A STUDY ON HAND GRIP FORCE FOR PUSH ACTIVITY AT AEROSPACE INDUSTRY

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ABSTRACT: Grip strength is the force applied by the hand to push objects and is a specific part of hand strength. It is generally considered that all aspects of the hand must be exercised to produce a healthy and strong grip. The purpose of this study is to analyze the hand grip force that causes discomfort for push activity among the workers in the aerospace industry while workers performing their task. Data were collected by using observation, interview, questionnaires, and Tekscan grip system tools were used to evaluate hand grip pressure force of the workers. Findings show that the individual factors such as age and body size have affected the hand pressure grip force. Besides, the study shows that the hand grip pressure forces when pushing the mold with the right hand are higher than left hand. At the end of this study, the authors concluded that high grip forces will lead to a risk factor for the development of MSDs.

KEYWORDS: *Grip Strength; Hand Grip Pressure Force; Tekscan Grip System; Carpal Tunnel Syndrome*

1.0 INTRODUCTION

Pushing or pulling can be defined as an exertion of hand force in a horizontal direction; away from the body for pushing and toward the body for pulling. Generally, the vertical component for pushing is downward [1]. Pushing or pulling forces are characterized by (i) initial force required to start the movement of an object, (ii) sustained force; a lower force required to sustain the movement and (iii) stopping force required to stop the movement of an object [2]. Boocock et al. [1] reported that the maximum acceptable pushing forces were slightly higher than those for pulling. Yet, Hoozemans et al. [3] stated that pushing results in lower compressive force than pulling. Others have reported that pulling tasks as compared to pushing tasks to result in lower compressive and shear forces [4]. The between pushing/pulling and shoulder pain, such as increased shoulder pain from pushing/pulling wheeled equipment heavy weight have been reported by a few studies. [3, 5] Although pushing and pulling is very common in occupational settings, this type of manual materials handling is under studied than lifting and carrying. Pushing and pulling activities is one of the activities for manual material handling (MMH) that can increase the risks of back pain problem [6]. Pushing and pulling is a frequent activity for a great segment of the workforce, including hospital workers, manufacturing workers, construction workers, forest workers, and others [7-13]. Baril-Gingras and Lortie [14] estimated that nearly half of manual material handling consists of pushing and pulling. Some recommendation for push and pull activities have been studied. For example, for pulling tasks, Lett and McGill [4] recommended waist height over shoulder height to minimize compressive and shear forces on the low back. On the other hand, Hoozemans et al. [3] recommended that carts should be designed and used to push or pull at shoulder height to minimize moments at the shoulder by keeping the wrist, elbow, and shoulder close to the line of action of the exerted force.

The higher hand grip pressure force will contribute to the development of musculoskeletal disorders. Musculoskeletal disorders can be caused by repetitive usage of hand-held tools due to factors such as awkward hand posture [5]; static loading of the muscle during repetitive gripping of the handle [16]; excessive force exertions [17]; the weight of the tool being supported exposure to hand-arm vibration [18] and others. To determine the optimal diameter for handle use for the general population an extensive research has been conducted. Tool handle diameter has been identified as the most significant factors that affect grip force production [19]. Grip production, the local contact pressure of a handle configuration and the perceived acceptability can be affected by factors such as handle orientation; texture, angle, and shape [20].

Work-related MSD contributes a major problem in many industrialized countries [21], despite the attention given to ergonomics during recent years [22]. The occurrence of musculoskeletal disorders (MSDs) can be the result of accumulated muscle fatigue which causes functional disability of the musculoskeletal system as stated by Ma et al. [23]. Another effect of the higher hand grip pressure force is Carpal tunnel syndrome (CTS). CTS can be a cause of pain and functional impairment of the hand due to compression of the median nerve at the wrist [24-25]. Usual symptoms include numbness, tingling, and pain, predominantly in the median nerve distribution of the hand. However, the symptoms can frequently be present in all fingers of the hand or proximally in the forearm [26]. The symptoms may or may not be accompanied by objective changes in sensation and strength of median-innervated structures in the hand [27]. Previous studies show that individuals with CTS lack the ergonomic efficiency of hand tool usage because they apply large than necessary grip force [28]. Additionally, CTS causes impairment of grasp force regulation and dexterity of digits.

