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Understanding Grip Choice and Comfort Whilst Hoovering

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***Abstract*—**The hand is one of the essential parts of the body for carrying out Activities of Daily Living (ADLs). Individuals use their hands and fingers in everyday activities in the both the workplace and home. Hand-intensive tasks require diverse and sometimes extreme levels of exertion, depending on the action, movement or manipulation involved. The authors have undertaken several studies looking at grip choice and comfort. It is hoped that in providing improved understanding of discomfort during ADLs this will aid in the design of consumer products.

Previous work by the authors outlined a methodology for calculating pain frequency and pain level for a range of tasks. From an online survey undertaken by the authors with regards manipulating objects during everyday tasks, tasks involving gripping were seen to produce the highest levels of pain and discomfort. Questioning of the participants showed that cleaning tasks were seen to be ADL's that produced the highest levels of discomfort, with women feeling higher levels of discomfort than men.

This paper looks at the methodology for calculating pain frequency and pain level with particular regards to gripping activities. This methodology shows that activities such as mopping, sweeping and hoovering shows the highest numbers of pain frequency and pain level at 3112.5 frequency per month while the pain level per person doing this action was 0.78.The study then uses thin-film force sensors to analyze the force distribution in the hand whilst hoovering and compares this for differing grip styles and genders. Women were seen to have more of their hand under a higher pressure than men when undertaking hoovering. This suggests that women may feel greater discomfort than men since their hand is at a higher pressure more of the time.

***Keywords*—**hovering, grip, pain

I. Introduction

HAND-intensive tasks require diverse and extreme levels of exertion depending on the action, movement or manipulation that is being undertaken. Research by Fellow et al., (1991) showed that movements and exertions such as reaching, gripping and pinching, combined with repetition in a forceful and/or awkward manner is a known contributing factor to the precipitation and aggravation of CTS (Cumulative Tunnel Syndrome) [1]. Further, pain or discomfort is one of the human body's natural defence mechanisms, causing a reflex action to stop a harmful activity and encouraging a modification in behaviour to prevent it from being repeated in the future (Ingrid et al, 2005). Therefore, people instinctively tend to behave in ways that avoid or minimise painful sensations during activities of daily living. They will tend to adopt postures that are the most comfortable for them. It is extremely difficult to quantify pain, since it is not possible to measure it directly and the personal experience of the individual must be relied on instead. In addition, the experience of pain varies between individuals (possibly due to genetic reasons and the fact that people may react very differently to the same stimulus). Although it is difficult to measure pain, it can be classified into different types. The most common of which are acute and chronic.

Acute pain is of the most relevance to the current study, since it is that which is experienced due to an injury or some malfunction of the body. Chronic pain is more likely to be caused by a developing disease or even be psychosomatic. It is therefore unlikely to cause an individual to cease an activity, although it may prevent them from attempting it in the first place. Previous studies on hand comfort have generally focused on the use of hand tools, for example screw drivers, pneumatic drills, grinding tools and chipping hammers etc. (Fellow et al, 1991), but less work has been carried out on Activities of Daily Living (ADLs) such as hoovering and mopping as shown in Figure1. Activities of Daily Living (ADL) such as cleaning, hoovering, mopping and so on have hand diminutive previous research undertaken on them. Most of the previous research undertaken in understanding cleaning tasks has concentrated on upper and lower back pain and discomfort, with less attention to hand and finger pain.

II. Previous Work

Hand tools have been developed over thousands of years to make many everyday tasks easier, from simple hunting tools to modern human computer interfaces. As time has progressed and tool functionality has improved, modern designers are able to pay more attention to designing high quality and comfortable hand tools that can reduce the risk of occupational injury for the user. Previous investigations show that the feelings of discomfort can reduce efficiency and job satisfaction of workers [2], and that in the longer term, use of hand tools can also cause musculoskeletal disorders [3],[4],[5]. Therefore, a clear definition of “comfort” and “discomfort” is very important to a designer; as well as knowledge about the factors which improve the level of comfort for the user.

