ever had a situation where you felt unsure about performing a task with the current equipment?
11. Are there any aspects of the current equipment that you find confusing or annoying?

The researcher was allowed to direct more questions into certain topics if the conversation warranted it. The participants identified many design issues related to lifts and slings that could potentially lead to mistakes when using the equipment. The participants discussed the slings being often times too small for the patient they were lifting, and stated that the colors on the sling (which are supposed to indicate size) are not effective and are not standardized across the industry. One way that this problem was addressed at this healthcare facility was to hang flyers on bulletin boards throughout the facility depicting what each color indicated.

Problems with the sling's straps were also a major part of the focus group discussion. The loops and hooks on the slings were indicated as being difficult to use because they would become entangled. The type of hook to use with each type of sling was also not clear. One person suggested using slings with clips instead of slings with loops and hooks. This person's preference was to use clips instead of loops to avoid guessing on the loops and hooks. Taking the guessing out of performing the task was mentioned repeatedly as a challenge. Arbitrary, unstandardized colors for determining the size of the sling, as well as determining the position of the patient when looping the sling to the lift, were identified as the two most important areas to address. A lack of information about height and weight capacities for each sling size was indicated as another design challenge. Difficulty with orienting the sling correctly with respect to the patient was another area of concern. This suggests that the design of the sling does not adequately indicate which side should be facing up.

The current lift used in the present study was the BHM Medical Ergolift 600 WO. The Ergolift 600 WO weighs 116.6lb/53kg/8.33st and has a lifting capacity of 600lb/272kg/42.86st. The slings used in the present study were the BHM Medical ErgoFit® Hammock slings. The current study used the BHM Medical medium and large hammock sling. All of the patient transfers were performed using the medium hammock sling. The dimensions and specifications of the sling used are shown in Table 2 along with the corresponding Figure 6.

Table2: This shows the dimensions and specifications for the BHM Medical ErgoFit® Hammock slings.

		Capacity		Dimensions	
Description	# Product	(lb./kg/st)		in	cm
Medium Hammock Sling	THA-M	100-200 lb. / 45-90 kg / 7.14-14.29 st	A	49	124
			B	37	94
			C	34	86
			D	11	28
Large Hammock Sling	THA-L	200-400 lb. / 90-180 kg / 14.29-28.57 st	A	57	145
			B	42	106
			C	38	96
			D	11	28

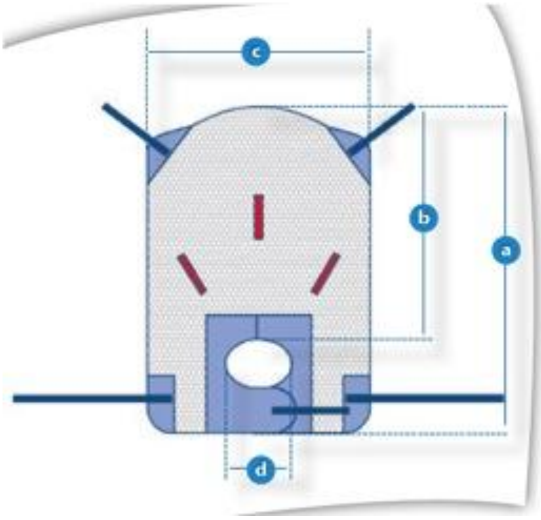


Figure 6: This shows the sling dimension areas (a, b, c, and d) that correspond with Table 2 for the BHM Medical ErgoFit® Hammock slings.

Modifications:

Some design modifications were made to existing slings and lift in an attempt to address the concerns identified by the focus group

1.) Labels to identify the size and capacities were added to two conventional slings. . "M" and "L" patches were placed on the slings to signify medium and large sized slings. The "M" patch is yellow matching the color of the sling that indicates the size. The "L" patch is green matching the color of the sling that indicates the size. The patches are shown in the Figure 7 and 8.

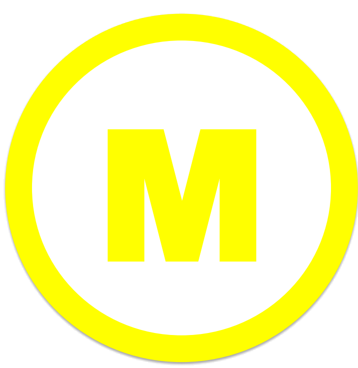


Figure 7: The "M" patch signifies a medium sized sling.

Figure 8: The "L" patch signifies a large sized sling.

The colors used on the slings varies by manufacturer so placing patches with "S", "M", and "L" which can have a specific color associated, but using the letters "S", "M", and "L" are a common tool recognized to size people. Examples include clothing (T-shirts, gym shorts, etc.); drink sizes, food or meal sizes.

Height and weight capacity labels were made and placed on the sling under the "M" and "L". The medium and large labels are shown in Figures 9 and 10. The labels placed on the slings are shown in Figure 11.

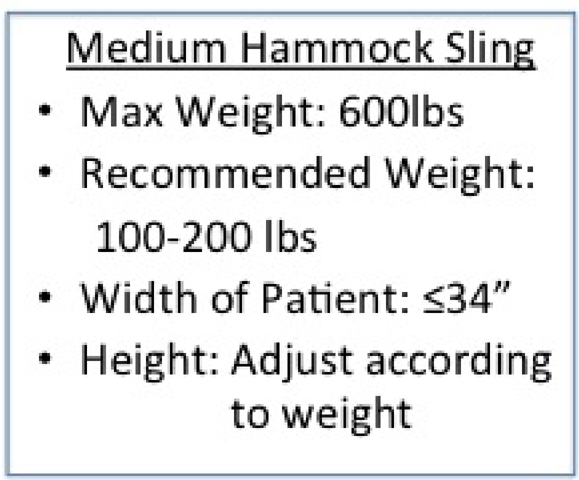


Figure 9: This is the Medium Hammock Sling label used in the study, which displays the maximum weight the sling can hold, the recommended weight, the maximum width the patient can be, and how to consider height.

Figure 10: This is the Large Hammock Sling label used in the study, which displays the maximum weight the sling can hold, the recommended weight, the maximum width the patient can be, and how to consider height.

Figure 11: This shows the placement of the labels on the sling. Both the "L" and "M" patches with the corresponding labels with recommendations are shown in the figure.

2.) An imprint of a person's figure on the topside of the sling was the also added to each of the slings. This was an attempt to indicate what side should be facing up under the patient and how to orient the sling correctly. The imprints placed on the large and medium sized slings are shown in Figure 12.

Figure 12: This shows the imprint placed on the slings (Large on the left and medium on the right).

3.) Modifications were also made to the hooks and positioning system. Attaching the right colored hooks to the lift is an area where a good amount of knowledge is required in order to correctly perform this part of the transfer. The modification made was to present the information needed in a way where it could easily be seen and followed. The label on the lift that displays what color hooks should be connected to put the patient in one of 4 positions (sit-up, slightly leaned back, leaned back, and fully laid back) was originally located by the handlebars. The label displaying the positions is shown in the picture on the left in Figure 8. This is not in a highly visible area and is not located near the area where they connect the hooks to the lift. The label was duplicated by placing the same label on both sides of the bar near the area where the nurse would connect the hooks to the lift. This modification was an attempt to make the instructions more visible during lift use. The original label area and the new label areas are shown in Figures 13 and 14.

Figure 13: The original label area is shown. The label is behind the handlebars of the equipment and only shown on one side the lift.

Figure 14: The new label areas are shown here. The labels are now on the bar making them more visible.

Placing the bar horizontally over the patient's chest is another area where nurses may need knowledge displayed to inform them to place the horizontal bar horizontally, instead of longitudinally, over the patient's chest. In an attempt to eliminate uncertainties about how to correctly perform this sub-task, labels were placed on both sides of the horizontal bar informing the participants of which way to place the horizontal bar. The words "Horizontal Over Chest" were used along with a picture to inform the nurses. The labels are shown in Figure 15 and 16. The original equipment with no labels is shown in Figure 17.

Figure 15: The Horizontal bar labels are shown here providing the nurses instructions on how to place the bar over the patient.

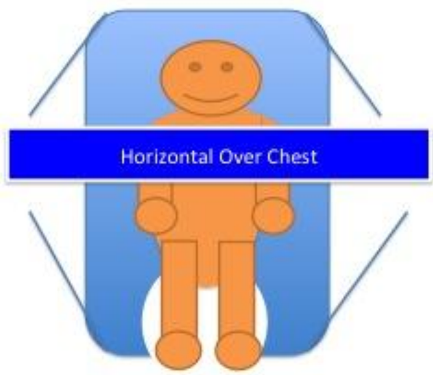


Figure 16: The image used to inform the nurse to place the bar horizontally over the patient's chest is shown here.

Figure 17: The original equipment is shown here with no labels on the horizontal bar.

Positioning the commode next to the bed could also be an area where nurses could look for instructions on where to place the commode. The modification made consisted of a commode label being placed on the floor next to the bed indicating where the participant should place the commode while performing the patient transfer. The training class indicated to keep the patient lifted up in the air to a minimum, and the focus group discussed performing the task efficiently. In the field, the nurse will have to bring the commode into the room and position it in the room as they see fit. The current study attempted to provide information about where to place the commode by placing the commode label on the floor next to the bed, in order to help the participants correctly perform the task. Not only for time efficiency, but this placement is also important because increased turning and moving of the lift increases A/P shear forces to problematic levels (Marras et al. 2009). The time the patient is in the air is expected to decrease with this placement because the participant no longer needs to push/pull the lift as far. Decreasing the movement involved with turning the lift, the safer and more efficient the task becomes. The original floor layout and the floor layout with the commode label are shown in Figure 18 and 19 respectively.

Figure 18: The original floor layout with no markings on the floor is shown the figure.

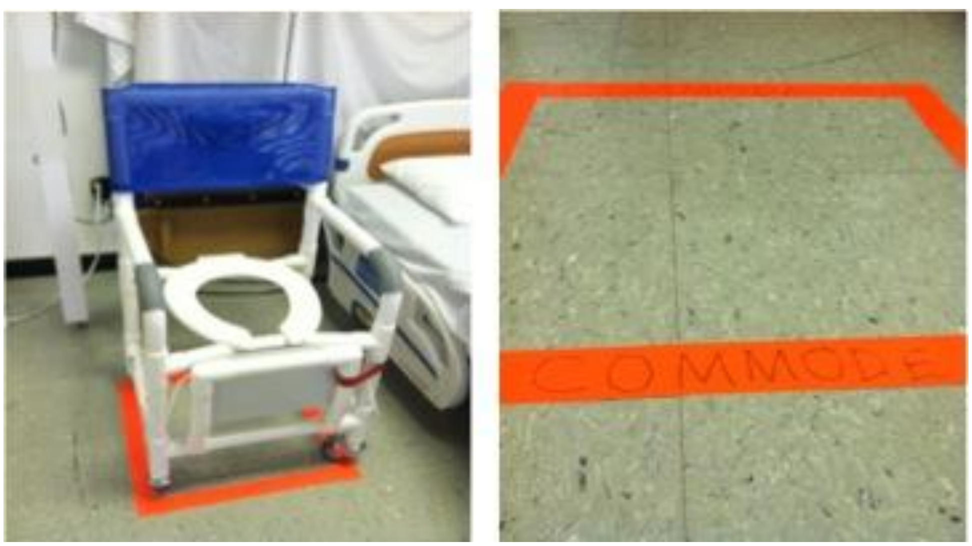


Figure 19: The commode label is shown on the right and the how the commode label is intended to work with the commode over label positioned correctly next to the bed on the left.

Usability Study

The objectives of the usability study were to determine if the modifications improved the usability of the lift and sling, reduced RPE, and reduced task time.

Participants

The usability study consisted of 12 participants (11 females and 1 male) ranging in age from 20 to 34 years of age. All of the participants went through the same training by going through the Safe Patient Handling Training Class taught at the University at Buffalo. All of the participants were young healthy nurses or nursing students with less than two years of experience. None of the participants were currently experiencing back pain.

Nine participants described their expertise using the patient handling equipment as well as the sling as "novice" by answering that they have attended a safe patient handling training class, but still do not feel comfortable using the equipment and slings without supervision, one participant rated their experience as "intermediate" by answering they have attended a safe patient handling training class and feel comfortable using the equipment and slings without supervision, but have never lifted a patient, and two participants rated their experience as being "experts" by answering they have attended a safe patient handling training class, feel comfortable using the equipment and slings, and have experience lifting patients with the equipment.

Independent Variables

The first independent variable tested was equipment (Original and Modified). The researcher expected to find differences between the original and modified equipment groups, with the expectation that the modifications would result in improved performance and perceived usability. The modifications were made to increase the usability of both the lift and sling (11 usability scale scores given by research participants after completing tasks), possibly decrease the amount of time it takes to complete Sling Positioning, Lifting the Patient, and the overall task time (Sling Positioning plus Lifting the Patient), produce lower RPE scores, and decrease the number of errors. Equipment errors, and consequently overall errors, are expected to be directly affected by the modifications. Training errors were not expected to be affected by the modifications. Trial effect was another independent variable tested to determine if learning from the first trial impacted performance during the second trial. This was used to determine if there was a learning effect experienced within the two equipment groups. The trials were also tested between the two conditions to see if there was a difference in time. Trial 1 was expected to take more time in the modified equipment group compared to the original equipment group due to the participant trying to understand the labels and modifications made. Additionally, Sling Positioning which has more sub-tasks than Lifting the Patient might experience bigger differences in time between trials.

Dependent Variables

The dependent variables which include time, RPE, errors, and usability scale scores for both the lift and sling are shown in Table 3.

Table 3: The table displays the dependent variables collected in the current study which include time, RPE, errors, and usability scale scores for the both the lift and sling

Dependent Variables	
Time (seconds)	
Ratings perceived exertion (RPE)	
Errors	Equipment Errors
	Training Errors
	Total Errors
Usability Scale Scores (Lift and Sling)	Low physical effort
	Perceptible Information
	Flexibility in use
	Adaptability to user pace
	Intuitive use
	Reach and access for use
	Simple use
	Equitable use
	Secure, safe and private use
	Tolerance for error
	Size for use

Procedures

Before the usability study, the participants read and signed the UB informed consent (see Appendix C). Each then completed the same short questionnaire used for the focus group that inquired about their training and experience. It also contained several items related to demographics (See Appendix B). After completing the demographic information questionnaire, the participants were instructed to perform three tasks during the study: 1) Sling Selection, 2) Sling

Positioning, and 3) Lifting the Patient. The three tasks were broke down into sub-tasks for analysis. The three tasks were tested in two condition groups: (1) the original equipment and (2) modified equipment group. The twelve research participants were randomly assigned to one of the two groups (6 in the original equipment group and 6 in the modified equipment group).

