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Assessment of Isometric Pulls Strength of Industrial Cart Pullers - An Electromyography Study from an Apparel Manufacturing Industry

Zahid Rashid[a], Muhammad Shafiq[a]*, Muhammad Awais Aslam[a], Marialuisa Menanno[b], Neelum Iqbal[a], Haji Bahader Khan[a], Pasquale Ragno[b]

[a]*Industrial Engineering Department, University of Engineering & Technology, Taxila 47050, Pakistan*
[b]*Department of Engineering, University of Sannio, 82100 Benevento, Italy*

Abstract

Manual material handling and occupational tasks demanding physical push-pull activities are very common in various industrial settings regardless of automation. These activities may become the cause of fatigue, accidents and/or different occupational hazards if not properly focused to balance workload as per physical strength and stamina of the worker. This cross-sectional study was conducted to assess the isometric pull strength of apparel cart/trolley pullers and muscular activity of upper limbs. Jackson strength evaluation system was used to measure isometric pull strengths while IXTA Data Acquisition System to measure and analyze the muscle activity. The experiments were conducted with twenty work-in-process (WIP) manual material handlers of an apparel manufacturing industry. Electromyographical (EMG) data of muscle activity was collected by placing electrodes on pronator teres, brachial biceps, pectoralis major and lower trapezius muscles during the pull tasks. The results show that torso pull in seated posture has the maximum isometric average value of 62.20 ± 5.91 kg while arm lift has the minimum strength value of 37.10 ± 4.61 kg. Assessment of muscle fatigue caused by pulling force is important in determining job severity of workers and mitigating occupational injuries which help in balancing workloads for effective management.

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* Corresponding author. Tel.: +92-346-763-8751
E-mail address: shafiqaatir1@gmail.com

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1. Introduction

Push/Pull activities are common in industrial production settings. Measurement of isometric strength and endurance time of the workers can help in estimating rest allowance, better task design and improvement of tools and equipment[1, 2]. A cross-sectional study of flight attendants in German airlines found that the inclination of the plane causing different handling postures significantly increases the workload stress[3]. Push/pull forces are defined as the hand forces; the major resultant force of which causing the object to move in horizontal direction[4]. Although literature reports human strength data for variable work profile and postures, longitudinal forecasting of human strength for designing an optimum work–rest schedule was not found. Assessment of human strength capabilities of workers performing manual material handling jobs is an important parameter to be considered for the development of ergonomic guidelines for pre-employment screening. Floors with low friction causes a drop of almost two to three times of actual push/pull strength [5].

Apparel manufacturing industry is labor intensive and measurement of physical strength capabilities is an important concern in the selection of workers who will work in push/pull maneuvers of cart/trolleys and other manual material handling tasks.

Anthropometric measures varies significantly with different ethnic backgrounds and causes impact on isometric strength data [6].Muscle activation in pushing tasks are found to be almost two times of pulling activities and a higher in females for the same working task and hence more prone to muscular overload [7].Work related musculoskeletal disorders can be associated with gender. It is well established that occurrence of upper extremities musculoskeletal symptoms in women are more common than men. Only few studies reported the opposite[8].

Physical capabilities of workers are important in designing workplaces manual material handling tasks in manufacturing industries are very common. Physical risk factors in working environment occurred due to the tasks which includes peak forces, repetitive motions, awkward postures and physical working environment like humidity, temperature, vibration etc[9].

The isometric pull strength is found to be maximum when the pull force location is at distant reach and applied form above shoulders [10].In general the isometric push/pull force of males are higher than that of females [2].Also it is important to note that peak isometric force can be obtained only with one time task performance; after that fatigue level increase with increase in time duration of task [11]. One of the study related to nursing carts suggested that pushing is more effective than pulling and more ease can be created for the worker if the flooring is smooth and not inclined. Also proper distribution of load on the carts at the bottom, in the center and near the handle can significantly reduce the physical workload [12]. One study reported that putting the load in the anterior section of one-wheeled wheelbarrow task can reduce the muscle activity [13].

The muscle activities during pushing was found to be lower than the pulling tasks[14].The average heartbeat of workers doing pushing tasks is lower than the ones doing pulling tasks [15]. Hence, we tried to investigate the isometric pull strength of cart pullers and consequently the electromyographical muscle activity due to that task performance.

2. Method

2.1. Participants

There were a total of 20 (22.57 ± 2.14 years) young healthy trolley/cart pullers workers in cutting, washing and production department of an apparel manufacturing unit. None of the workers had any previous physical disorders or any sort of musculoskeletal pains and were properly screened before experimentation.