Webster‟s dictionary [6] defines comfort as a state or feeling of having relief, encouragement and enjoyment. However, many researchers give different meanings for the definition of comfort such as: a pleasant state of physiological, psychological and physical harmony between a human being and its environment [7] , a state of a person involving a sense of subjective well-being, in reaction to an environment or situation [8], a construct of a subjectively defined personal nature; various natures (physical,

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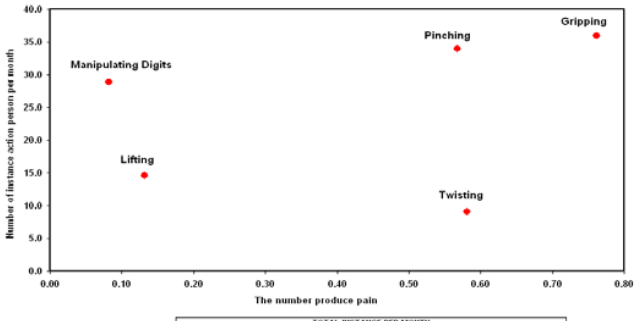
physiological, psychological); and a reaction to the environment [9], that which is associated with feelings of relaxation and well-being [10]. Several objective measures are in use to evaluate hand tools including muscle activity (EMG) [1],[11-14], grip force level and distribution [1],[14-16] and hand-wrist postures [1], [3], [13-15].

In 2004, L.F.M.Kuijt-Evers [17], established six comfort factors for using hand tools. The six factors could be distinguished as functionality, posture and muscle, irritation and pain of hand and finger, irritation of a hand surface, handle characteristics and aesthetics. The methodology used in the study was simply a questionnaire linked to comfort during use. The respondents were split into two groups, one a set of DIY enthusiasts and the other professional users. The result showed that the six factors above can be classified into three meaningful groups: functionality is most related to comfort in using hand tools, physical interaction and appearance. However, the study is not as helpful as it could be in the design of hand tools, because of the limitation of the value on grip force and friction when people handle the tools which are not given in this study.



TOTAL INSTANCE PER MONTH				
ACTION	Total pain	Total action	Action / person	Pain / person
GRIPPING	481.80	22746.80	36.93	0.78
MANIPULATION	51.80	18248.50	29.62	0.08
TWISTING	367.60	5761.90	9.35	0.60
LIFTING	83.20	9200.50	14.94	0.14
PINCHING	359.20	21525.40	34.94	0.58

Fig. 2 Number of instances that actions are carried out on average, per person per month plotted against the number that produces [19].

Work undertaken by Ingrid et al., [18], evaluated ADLs activity limitation in patients with rheumatoid arthritis through the Health Assessment Questionnaire (HAQ) and the Evaluation of Daily Activities Questionnaire (EDAQ) in relation to grip force and gender using digital electronic device (Grippit instrument), indicated that increasing grip force may result in reduced activity and that the activity limitations are closely related to grip force. Women had a significantly lower grip force and more activity limitation (HAQ and EDAQ) than men. Low grip force was found to be closely related to activity limitation regardless of gender.

Based on the results of preliminary work using an online survey of over 600 participants [19], gripping was found to be the action the action that produced the most pain in the hands. Gripping was also found to be the most detrimental action in terms of producing pain in the hand and finger. In this study each person was seen to carry out 36.3 gripping actions per month and 2.4 of these gripping actions lead to pain being experienced. Figure 2 illustrates the relationship between the actions which are most commonly occurring and those which lead to pain. The Figure summarizes the total common daily activities for each action such as gripping, manipulating digits, twisting, lifting and pinching and instance of occurred per month.

Separating this data by gender, as shown in Figure 3, reveals that most actions show similar results. However, gripping is a more significant action amongst females, leading to 0.86 pain instances per person per month compared to 0.63 for males.

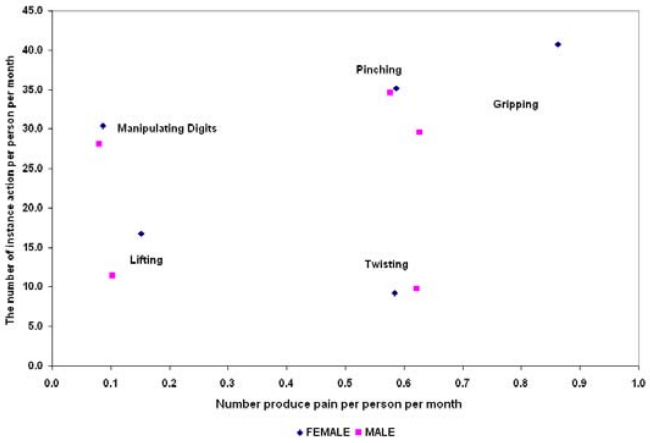


Fig. 3 Number of instances that actions are carried out on average, per person per month plotted against the number that produces pain, separated by gender [19].

