

## **A Pilot Study Investigating Manual Material Handling Of Ladders From Construction Service Vans**

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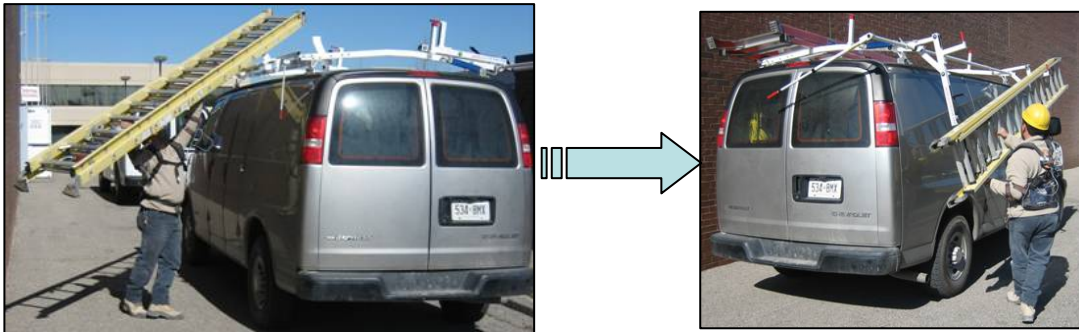
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The purpose of this pilot study was to evaluate the low-back compression force and users feedback in loading ladders from vans using a hydraulic ladder rack and a tradition fixed ladder rack. Simulated ladder lifting task was used to evaluate the differences in peak compression force while workers load ladder from vans using the fixed ladder rack and the hydraulic ladder rack. Usability questionnaires were also distributed to workers who were invited to use the hydraulic ladder rack for three months to evaluate their preferences and perception of effort when working with the fixed and the hydraulic ladder rack. Significantly ( $p < 0.1$ ) higher peak compression force was found when participants used the fixed ladder racks. The upper arm angles for both of the left and right arms was also significantly ( $p < 0.05$ ) higher when workers worked with the fixed ladder rack. The majority of responses in the usability questionnaires significantly ( $p < 0.05$ ) favored working with the hydraulic ladder rack.

Key words: Ladder, Intervention, Lift assistance

## 1.0 Introduction

Currently maintenance and repair technicians use vans as mobile tool rooms and workshops when responding to service calls. A large ladder (24' long & 55 lb weight) is used for many of the repair and maintenance tasks. It is carried on racks on top of the vans. Lifting of heavy objects overhead can put workers at risk of injury to the back and shoulders because of the weight of the ladder and the extended reach that is needed to handle the ladders. One potential solution to improve the handling of ladders from the roof of vans is to use a hydraulic drop-down ladder rack system. By using the drop-down ladder rack, workers can load/unload their ladders from the side of the vans versus handling them from the top of the vans (see Figure 1), and in this way, eliminate overhead lifting. Another potential benefit of the hydraulic ladder loader is that it lowers the ladder to the curbside, eliminating the additional risk of traffic hazards, and slip-and-fall-related injury due to stepping onto the bumper of the van in order to reach the top of the van. The purpose of this pilot study was to evaluate the low-back compression forces and users feedback in loading of ladders from vans using a hydraulic drop-down ladder rack and using a tradition fixed ladder rack.



**Figure 1:** Lifting ladder onto a fixed (left photo) rack and a hydraulic drop down ladder rack (right photo).

## 2.0 Methods

### 2.1 Study Designs:

A before-and-after design was used in this study to evaluate the effectiveness of the hydraulic drop-down ladder rack in reducing low-back loads and users' effort perception. The design was chosen because it is the most useful in demonstrating the immediate impacts of short-term programs (Robson et al, 2001). In this study, only the loading/unloading of the ladder rack task was used to evaluate the intervention. Before implementing the intervention, all participants were asked to fill out a usability questionnaire regarding their regular ladder racks (see section 2.3). After the initial observation, the hydraulic racks were installed and each participant was trained on the proper use of the ladder racks. Training covered proper use of the ladder racks, including procedures to troubleshooting and ladder rack maintenance.