2.2. Experimentation

The trolley/cart pullers were first demonstrated about the standard way of pull and then were instructed to apply the maximum isometric pull strength without jerk. Jackson Strength Evaluation system Model 32728 is used for the isometric pull strength measurement. The electronic load cell of the system is connected with the NEXUS tablet via Bluetooth for the acquisition of pull strength data. Four isometric pull strength measurements were taken (a) isometric torso pull standing; (b) isometric torso pull seated; (c) shoulder lift test; (d) arm lift test as shown in the Figure 1.

After a warm up trial session; the preparation time and test time on the tablet was set to one second and two seconds, respectively. When participants fully understood experimentation, the scores for the isometric pull strength were administered for maximum voluntary isometric effort. External motivators like the presence of other participants during the test were eliminated to ensure accurate and precise readings and the scores were not told to the participants till the end of trial. For all the pull strength tests three readings were taken after giving adequate rest allowance to the participants and average of those readings were included in the results.

(a) (b) (c) (d)

Fig.1. (a) Isometric Torso Pull standing; (b) Isometric Torso Pull seated; (c) Shoulder Lift test; (d) Arm Lift test

2.3. EMG

Electromyographical study was conducted in the human factors and engineering laboratory of the University, Pakistan. IXTA Data Acquisition System with integrated sensors was used for EMG recording and analysis was done with Lab Scribe software (iWorx Systems, Inc). Alcoholic swabs were used to scrub and clean the skin before the attachment of electrodes for precise readings. Four muscles (a) pronator teres (b) brachial biceps (c) pectoralis major and (d) lower trapezius were examined during the isometric pull strength test.

Electrodes were attached on the pronator teres (forearm muscle) and two on the brachial biceps. Few illustrations are shown in the Fig. 2.

(a) (b)

Fig.2. (a) Position of electrodes on pronatorteres (forearm) (b) brachial biceps (upper arm) muscles

3. Results and Discussion

General biodata and some anthropometric measurements of workers were taken before the experimentation to check the likelihood of any impact of the characteristic on the pull isometric strength. Table1 shows the anthropometric measurements of trolley/cart pullers.

Table 1. Anthropometric measurements of workers (n=20)

Characteristic	Average Value	Standard deviation
Age (yrs)	22.57	2.14
Mass (kg)	63.89	9.51
Height (cm)	170.66	6.21
Shoulder Height (cm)	139.5	6.06
Elbow Height (cm)	105.63	5.54
Tibial Height (cm)	48.31	2.79
Sitting Height (cm)	130.37	3.79
Shoulder height seated (cm)	102.14	3.93
Shoulder Breadth (cm)	46.66	2.58
Knee Height (cm)	52.63	2.54
Hand Length (cm)	18.43	0.98
Hand Breadth (cm)	8.43	0.57
Waist Circumference (cm)	89.27	29.32
Body Mass Index BMI($kg\ m^{-2}$)	21.62	2.37

All of the participants fall under a normal body mass index (BMI) classification. The anthropometric measurements are taken with the accuracy of 0.4 to 0.6 cm and weight with the accuracy of 50 to 100 gm. During measuring the sitting, knee and tibial height, the angle was maintained 90° between upper and the lower leg by adjusting the height of the stool for the participants.

3.1. Isometric Pull strength

The torso pull strength was tested in seated and standing postures with palms of hands facing down. The arm lift and shoulder lift test were tested in standing posture. The palms of hands were facing up for arm lift and down for shoulder lift, respectively. The participants were asked to apply a steady forceful effort without jerk.

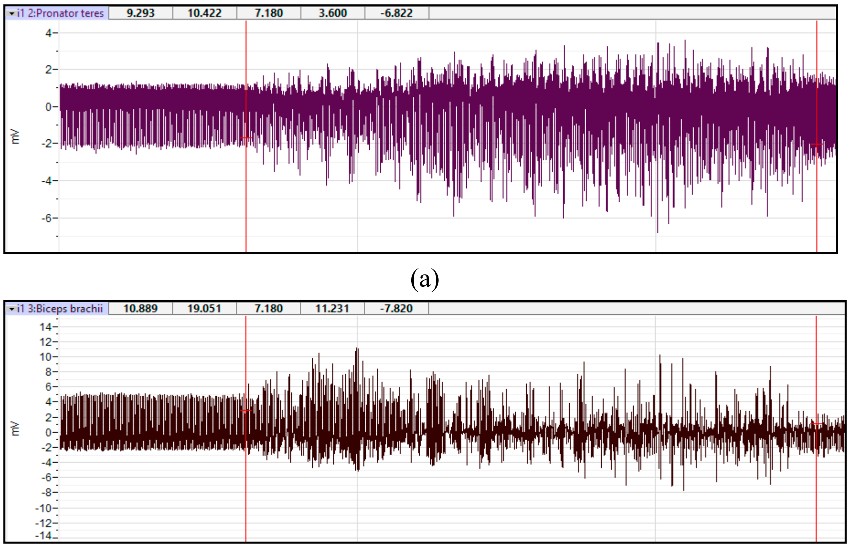
Table 2. Isometric pull strength of participants (n=20)