All participants lifted the same patient. The patient was male, 69" in height and weighed approximately 150lbs. This ensured that the physical task requirements were the same for each of the research participants.

All participants operated the same lift. It was the BHM Medical Ergolift 600 WO. All lifts were made from the same bed and the bed height was held constant. A study performed by Caboor et al. 2000 consisted of four (4) tasks including a patient transfer. This was indicated as being the most prominent action during the conduct of the tasks. The researchers used a standard bed height of .515 m. The researchers tested two bed height conditions. They measured ratings of perceived exertion using a 15-graded Borg Scale did not differ significantly between the two conditions. Also, muscle activity did not alter for the changeable bed heights. Therefore the current study set the bed height to .515 m and allowed the participants to change the bed heights as they saw fit. The lift height was held constant by having the horizontal bar be 1 meter higher than the height of the bed.

After being randomly assigned to either the original or modified equipment group, along with the bed and lift being properly adjusted, the participants were then asked to perform Sling Selection (Task 1) which tested to see if the participant could correctly pick the medium sized sling for the 69" in height 150 lb. patient. The participant was given a choice of two slings to choose from (medium and large sized sling). Sling Selection was only performed once, at the beginning of the study. The medium sized sling was used regardless of whether the participant chose it or not. It was recorded as an error if the participant chose the large sling, but was not used in the overall error analysis because the large sling technically could be used to transport the patient. The researcher asked what the reason(s) were for choosing the sling they did immediately following their selection.

The medium sized sling was the correct size for a 69" in height, 150 lb. patient. The recommended weight of the patient to be lifted for the medium sling would be between 100-200lbs and not be greater in width than the 34" wide sling. The participants had to make the decision with the slings hanging over the frame of the bed shown in Figure 20 and 21.

Figure 20: This shows the original condition slings. The medium (left) and large (right) are hanging over the frame of the bed where the participant was asked to correctly pick out the sling that fit the patient size.

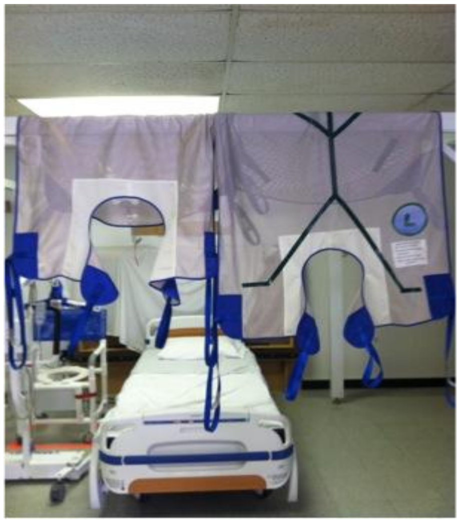


Figure 21: This shows the modified sling (Large on the right) and the original sling (Medium on the left) hanging side by side to show the contrast of the two.

The participants were then instructed to perform Sling Positioning (Task 2). Sling Positioning started with the patient in a supine position on the bed with the patient lying on their back. The participant was asked to transfer them to the commode in either a sit-up or slightly leaned back position in the sling. The order that the participants experienced having to position the patient in either the sit-up or slightly leaned back position was randomized (3 participants in both original and modified equipment groups performed the sit-up sling positioning first followed by the slightly leaned back positioning, and 3 participants in both the original and modified equipment groups performed the slightly leaned back positioning first followed by the sit-up positioning).

Sling Positioning required the participant to place the sling under the patient, and then attach the sling to the lift to put the patient in either a sit-up or slightly leaned back position. The task ended when the participant attached the sling to the lift, and believed that position was correct to make the lift. At this point, the participant was asked to leave the room. Once the participant was out of the room, all the errors made during Sling Positioning were recorded. The researcher and trained assistant adjusted the sling and lift to ensure a safe patient transfer to the commode. The participant was then called back into the room and was asked to perform the task of Lifting the Patient (Task 3).

Lifting the Patient required the participant to transfer the patient to the commode. The participant was allowed to move and position the commode anywhere in the room. The commode was always placed in the same position which was approximately 6 feet away from the bed before the start of the task. The task ended when the participant had placed the patient on the commode and had completely removed the sling from under the patient.

After the task of Lifting the Patient was completed, the participants were asked to provide answers regarding the usability of the lift and sling using the consumer product universal design scale used by Beecher and Paquet (2005). Universal design by definition promotes the development of products than can be used effectively by all users without adaptation or stigmatization. Steinfeld and Mullick (1990) described universal design as "designing products that all people can use easily." Beecher and Paquet (2005) developed the survey tool using statistical procedures to develop scales from a large set of survey items that individuals responded to after completing standardized tasks with a wide-range of products that included pens, food storage containers, pliers, and calculators. The initial survey tool was then refined into a simpler version of that survey which described the results in the same way. The shortened version is used in the current study and is shown in Appendix D.

The participants filled out the survey tool for both the lift and sling. An example of one of the surveys given for the lift is shown in Appendix E. The participants were also asked to rate their perceived physical exertion (RPE) for dynamic work of pushing/pulling the lift. Ratings of perceived overall exertion for the push/pull task were recorded (Borg, 2001). The Borg scale is shown in Appendix F. Time to complete each task was recorded for the both the task of Sling Positioning and Lifting the Patient. Errors were recorded for all three tasks. Sling Selection errors were not used in the overall error analysis. The Error Checklist tool used is shown in Appendix G. If any of the sub-tasks analyzed in the Sling Positioning or Lifting the Patient task were either not completed or incorrect, they were then checked off as errors.

Errors were categorized as training errors, equipment errors, and preferences. The training error sub-tasks are tasks that have no affiliation with either the usability of the lift or sling, or no modification was made in order to directly impact these actions. The equipment error sub-tasks are tasks that have direct affiliation with the use of the lift or sling, or have a modification that attempted to directly impact these actions. Preferences were collected and examined in order to see if the participants preferred to use the movable remote or the stationary control panel on the lift to lift and lower the patient during the transfer to the commode. Preferences were not used in total error count. The remote and control panel on the lift are shown in Figure 22. The categories with their corresponding sub-tasks are shown in Figure 23.

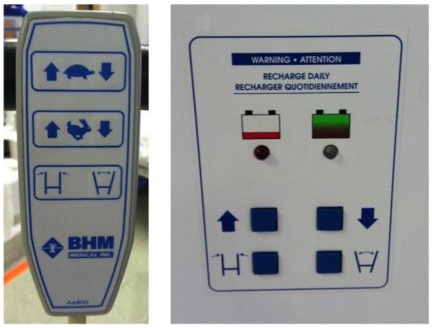


Figure 22: The remote (left) and control panel on the lift (right) are shown.

Training Error Sub-tasks
Had patient lift knee to chest
Pulled patient towards the them
Pushed patient away from them
Moved equipment on angle over bed

Equipment Error Sub-tasks
Selected Correct Sling (M)*
Sling is right side up under patient
Upper/Lower Body Oriented Correctly on Sling
Place the bar horizontally over patient's chest
Looped right leg strap correctly
Looped left leg strap correctly
Attached right arm hook to equipment correctly
Attached left arm hook to equipment correctly
Attached right leg hook to equipment correctly
Attached left leg hook to equipment correctly
Positioned commode next to bed
Adjust lift legs width to fit around commode chair

**This was Task 1 (Sling Selection) and not used in total error count*

*Preferences
*Lifted patient using remote
*Lifted patient using control panel on lift
*Lowered patient onto commode using remote
*Lowered patient onto commode using control panel on lift

**Not used in total error count*

Figure 23: This shows the categories of tasks which included training error tasks, equipment error tasks, and preference tasks.

Each session was video recorded and the video recordings were reviewed to measure the task time and to ensure that the number and types of errors were coded correctly.

Statistical Analysis:

Non-parametric statistical tests were used to evaluate differences between conditions in scale scores and error rates that did not follow a normal distribution. Kruskal-Wallis tests were run on each of the 11 usability scale scores (US-1 through US-11) which include: low physical effort; perceptible information; flexibility in use; adaptability to user pace; intuitive use; reach and access for use; simple use; equitable use; secure, safe and private use; tolerance for error; size for use. The Kruskal-Wallis test was performed in Minitab® 16.1.1(© 2010 Minitab Inc.) for the 11 usability scale scores for both the lift and sling. The original lift was compared with the modified lift, and the original sling was compared with modified sling.

The Kruskal-Wallis test was performed on the equipment errors, training errors, and overall errors to compare the original to modified equipment groups. The Kruskal-Wallis test reported the medians, average ranks, and p-values to determine whether there were differences between the original and modified equipment conditions for both the lift and sling. The alpha error was set at 0.05, and p-values less than or equal to 0.05 were reported as being statistically significant.

RPE and time of task were analyzed using Minitab® 16.1.1 by running two-sample T-tests for the existing and modified design conditions. RPE was reported by using the overall difference between the original and modified equipment groups. Task times within the two groups were tested for trial 1 and trial 2 for Sling

Positioning, Lifting the Patient, and overall task time. The task times were also tested between groups, meaning original equipment trial 1, Sling Positioning times were compared with modified equipment trial 1, Sling Positioning times. Sling Positioning, Lifting the Patient, and overall task times were compared against each other for the two groups. P-values less than 0.05 were considered to be statistically significant.

Chapter 4: Results

Errors

There were no differences between sling design conditions in errors during Sling Selection. Only one error was observed during Sling Selection for the original equipment group. One participant misjudged the sling size by selecting the large sling. The participants were asked why they had selected the sling they chose, and it was observed that the participants in the original equipment group judged based on the length and width of the sling to size up the patient. The individual who chose the large sling was concerned that the medium sling looked small and did not want to risk lifting the patient with that size sling.

There was one error in Sling Selection for the modified sling. However, it was observed that the answers were different of why they chose the sling they did. The 5 participants who chose the medium sling based on the recommendations provided by the label added to the sling. The participants all stated that they picked the medium because the patient fell between the 100 and 200 lbs. The one participant who chose the large sling also looked into the recommendations, but wanted to ensure the safety of the patient by choosing the large sling because that individual decided to select the larger sling because was unsure of the patient's weight. . The modified condition clearly provided a guideline to the participants on how to select the slings. In a real hospital setting, the patient's weight would be recorded and available on a chart. Without the labels, the participants were taking an educated guess.

Errors were collected during Sling Positioning and Lifting the Patient. A total of 102 errors were made using the original equipment compared to 82 errors were made in the modified equipment group. The number of equipment errors totaled 63 and 47 in the original and modified groups respectively. Training errors totaled 39 and 35 in the original and modified groups respectively. The number of equipment errors, which the modified equipment directly impacted, was 25% lower for the modified condition. Figure 24 summarizes the frequency of training, equipment, and total errors for the two conditions.

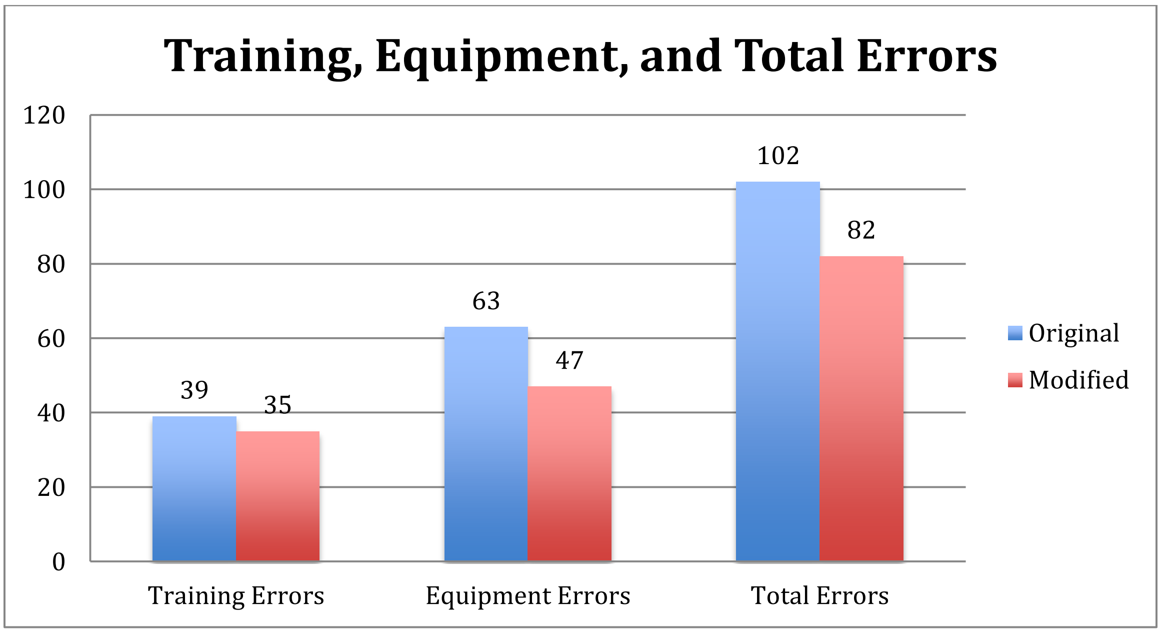


Figure 24: Total errors and the breakdown into training and equipment errors are shown here for both the original and modified equipment group.

Total errors, equipment errors, and training errors are broken down even further in Tables 4, 5, and 6. No statistically significant differences were determined between the original and modified equipment groups for total errors, equipment errors, or training errors (See Appendix H).

Table 4: Total errors are displayed below in original and modified groups, by trials 1, 2, and total errors, and by sub-tasks.

