Investigation of a maximum step height to establish design parameter for a rehabilitative medical transfer device

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Abstract

In many medical situations, patients may be requested to sit on an exam table, however individuals who are post-operative or elderly may find this difficult given only the 10” built into the table. Current lifting methods are inconvenient, uncomfortable, or unsafe for both patients and medical personnel, so a new device is needed to assist patients in accessing the exam table from a standing position. To determine appropriate design parameters for the device, test 30 engineering students were asked to step onto platforms of five different heights (2”, 4”, 6”, 8”, 10”) and rate the level of difficulty for each step. The results were analyzed and it was found that a 4” step height should be set as the maximum allowable step height for the design due to the increase in difficulty between the 4” and 6” step.

Introduction

In many medical situations, it is necessary to lift patients. This need for assistance could be due to reduced patient strength as a result of an extensively invasive operation, inherent weakness, or old age. As people age, their muscles degenerate, causing a reduction in their strength capabilities and increasing their force buildup time as shown by Abate et. al [1]. In addition to causing problems for the person in everyday activities (i.e. climbing stairs), it also makes difficult the routine examinations where a patient is required to climb up onto an exam table. This problem is compounded with more frail or obese patients. Generally, elderly or post-operative patients come to examinations in wheelchairs or with the assistance of a walker. In these situations, it is difficult for the medical assistant to help patients out of wheelchairs and lift them up to the top of exam tables.

Figure 1 - Medical assistant lifting patient out of wheelchair [2]

One of the most common methods for lifting patients is manual labor. In this method, trained medical assistant wraps their arms around a patient underneath the shoulder joint (figure 1). The assistant then carefully lifts the patient vertically. Carefully walking backwards while holding the patient, the assistant must then rotate slowly and lower the patient down onto the desired destination which is, in many clinical settings, an exam table. If the patient’s lower body is partially incapacitated, it is often necessary for a second assistant to hold the patient while the other assistant steadies the patient’s legs. If the patient is totally incapable of using their legs, they are then placed onto a hammock type sling in the lying position. Two assistants are then required to hold the two ends of the sling and lift the patient. Although manual lifting is mechanically simple, it requires a lot of physical exertion by the assistant. The level to which patients can be lifted is solely dependent on the assistant’s strength. Because of the large effort required for the lifting, there is a significant risk of injury for the assistant and a risk of injury for the patient if the assistant drops them.

To alleviate the required effort in patient lifting, several devices have been developed. The first and most commonly used lifting device is the Hoyer Lift (figure 2). This device uses a non-automated hydraulic system to elevate patients. It also includes several adjusting mechanisms to widen or narrow the supporting base and wheels for easy transport. The cost of a Hoyer lift can range from $600-2000 according to Preferred Health Choice Online [3]. To lift a patient, the device is first strategically positioned near the patient's desired destination. The patient is then inserted into a nylon or cotton sling that supports their back and upper legs. After the patient is secured in the sling, the assistant elevates the patient by operating a foot or hand pump. When the patient is fully suspended in air, the assistant then rotates the patient over the destination and then releases the hydraulic system so that the patient is lowered slowly into position. Although the Hoyer lift lessens the amount of effort required by the patient and by the assistant, it can cause emotional unease for the patient since they are in full air suspension during the lifting process. Additionally, several expensive modifications to the Hoyer lift are available. These devices include automated systems, a larger weight capacity, finer adjustment mechanisms, and different sling sizes.

Figure 2 - Elderly patient being lifted by Hoyer lift. [4]

To facilitate lifting of elderly or post-operative patients, it is necessary to design a device that is capable of safely transferring patients from a standing position on the ground to a level where they can easily get onto an exam table. To reduce patient anxiety, the device will include handles or another similar structure for patients to hold onto as they are being transferred. Finally, the device will be easy to operate and will minimize the required effort by the patient and medical personnel.