In the aerospace industry, most of the task involved performing the job tasks such as pushing and pulling activity, the operators might feel the discomfort and pain in their arms and wrist. This study focus on analyzing the activity related to push activity that gives discomfort for workers in layup room by using the Tekscan system.

2.0 METHODOLOGY

The experiment is done in layup department at XYZ Company, which is an aerospace company situated in Malaysia. In this department, all the workers are males and national citizen. Most working activity in this company is manual material handling (henceforth MMH) activities. One of the MMH activities is pushing and pulling activity. Five production workers participated as subjects in this study. Tekscan Grip Pressure Measurement System is used in this study to measure the hand grip pressure force of the workers while carried out pushing activities. The Grip system uses a thin, high-resolution sensor that can be used directly on a hand or built into a glove, which is an ideal device for measuring and evaluating pressure and force of the hand. Tekscan patented, paper thin (0.1mm), flexible sensors are minimally intrusive and have fast scanning rates, which means difficulty gripping application such as vibration and transients from power tools can be easily measured. The Tekscan grip system built in with the glove was attached to subjects as shown in Figure 1. The Tekscan software can show the output data graphically, show the distribution areas of the force, maximum and minimum force and pressure. The operators were measured during their normal working activities.

Five production workers were recruited as subjects in this study. They are selected from lay-up process lines. For the basic requirement of this study, the workers are selected in performing the pushing activity. In this experiment, the sensor was connected to the arm of the operator's hand, most people usually grip at the locations shown in Figure 1 below. The output parameter from the analysis is the value of the maximum and minimum hand grip pressure force of the subjects. While two factors were studied as the input parameters which are age and weight.

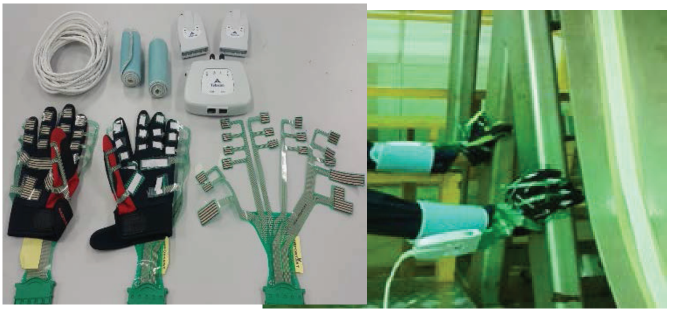


Figure 1: The Tekscan grip system built in the glove and attached to subject

3.0 RESULTS AND DISCUSSION

3.1 Hand Grip Pressure Force with Respect to Individual Factors

The analysis begins by studying the relationship between the hand grip pressure force with individual factors such as age, body size, and the interaction between the age and body size. The data for hand grip pressure force was tabulated in Table 1. These data indicate the distribution force of the operator while they are doing their task. The table 1 shows the highest grip force recorded when performs tasks for both left and right hands on at operator C with maximum force at 1,466.83N and followed by 2,913.92N respectively. This score was influenced by factors such as age and body size. Operator C is bigger in body size and is the youngest compared to other operators. Hence, this operator produced the highest hand grip force. The author believes that the interaction between the age and body size has influenced the hand grip pressure force of the subject as the youngest and biggest subject produced high hand grip pressure force.