Total Errors						
	Original			Modified		
	Trial 1	Trial 2	Total	Trial 1	Trial 2	Total
Had patient lift knee to chest	5	5	10	3	4	7
Pulled patient towards them	5	5	10	5	5	10
Pushed patient away from them	5	5	10	4	4	8
Sling is right side up under patient	1	1	2	3	2	5
Upper/Lower Body Oriented Correctly on Sling	1	0	1	1	0	1
Moved Equipment on angle over bed	5	4	9	5	5	10
Placed the bar horizontally over patient's chest	3	2	5	0	0	0
Looped right leg strap correctly	5	2	7	3	1	4
Looped Left leg strap correctly	5	1	6	3	1	4
Attached right arm hook to equipment correctly	6	3	9	4	4	8
Attached left arm hook to equipment correctly	6	3	9	4	4	8
Attached right leg hook to equipment correctly	3	5	8	3	2	5
Attached left leg hook to equipment correctly	3	3	6	3	1	4
Position commode next to bed	4	3	7	2	2	4
Adjust lift legs width to fit around commode chair	2	1	3	2	2	4

Table 5: Equipment errors are displayed below in original and modified groups, by trials 1, 2, and total errors, and by sub-tasks.

Equipment Errors						
	Original			Modified		
	Trial 1	Trial 2	Total	Trial 1	Trial 2	Total
Sling is right side up under patient	1	1	2	3	2	5
Upper/Lower Body Oriented Correctly on Sling	1	0	1	1	0	1
Placed the bar horizontally over patient's chest	3	2	5	0	0	0
Looped right leg strap correctly	5	2	7	3	1	4
Looped Left leg strap correctly	5	1	6	3	1	4
Attached right arm hook to equipment correctly	6	3	9	4	4	8
Attached left arm hook to equipment correctly	6	3	9	4	4	8
Attached right leg hook to equipment correctly	3	5	8	3	2	5
Attached left leg hook to equipment correctly	3	3	6	3	1	4
Position commode next to bed	4	3	7	2	2	4
Adjust lift legs width to fit around commode chair	2	1	3	2	2	4

Table 6: Training errors are displayed below in original and modified groups, by trials 1, 2, and total errors, and by sub-tasks.

Training Errors						
	Original			Modified		
	Trial 1	Trial 2	Total	Trial 1	Trial 2	Total
Had patient lift knee to chest	5	5	10	3	4	7
Pulled patient towards them	5	5	10	5	5	10
Pushed patient away from them	5	5	10	4	4	8
Moved Equipment on angle over bed	5	4	9	5	5	10

The preferences resulted in all of the participants in both conditions using the remote to lift and lower the patient onto the commode. Only one participant used the button on the machine to lift the patient. It is important to note that the same individual switched part way through to use the remote to lift the patient the rest of the time.

Time

For the original equipment during lifting patients, there was a statistically significant difference between first and second trials in the time for lifting patients during the original condition ($p<0.05$) Lifting the Patient had a mean time for trial 1 of 244.7 seconds and 168.0 seconds trial 2 ($p<0.05$). The mean for total time of task for trial 1 was 505.0 seconds and 378.7 seconds trial 2 ($p<0.05$).

The modified equipment trial 1 vs. trial 2 for Sling Positioning, Lifting the Patient, and the overall total time showed statistically significant differences between the trial 1 and trial 2 ($p<0.05$). Two-sample T-test tables and boxplots are shown in Appendix H. The mean values for time for trial 1 of Sling Positioning were 404 seconds and the mean time for trial 2 was 253.5 seconds. Lifting the Patient had a trial 1 mean time of 206.5 seconds and a trial 2 mean time of 151.0 seconds.

The overall total time (Sling Positioning and Lifting the Patient combined) had a trial 1 mean time of 610 seconds and trial 2 had a mean time of 404.5 seconds.

The data suggests there to be differences in within subject variation when it comes to task trial, suggesting a learning effect. Time is influenced by the trial. The trial 1 Original vs. Modified results produced a statistically significant difference for time of Sling Positioning between the original and modified equipment. The original equipment showed a trial 1 mean time of 260.3 seconds and the modified equipment mean time was 404 seconds ($p<.05$). Lifting the Patient and overall total task time did not produce statistically significant results for the Original vs. Modified in trial 1. The Original vs. Modified trial 2 mean time results produced no statistically significant results. All of the time results are shown in Appendix I.

Ratings of Perceived Exertion

No statistically significant differences in perceived exertion between design conditions for the overall results were found. There was a mean of 10.75 (s.d. = 2.96) for the original equipment, and a mean of 12.0 (0.739) for the modified equipment. All of the RPE two-sample T-test tables and boxplots are shown in Appendix J.

Usability Tool Sling Results

Only one statistically significant result ($p \leq .05$) was produced. Tolerance for error (US-10) had a median of 5.5 with average rank 9.8 for the original equipment group, and had a median of 8.0 with average rank of 15.3 for the modified equipment group. The p-value was 0.057 (0.050 adjusted for ties). This produced a statistically significant difference between the original and modified equipment groups. The participants scored the tolerance for error higher with the modified sling compared to the original sling. All of the usability scale Kruskal-Wallis tables for the sling are shown in Appendix K.

Usability Tool Lift Results

All of the usability scale Kruskal-Wallis tables for the lift are shown in Appendix L. Six of the eleven usability scale scores produced statistically significant differences between the original and modified groups ($p \leq .05$). Perceptible information (US-2) produced a median score of 15.5 with average rank of 8.8 for the original equipment group, and a median score of 24.5 with average rank of 16.2 for the modified equipment group. A p-value of 0.01 (0.01 adjusted for ties) shows there was a statistically significant difference between the two conditions. The modified lift had the participants score the perceptible information higher compared to the original lift. Therefore, this suggests that the modified lift provided more perceptible information that the original lift.

Flexibility in use (US-3) showed a 17.0 median with average rank of 9.6 for the original condition, and 18.5 median with average rank of 15.4 for the modified condition. The p-value was 0.043 (0.041 adjusted for ties) shows there was a statistically significant difference between the original and modified equipment groups. The modified lift produced higher scores than that of the original lift. This suggests that the modified lift is more provided more flexibility.

Adaptability to user pace (US-4) produced a median of 16.0 with average rank 9.1 for the original equipment group, and a median of 17.0 with average rank 15.9 for modified equipment group. The p-value was 0.019 (.012 adjusted for ties) shows a statistically significant difference between the two groups. The modified lift scored higher for adaptability to user pace than that of the original equipment.

Simple use (US-7) produced a median of 14.0 with average rank 7.9 for the original equipment group, and a median of 16.0 with average rank of 17.1 for the modified equipment group. The p-value was 0.001 (0.001 adjusted for ties) which means there is a statistically significant difference between the original and modified lifts as it relates to simple use. The participants score modified lift higher compared to the original lift. Therefore, this suggests the modified lift was simpler to use.

Equitable use (US-8) had a median of 7.0 with average rank of 9.3 for the original equipment group, and had a median of 8.0 with average rank of 15.8 for the modified equipment group. The p-value was 0.024 (0.019 adjusted for ties) which means there was a statistical significance between the two conditions. As it pertains to equitable use, the modified lift produced higher scores than the original lift. This suggests that the modified lift provides more equitable use.

Tolerance for error (US-10) had a median of 4.0 with average rank 7.7 for the original equipment group, and had a median of 8.0 with average rank of 17.3 for the modified equipment group. The p-value was 0.001 (0.001 adjusted for ties). This produced a statistically significant difference between the original and modified equipment groups. The participants scored the tolerance for error higher with the modified sling compared to the original sling. This suggests the modified lift provided more of a tolerance for error.

Chapter 5: Discussion

The goal of this study was to determine the usability of existing patient handling equipment, and to test whether there are simple design changes that can make the equipment easier to use. The original equipment was tested against the modified equipment by collecting errors, time, RPE, and the usability survey for the lift and sling to determine if the simple modifications could make the equipment easier to use.

A total of 102 errors were made using the original equipment compared to 82 errors were made in the modified equipment group. This approximately 17% reduction in error suggests that the modifications may have influenced the decision made by the participants. Equipment errors totaled 63 and 47 in the original and modified groups respectively. Training errors totaled 39 and 35 in the original and modified groups respectively. The training error of pushing the patient away from them to place the sling under the patient was clearly seen in both conditions. This is supported by previous research (Zhuang et al., 1999) which shows that a majority of nurses performed the task this way. Both equipment and training errors experienced a reduction in errors. The equipment errors, which the modified equipment directly impacted, had approximately a 25% reduction in error.

The tasks that were specifically targeted by the modifications, the results showed that 6 out of these 8 tasks experienced a decrease in errors, one experienced an increase in errors, and one experience the same amount of errors after the modifications were made. The one sub-task that experienced an increase in going from 2 to 5 errors from original to modified was the sub-task of having the sling right side up under the patient. The imprint of the person on top of the sling had a negative effect when it came to putting the sling inside/out under the patient. Reasons for this may be from the electrical tape used as the imprint or the 'M' patch with the label being viewed in the same way as it would on the inside of a t-shirt. Medium tags are found on the inside collar of t-shirt, which may have caused this thinking when looking at the sling.

The upper/lower body of the patient being oriented correctly on top of the sling experienced the same amount errors. One error was made in both conditions, and was corrected in the second ordered task for the two participants. In the modified equipment group, this participant may have not noticed or did not understand the imprint. Once again, the electrical tape may have had an influence. All of the other 6 tasks that were directly impacted by the modifications experienced a decrease in errors.

In the modified equipment group, this participant may have not noticed or did not understand the imprint. Once again, the electrical tape may have had an influence. All of the other 6 tasks that were directly impacted by the modifications experienced a decrease in errors. Placing the bar horizontally over the patient's chest was the most successful for the modifications. There were 5 errors committed in the original equipment group and then was reduced to zero after the modification was made with labels being placed on the horizontal bar. A decrease of errors in attaching the straps on the hooks was observed for the modified condition. , as well as positioning the commode next to the bed. The tasks along with the errors experienced that were impacted by the modifications are shown in Table 7.

Table 7: This shows the errors that had the intention of being directly targeted by the modifications.

Errors Directly Targeted by Modifications

	Original	Modified	Increase/Decrease/Same
Sling is right side up under patient	2	5	Increase
Upper/Lower Body Oriented Correctly on Sling	1	1	Same
Place the bar horizontally over patient's chest	5	0	Decrease
Attached right arm hook to equipment correctly	7	4	Decrease
Attached left arm hook to equipment correctly	6	4	Decrease
Attached right leg hook to equipment correctly	9	8	Decrease
Attached left leg hook to equipment correctly	9	8	Decrease
Positioned commode next to bed	7	4	Decrease
Total Errors	46	34	

Preference was important to keep track of from a design perspective. The remote may be easier to use because it can be held in the participant's hand and moved around. One reason the button on the machine may not be used could be due to the layout of the buttons. The buttons that move the lift up and down are placed on the lift going from left to right and not up and down. They do not have a grouping box placed around them like that seen on the remote. Grouping these buttons better may have an influence on how this product is used.

After trial 1 was performed the participant could then have produced one of four results: (1) No errors were made either time, (2) errors were made both times, (3) a corrective action was taken where a participant followed an error with a correct action, or (4) a reverse action was taken where the participant was correct the first time and then made an error the second time through in the same task. Examining the tasks that would have been directly impacted by the modifications can help determine whether the participants understood how to perform the task.

The most telling aspect of whether the individual would be able to correctly, and possibly safely, lift the patient was to ensure that all 4 straps were correctly hooked to the lift. Two participants attached all 4 straps correctly to the hooks both times using the modified equipment. It is important to note that the two individuals who performed this without error were self-reported as novice users as their experience with using both the slings and the equipment. The remaining four participants in the modified equipment group experienced an error both times, as well as all six participants in the original equipment group. This suggests that the modification provided more visible an appropriate areas to place the label that is currently used. It was observed that the participant had difficulty understanding the symbols used on the label depicting both the arm and leg straps. Figure 25 shows the results of the 4 straps being hooked correctly to the lift in both the original and modified equipment groups.

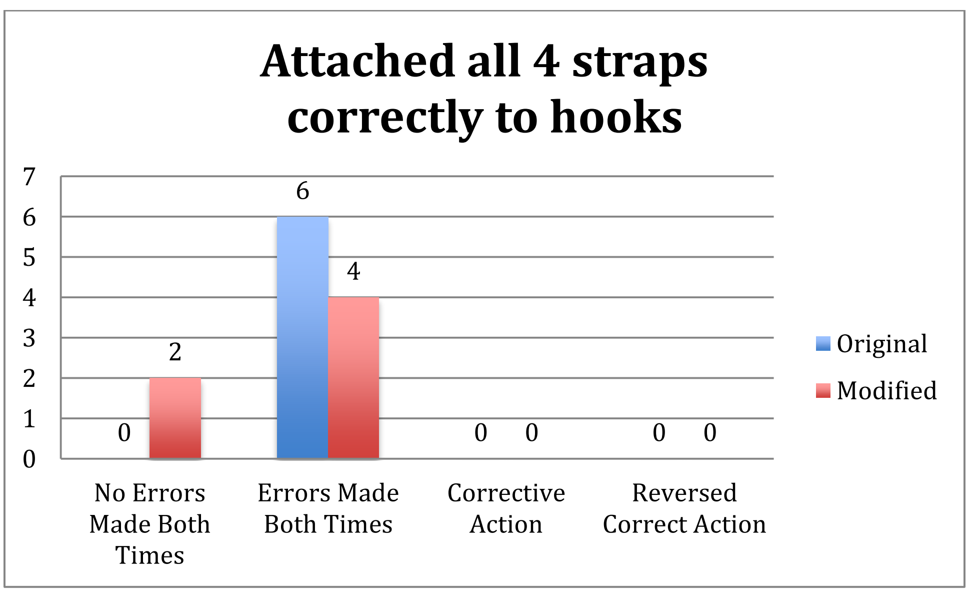


Figure 25: This shows the results of the participants and how they performed for the task of having all 4 straps correctly attached to the lift.

The perceived physical exertion (RPE) was found not to have changed significantly between the original and modified conditions. However, more participants did place the commode next to the bed with the label being placed next to the bed. Therefore, more trials may be necessary to see if there is a significant difference between the two conditions. A weakness of the study was that the tasks did not take that long to complete so physical exertion most likely will be need to assessed over many trials. Future studies may test more trials with the two equipment conditions, and collect muscle activity level data and other objective physical tools for this information.