After introducing the interventions, each participant was allowed to use the hydraulic ladder rack continuously for three months. All participants were encouraged to use the hydraulic ladder rack whenever it was appropriate. Although the participants were allowed to use the hydraulic ladder rack continuously for three months, the duration and frequency of use in the field were not evaluated. Following the intervention period, each participant was asked to fill

out a questionnaire regarding the usability of the hydraulic ladder rack. The questionnaire given after intervention was similar to the questions on the regular ladder rack.

### **2.2 Low-back load Analyses:**

Four workers volunteered to participate in this low-back load evaluation. After explaining the purpose of the study and obtaining a signed consent, each participant was attached with an Xbus Master (Xsens Motion Technologies, The Netherlands, 2007) data acquisition device and six MTx. The Xsens MTx is a self-contained sensor system that measures the three degrees of its orientation in space with respect to Earth's cardinal axes. The measurement outputs by the Xsens MTx provided work postures of the bilateral upper and lower arms, trunk and pelvis. The validity of the MTx to measure angle has been tested by Godwin et al (2006). Once the MTx were attached to the participants, they were asked to perform simulated ladder lifting task from the top of the vans using a fixed ladder rack and a hydraulic drop down ladder rack system. While performing the loading/unloading of ladders from the vans, video tape of the work task was also performed. The collected data from the MTx and the video tape information were used to calculate the 2-dimensional peak L4/L5 compression force. Due to the small number of subjects, a statistical tests with  $p < 0.1$  was considered significant.

### **2.3 Usability Questionnaire:**

In addition to the low-back load analyses, a self-report usability questionnaire was given to 12 participants who have used both the regular ladder racks and the hydraulic ladder rack. The self-report questionnaire used in this study was based on past studies conducted by Spielholz, Bao and Howard (2001) and Punnett L. (1998). Questions contained in the instrument asked for participant subjective estimations of overall level of physical effort, shoulders effort, back effort, suitability of the rack design to reduce work load, how easy was the ladder rack to load/unload ladder, level of slip/fall hazard, and level of struck by/against hazards. Participants were also asked whether they would prefer to work with the tool, recommend the tool to others, and relate additional comments about the tool.

SPSS (version 10) was used to analyze the data. Statistical tests with  $p < 0.05$  was considered significant. Univariate analysis using T-test (within group comparison) statistics was used to determine the differences between the tradition method versus the alternative intervention method.