Type of Pull strength	Average Value (kg)	Standard Deviation
Torso Pull seated	62.20	5.91
Torso Pull standing	51.94	4.76
Arm Lift	37.10	4.61
Shoulder Lift	48.74	5.30
Average Isometric Pull Strength	50.04	5.14

Table 2 shows isometric pull strength values of the cart/trolley pullers. The average value for torso pull seated, torso pull standing, arm lift and shoulder lift are found to be 62.02 ± 5.91, 51.94 ± 4.76, 37.10 ± 4.61 and 48.74±5.30 kg, respectively. The average summation of all these pull strengths is 50.04 kg with a standard deviation of 5.14 kg. The torso pull in a seated position has the maximum isometric pull strength that is 62.20 ± 5.91 kg. Since arm lift shows least amount of isometric force; appropriate height of trolley/cart is recommended otherwise it can cause excessive strain on muscles. Trunk/leg/foot support can increase the pull force to a great extent as we can see in torso pull seated position.

3.2. Electromyographical study

Participants were first introduced about the electromyographical procedure so that they can apply pull forces without any resistive motions. Muscle activity data was collected at frequency of 1000 Hz. The participants were asked to perform the isometric pull tasks while applying maximum force for duration of 3-4 seconds. The isometric pull strength values were then normalized and converted in maximum voluntary isometric contraction (%MVC).



(a)

(b)

Fig.3. Electromyographical (EMG) activity of (a) pronatorteres and (b) brachial biceps muscles

Few illustrations related to muscled activity are shown in Fig.3

Table 3. shows the relative electromyographical activity of four muscles during the isometric pull strength testing.

Table 3.Relative EMG (%MVIC) activity of muscles

Forearm Action	Pronator teres	Brachial biceps	Pectoralis major	Lower trapezius	Abs.Int	Max-Min (mV)
Torso Pull seated	34.09	45.32	39.12	44.61	9.268	10.42
Torso pull standing	30.56	31.79	32.91	36.11	7.84	9.05
Arm lift	43.65	33.58	48.95	40.74	13.79	15.05
Shoulder lift	40.25	43.19	41.30	48.35	10.79	19.05

Fig. 4 shows the relative electromyographical activity of four muscles during the isometric pulls strength testing. The brachial biceps activation in Fig 4(a) is maximum 45.32% of MVIC during the torso pull in seated posture while minimum 31.79% of MVIC during the torso lift standing posture.