The usability survey assessed both the lift and the sling for both conditions. Only one significant result was found for the sling between the original and modified equipment groups. The participants rated the modified sling to score higher for tolerance error. This suggests the participants felt the modified sling allowed them more flexibility as it related to correcting errors. A possible reason for this was that the labels showing the recommended height, weight, and width conditions allowed them to feel more comfortable about using the correct size product.

The usability survey found six significant results for the lift between the original and modified equipment groups. Perceptible information, flexibility, adaptability to user pace, simple use, equitable use, and tolerance for error were all scored higher for the modified lift than that of the original lift.   The modified lift with the horizontal bar label instructing them how to position the bar over the patient, along with moving the labels for hooking the straps correctly to the lift may have influenced the decision making of the participants. These modifications possibly provided better feedback, helped them to better understand how to use the product, and warned them of potential errors. The lift was also rated to be more flexibly and more adaptable to user pace.

The flexibility suggests the participants were more comfortable with the product and felt more effective at using it. Being more adaptable to user pace suggests the product works how they expect it to work and that it is straight forward when it comes to using it. The modified lift was determined to be simpler to use which suggests the important features are more obvious to the user, and that they can identify the features easily in order to use it. This also suggests that the features they use most are easier to access. The modified lift provided more equitable use which means the lift may have been more accepted by the participants because the product was not as likely to make them feel different, which leads to the participants feeling more comfortable about using the lift. The modified lift also provided more tolerance for error meaning they also felt the lift allowed them to correct their errors easier. The labels giving them instructions on how to complete the sub-tasks required for performing a safe patient transfer clearly impacted the usability of the lift.

The usability survey tool assessment of the lift is supported by the error results. Participants placed the bar horizontally over the patient's chest every time in the modified condition. Correctly strapping all for 4 hooks to the lift was completed without error for the both trial 1 and trial 2 for two participants in the modified group, where as zero participants correctly all strapped all 4 hooks in either trial in the original equipment group. This suggests that the placement of the labels, near the area where they strap the hooks to the lift, did have a positive impact. Not all the participants noticed the labels, but more participants understood how to connect the hooks in the modified condition compared to the original condition. Therefore, the question may not be what information is being displayed, but rather the question may be where and how the information is being displayed.

The simple modifications made have been shown to influence the usability of the patient handling equipment. The reduction of errors, along with the differences in the usability scale scores between the original and modified equipment conditions, especially the lift, suggest that the simple modifications made, resulted in the equipment being easier to use.

References

Baldasseroni, A., Tartaglia, R., Sgarrella, C., and Carnevale, F. (1998). Frequency of lumbago in a cohort of nursing students. La Medicina del lavoro, 89 (3), 242–253.

Beecher, V. and Paquet, V. (2005), Survey instrument for the universal design of consumer products. Applied Ergonomics, 36, 363-372.

Bell, F. (1984). Patient Lifting Devices in Hospitals. Groom Helm, London.

Borg, G. (2001). Borg's range model and scales. International Journal of Sport Psychology, 32, 110–126.

US Department of Health and Human Services (USDHHS) (1999). Federal Register, Part II, Department of Labor, Occupational Safety and Health Administration. 29 CFR Part 1910; Ergonomics Program: Proposal Rule (Tuesday, 23 November 1999).

Bureau of Labor Statistics (BLS) (2002). Survey of occupational inquiries and illnesses, 2001. US Department of Labor. USDL December 19, 2002.

Bureau of Labor Statistics (BLS) (2003). Highest Incidence Rates of Total Nonfatal Occupational Injury and Illness Cases, Private Industry, 2002. Author, Washington, DC.

Buurman, R.D. (1997). User-centered design of smart products. Ergonomics, 40, 1159–1169.

Caboor, D.E., Verlinden, M.O., Zinzen, E., Van Roy, P., Van Riel, M.P., and Clarys, J.P. (2000). Implications of an adjustable bed height during standard nursing tasks on spinal motion, perceived exertion and muscular activity. Ergonomics, 43 (10), 1771-1780.

Garg, A., Owen, B.D., Beller, D., and Banaag, J. (1991). A biomechanical and ergonomic evaluation of patient transferring tasks: bed to wheelchair and wheelchair to bed. Ergonomics, 34, 289-312.

Garg, A., Owen, B.D., and Carlson, B. (1992). An ergonomic evaluation of nursing assistants' job in a nursing home. Ergonomics, 35 (9), 979–995.

Hignett, S. (1996). Work-related back pain in nurses. Journal of Advanced Nursing, 23 (6), 1238–1246.

Jang, R., Karwowski, W., Quesada, P.M., Rodrick, D., Sherehiy, B., Cronin, S.N., and Layer, J.K. (2007). Biomechanical evaluation of nursing tasks in a hospital setting. Ergonomics, 50 (11), 1835-1855.

Kontogiannis, T. and Embrey, D. (1997). A user-centered design approach for introducing computer-based process information systems. Applied Ergonomics, 28, 109–119.

Marras, W.S., Knapik, G.G., and Ferguson, S., (2009). Lumbar spine forces during manoeuvring of ceiling-based and floor-based patient transfer devices. Ergonomics, 52, 384-397.

Nelson, A.L., Fragala, G., and Menzel, N., (2003). Myths and facts about back injuries in nursing. American Journal of Nursing, 103 (2), 32–40.

Nelson, A.L., Matz, M., Chen, F., Siddharthan, K., Lloyd, J., and Fragala, G. (2006). Development and evaluation of a multifaceted ergonomics program to prevent injuries associated with patient handling tasks. International Journal of Nursing Studies, 43, 717-733.

Owen, B.D. (1988). Patient handling devices: an ergonomic approach to lifting patients. In: Aghazabeth, F. (Ed.), Trends in Ergonomics/Human Factors V. Elsevier Science Publishers, North-Holland, Amsterdam, pp. 721–728.

Owen, B.D., Keene, K., and Olson, S. (2002). An ergonomic approach to reducing back/shoulder stress in hospital nursing personnel: a five year follow up. International Journal of Nursing Studies, 39 (3), 295–302.

Smedley, J., Egger, P., Cooper, C., and Coggon, D. (1997). Prospective cohort study of predictors of incident low back pain in nurses. British Medical Journal, 314 (7089), 1225–1228.

Steinfeld, E. and Mullick, A. (1990). Universal design: the case of the hand. Innovation, Fall, 27–30.

Story, M.F., Mueller, J.L., and Montoya-Weiss, M. (2000). Progress in the development of universal design performance measures. In Proceedings of the RESNA 2000 Annual Conference (pp. 132–134).

Story, M.F., Mueller, J.L., and Montoya-Weiss, M. (2001). Completion of universal design performance measures. In Proceedings of the RESNA 2001 Annual Conference (pp. 109–111).

Zhuang, Z., Stobbe, T.J., Collins, J.W., Hsiao, H., and Hobbs, G.R. (1999). Biomechanical evaluation of assistive devices for transferring residents. Applied Ergonomics, 30, 285-294.

Zhuang, Z., Stobbe, T.J., Collins, J.W., Hsiao, H., and Hobbs, G.R., (2000). Psychophysical assessment of assistive devices for transferring patients/residents. Applied Ergonomics, 31, 35-44.

Appendix A

Informed Consent for Focus Group

The Effects of User-Centered Design on the Usability of Patient Handling Equipment

Department of Industrial and Systems Engineering
State University of New York at Buffalo

Investigators: Mark Fenzl, Victor Paquet

You are invited to take part in a focus group that assesses usability of patient handling equipment and slings.

A. What is the purpose of this focus group?
The purpose of the current focus group is to determine the usability of safe patient handling equipment and slings during patient transfer tasks.

B. Why have you been selected?
We are recruiting healthcare professionals who are currently using patient handling equipment who can give us feedback on the usability of safe patient handling equipment and slings.

C. What does the research consist of?
Your participation consists of providing feedback in a group setting to give insights on the challenges and possible solutions in the usability of patient handling equipment and slings. The focus group discussion will be video recorded to enable the researchers the ability to analyze the discussion after the session.

D. Is there any risk of discomfort?
No discomfort is expected. The discussion will be kept private. The researchers will ask you and the other people in the group not to tell anyone outside the group not to tell anyone outside the group what any particular person said in the group. However, the researchers cannot guarantee that everyone will keep the discussions private.

E. Where and when will this focus group be done?
The focus group will be conducted in a private room at Gowanda Nursing Rehab at 100 Miller Street in Gowanda, NY.

F. Will compensation be made for any injury resulting from this research study?
No injury is anticipated as a result of participating in this research. In the event that physical injury does occur as a result of this research, the University at Buffalo, SUNY does not make provisions for medical care nor is there any protection from

the State University of New York for payment or compensation for medical care in the event of injury as a result of participating in this research project.

G. What are the benefits for me in participating in this study?
There are no direct benefits to you for participating in this study. The study results may help designers and manufacturers improve future patient handling equipment.

H. What are the costs and compensation for participating in this study?
There is no cost to you for participating in this research. In consideration for your time and participation, the researcher will provide snacks for the group.

I. What about my confidentiality?
The information you provide is confidential, therefore no one outside the research team will be able to identify your responses. The researchers will ask you and the other people in the group not to tell anyone outside the group what any particular person said in the group. However, the researchers cannot guarantee that everyone will keep the discussions private. Coding your information using a unique person number will protect your identity. The information you provide will be viewed only by approved members of the research team. Your identity will not be made part of any published findings resulting from this study. In order to monitor this research study representatives from federal agencies such as NIH (Nation Institutes of Health) and OHRP (Office of Human Research Protection) or representatives from the UB Human Research Protections Program may inspect the research records. This process may reveal your identity. If you withdraw from this study, no further data will be collected but any information that you have provided may be retained by the researcher and analyzed. If you withdraw from this study, all individually identifiable data provided by you will be destroyed and not used for analysis. The focus group is being video recorded to allow the researchers to capture the focus group participants pointing out certain aspects of the lifting equipment. The lifting equipment will be present in the room, and allowing the focus group to visually see the equipment may help bring out solutions to some of their concerns. The focus group video will use a identification code that only the researcher will be able to identify in order to protect the identity of the participants in the focus group. The video recordings for the focus group will be destroyed following the completion of the thesis project or by August 31, 2012, whichever one comes first.

J. What if I change my mind about participating?
Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You do not have to answer every question and may refuse to answer any questions that you do not want answer. You may withdraw from the study at any time and any information associated with your participation in the study will be destroyed.

K. What if I have a question or complaint?
If you believe that the procedures outlined above have not been followed, if you believe the risk or discomfort is greater than indicated in the description provided

or if you have any questions, concerns or complaints about the study they can be answered by Dr. Victor Paquet can be contacted at 411 Bell Hall, Department of Industrial and Systems Engineering, University at Buffalo, Buffalo, NY 14260 or by telephone at (716) 645-4712.

If you have any questions about your rights as a participant in a research project, or questions, concerns or complaints about the research and wish to speak with someone who is not a member of the research team, you should contact (anonymously, if you wish) the Social and Behavioral Sciences Institutional Review Board, 515 Capen Hall, University at Buffalo, Buffalo, NY 14260, e-mail SBSIRB@research.buffalo.edu, phone (716) 645-6474.

L. Authorization:

I have read the explanation provided to me. I have had all my questions answered to my satisfaction and I voluntarily agree to participate in this study. I have been given a copy of this consent form.

Printed Name of the Participant:

____

Signature of the Participant and Date:

________________________________ ___________

Signature *Date*

I allow the researchers to Video Record my responses in this focus group:

________________________________ ___________

Participant Signature *Date*

M. Signature of the Investigator or Person Obtaining the Consent and Date:

________________________________ ___________

Signature *Date*

Appendix B

Demographic Information Questionnaire

Please answer the following questions, by providing or circling the correct response:

What is your age? __________ years

What is your gender? Male Female

Did you attend the Safe Patient Handling Training Class at UB? Yes No

Are you currently experiencing low back pain? Yes No

What is your major in college that you are currently pursuing? ______________________

Height? ______________

Weight? ______________

My experience in using patient handling equipment is best described:

a. I have attended a safe patient handling training class, but still do not feel comfortable using the equipment without supervision

b. I have attended a safe patient handling training class and feel comfortable using the equipment without supervision, but have never lifted a patient

c. I have attended a safe patient handling training class feel comfortable using the equipment, and have experience lifting patients with the equipment

My experience using slings is best described:

a. I have attended a safe patient handling training class, but still do not feel comfortable using the slings without supervision

b. I have attended a safe patient handling training class and feel comfortable using the slings without supervision, but have never attached a sling to a lift with a patient in the sling

c. I have attended a safe patient handling training class, feel comfortable using the sling, and have experience attaching a sling to a lift with a patient in the sling

Appendix C

Informed Consent

The Effects of User-Centered Design on the Usability of Patient Handling Equipment

Department of Industrial and Systems Engineering
State University of New York at Buffalo

Investigators: Mark Fenzl, Victor Paquet

You are invited to take part in a research study that assesses usability of patient handling equipment and slings.

A. What is the purpose of this study?
The purpose of the current study is to determine the usability of safe patient handling equipment and slings during patient transfer tasks

B. Why have you been selected?
We are recruiting individual adults who have attended the safe patient handling training class at the University at Buffalo Safe Patient Handling Training Center, and who can give us feedback on the usability of safe patient handling equipment and slings.

C. What does the research consist of?
Your participation consists of tasks specifically associated with performing safe patient transfers from a bed to a commode/chair using the lifting equipment and slings showcased in the training class. The study may last up to 2 hours long.

D. Is there any risk of discomfort?
There is a risk involved in connecting the sling to the lift. The sling must be connected correctly to the lift to ensure the safety of both the researcher acting as the patient and you acting as the nurse/healthcare worker. The tasks are designed to allow for the researchers to correct the possible errors made by you, in particular the case of correctly connecting the sling to the lift. The risk of having the patient (researcher) fall from the sling possibly could injure the patient (researcher). There is also a risk involved with you, the participant, because the patient (researcher) could fall on you if the sling is not attached to the lift correctly. This is not expected to happen with the oversight of both researchers (the principal investigator and a trained observer) present in the room. Again, the researchers will be able to intervene if the sling is not properly connected to the lift. In addition, you will be provided with rest breaks during the protocol and at request to minimize fatigue.