Table 1: The hand grip pressure force of the subjects

Subject	Age	Weight (kg)	Push(left)		Push(right)	
			Max Force (N)	Min Force (N)	Max Force (N)	Min Force (N)
Operator A	25	70	516.88	72.95	683.69	132.56
Operator B	30	75	378.09	71.17	514.65	93.41
Operator C	20	90	1466.83	158.80	2913.92	497.81
Operator D	23	80	1280.10	130.78	2431.48	322.91
Operator E	35	65	39.14	9.95	192.42	33.59

This followed by the operator D, operator A, operator B and finally, operator E which is the oldest operator obtained the score that shows the lowest hand grip force. This study has also proven by Sancho-Bru et al. [20] that investigated the relationship between handgrip strength and individual factors such as age and body size. The study found the most appropriate body size component affecting the grip force strength was weight. Hand grip force strength increased with body weight until it reaches a peak value at a body weight of approximately 100 kg for male subjects. There is a few research prove that males primarily due to larger average body size and muscle mass, always produced greater grip force, a pattern that has been repeatedly documented [29-34].

3.2 Hand Grip Pressure Force with Respect to Side of the Hand

The second part of the analysis is studying the relationship between the sides of the subject's hand. The study found that the hand grip pressure forces when pushing the mold or perform the task with the right hand is higher rather than doing it with the left hand as shown in Table 1 and Figure 2. When looking at the entire sample, the maximum force for the right hand for all five operator's shows that the dominant hands produce greater absolute force than the non-dominant hand. Muscle on dominant hand has a higher capacity of used and due to be used more frequently, the fatigue rate was faster than the other side of the hand.

The previous studies have found that the significantly greater force in the dominant hand, especially of right-handed individuals [30, 35]. However, the studies of handedness in grip strength have been inconsistent in their findings [36] and different degrees of handedness certainly exist [37].

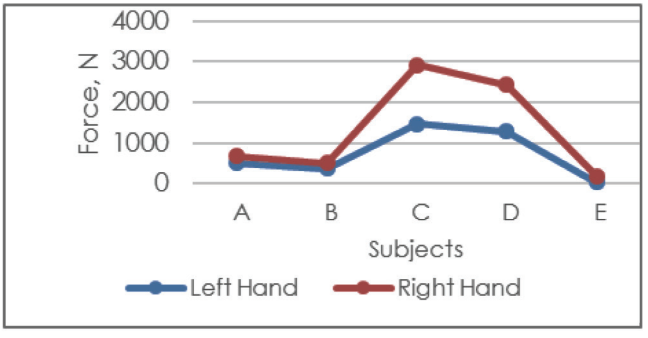


Figure 2: Hand grip pressure force of the both side of the hands

3.3 Pressure Distribution Area with Respect to Individual Factors

The distribution of localized peak pressure contact, overall contact area and peak distribution area over the hand surface can also be investigated through measurements performed under Tekscan application. In order to calculate the overall contact area, the number of all boxes involved which is the colored one is multiplied with the area of 1 box equals to 144mm^2 (Figure 3) while for the pressure distribution area of the box that have red colored with the calibrated pressure greater or equals to 94KPa is only counted using

Figure 3: Each box area

$$\frac{(\sum \text{number of box})}{1000} \times 144mm \qquad (1)$$

Tables 2 until 6 show the overall contact areas and the higher pressure force (pressure more than 181 KPa) for five workers that involved on the pushing activities at layup process. The result of the high pressure distribution area is selected to be discussed. When the comparison is made between these five workers thus, there is a significant difference between them.

Table 2: The distribution of hand pressure grip force while perform push task for operator A

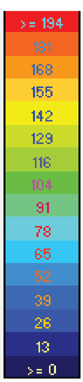
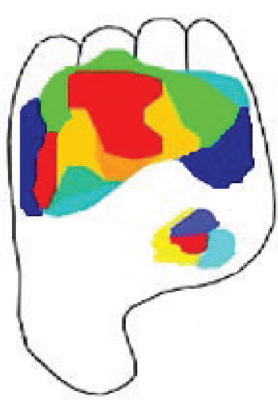
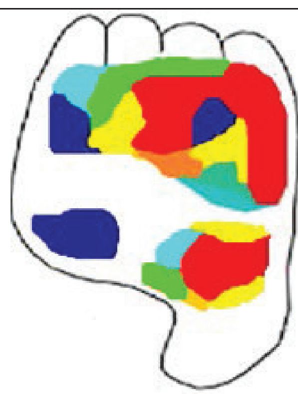
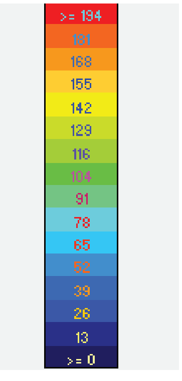
Palm length: (0.173-0.180m) Palm width: (0.09-0.092m)	Maximum distribution force of operator A  	
Scale KPa	Left Hand/Max Grip	Right Hand/Max Grip
 		