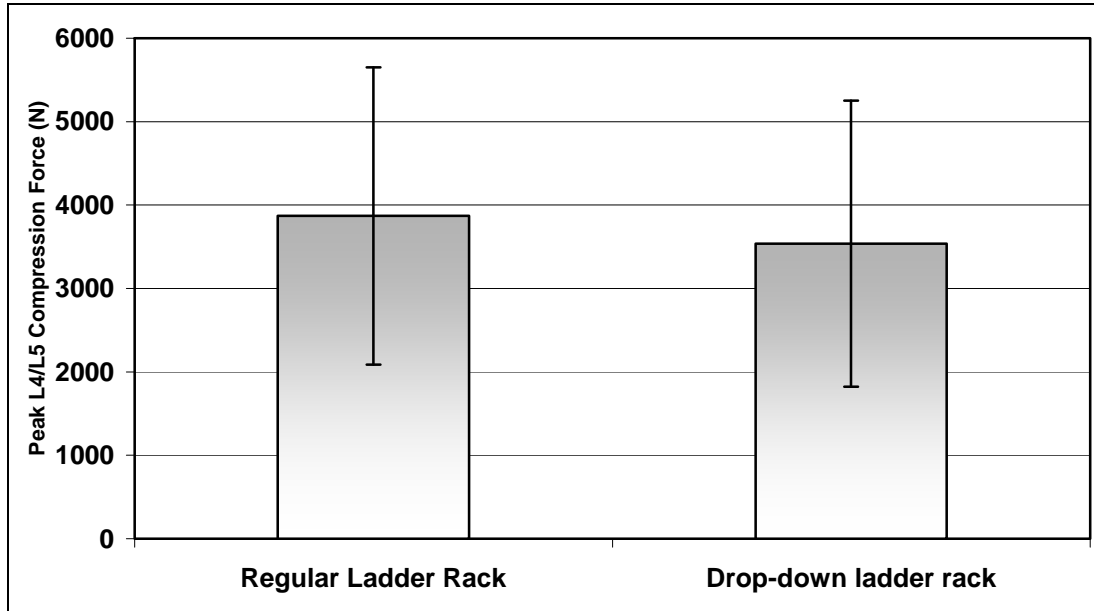
## **3.0 Results**

### **3.1 Low-back load Analyses:**

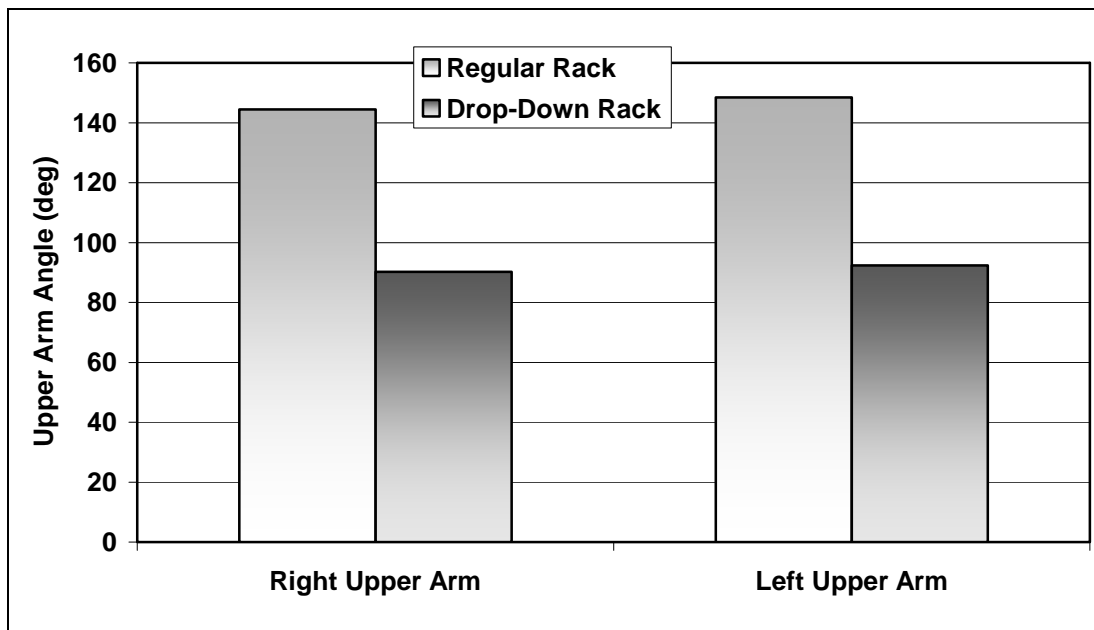
A mean peak low back compression force of 3870 N (SD = 1120 N) was observed when participants lifted the ladder to the top of the fixed ladder rack (see Figure 2). Using the hydraulic drop down ladder rack system, a mean peak low back compression force of 3540 N (SD = 1080 N) was observed (see Figure 2). The peak forces occurred when participants lifted the ladder onto the ladder rack. A paired T-test was performed and a significantly ( $p < 0.1$ ) higher peak low back compression force was found when participants used the fixed ladder racks.

Upper arms posture at the instance of peak low-back compression force was also quantify during the ladder lifting task. While lifting the ladder onto the fixed ladder rack, an average right and left upper arm angle of 144° and 149°, respectively, was found. For the hydraulic ladder rack condition, an average right upper arm angle of 90.2° and left upper arm angle of

92.4° was observed. The upper arm angles for both of the left and right arms was significantly different ( $p < 0.05$ ) between the fixed and hydraulic ladder rack.



**Figure 2:** Peak low-back compression forces while loading ladder onto the regular ladder rack and the drop-down (hydraulic) ladder rack.