E. Where and when will this study be done?
The study will be carried out at the Safe Patient Handling and Training Center in the Diefendorf Annex at the University at Buffalo South Campus at a time mutually convenient to you and the researchers.

F. Will compensation be made for any injury resulting from this research study?
No injury is anticipated as a result of participating in this research. In the event that physical injury does occur as a result of this research, the University at Buffalo, SUNY does not make provisions for medical care nor is there any protection from the State University of New York for payment or compensation for medical care in the event of injury as a result of participating in this research project.

G. What are the benefits for me in participating in this study?
There are no direct benefits to you for participating in this study. The study results may help designers and manufacturers improve future patient handling equipment.

H. What are the costs and compensation for participating in this study?
There is no cost to you for participating in this research. In consideration for your time and participation, you will be paid $15 per hour for up to 2 hours of participation.

I. What about my confidentiality?
The information you provide is confidential, therefore no one outside the research team will be able to identify your responses. Your identity will be protected by coding your information using a unique person number. The information you provide will be viewed only by approved members of the research team. Your identity will not be made part of any published findings resulting from this study. The usability study tasks will be video recorded enabling the researchers to analyze the tasks at a later time. In order to monitor this research study representatives from federal agencies such as NIH (Nation Institutes of Health) and OHRP (Office of Human Research Protection) or representatives from the UB Human Research Protections Program may inspect the research records. This process may reveal your identity. If you withdraw from this study, all individually identifiable data provided by you will be destroyed and not used for analysis. The video recording will use unique identification codes correlated with the unique person numbers of the participants in the study to protect the identity of the individuals in the videos. The video recordings for the usability study will be destroyed following the completion of the thesis project or by August 31, 2012, whichever one comes first.

J. What if I change my mind about participating?
Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You do not have to answer every question and may refuse to answer any questions that you do not want answer. You may withdraw from the study at any time and any information associated with your participation in the study will be destroyed.

K. What if I have a question or complaint?
If you believe that the procedures outlined above have not been followed, if you believe the risk or discomfort is greater than indicated in the description provided or if you have any questions, concerns or complaints about the study they can be answered by Dr. Victor Paquet can be contacted at 411 Bell Hall, Department of Industrial and Systems Engineering, University at Buffalo, Buffalo, NY 14260 or by telephone at (716) 645-4712.

If you have any questions about your rights as a participant in a research project, or questions, concerns or complaints about the research and wish to speak with someone who is not a member of the research team, you should contact (anonymously, if you wish) the Social and Behavioral Sciences Institutional Review Board, 515 Capen Hall, University at Buffalo, Buffalo, NY 14260, e-mail SBSIRB@research.buffalo.edu, phone (716) 645-6474.

L. Authorization:

I have read the explanation provided to me. I have had all my questions answered to my satisfaction and I voluntarily agree to participate in this study. I have been given a copy of this consent form.

Printed Name of the Participant:

____

Signature of the Participant and Date:

__________________________________	__________
Signature	*Date*

M. Signature of the Investigator or Person Obtaining the Consent and Date:

__________________________________	__________
Signature	*Date*

Appendix D

Consumer product universal design scales

Some items in these scales came from the Consumers' Product Evaluation Survey and the Universal Design Performance Measures for Products (Story et al., 2000, 2001)

Title (range of scale values, maximum to 5 points per item)

SA—strongly agree, A—agree, N—neither agree or disagree, D—disagree, SD—strongly disagree, NA—not applicable.

1. Low physical effort (10– 50)

1 Using this product does not tire me.
2 I can use this product without having to repeat any motion enough to cause pain.
3 I can use this product as long as I want without causing fatigue.
4 I can use this product without having to repeat any motion enough to cause fatigue.
5 I can use this product as long as I want without causing pain.
6 I do not have to rest after using this product.
7 Using this product does not make me need to rest.
8 I can use this product without awkward movements.
9 I can use this product without overexerting myself.
10 I can use this product without uncomfortable postures.

2. Perceptible information (7– 35)

1 This product gives me helpful feedback as I use it.
2 This product prompts me to pay attention during a critical action.
3 This product gives me useful feedback as I use it.
4 This product warns me about potential errors.
5 This product prompts me to pay attention during a hazardous action.
6 This product warns me about potential hazards.
7 This product helps me understand how to use it.

3. Flexibility in use (5– 25)

1 I can use this product in whatever way(s) are efficient for me.
2 I can use this product in whatever way(s) are effective for me.
3 I think this product looks attractive.
4 I have choices in the way I can use this product.
5 I can find at least one way to use this product effectively.

4. Adaptability to user pace (4– 20)

1 I have a choice in the speed of use of this product.
2 I can use this product as slowly as I want.
3 This product works just like I expect it to work.
4 The use of this product is straightforward.

5. Intuitive use (3– 15)
1 I do not need instructions to use this product.
2 I understand any language used in this product.
3 I can use this product without sight.

6. Reach and access for use (3–15)
1 I can reach all the important elements of this product from positions I would like to be in.
2 I can access all the important elements of this product from positions I would like to be in.
3 I can use this product with any aids, devices, or techniques I use.

7. Simple use (4– 20)
1 This product is simple to use.
2 I can easily identify the features of this product in order to use it.
3 The most important features of this product are the most obvious.
4 The features of this product that I use the most are the easiest to access.

8. Equitable use (2– 10)
1 Using this product does not make me feel different.
2 I can use this product with the hand (or foot) that I prefer to use.

9. Secure, safe and private use (3– 15)
1 This product does not threaten my privacy.
2 This product does not threaten my security.
3 I can use this product in whatever way(s) are safe for me.

10. Tolerance for error (2– 10)
1 This product gives me an opportunity to undo errors.
2 This product gives me an opportunity to correct errors.

11. Size for use (1– 5)
1 This product fits my hand size.

Appendix E

Example of usability tool for the lift

Instructions: Please mark an "X" in the box that correlates most closely with the sentence.

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	PARTICIPANT NO. ____ PRODUCT - LIFT POSITION_________	SA	A	N	D	SD	NA
1	Using this product does not tire me.						
2	I can use this product without having to repeat any motion enough to cause pain.						
3	I can use this product as long as I want without causing fatigue.						
4	I can use this product without having to repeat any motion enough to cause fatigue.						
5	I can use this product as long as I want without causing pain.						
6	I do not have to rest after using this product.						
7	Using this product does not make me need to rest.						
8	I can use this product without awkward movements.						
9	I can use this product without overexerting myself.						
10	I can use this product without uncomfortable postures.						
11	This product gives me helpful feedback as I use it.						
12	This product prompts me to pay attention during a critical action.						
13	This product gives me useful feedback as I use it.						
14	This product warns me about potential errors.						
15	This product prompts me to pay attention during a hazardous action.						
16	This product warns me about potential hazards.						
17	This product helps me understand how to use it.						
18	I can use this product in whatever way(s) are efficient for me.						
19	I can use this product in whatever way(s) are effective for me.						
20	I think this product looks attractive.						
21	I have choices in the way I can use this product.						
22	I can find at least one way to use this product effectively.						
23	I have a choice in the speed of use of this product.						
24	I can use this product as slowly as I want.						
25	This product works just like I expect it to work.						
26	The use of this product is straightforward.						
27	I do not need instructions to use this product.						
28	I understand any language used in this product.						
29	I can use this product without sight.						
30	I can reach all the important elements of this product from positions I would like to be in.						
31	I can access all the important elements of this product from positions I would like to be in.						
32	I can use this product with any aids, devices, or techniques I use.						
33	This product is simple to use.						
34	I can easily identify the features of this product in order to use it.						

35	The most important features of this product are the most obvious.						
36	The features of this product that I use the most are the easiest to access.						
37	Using this product does not make me feel different.						
38	I can use this product with the hand (or foot) that I prefer to use.						
39	This product does not threaten my privacy.						
40	This product does not threaten my security.						
41	I can use this product in whatever way(s) are safe for me.						
42	This product gives me an opportunity to undo errors.						
43	This product gives me an opportunity to correct errors.						
44	This product fits my hand size.						

Appendix F

Borg Scale

What is your perceived level of exertion for pushing/pulling the lift?

6 – no exertion at all
7 –
8 – Very light
9 –
10 –
11 – light
12 –
13 – somewhat hard
14 –
15 – Hard (heavy)
16 –
17 – Very hard
18 –
19 – Extremely hard
20 – Maximal exertion

Appendix G

Error Checklist Example

SIT UP POSITION

Task 1

	YES	**NO**
Selected Correct Sling (M)		

Task 2

	YES	**NO**
Placed sling next to/under back of patient		
Had patient lift knee to chest		
Pulled patient towards the them		
Pushed patient away from them		
Rolled patient back onto their back		
Sling is right side up under patient		
"Leg straps"/lower body part of sling positioned correctly		
"Arm straps"/upper body part of sling positioned correctly		
Moved equipment on angle over bed		
Place the bar horizontally over patient's chest		
Looped right leg strap correctly		
Looped left leg strap correctly		
Attached right arm hook to equipment correctly-BLACK		
Attached left arm hook to equipment correctly-BLACK		
Attached right leg hook to equipment correctly-BLUE		
Attached left leg hook to equipment correctly-BLUE		

STOP TASKS AND MAKE SURE HOOKS/STRAPS ARE CORRECTLY ATTACHED

FOR RESEARCHER ONLY: SIT UP POSITION	**YES**	**NO**
Left leg strap properly looped-BLUE		
Right leg strap properly looped-BLUE		
Left arm strap attached properly-BLACK		
Right arm strap attached properly-BLACK		

Task 3-----Research assistant stand behind commode and hold to assist participant

	YES	NO
Positioned commode next to bed		
Lifted patient using remote		
Lifted patient using button on machine		
Adjust lift legs width to fit around commode chair		
Lowered patient onto commode using remote		
Lowered patient onto commode using button on machine		
Unstrapped sling		
Removed sling		

Appendix H

Error Results

5/7/2012 6:47:57 PM

```
Welcome to Minitab, press F1 for help.
```

Kruskal-Wallis Test: Original_Errors versus Trial

```
Kruskal-Wallis Test on Original_Errors

Trial     N  Median  Ave Rank      Z
1        15   5.000      18.2   1.66
2        15   3.000      12.8  -1.66
Overall  30              15.5

H = 2.75  DF = 1  P = 0.097
H = 2.91  DF = 1  P = 0.088  (adjusted for ties)
```

Kruskal-Wallis Test: Modified_Errors versus Trial

```
Kruskal-Wallis Test on Modified_Errors

Trial     N  Median  Ave Rank      Z
1        15   3.000      16.9   0.87
2        15   2.000      14.1  -0.87
Overall  30              15.5

H = 0.76  DF = 1  P = 0.384
H = 0.78  DF = 1  P = 0.376  (adjusted for ties)
```

Kruskal-Wallis Test: Total Errors versus Original_1 / Modified_2

```
Kruskal-Wallis Test on Total Errors

Original_1 /
Modified_2     N  Median  Ave Rank      Z
1             15   7.000      17.5   1.27
2             15   5.000      13.5  -1.27
Overall       30              15.5

H = 1.60  DF = 1  P = 0.206
H = 1.62  DF = 1  P = 0.203  (adjusted for ties)
```

5/7/2012 7:12:22 PM

Welcome to Minitab, press F1 for help.

Kruskal-Wallis Test: Original Equipment Errors versus Trial

Kruskal-Wallis Test on Original Equipment Errors

Trial	N	Median	Ave Rank	Z
1	11	3.000	13.9	1.74
2	11	2.000	9.1	-1.74
Overall	22		11.5	

H = 3.03 DF = 1 P = 0.082
H = 3.18 DF = 1 P = 0.075 (adjusted for ties)

Kruskal-Wallis Test: Modified Equipment Errors versus Trial

Kruskal-Wallis Test on Modified Equipment Errors

Trial	N	Median	Ave Rank	Z
1	11	3.000	13.6	1.51
2	11	2.000	9.4	-1.51
Overall	22		11.5	

H = 2.28 DF = 1 P = 0.131
H = 2.39 DF = 1 P = 0.122 (adjusted for ties)

Kruskal-Wallis Test: Total Equipment versus Original_1/ Modi

Kruskal-Wallis Test on Total Equipment Errors

Original_1/ Modified_2	N	Median	Ave Rank	Z
1	11	6.000	13.4	1.38
2	11	4.000	9.6	-1.38
Overall	22		11.5	

H = 1.90 DF = 1 P = 0.168
H = 1.94 DF = 1 P = 0.164 (adjusted for ties)

Kruskal-Wallis Test: Total Training E versus Original_1 / Mod

Kruskal-Wallis Test on Total Training Errors

Original_1 / Modified_2	N	Median	Ave Rank	Z
1	4	10.000	5.3	0.87
2	4	9.000	3.8	-0.87
Overall	8		4.5	

H = 0.75 DF = 1 P = 0.386
H = 0.98 DF = 1 P = 0.321 (adjusted for ties)