Looking at previous studies many researchers are interested in hand tools but few previous studies have been undertaken on ADL's such as cleaning, hoovering, carrying, polishing and ironing to name but a few. In this project we have attempted to evaluate the distribution force and distribution location at the hand and finger when professional cleaners perform a maximum grip on the vacuum handle; and the relationship between the pain experience and location of hand pain compare with an on line survey data.

III. HYPOTHESIS

From the preliminary work online survey [19], the authors developed a set of formulae to determine the pain responses for ADL's. The formula uses data from the survey questions, “during what action did you feel pain?”, “how often did the action cause pain to the hand?" and "how often does the pain occur?" and it was then possible to calculate the action frequency and pain frequency per person. These formulas can be used to calculate pain for every action and to define which action is linked to the highest frequency of pain whilst undertaking ADL. The formula to calculate the action frequency and pain frequency as follows:

$$\text{Total Instances of Pain for a paticular Action (PA)} = \text{Action Frequency (AF)} \times \text{Number of Times Pain Occured (np)} \times \text{Fraction of instance produced pain } (\mu p) \quad (1)$$

$$\text{Action Frequency Per Person } (AFP_p) = \frac{\sum (TAF)}{\text{Total Number of responses } (R_n)} \quad (2)$$

$$\text{Pain Frequency Per Person } (PFP_p) = \frac{\sum (TPA)}{\text{Total Number of responses } (R_n)} \quad (3)$$

Hence, a measurement of how strongly a particular action is linked to pain can be given by,

$$\text{Pain Liklihood} = \text{number of times action is carried out(N)} \times \text{number of responses (R)} \times \text{number tim es of pain occured(np)} \quad (4)$$

Another measurement to assess the severity of pain when experienced is given by,

$$\text{Averagepain rating(APA)} = \frac{\text{Numberof responseson each action (R)} \times \text{Pain ratingscale(S)}}{\text{Numberof painfulresponses(P)}} \quad (5)$$

Using these formulae the activities and actions can be examined further to evaluate which give the highest levels and frequency of pain**.** From this survey on ADLs regarding manipulating objects undertaken by the authors [19], it was found that cleaning tasks rated highly in terms of discomfort.

VI. RESULT AND DISCUSSION

According to the online survey data, the gripping action has the highest total number of painful occurrences (over 65% of all total pain experiences recorded). Gripping is also the most detrimental action in term of producing pain in the hands. On average each person carries out 36.3 gripping actions per month and 2.4 of these gripping action lead to pain being experience [19].

Table 1: The ADLs activities have experience on painful while doing gripping action

Activities Gripping	Male			Female		
	Frequency	Pain Frequency	Pain level per person	Frequency	Pain Frequency	Pain level per person
Sweeping activities eg. hovering, mopping etc	1110.5	106.8	0.305	2002	165.2	0.472
Wiping activities eg. polishing, dusting etc	969.5	119	0.29	1581.5	148.8	0.362
Pushing a 'trolley' eg shopping trolley, pushchair or lawnmower	768	78.6	0.206	1760.5	152.4	0.43
Kitchen activities eg. chopping, can opening etc.	425	14.2	0.167	829.5	36.2	0.426
DIY using hand tools eg. hammer, screwdriver etc.	581	80.2	0.436	63	34.2	0.186
Painting and decorating	213	112.8	0.325	185	87.6	0.252
Mountain biking / Cycling	316	108.2	0.4	130.0	73.6	0.247
Skiing	47	10	0.2	20.5	13.0	0.26
Horse riding	10	2	0.4	18.0	2.6	0.28

Table 1 shows the data for frequency action and pain frequency per person from this online survey regarding the manipulation of objects. According the data it can be seen that sweeping activities show the highest number of pain frequencies per month at 165.2 follow by pushing a „trolley" at 152.4 pain frequencies per month for female response. However, males show a higher pain frequency on wiping activities at about 119 followed by painting and decorating activities at 112.8 pain frequencies per month. From the table we can summarize that sweeping activities are the worst activities cause that pain because the frequency is 3112.5 but the pain frequency is higher 272 compare with pushing a „trolley" have higher frequency 2528.5 per month but the pain frequency are 231 per month.