Research conducted by Bergland et. al [5] indicates that 80% elderly females (ages 75-93) were able to step higher than an 8" step and McIlroy et. al [6] found that stance widths range from 2" to 11.4" from a point centered below the body to the center of the foot. This research indicates the maximum flexion and step height for elderly people, but does not give any indication of what is comfortable for the patients. Ideally, the assistive transfer device would not force patients to strain themselves to get onto the device.

Methods

Thirty engineering students aged 18-25 were asked to step onto 5 different platforms, each of a different height (2", 4", 6", 8", 10"), and subsequently rate them on their difficulty with an open ended scale between 0-10 (10 representing maximum effort and 0 representing minimum effort). The order of step height was randomized to ensure there was no bias due to the order that they were stepped on. To normalize the data, the subjects were asked to associate the value of 10 to the 10 inch step, and 0 to walking on flat ground.

The original goal of the study was to have the same population of people that would use the assistive transfer device be the participants in the study, however, IRB approval was not able to be obtained and thus the authors could not conduct the study on the elderly and post-operative patient. The subjects were volunteers that were available during the time of the study.

Statistics

The statistical analysis software package Minitab was used to analyze the data. Simple 2-sample t tests were used to compare the difference among the different step heights. Data was acquired in 5 blocks, where each block of test subjects encountered the platforms in a given randomized order. This was to ensure that the data was not biased due to the order the platforms were encountered. ANOVA tables were generated for each of the blocks. The Tukey method was used to determine if the results were statistically significant between the blocks.

Results

A significant difference was found between all step heights based on their ratings (p-value<0.001). There was no difference between any of the blocks. There was a difference between the various 2" transitions, with the term transition referring to the 2" increment between platform heights. There are 4 transitions—the 2" to 4" transition, the 4" to 6" transition, etc. These transitions were compared by subtracting the ratings individuals gave for one step height from another. For example the 4" step difficulty rating was subtracted from the 2" step rating to give the 2" to 4" transitions. The ANOVA tables are shown in table 1 and 2 in addition to a box plot (figure 3), which was generated to illustrate these differences.

Table 1 - ANOVA table for step height transitions

	N	Mean	Std Dev	Std Error Mean
(4"-2")	30	1.717	0.971	0.18
(6"-4")	30	2.62	1.05	0.19
(8"-6")	30	1.27	1.63	0.30
(10"-8")	30	3.02	1.49	0.27

Table 2 - Summary of T-test for step height transition comparisons

	T-statistic	P-value	Degrees of Freedom	95% Confidence Interval
(4"-2"), (6"-4")	-3.45	0.001	57	(-1.422, -0.378)
(4"-2"), (8"-6")	1.30	0.201	47	(-0.248, 1.148)
(4"-2"), (10"-8")	-4.01	0.000	49	(-1.952, -0.648)
(6"-4"), (8"-6")	3.81	0.000	49	(0.638, 2.062)

(6"-4"), (10"-8")	-1.20	0.234	52	(-1.067, 0.267)
(8"-6"), (10"-8")	-4.34	0.000	57	(-2.558, -0.942)