* NOTE * One or more small samples

Appendix I

Time Results

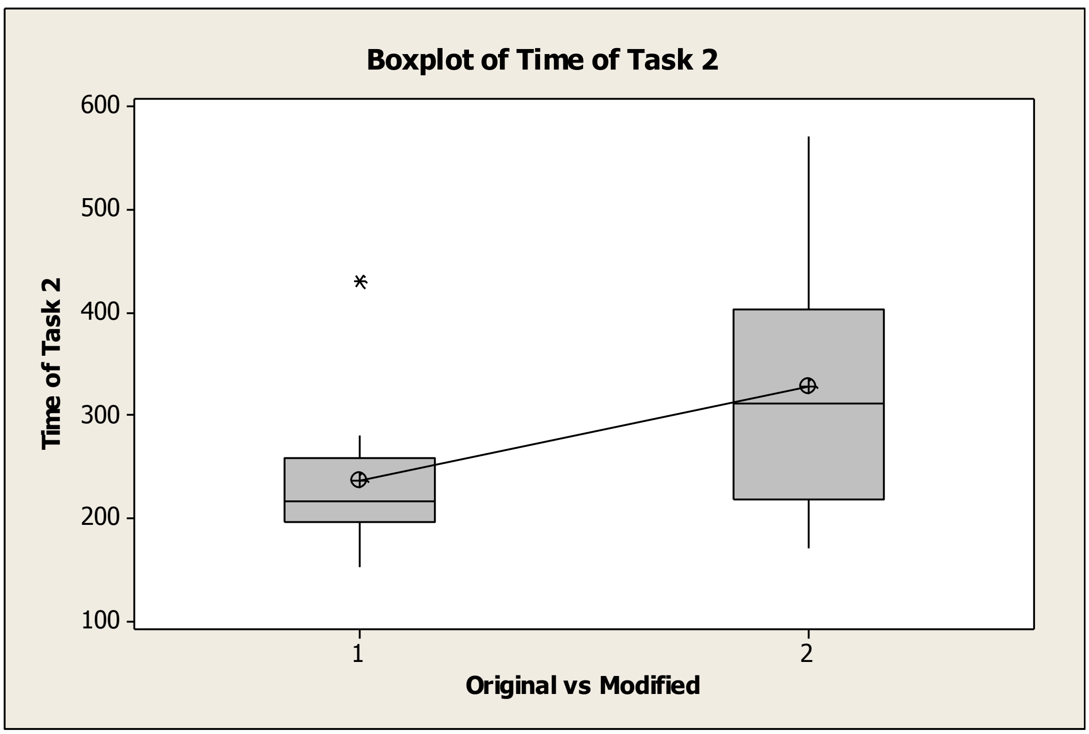
Two-Sample T-Test and CI: Time of Task 2, Original vs Modified

```
Two-sample T for Time of Task 2

Original
vs                              SE
Modified   N   Mean  StDev  Mean
1         12  235.5   72.3    21
2         12    329    121    35


Difference = mu (1) - mu (2)
Estimate for difference:  -93.2
95% CI for difference:  (-179.0, -7.3)
T-Test of difference = 0 (vs not =): T-Value = -2.29  P-Value = 0.035  DF = 17
```

Boxplot of Time of Task 2



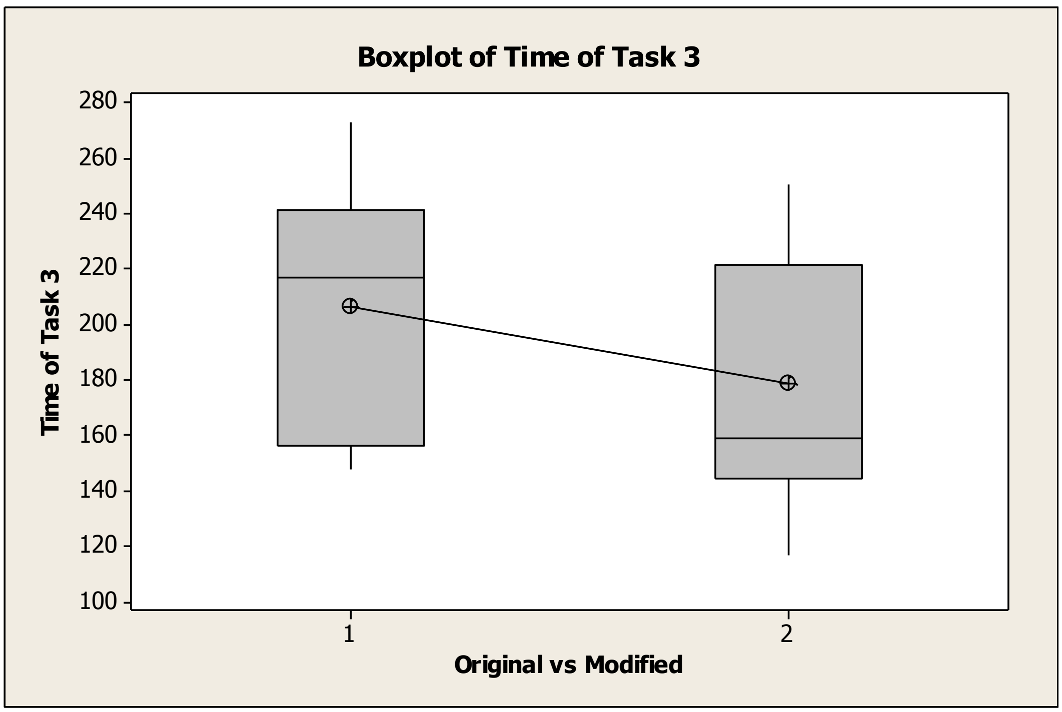
Two-Sample T-Test and CI: Time of Task 3, Original vs Modified

```
Two-sample T for Time of Task 3

Original
vs                               SE
Modified   N   Mean  StDev  Mean
1         12  206.3   46.6    13
2         12  178.8   45.5    13


Difference = mu (1) - mu (2)
Estimate for difference:  27.6
95% CI for difference:  (-11.5, 66.7)
T-Test of difference = 0 (vs not =): T-Value = 1.47  P-Value = 0.157  DF = 21
```

Boxplot of Time of Task 3



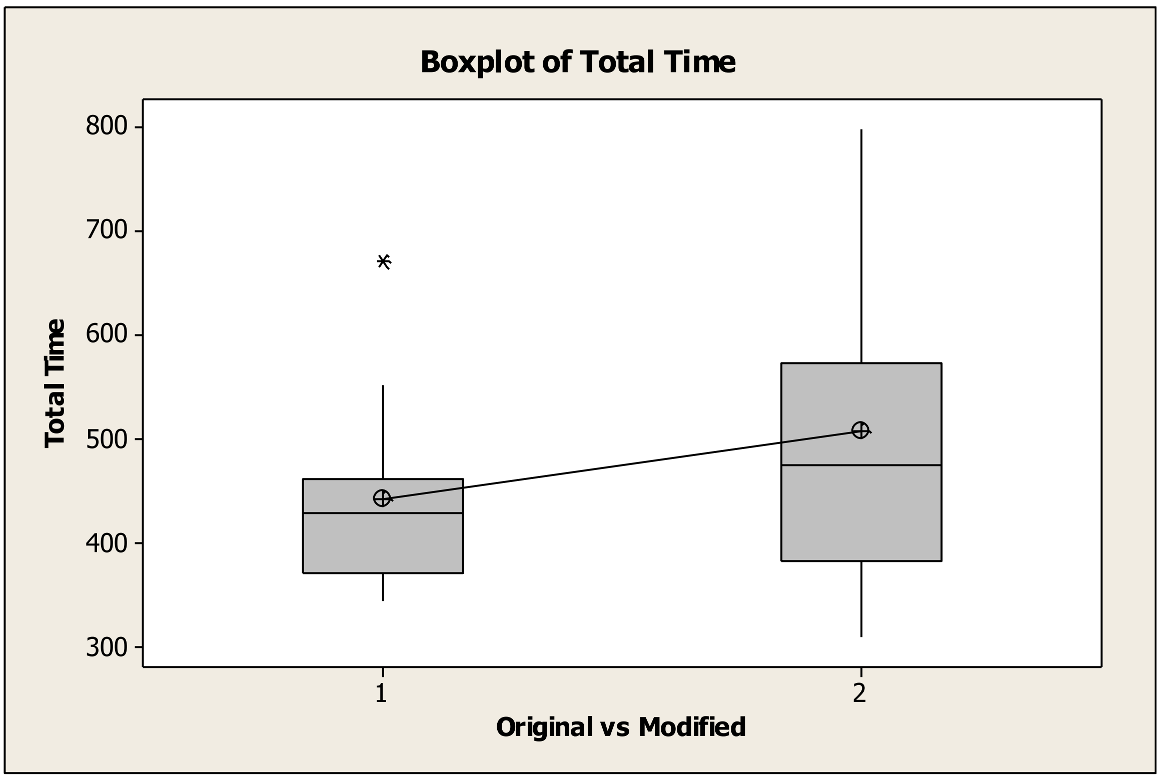
Two-Sample T-Test and CI: Total Time, Original vs Modified

```
Two-sample T for Total Time

Original
vs                             SE
Modified   N   Mean  StDev   Mean
1         12  441.8   92.4     27
2         12    507    149     43


Difference = mu (1) - mu (2)
Estimate for difference:  -65.6
95% CI for difference:  (-171.9, 40.7)
T-Test of difference = 0 (vs not =): T-Value = -1.30  P-Value = 0.211  DF = 18
```

Boxplot of Total Time



—— **5/8/2012 2:05:35 PM** ——

```
Welcome to Minitab, press F1 for help.
Retrieving project from file: 'N:\SLING_ORIGINAL VS MODIFIED
EVERYTHING1.MPJ'
```

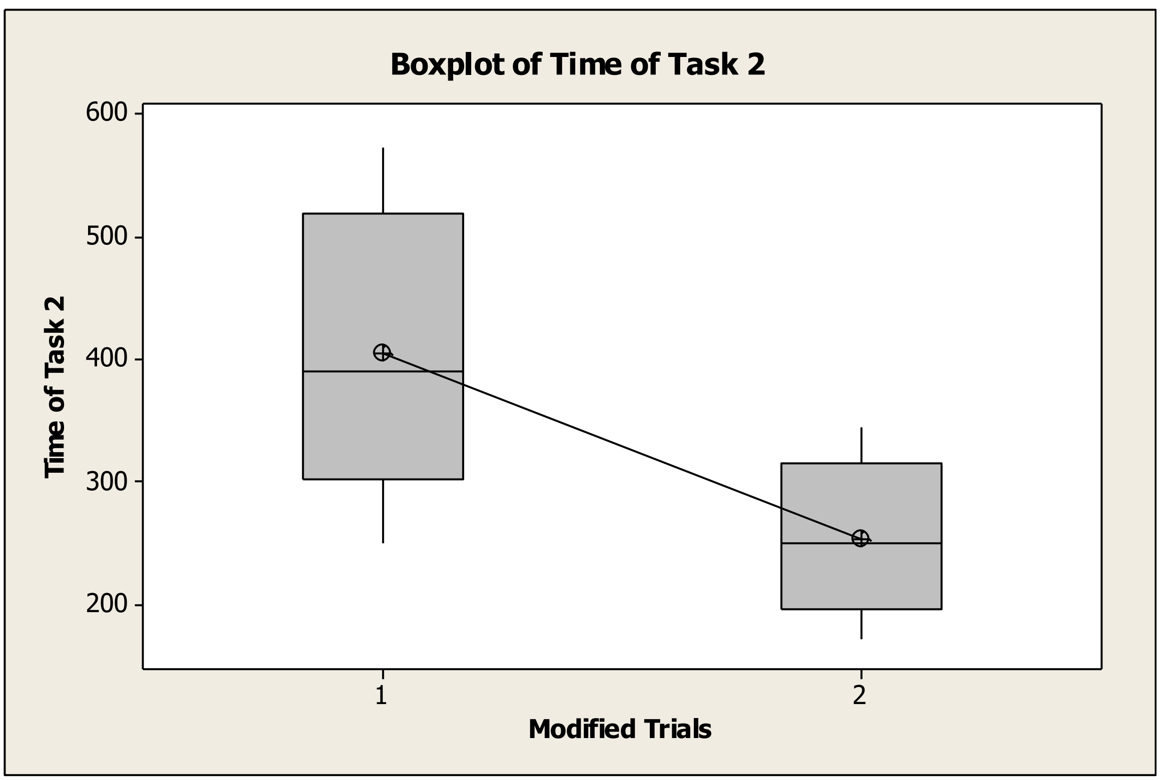
Two-Sample T-Test and CI: Time of Task 2, Modified Trials

```
Two-sample T for Time of Task 2

Modified                        SE
Trials    N   Mean  StDev  Mean
1         6    404    118    48
2         6  253.5   68.4    28


Difference = mu (1) - mu (2)
Estimate for difference:  150.3
95% CI for difference:  (21.7, 279.0)
T-Test of difference = 0 (vs not =): T-Value = 2.69  P-Value = 0.027  DF = 8
```

Boxplot of Time of Task 2



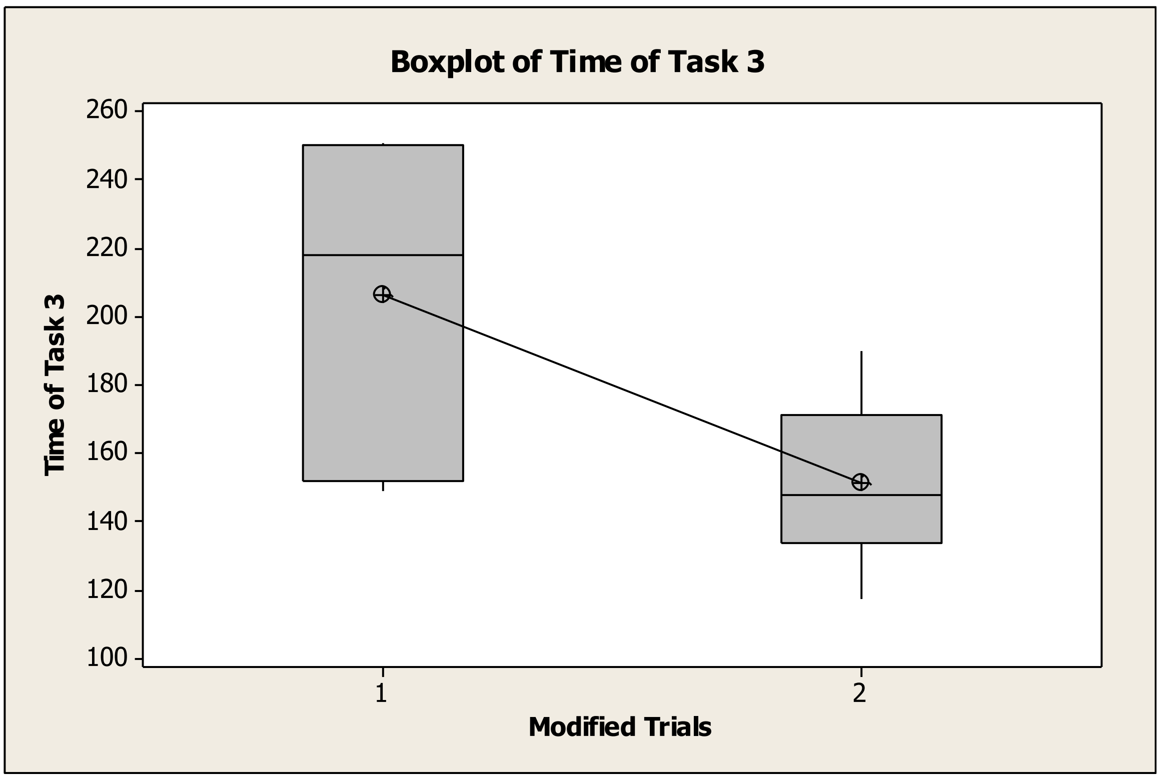
Two-Sample T-Test and CI: Time of Task 3, Modified Trials

```
Two-sample T for Time of Task 3

Modified                       SE
Trials    N   Mean  StDev  Mean
1         6  206.5   45.7    19
2         6  151.0   24.8    10


Difference = mu (1) - mu (2)
Estimate for difference:  55.5
95% CI for difference:  (5.3, 105.7)
T-Test of difference = 0 (vs not =): T-Value = 2.61  P-Value = 0.035  DF = 7
```