Table 2 shows the force distribution for operator A when doing the pushing task at layup room. The overall contact area for pushing the mould was 12.528 m^2 under pressure with, 5.760 m^2 above 181KPa occurred at the left hand. In comparison with the right hand, the overall contact area for pushing the mould was 15.120 m^2 under pressure with, 6.480 m^2 above 181KPa at the max grip force. We can see that the right hand has more distribution force area rather than the left hand. This is because the right hand is the dominant hand and producing more grip strength rather than the non-dominant hand.

Table 3: The distribution of hand pressure grip force while perform push task for operator B

Palm length: (0.176-0.185m) Palm width: (0.08-0.085m)	Maximum distribution force of operator B 	
Scale KPa	Left Hand/Max Grip	Right Hand/Max Grip
		

The force distribution of the operator B when pushing the mould panel is depicted in Table 3. The overall contact area for pushing the mould was 7.20m^2 under pressure with, 4.912 m^2 above 181KPa (left hand). Whereas the overall contact area for pushing the mould with right hand was 9.119 m^2 under pressure with, 6.760 m^2 above 181KPa.

We can see that the right hand has more distribution force area rather than the left hand. Hand size is likely to be one of the factors why the operator area of distribution force at the hand is significantly different. Operator B with right hand size is larger than the left hand. When performing the task, the right hand gives more grip strength and the grip force.

Table 4: The distribution of hand pressure grip force while perform push task for operator C

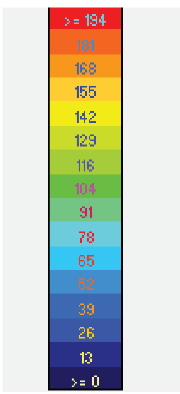
<table>
<tr><td>Palm length:
(0.170-0.175m)
Palm width:
(0.093-0.096m)</td><td colspan="2">Maximum distribution force of operator C
</td></tr>
<tr><td>Scale (KPa)</td><td>Left Hand/Max Grip</td><td>Right Hand/Max Grip</td></tr>
<tr><td>
</td><td></td><td></td></tr>
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Table 4 shows the distribution force area for operator C when pushing the mould panel at layup room. The overall contact area during pushing the mould was 12.960 m^2 under pressure with, 6.048 m^2 above 181KPa (left hand). Whereas the overall contact area for pushing the mould at the right hand was 15.120 m^2 under pressure with, 8.344 mm^2 above 181KPa. We can see that the right hand has more distribution force area rather than the left hand. This is because the right hand is the dominant hand. This also showed that the right handed operator used more energy from the dominant hand while doing the task. Age is one of the factors that influenced the producing of the grip force and operator B is the youngest among the five operator samples. Therefore, this operator has the highest grip force for both the right and left hand compared to other operator samples. Measurements of the hand and forearm generally served as better predictors of grip force strength than the more commonly recorded quantities of height and weight. The best single linear measurement to predict grip force was palm width. A greater palm width suggests that an individual has larger muscles and bones but a greater palm width also providing an advantage in gripping of the handle.