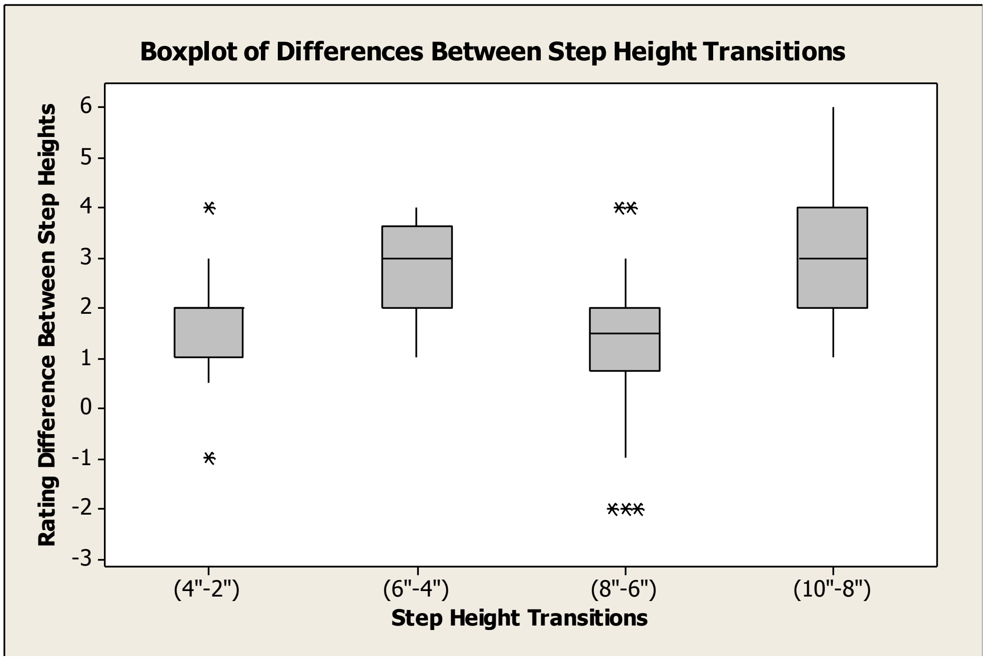

Figure 3: Boxplot illustrating the differences between step height transitions. Note that the 2" to 4" transition is significantly different than both the 4" to 6" transition and the 8" to 10" transition.

Discussion

The results from the study do not offer an exact step height which can be implemented as a new design parameter for the maximum allowable step height. Based on the results illustrated in Figure 3, it is clear that the transition between the 2" and 4" platforms is significantly smaller (easier for test subject) than the transition between the 4" and 6" platform transition. This means that the increase in difficulty is larger between the 4" and 6" step height.

The goal of the study was to determine how high of a step height would be "too high" and this difference in difficulty shown by a 18-25 year old population, may suggest that the elderly population begins to have problems traversing steps of heights somewhere between 4" and 6". Based on the results of this study, a 4" step height appears to be a reasonable parameter for the device. A proposed design for the assistive transfer device is shown in figure 4.

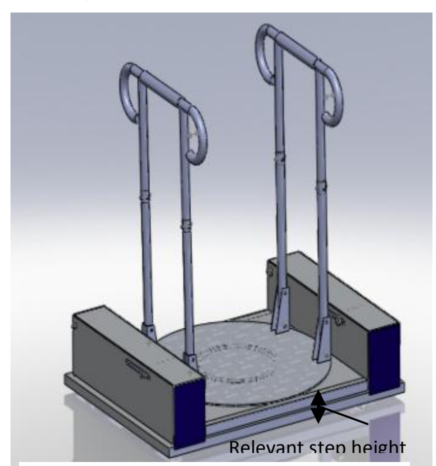

Figure 4 – SolidWorks of proposed design.

Although the outcome of the study serves as a good starting point for the device design, further research is necessary to specifically determine a discrete step height for the assistive transfer device. Since this study was not conducted on the appropriate population, the results are not directly useful. Future research would be conducted on an elderly population (ages >65). In addition to testing on an inappropriate population, error in the results could potentially be attributed to an unbalanced group of test subjects—unequal number of male and female subjects. Furthermore, there could have been error introduced due to the platforms used in the study. It is possible that the platform heights were inexact and would have resulted in higher or lower ratings.

References

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Figure Legends

(1) Medical assistant transferring patient from wheelchair to exam table. It illustrates the shape of the assistant’s spine during the transfer to highlight the amount of stress that would be on the lower back.

(2) Elderly patient in being lifted in a Hoyer lift.

(3) Boxplot illustrating the differences between step height transitions. Note that the 2” to 4” transition is significantly different than both the 4” to 6” transition and the 8” to 10” transition.

(4) SolidWorks model of proposed design for assistive transfer device. The step height of the current design is 2.25” high, as indicated by arrows.