

# Effect of One-Handed Pushing and Pulling Strength at Different Handle Heights in Vertical Direction

Tarik H. Badi, and Amer A. Boushaala

**Abstract**—The purpose of this study was to measure the maximal isometric strength and to investigate the effects of different handle-heights and elbow angles with respect to Mid. sagittal plane on the pushing and pulling strength in vertical direction. Eight male subjects performed a series of static strength measurement for each subject. The highest isometric strength was found in pulling at shoulder height (S.H.) (Mean = 60.29 lb., SD = 16.78 lb.) and the lowest isometric strength was found also in pulling at elbow height (E.H.) (Mean = 33.06 lb., SD = 6.56 lb.). Although the isometric strengths were higher at S.H than at E.H. for both activities, the maximal isometric strengths were compared statistically. ANOVA was performed. The results of the experiment revealed that there was a significant different between handle heights. However, there were no significant different between angles and activities, also no correlation between grip strength and activities.

**Keywords**—Pushing and pulling, one arm, vertical direction, isometric strength.

## I. INTRODUCTION

**P**USH-PULL activities occur in many types of work environments shipping and receiving, moving, warehousing, department stores, supermarkets, agriculture and farming, retailing, etc. and are becoming more common as a result of efforts to minimize lifting, lowering, holding and carrying, the most debilitating and costly manual materials handling (MMH) activities. Reference [2] studied over nine hundred tasks, estimated that nearly half of all materials handling activities were push-pull ones. However, push-pull activities also account for a significant proportion of overexertion musculoskeletal disorders approximately 9-20 % of all back injuries from MMH activities [5], [8].

Unlike the act of lifting, pushing and pulling capabilities have been studied only within a very limited scope. Furthermore, estimates of the number of injuries that occur during pushing or pulling of loads are not complete, though approximately 20% of overexertion injuries have been associated with pushing and pulling acts (NIOSH, 1981) [10]. It is expected that this injury rate will increase in response to the trend toward a growing number of push-related tasks in the workplace. Despite the fact that 50% of industrial manual materials handling includes pushing and pulling tasks [6], until recently, most of the studies reporting on pull/push activities have used an isometric mode with a standardized

posture, with a view to maximizing strength exertion [1], [3], and [9].

Most the studies have been concerned with vertical two-handed lifting or horizontal pushing and pulling with very few reports on one-handed strengths. One area where data are scarce is in whole-body human strength capabilities during tasks requiring one-handed exertions. In addition, few investigators have explored human strength capabilities in the more general case involving exertions in all directions in the fore and aft plane [4].

Reference [7] presented a study to determine the validity of methods to assess push/pull forces exerted in a construction task. They concluded that a relative simple hand-held force gauge can be used for the assessment of push/pull force at the workplace. Attention should be paid to a firm and stable connection between the force gauge and the object that has to be pushed. However, this connection should not disturb the push/pull task that has to be performed. Since most of the studies have been concerned with vertical two-handed lifting or horizontal pulling and pushing, this study will be restricted to investigate the effect of one arm pulling and pushing tasks on vertical direction.

## II. MATERIAL AND METHOD

### A. Subjects

Eight normal young men volunteered for the study. The study involved pushing and pulling in vertical direction. All were students at University of Windsor. The mean age was 30.63 years, mean weight was 94.98-kg, mean height was 163.68-cm, mean shoulder height was 145.69 cm, and mean elbow height was 111.88 cm. All volunteers were free of any musculoskeletal limitations and right handed. All subjects were healthy at the time of testing and had no medical history of musculoskeletal disorder. Subjects received information on the purpose and protocol of the project and signed the informed consent form.

### B. Apparatus

An isometric strength-testing fixture was used to measure the push/pull hand strength. To measure static strength a handle and a load cell were attached to an adjustable metal arm so that can be raised and lowered to match the height requirements of each subject. The strength-testing fixture

measures the isometric forces applied to handle connected to an electronic load cell and read out device. For this study, the load cell measured only vertical push-pull force components.