Table 5: The distribution of hand pressure grip force while perform push task for operator D

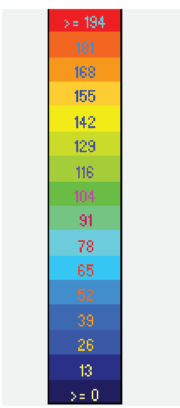
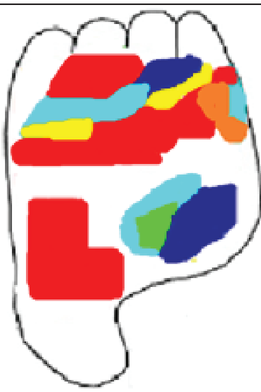
<table>
<tr><td rowspan="2">Palm length:
(0.17-0.178m)
Palm width:
(0.093-0.095m)</td><td colspan="2">Maximum distribution force of operator D</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Scale</td><td>Left Hand/Max Grip</td><td>Right Hand/Max Grip</td></tr>
<tr><td>
</td><td></td><td></td></tr>
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Table 5 shows the distribution force area for operator D when doing the push task at layup room. The overall contact area for pushing the mould was 18.720 m² under pressure with, 6.896 m² above 181KPa when at the max grip force for the left hand. However, the overall contact area for pushing the mould with right hand was 17.840 m² under pressure with, 8.488 m² above 181KPa. The right hand has more distribution force area rather than the left hand due to the right hand is the dominant hand and producing more grip strength rather than the non-dominant hand. Right hand is a dominant hand used to push the mould cart and the left hand is only supporting the right hand. Therefore, the area distribution of grip force for dominant hand is much higher than the non-dominant hand.

Table 6: The distribution of hand pressure grip force while perform push task for operator E

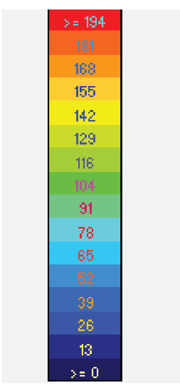
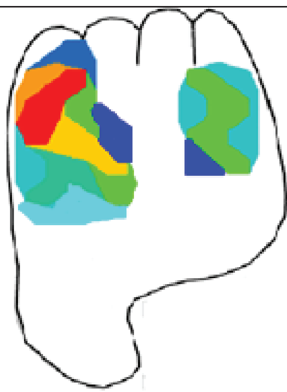
Palm length: (0.016-0.0165m) Palm width: (0.090-0.092m)	Maximum distribution force of operator E 	
Scale	Left Hand/Max Grip	Right Hand/Max Grip
		

Table 6 shows the force distribution for operator E when doing the push task at layup room. The overall contact area for pushing the mould was 9.528 m² under pressure with, 1.760 m² above 181KPa (left hand). Whereas the overall contact area for pushing the mould with right hand was 10.920 m^2 under pressure with, 5.480 m^2 above 181KPa. From this table, we can see that the right hand has more distribution force area rather than the left hand. Operator E has the lowest grip force compared to other operators. This is because this operator E has health issues (accident affected) compared to other operators.

4.0 CONCLUSION AND RECOMMENDATIONS

In this study, the individual factors and side of the hand did influence the hand grip pressure force of the subjects while performing the pushing activities. In general, higher grip force means a higher degree of risk for development of MSDs and CTS. Industrial workers who move their hands and wrists repeatedly and/or forcefully are at higher risk of upper extremity MSDs [38]. Forceful and repetitive hand motions have been proposed as risk factors for the development of carpal tunnel syndrome [39]. High grip forces may also be a contributing risk factor for the development of MSDs of the upper extremity. It may as well contribute to musculoskeletal problems when there is insufficient time for relaxation or recovery. From these results, this study concludes that the use of the dominant hand in daily activities may train muscle fibers towards the properties of fast-twitch fibers, for example by fibers synthesizing more myofilaments relative to mitochondria. This would result in greater strength, but relatively less endurance that easily causes muscle fatigue. Other studies have found significantly greater force in the dominant hand, especially of right-handed individuals [30, 35]

The study had recommended some countermeasures or precautions in order to reduce the risk factor for the development of CTS and MSD among the workers in the aerospace industry as listed as follows:

i. Prevent ergonomic hazards at the workplace.
ii. Using the appropriate manpower for a task that involves heavy equipment.
iii. Medical check-up for the workers.
iv. Hands massage (once per week).
v. A suitable glove that can reduce discomfort.
vi. Regular exercise hand to improve the blood circulation.
vii. Reduce the exposure time or job rotation.

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