Boxplot of Time of Task 3



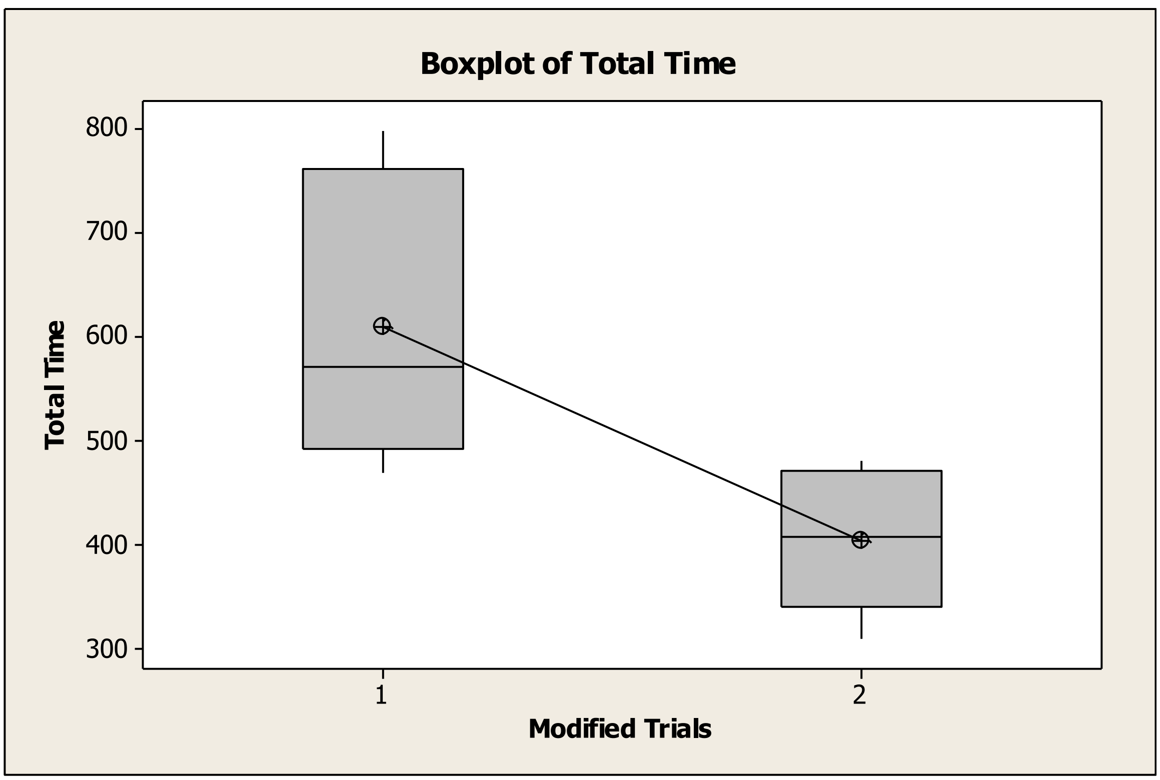
Two-Sample T-Test and CI: Total Time, Modified Trials

```
Two-sample T for Total Time

Modified                        SE
Trials     N   Mean  StDev  Mean
1          6    610    134    55
2          6  404.5   73.8    30


Difference = mu (1) - mu (2)
Estimate for difference:  205.8
95% CI for difference:  (58.3, 353.4)
T-Test of difference = 0 (vs not =): T-Value = 3.30  P-Value = 0.013  DF = 7
```

Boxplot of Total Time



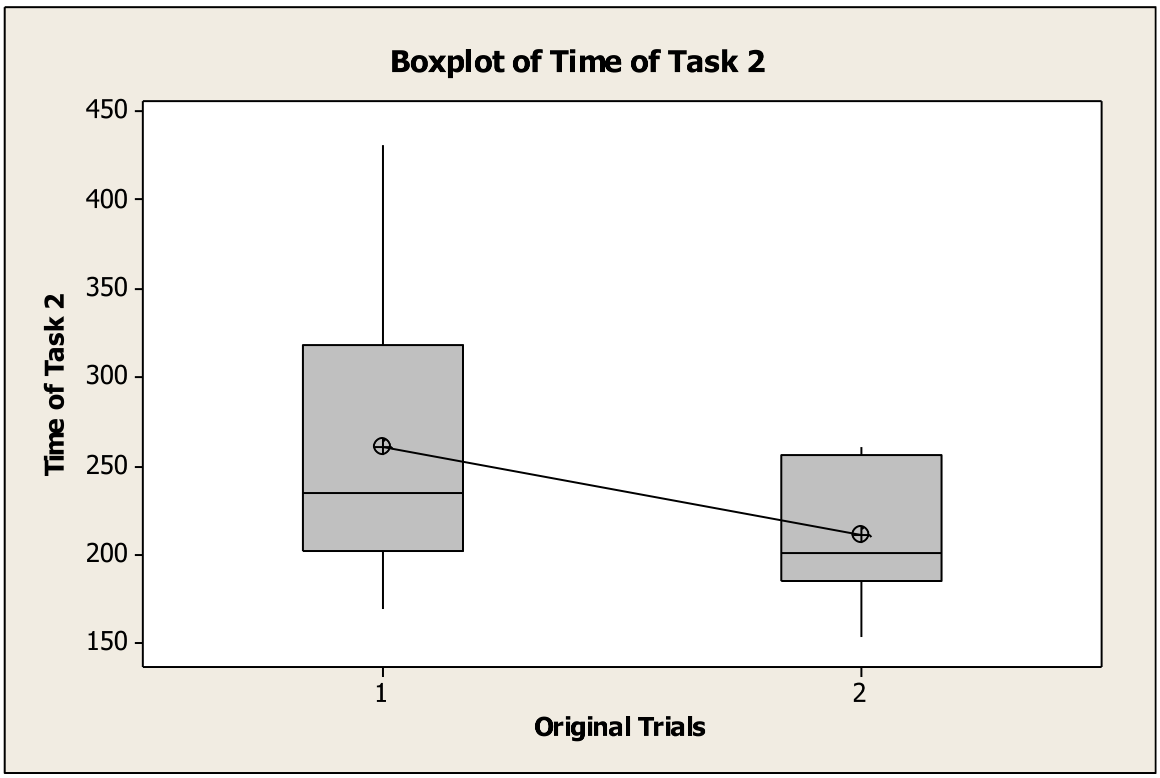
Two-Sample T-Test and CI: Time of Task 2, Original Trials

```
Two-sample T for Time of Task 2

Original                       SE
Trials    N   Mean  StDev  Mean
1         6  260.3   91.6    37
2         6  210.7   40.5    17


Difference = mu (1) - mu (2)
Estimate for difference:  49.7
95% CI for difference:  (-50.3, 149.7)
T-Test of difference = 0 (vs not =): T-Value = 1.22  P-Value = 0.270  DF = 6
```

Boxplot of Time of Task 2



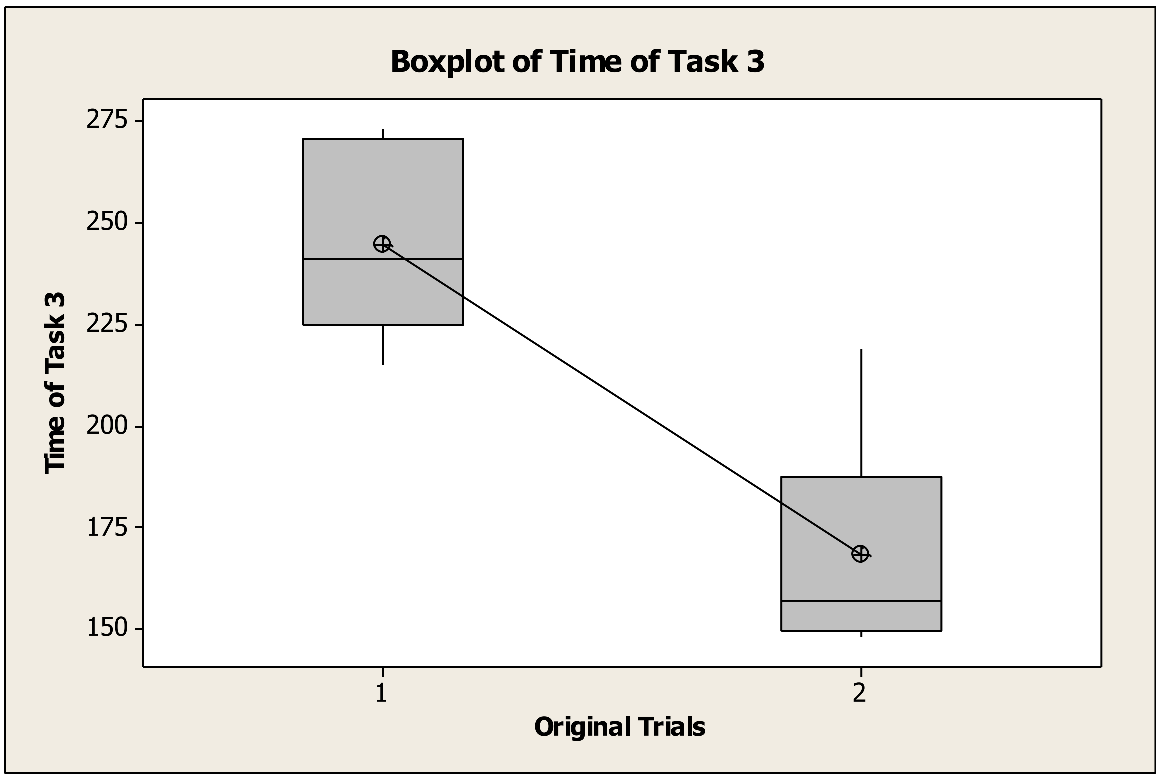
Two-Sample T-Test and CI: Time of Task 3, Original Trials

```
Two-sample T for Time of Task 3

Original
Trials     N   Mean  StDev  SE Mean
1          6  244.7   22.9      9.4
2          6  168.0   27.0       11


Difference = mu (1) - mu (2)
Estimate for difference:  76.7
95% CI for difference:  (43.9, 109.4)
T-Test of difference = 0 (vs not =): T-Value = 5.30  P-Value = 0.000  DF = 9
```

Boxplot of Time of Task 3



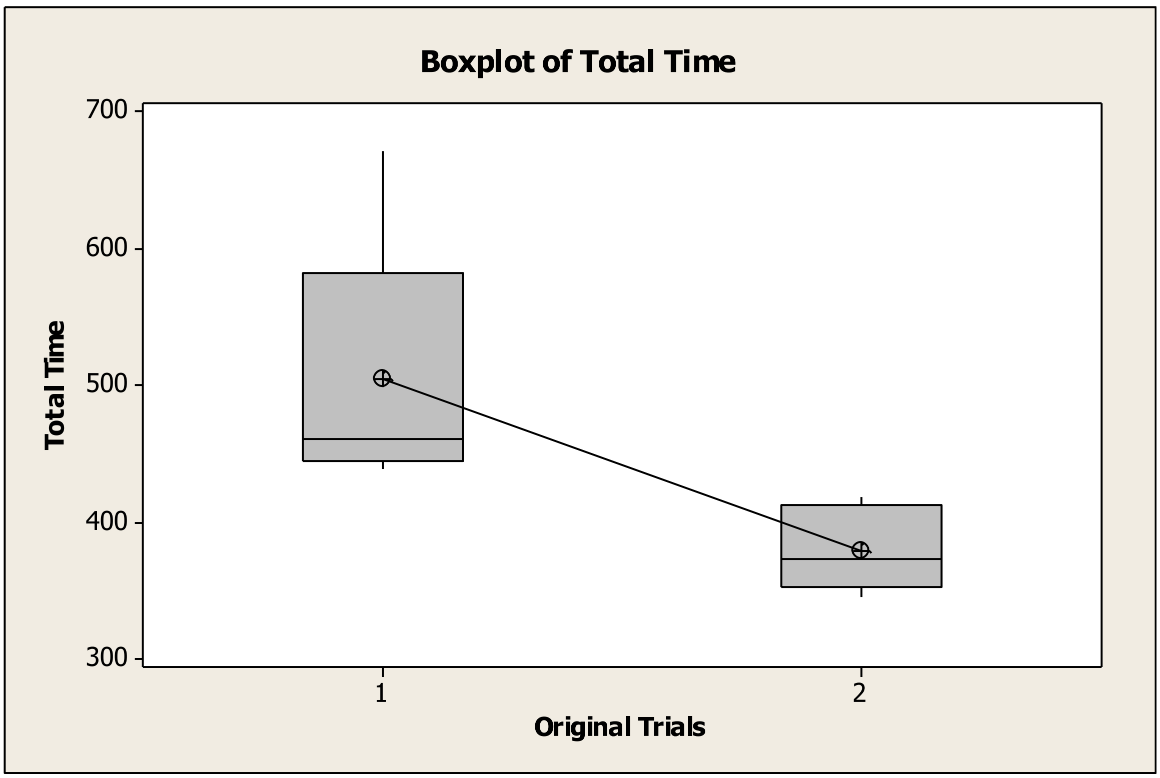
Two-Sample T-Test and CI: Total Time, Original Trials

```
Two-sample T for Total Time

Original                      SE
Trials    N   Mean  StDev  Mean
1         6  505.0   91.3    37
2         6  378.7   29.7    12


Difference = mu (1) - mu (2)
Estimate for difference:  126.3
95% CI for difference:  (30.4, 222.3)
T-Test of difference = 0 (vs not =): T-Value = 3.22  P-Value = 0.018  DF = 6
```