From the ethnographic studies to understand grip action during the ADL of hoovering using thin-film Tekscan Software, we found some workers said the grip style as shown Figure 4a are more comfortable (reduce pain at thumb, metacarpals and phalanges) in comparison to style as show Figure 4b. However, during this study we found that many female workers like to apply the style as shown in Figure 4b because they felt that this style gives more control when hoovering.

Fig. 4a*:* Comfort Grip

Fig. 4b: Power Grip

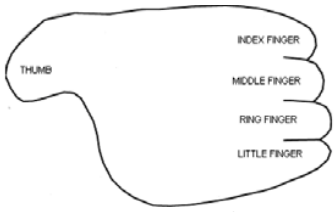


Fig. 5: Schematic diagrams of the human hand

Through the hoovering experiment, we found that the distribution forces are dependent on the style of the gripping. Form the observation, grip style can be classified into 2 types. The 2 types are power grip and comfort grip. Figure 6 shows grip handle style performed by the majority of female workers. According to the female participants, this style was found to be more comfortable and gives the most control whilst hoovering, especially under the table and chair, around the corner and under the stair.

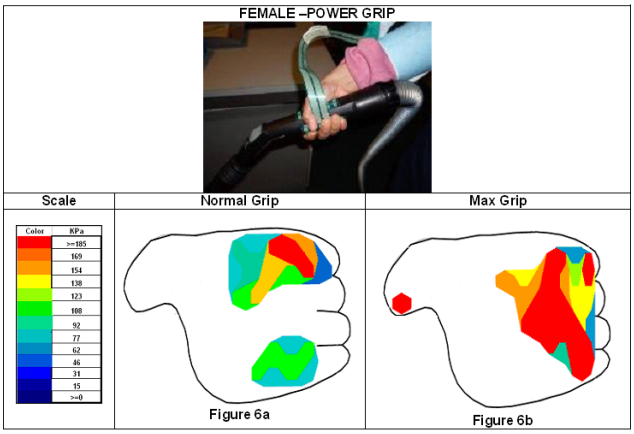


Fig. 6 Handle grip style1 and the distribution contact force on normal grip and maximum grip for female workers

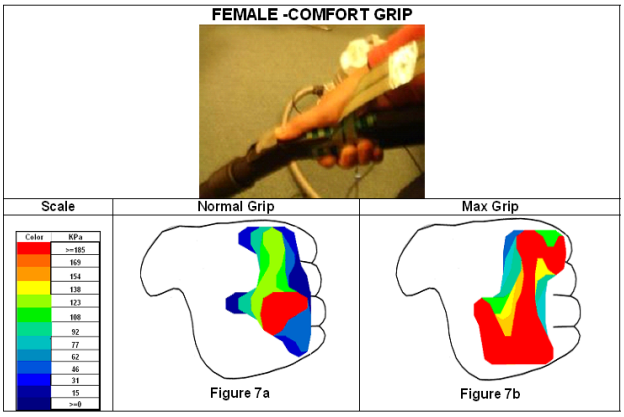


Fig. 7 Handle grip style2 and the distribution contact force on normal grip and maximum grip for female workers

On the other hand, the male workers preferred to handle the vacuum using the technique grip as shown in Figure 8. They commented that this technique could reduce the hand and finger pain during hoovering. Some of them said that this technique is suitable while hoovering the empty area because it required less force. Further, they sometimes used a different technique shown in Figure 9 to clean the furnished area especially under the chair and table and between corners.

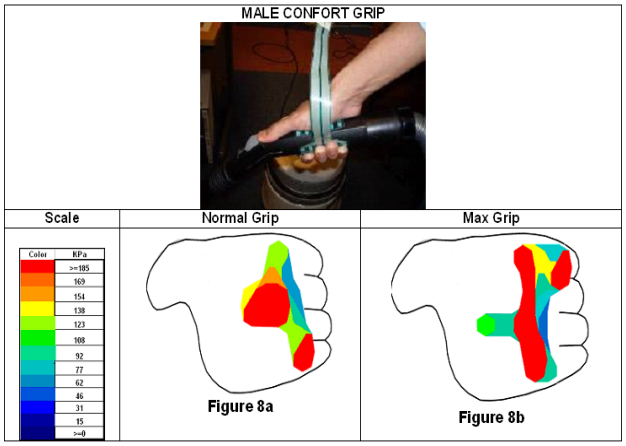


Fig. 8 Handle grip style 2 and the distribution contact force on normal grip and maximum grip for male workers