### C. Procedure

Before the beginning of the experiment, the procedure was thoroughly explained to each subject. Subject was asked to sign the consent form. At this point in the procedure with each subject a few anthropometric characteristic data were obtained and recorded (age, weight, standing height, shoulder height, and elbow height). To determine randomly the arrangement of the conditions, arrangement was prepared previously by picking a number from 1 to 12; each number corresponded to one condition. After completing all the preparation, subjects were required to perform one-handed maximum push/pull activities. These efforts were performed when subjects standing erect, looking straight ahead with both feet on the foot sign, at two handle heights of elbow height (E.H) and shoulder height (S.H), at three elbow joint angles with respect to Mid-sagittal plane ( $30^\circ$ ,  $0^\circ$ , and  $-30^\circ$ ) and two directions of activities pushing up (palm face-up) and pulling down (palm face-down). Subjects were instructed to begin exerting their maximum force and hold for five second. Between each trial we allowed at least 2 min of rest. The subjects should exerted maximum effort without any jerking. They were not encouraged during the activity; however, they were reminded of the significance of their maximal effort. Subjects were given instructions and demonstration of the way they were supposed to hold the handle and the trunk posture they were expected to assume.

### D. Experimental Design and Data Analysis

An experiment is conducted to determine the effects of three different angles, two handle-heights and two activities on the maximal isometric strength. The combination of two activities (pull and push), two handle-heights (E.H and S.H), and three angles ( $30^\circ$ ,  $0^\circ$ , and  $-30^\circ$ ) yielded 12 conditions. Each condition was treated as a cell. Between each trial subjects allowed at least 2 min of rest. The experiment now would be a  $3 \times 2 \times 2$  factorial experiment. All factors are at fixed levels. For the design of experiment, it was agreed to take three observations under each of the twelve- ( $3 \times 2 \times 2$ ) experimental condition. We agreed that it would be no problem to completely randomize the order for running the 36 experiments, three at each of twelve experimental conditions, and select the closest two at each of twelve experimental conditions from the three. The tests were carried out in two hours session on one day. The peak isometric strengths were extracted from the collected data and compared. Descriptive statistics were calculated and subjected to analysis of variance, Multifactor ANOVA to deduce the main effects of, and interaction between, activities, angles, and handle-heights.

## III. RESULTS

All data were subjected to analysis of variance (ANOVA). The purpose of carrying out ANOVA was to determine the

effects of each factor on isometric strength exertion capability. Table I is shown the ANOVA results of the data for the peak isometric strength.

The mean peak isometric strengths (with their standard deviations) of the experimental for pushing and pulling strength in vertical direction are presented in Table II. The peak isometric strength recorded in pushing and pulling at elbow height (E.H) for all angles were lower than other isometric strength recorded at shoulder height (S.H). Moreover the isometric strength in pushing was stronger than pulling at E.H however it was lower at S.H. Fig. 1 and 2 represent the comparison between the peak isometric strength of pushing and pulling at E.H. and S.H. respectively.

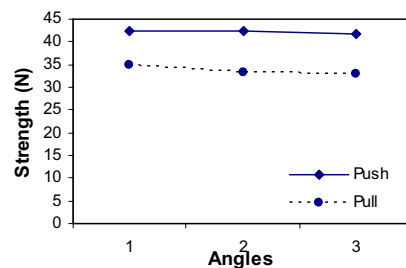


Fig. 1 Comparison between peak force of pushing-pulling activity at elbow height

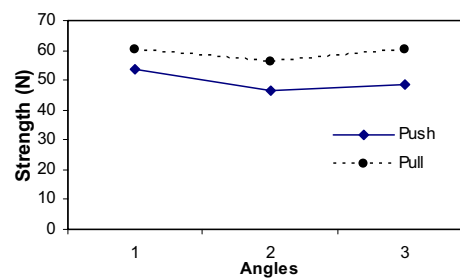


Fig. 2 Comparison between peak force of pushing-pulling activity at shoulder height

The analysis of variance revealed that the heights of the handle were highly significant in affecting the peak isometric strengths ( $p < 0.05$ ). However there were no significant difference on both angles and activities affecting the peak isometric strengths, while; we can consider the angles were significant in affecting isometric strength at ( $p = 0.1$ ). A significant two-way and three-way interaction occurred only between activities and handle-heights ( $p < 0.01$ ) for peak isometric strength.

To investigate the relationship between the activities (push/pull) and the grip strength, the collected data for grip strength were analyzed by using the correlation analysis as shown in Table III. The results indicated that there is no significant correlation between the activities and the grip strength.