**Figure 3:** Upper arms posture (relative to the vertical axis) at peak low-back compression force level.

### 3.2 Usability Questionnaire:

Summaries of the average subjective score for each item on the usability questionnaire are shown in Table 1. The self-report questionnaires identify several user preferences among the two ladder rack systems. Generally, working with the hydraulic ladder rack system was the preferred work method in several categories on the questionnaire. Users found significantly ( $p < 0.05$ ) lower overall physical effort, lower shoulders and back efforts, ease of use, and suitability of the hydraulic ladder rack in reducing physical work load. Significantly ( $p < 0.05$ ) lower perceived risk of slip or falls hazards were found when participants used the hydraulic ladder rack when compared to participant's current ladder rack system. When asked whether they would prefer to work with the hydraulic ladder rack system, 77% said they would prefer to work with the intervention ladder design. Participants were also asked whether or not they would recommend a particular ladder rack system to load/unload ladders from the top of service vans. The results revealed that all of the participants (100%) would recommend the hydraulic ladder rack systems.

Table 1: Mean results of self-reports across two ladder rack systems. Low score on each item represent favoring for a specific method. \* $p < 0.05$ ,  $n = 12$

Question	Current Ladder Rack System (Control)		Hydraulic Ladder Rack System (Intervention)		Wilcoxon Signed Ranks Test P-value
	Mean	SD	Mean	SD	
Level of physical effort to load/unload ladder	6.9	1.8	3.1	1.7	<b>0.007*</b>
Level of shoulders effort to load/unload ladder	6.4	2.6	3.2	2.5	<b>0.011*</b>
Level of back effort to load/unload ladder	5.6	2.6	2.7	1.8	<b>0.012*</b>
Suitability of design in reducing work load	5.6	1.8	1.5	1.3	<b>0.007*</b>
How easy was it to load/unload ladder?	5.9	2.0	2.35	1.2	<b>0.011*</b>
Level of slip/fall hazard while load/unload ladder	5.5	2.3	1.6	1.1	<b>0.007*</b>
Level of struck by/against hazard while load/unload ladder	4.2	2.7	2.0	1.2	0.067

**Scale:**  
 0 ----- 0.5 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ----- 7 ----- 8 ----- 9 ----- 10  
 Very good                      Good                                      Fair                                      Bad                                      Very Bad

## 4.0 Discussion

### 4.1 Low-back load Analyses:

A mean peak low back compression force of 3870 N (SD = 1120 N) was observed when participants lifted the ladder to the top of the fixed-regular ladder rack (see Figure 2). While lifting the ladder onto the hydraulic (drop down) ladder rack, a peak compression force of 3540 N (SD = 1080 N) was observed (see Figure 2). Both lifting methods surpassed the NIOSH Action Limit (AL) for low-back compression force of 3425 N (Waters et al, 1993). For the hydraulic ladder rack, however, the differences between the average peak compression

force relative to the NIOSH AL was only 3.3%; versus 13% for the fixed ladder rack work condition.

A paired T-test was performed and a significantly higher peak low back compression force was found at the  $p < 0.1$  level when participants used the fixed ladder racks. The results indicated a trend toward a reduction in low back load when participants used the hydraulic ladder rack system. The differences in peak low-back compression between the hydraulic and fixed ladder rack was due to the vertical location of the ladder rack between the two work conditions. On average, workers reached for the ladder at a height of approximately shoulder-standing level when using the hydraulic ladder rack. For the fixed ladder rack, however, workers have to reach above their standing height level (see Figure 3). To further reduce the low-back compression force, it is recommended that the manufacturers of the hydraulic ladder rack should lower the top level of the ladder below worker's shoulder height. By implementing this recommendation, the peak low-back compression force will be lower than the NIOSH AL level – which currently at 3.3% above the AL when working with the hydraulic ladder rack.

### **3.2 Usability Questionnaire:**

The majority of responses in the usability questionnaires significantly favored working with the hydraulic drop-down ladder rack. Answers relating to level of physical effort, shoulders effort, back effort, easy to load/unload ladder and suitability of the rack designs in reducing work load were all in favor of the hydraulic drop-down ladder rack. Workers also felt that working with the hydraulic ladder rack can significantly reduce the level of slip/fall hazard while loading/unloading the ladder from vans.

## **5.0 References**

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