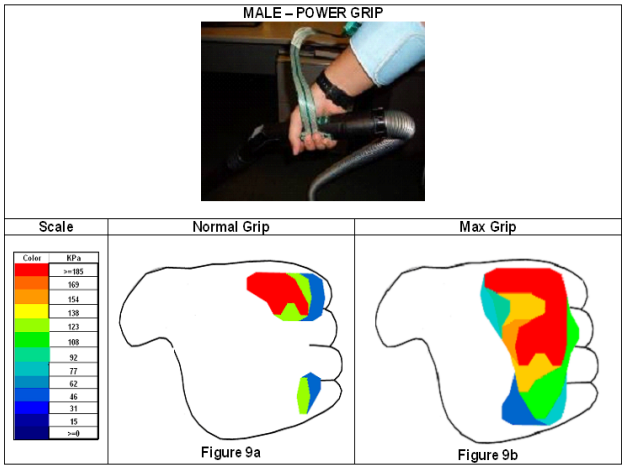


Fig. 9 Handle grip style1 and the distribution contact force on normal grip and maximum grip for male workers

In the experiment, subjects held the vacuum handle in their normal style referred to as the minimum grip. Force distribution data for the differing grip styles is shown schematically on the hand of the user. This schematic hand is shown in Figure 5 The force distribution produced by hand and finger for this grip is shown in Figures 6a, 7a, 8a and Figure 9a. Participants were also instructed to hold the vacuum handle with their maximum grip. This is to distinguish the difference in distribution forces between those gripping actions. The maximum grip distribution force is shown in Figures 6b and 7b for females. Whilst for male subjects, the maximum gripping distribution force is shown in Figures 8b and 9b.

In discussions with the participants, female workers stated that they found the power grip as shown in Figure 6 the most comfortable to use even though it was more painful than the grip shown in Figure 7. This anomaly can be explained since female workers stated they did not like to use the comfort grip as they felt they could not control the vacuum handle.

Hand size is one of the likely factors why the distribution area on force at the hand and finger for both genders are significant different. The average male hand size is bigger (0.192 m) when compared with females (0.174.5 m). The power grip shows a bigger distribution of force over the hand when compared with the comfort grip.

Table 2: Distribution Area Using Two style of Grip for both Gender

	Comfort Grip				Power Grip			
	Min		Max		Min		Max	
Sex	Overall Area (m^2)	Higher Force (>15KPa)	Overall Area (m^2)	Higher Force (>15KPa)	Overall Area (m^2)	Higher Force (>15KPa)	Overall Area (m^2)	Higher Force (>15KPa)
Male	0.0029	0.0012	0.0037	0.0024	0.0021	0.0008	0.0042	0.0032
Female	0.0035	0.0008	0.0045	0.0035	0.0034	0.0007	0.0047	0.0040

Table 2 shows the overall contact areas and the higher pressure force (pressure more than 18.5 kPa) from both genders on the two types of grip styles. The overall contact area for the power grip style is larger when compared with comfort grip style, with males having an overall areas of 0.0042m2 under pressure, with 0.0032m2 above 185 kPa when using the power grip. In comparison the comfort grip style shows the overall areas as 0.0037m2 and 0.0024m2 respectively. For the female participants, the contact areas are 0.0047m2 and 0.0037m2 on when using power grip. The comparable the contact areas using the comfort grip are 0.0043 m2 and 0.0040m2. The average hand size area from our participants was 0.0169 m2 for males and 0.014m2 for females. Hence, for males when using the power grip it can be seen that 24.9% of the hand area was under pressure with 18.9% of the hand over 185kPa.

This compares with 21.8% and 14.2% for males when using the comfort grip. However, for females the area under pressure for both grips is significantly higher than for males (at over 31% for both grip types) and the comfort grip is seen to put the hand under higher pressure (over 15kPa) than the power grip. Both grip styles produce areas over 185 kPa that are higher than the total percentage area under pressure in the male participant's hands.