Boxplot of Total Time



Appendix J

Raw Time Data

Participant	Equipment	Position	Trial	Time of Task 2 (seconds)	Time of Task 3 (seconds)	Total Time (seconds)
P1	Original	Sit-up	1	280	273	553
P2	Original	Sit-up	1	213	242	455
P3	Original	Sit-up	2	195	177	372
P4	Original	Sit-up	2	204	150	354
P5	Original	Sit-up	1	431	240	671
P6	Original	Sit-up	2	260	158	418
P7	Modified	Sit-up	1	500	250	750
P8	Modified	Sit-up	2	290	190	480
P9	Modified	Sit-up	1	320	149	469
P10	Modified	Sit-up	2	204	152	356
P11	Modified	Sit-up	1	417	153	570
P12	Modified	Sit-up	2	171	139	310
P1	Original	Leaned	2	197	148	345
P2	Original	Leaned	2	255	156	411
P3	Original	Leaned	1	169	270	439
P4	Original	Leaned	1	250	215	465
P5	Original	Leaned	2	153	219	372
P6	Original	Leaned	1	219	228	447
P7	Modified	Leaned	2	304	165	469
P8	Modified	Leaned	1	572	226	798
P9	Modified	Leaned	2	208	143	351
P10	Modified	Leaned	1	250	251	501
P11	Modified	Leaned	2	344	117	461
P12	Modified	Leaned	1	364	210	574

Appendix K

Ratings of Perceived Exertion (RPE) Results

5/1/2012 3:48:12 PM

```
Welcome to Minitab, press F1 for help.
Retrieving project from file: 'N:\SLING_ORIGINAL VS MODIFIED
EVERYTHING.MPJ'
```

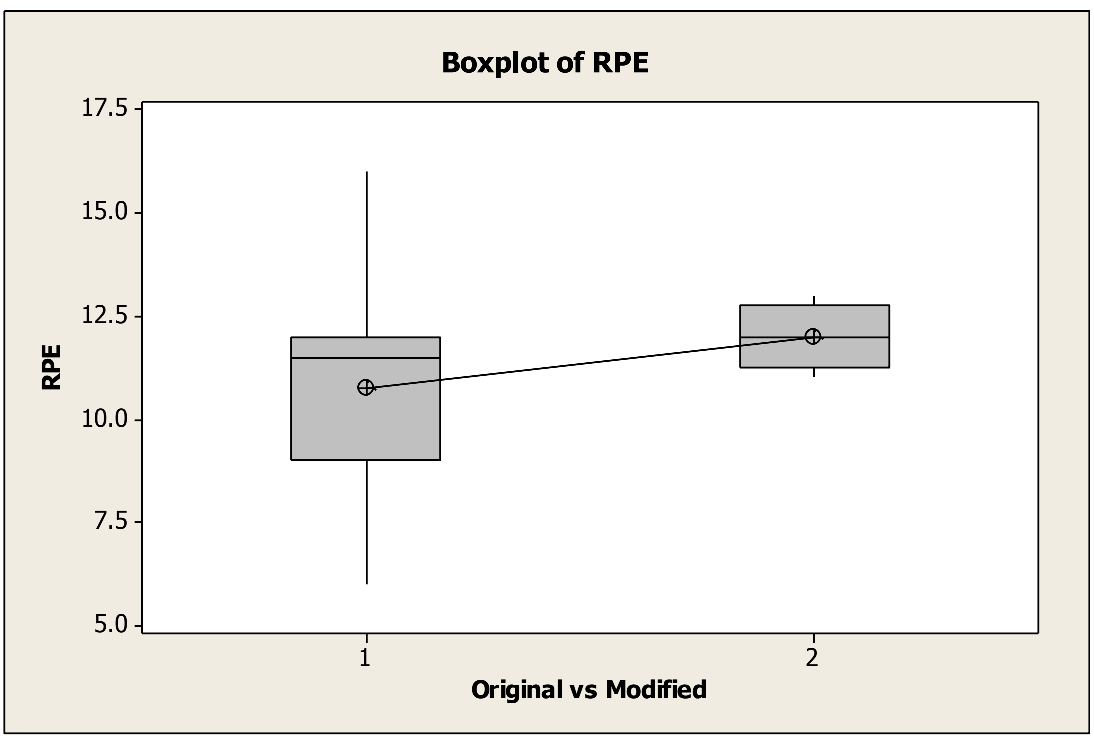
Two-Sample T-Test and CI: RPE, Original vs Modified

```
Two-sample T for RPE

Original
vs
Modified   N    Mean  StDev  SE Mean
1         12   10.75   2.96     0.85
2         12  12.000  0.739     0.21


Difference = mu (1) - mu (2)
Estimate for difference:  -1.250
95% CI for difference:  (-3.168, 0.668)
T-Test of difference = 0 (vs not =): T-Value = -1.42  P-Value = 0.181  DF = 12
```

Boxplot of RPE



Appendix L

Usability Scale Results for the Sling

5/1/2012 12:24:49 PM

```
Welcome to Minitab, press F1 for help.
```

Kruskal-Wallis Test: US-1 versus Original vs Modified

```
Kruskal-Wallis Test on US-1

Original vs
Modified      N  Median  Ave Rank      Z
1            12   39.00      11.8  -0.52
2            12   39.00      13.3   0.52
Overall      24              12.5

H = 0.27  DF = 1  P = 0.603
H = 0.28  DF = 1  P = 0.600  (adjusted for ties)
```

Kruskal-Wallis Test: US-2 versus Original vs Modified

```
Kruskal-Wallis Test on US-2

Original vs
Modified      N  Median  Ave Rank      Z
1            12   14.00      11.0  -1.04
2            12   17.50      14.0   1.04
Overall      24              12.5

H = 1.08  DF = 1  P = 0.299
H = 1.08  DF = 1  P = 0.298  (adjusted for ties)
```

Kruskal-Wallis Test: US-3 versus Original vs Modified

```
Kruskal-Wallis Test on US-3

Original vs
Modified      N  Median  Ave Rank      Z
1            12   18.50      12.8   0.17
2            12   18.00      12.3  -0.17
Overall      24              12.5

H = 0.03  DF = 1  P = 0.862
H = 0.03  DF = 1  P = 0.861  (adjusted for ties)
```

Kruskal-Wallis Test: US-4 versus Original vs Modified

```
Kruskal-Wallis Test on US-4

Original vs
Modified      N  Median  Ave Rank      Z
1            12   14.50      10.9  -1.13
2            12   16.00      14.1   1.13
Overall      24              12.5

H = 1.27  DF = 1  P = 0.260
H = 1.31  DF = 1  P = 0.252  (adjusted for ties)
```

Kruskal-Wallis Test: US-5 versus Original vs Modified

```
Kruskal-Wallis Test on US-5

Original vs
Modified      N  Median  Ave Rank      Z
1            12   3.500      11.1  -0.95
2            12   5.500      13.9   0.95
Overall      24              12.5

H = 0.91  DF = 1  P = 0.341
H = 0.93  DF = 1  P = 0.335  (adjusted for ties)
```

Kruskal-Wallis Test: US-6 versus Original vs Modified

```
Kruskal-Wallis Test on US-6

Original vs
Modified      N  Median  Ave Rank      Z
1            12   11.50      11.5  -0.69
2            12   12.00      13.5   0.69
Overall      24              12.5

H = 0.48  DF = 1  P = 0.488
H = 0.53  DF = 1  P = 0.466  (adjusted for ties)
```

Kruskal-Wallis Test: US-7 versus Original vs Modified

```
Kruskal-Wallis Test on US-7

Original vs
Modified      N  Median  Ave Rank      Z
1            12   12.50      10.9  -1.10
2            12   16.00      14.1   1.10
Overall      24              12.5

H = 1.20  DF = 1  P = 0.273
H = 1.28  DF = 1  P = 0.258  (adjusted for ties)
```

Kruskal-Wallis Test: US-8 versus Original vs Modified

```
Kruskal-Wallis Test on US-8

Original vs
Modified      N  Median  Ave Rank      Z
1            12   6.000      10.3  -1.50
2            12   8.000      14.7   1.50
Overall      24              12.5

H = 2.25  DF = 1  P = 0.133
H = 2.34  DF = 1  P = 0.126  (adjusted for ties)
```

Kruskal-Wallis Test: US-9 versus Original vs Modified

```
Kruskal-Wallis Test on US-9

Original vs
Modified      N  Median  Ave Rank      Z
1            12   12.00      11.5  -0.66
2            12   12.00      13.5   0.66
Overall      24              12.5

H = 0.44  DF = 1  P = 0.507
H = 0.46  DF = 1  P = 0.496  (adjusted for ties)
```

Kruskal-Wallis Test: US-10 versus Original vs Modified

```
Kruskal-Wallis Test on US-10

Original vs
Modified      N  Median  Ave Rank      Z
1            12   5.500       9.8  -1.91
2            12   8.000      15.3   1.91
Overall      24              12.5

H = 3.63  DF = 1  P = 0.057
H = 3.83  DF = 1  P = 0.050  (adjusted for ties)
```

Kruskal-Wallis Test: US-11 versus Original vs Modified

```
Kruskal-Wallis Test on US-11

Original vs
Modified      N  Median  Ave Rank      Z
1            12   3.000      11.0  -1.04
2            12   4.000      14.0   1.04
Overall      24              12.5

H = 1.08  DF = 1  P = 0.299
H = 1.26  DF = 1  P = 0.261  (adjusted for ties)
```

Appendix M

Usability Scale Results for the Lift

5/1/2012 1:39:46 PM

Welcome to Minitab, press F1 for help.

Kruskal-Wallis Test: US-1 versus Original vs Modified

Kruskal-Wallis Test on US-1

Original vs Modified	N	Median	Ave Rank	Z
1	12	39.00	11.8	-0.52
2	12	40.00	13.3	0.52
Overall	24		12.5	

H = 0.27 DF = 1 P = 0.603
H = 0.27 DF = 1 P = 0.600 (adjusted for ties)

Kruskal-Wallis Test: US-2 versus Original vs Modified

Kruskal-Wallis Test on US-2

Original vs Modified	N	Median	Ave Rank	Z
1	12	15.50	8.8	-2.57
2	12	24.50	16.2	2.57
Overall	24		12.5	

H = 6.60 DF = 1 P = 0.010
H = 6.66 DF = 1 P = 0.010 (adjusted for ties)

Kruskal-Wallis Test: US-3 versus Original vs Modified

Kruskal-Wallis Test on US-3

Original vs Modified	N	Median	Ave Rank	Z
1	12	17.00	9.6	-2.02
2	12	18.50	15.4	2.02
Overall	24		12.5	

H = 4.08 DF = 1 P = 0.043
H = 4.16 DF = 1 P = 0.041 (adjusted for ties)

Kruskal-Wallis Test: US-4 versus Original vs Modified

```
Kruskal-Wallis Test on US-4

Original vs
Modified      N  Median  Ave Rank      Z
1            12   16.00       9.1  -2.34
2            12   17.00      15.9   2.34
Overall      24              12.5

H = 5.47  DF = 1  P = 0.019
H = 6.28  DF = 1  P = 0.012  (adjusted for ties)
```

Kruskal-Wallis Test: US-5 versus Original vs Modified

```
Kruskal-Wallis Test on US-5

Original vs
Modified      N  Median  Ave Rank      Z
1            12   5.500      10.5  -1.41
2            12   7.000      14.5   1.41
Overall      24              12.5

H = 2.00  DF = 1  P = 0.157
H = 2.05  DF = 1  P = 0.152  (adjusted for ties)
```

Kruskal-Wallis Test: US-6 versus Original vs Modified

```
Kruskal-Wallis Test on US-6

Original vs
Modified      N  Median  Ave Rank      Z
1            12   11.50      10.4  -1.44
2            12   12.00      14.6   1.44
Overall      24              12.5

H = 2.08  DF = 1  P = 0.149
H = 2.25  DF = 1  P = 0.133  (adjusted for ties)
```

Kruskal-Wallis Test: US-7 versus Original vs Modified

```
Kruskal-Wallis Test on US-7

Original vs
Modified      N  Median  Ave Rank      Z
1            12   14.00       7.9  -3.20
2            12   16.00      17.1   3.20
Overall      24              12.5

H = 10.27  DF = 1  P = 0.001
H = 10.84  DF = 1  P = 0.001  (adjusted for ties)
```

Kruskal-Wallis Test: US-8 versus Original vs Modified

```
Kruskal-Wallis Test on US-8

Original vs
Modified      N  Median  Ave Rank      Z
1            12   7.000       9.3  -2.25
2            12   8.000      15.8   2.25
Overall      24              12.5

H = 5.07  DF = 1  P = 0.024
H = 5.47  DF = 1  P = 0.019  (adjusted for ties)
```

Kruskal-Wallis Test: US-9 versus Original vs Modified

```
Kruskal-Wallis Test on US-9

Original vs
Modified      N  Median  Ave Rank      Z
1            12   13.00      12.0  -0.35
2            12   12.00      13.0   0.35
Overall      24              12.5

H = 0.12  DF = 1  P = 0.729
H = 0.14  DF = 1  P = 0.712  (adjusted for ties)
```

Kruskal-Wallis Test: US-10 versus Original vs Modified

```
Kruskal-Wallis Test on US-10

Original vs
Modified      N  Median  Ave Rank      Z
1            12   4.000       7.7  -3.35
2            12   8.000      17.3   3.35
Overall      24              12.5

H = 11.21  DF = 1  P = 0.001
H = 11.66  DF = 1  P = 0.001  (adjusted for ties)
```

Kruskal-Wallis Test: US-11 versus Original vs Modified

```
Kruskal-Wallis Test on US-11

Original vs
Modified      N  Median  Ave Rank      Z
1            12   3.000      11.3  -0.87
2            12   4.000      13.8   0.87
Overall      24              12.5

H = 0.75  DF = 1  P = 0.386
H = 0.84  DF = 1  P = 0.360  (adjusted for ties)
```

5/8/2012 2:00:12 PM

```
Welcome to Minitab, press F1 for help.
Retrieving project from file: 'N:\LIFT_ORIGINAL VS MODIFIED EVERYTHING.MPJ'
```