TABLE I  
ANOVA RESULTS FOR PEAK ISOMETRIC STRENGTH  
ANALYSIS OF VARIANCE FOR PEAK STRENGTH (LB) - TYPE III SUMS OF SQUARES

Source of variation	Sum of Squares	d.f.	Mean Square	F-ratio
<b>Main Effects</b>				
A: Subjects	33743.203	7	4820.46	83.95*
B: Activities	10.55	1	10.55	0.18
C: Angles	167.792	2	83.90	1.46
D: Hand-Heights	12854.380	1	12854.38	223.85*
<b>Interactions</b>				
BC	38	2	19	0.33
BD	3951.26	1	3951.26	68.81*
CD	147.0417	2	73.521	1.28
BCD	146.7917	2	73.396	1.27
Residual	9933.9844	173	57.422	
<b>Total (Corrected)</b>	<b>60992.995</b>	<b>191</b>		

\* denotes a statistically significant difference ( $p < .01$ )

TABLE II  
THE MEANS AND STANDARD DEVIATION OF THE PEAK PULLING AND PUSHING STRENGTHS (LB)

	Push (EH)		Pull (EH)		Push (SH)		Pull (SH)	
	Av. Strength	SD	Av. Strength	SD	Av. Strength	SD	Av. Strength	SD
Ang.0	42.29	9.19	34.87	5.01	53.83	19.79	60.29	16.78
Ang.30	42.52	8.73	33.1	5.88	46.33	15.33	56.42	14.46
Ang.-30	41.67	10	33.06	6.56	48.62	12.95	60.04	15.64

TABLE III  
GRIP STRENGTH CORRELATION RESULTS

	Push	Pull	Grip
Push	1.0		
Pull	0.850	1.0	
Grip	0.259	0.139	1.0

#### IV. DISCUSSION

This experimental investigation shows that the effect of handle-heights must be accounted for in the determination of strength capabilities. It is generally believed that the strength of pushing at E.H was declined approximately 8-21% of pushing at S.H. The strength differences thus become more clear when pulling is exerted at E.H the static strength declined approximately 42% of the pulling strength at S.H. Table I summarized the mean and standard deviation of the peak pulling and pushing isometric strengths. As indicated by this study, pushing strength is stronger at E.H than pulling strength, while the pushing strength is lower at S.H than pulling strength. The results of this study also indicate that there is significant interaction only between the activities and handle-heights.

Finally, the strength data provided in this study are based on 8 males. Generalization of results, therefore, is not warranted. In the future, this sample size should expand by including more subjects and incorporating other factor.

#### V. SUMMARY AND CONCLUSION

In this study an experiments were conducted to investigate the effects of angles, handle height, and direction of activity on one-handed push-pull force capability.

The analysis of variance was performed. ANOVA results show a significant different in the handle-heights and the angles but there is not in the activities. There was an only significant difference interaction between activities and handle-heights.

Pulling strength was higher than pushing strength at S.H. and the reverse at E.H. The highest values were always recorded at the shoulder-height for both pulling and pushing activities.

The results of this study can be summarized as follows:

- The handle-height plays an important role in force capability in either pull or push.
- The best handle height in pulling-pushing activity is at S.H.
- The result shows a significant different between handle-heights, and angles but there isn't between activities.
- There was a significant difference interactions only between activities and handle-heights.
- The pulling strength is higher than pushing strength at S.H. and reverse at E.H.
- There was no correlation between grip strength and activities.

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**Tarik H. Badi** received a B.Sc. in Industrial Engineering from University of Garyounis (1991) and his M.A.Sc. in Industrial Engineering from University of Windsor, Ontario, Canada (1999).

Mr. Badi worked as Industrial Engineer and Project Engineer from at different automotive sector in Canada and currently he is an assistant lecturer at the Department of Industrial Engineering of the University of Garyounis, Libya. His recent work has involved Occupational ergonomics and industrial safety, supply chain management, and warehousing system design. His email address is boushaala@garyounis.edu.

**Amer Boushaala** received a B.Sc. in Industrial Engineering from University of Garyounis (1989), M.Sc. in Production Engineering from Suez Canal University, Egypt (1998), and his Ph.D. in Industrial Engineering and Systems from Zagazig University, Egypt (2007).

Dr. Boushaala is currently lecturer at the Department of Industrial Engineering of the University of Garyounis, Libya. His recent work has involved project management, warehousing system design, ergonomics and human factors, and operations research algorithms. His email address is boushaala@garyounis.edu.