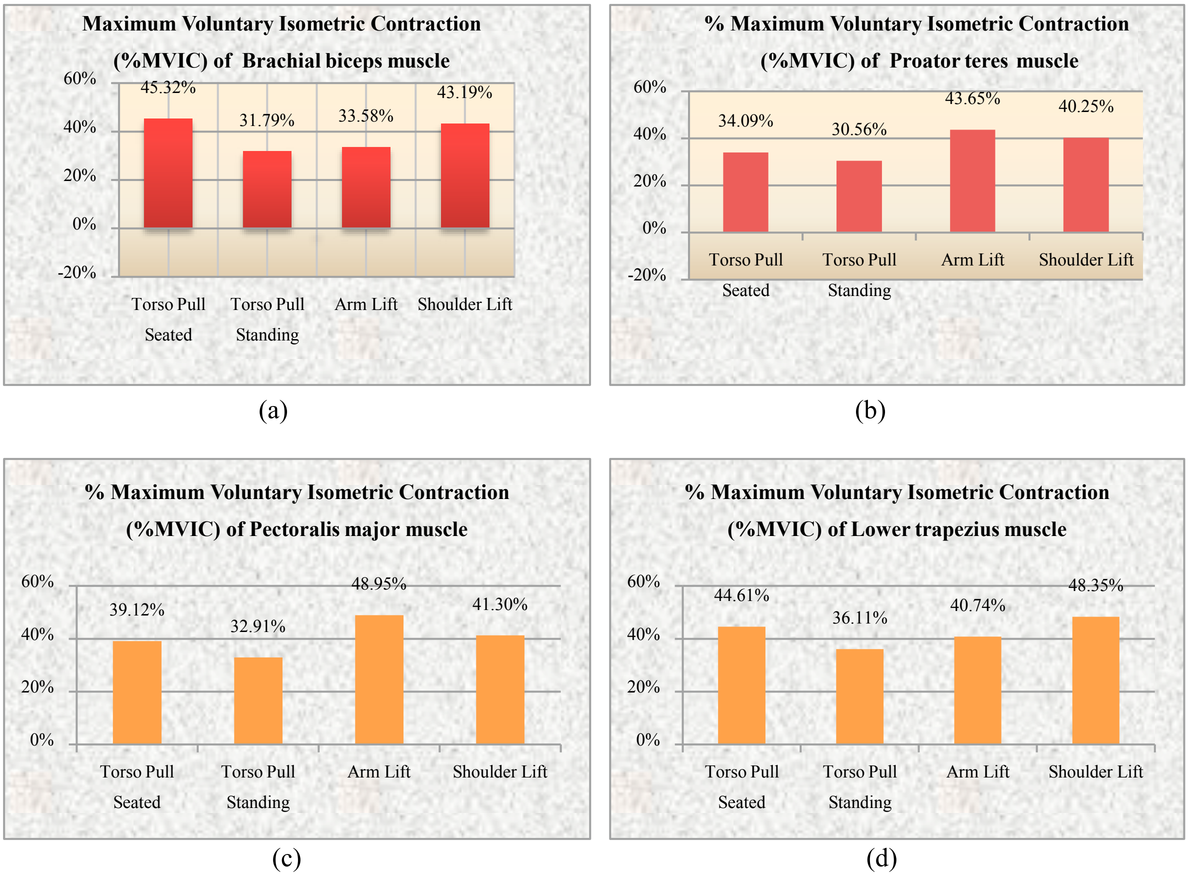


Fig.4. Muscle activation (%MVIC) for each isometric pull test of (a) brachial bicep; (b) pronator teres; (c) Pectoralis major; (d) Lower trapezius

The pronator teres activation in Fig 4(b) is maximum 43.65% of MVIC during the arm lift pull in standing posture while minimum 30.56% of MVIC during the torso lift standing posture. The pectoralis major activation in Fig. 4(c) is maximum 48.95% of MVIC during the arm lift pull in standing posture while minimum 32.91% of MVIC during the torso lift standing posture. The lower trapezius activation in Fig. 4(d) is maximum 48.35% of MVIC during the shoulder lift pull in standing posture while minimum 36.11% of MVIC during the torso lift standing posture.

4. Conclusions

The results showed seated torso pull as the maximum pull strength posture while the arm lift pull is the weakest. Trunk or leg support can significantly improve the pulling strength. Manual material handlers have to work for long working hours with odd postures. Usually these workers are rotated to different tasks such as loading/unloading of fabric from store and material movement in washing or finishing department with different types of pulling maneuvers. These shifting causes discomfort for the workers and limit their endurance time. Several muscles are involved in pulling tasks with different levels of activation. Limitation of each muscle involved in the pulling activity must be considered to the design of different pulling tasks.

4.1. Limitations

Only male participants were included in the study and fewer muscle activations were recorded. It would be more beneficial if female data and all muscles involved in isometric push/pull tasks are included. More focus was on pull tasks; so it is recommended to include more isometric push tasks in future studies. Another limitation of this study is to ignore the impact of environmental conditions (such as temperature, air quality etc.). Environmental impact can be studied in future research to find out the relation of these factors on isometric push/pull strength and maximum endurance time of the workers.

4.2. Relevance to industry

The isometric pull strength and EMG activities were measured in mostly in standing postures to emphasize the potential risk factors in apparel manufacturing industry. This study focused on workers those who are not considered main production workforce in apparel manufacturing industry. To date, the research related to those helping workers is not well presented in extant body of literature. Furthermore, this study and data obtained is unique in terms of the helping workers of Pakistani apparel industry.

It is important to note that actual working postures and weight in the carts/trolleys in production department changes significantly from normal standard loading depending on the production load and lead time constraints. Different types of handles and grips of trolleys in production workplaces have a great impact on the isometric push/pull strength values. The outcomes of this study highlights the importance of practical trainings on handling skills of the cart pullers with standard apparel loading on uneven and inclined planes which help in optimizing push/pull activities in a production setup.

The isometric strength values can be used for the standardization of loading for the cart pullers, design of cart handles, and flooring for better ergonomic workplace. Also the push/pull isometric strength data can be used as a data set of push/pull material handling workers.

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