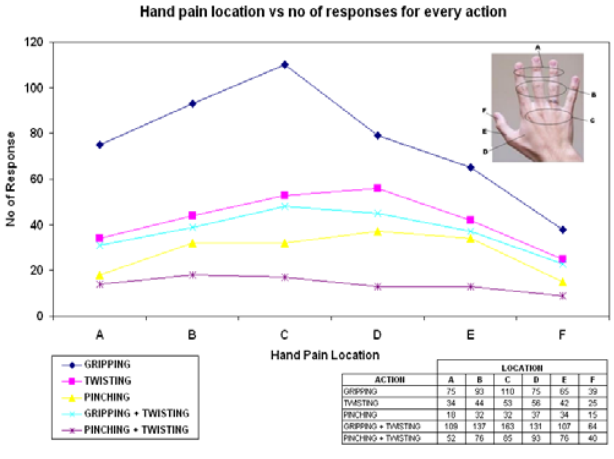


Fig. 10 Graph location hand pain for every action reference the hand model

Figure 10 shows the location of hand pain while performing different actions. Hand Pain in Location C is the most severe during a gripping action. 110 responses claimed

that they feel hand pain during their daily activities. Location B gave 93 responses, and locations A & D gave 75 responses. This means that a large percentage of hand pain during a gripping action is experienced at locations C, B and A.

Comparison was undertaken to determine the painful hand and finger location between the experimental hoovering task using the Tekscan software and the online survey questionnaire. The hand and finger pain location is similar in both instances with location C (flexor tendon sheath) being the most common location for hand pain whilst carrying out the gripping action. Figure 11b and 12 b shows the distribution contact force on maximum grip during the ADL of hoovering using thin-film Tekscan software.

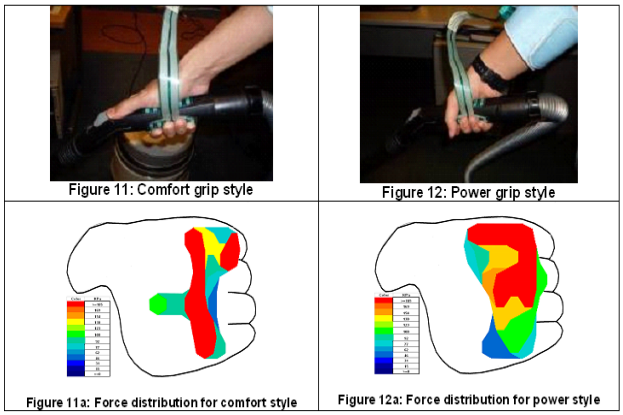


Figure 11: Comfort grip style

Figure 12: Power grip style

Figure 11a: Force distribution for comfort style

Figure 12a: Force distribution for power style

The Table illustrated as part of Figure 10 shows the survey result of object manipulation by hand in activities of daily Living. To aid in the determination of pain or discomfort locations, the hand was segregated into different parts. Those parts are A - distal interphalangeal, B - proximal interphalanges (PIP), C –Flexor Tendon Sheath, D- carpmetacarpal , E - metacarpophalangeal and F- distal phalanx. From the table, the averaging result found that 29% claimed that the most discomfort part is at B, 25% at C, followed by A, D, E and F. This compares well with our Tekscan data which showed the highest forces in the distal and proximal interphalanges.

Table 3: Pain Experience related with Action on On Line Survey Data

Pain Experience	GRIPPING	TWISTING	PINCHING	GRIPPING + TWISTING	PINCHING + TWISTING	RANGE (%)
SHARP	10	14	12	10	9	7 - 14%
THROBBING	10	10	10	6	28	6 - 10%
ACHE	34	36	30	33	7	28 - 35%
CRAMP	10	6	7	10	14	6 - 14%
STIFNESS	10	1	11	8	5	2 - 10%
STABBING	4	6	5	4	7	4 - 8%
TENDER	11	12	11	13	12	9 - 13%
TINGLING	11	14	12	6	12	5 - 13%
BURNING	1	1	2	8	5	1 - 8%

Table 3 shows a pain percentage for every action while manipulating objects. Aching records the highest number of painful experiences. Many respondents feel aches while performing their common daily activities. However, the pain types; sharp, throbbing, cramping, stiffness, and tenderness have values very close to each other. Gripping is the most painful activity compared to twisting and pinching actions. This means that people struggle more when carrying out gripping actions. It was also discussed in the previous studies that gripping caused pain and injury especially when using equipment such as manual hand tools and power hand tools.

V. CONCLUSIONS

Hand and finger discomfort and pain can often happen during and after ADL's. Analytical and experimental data showed that this was likely to occur during gripping actions than other hand manipulations. Further, pain level, and feeling was seen to vary between genders although they perform similar tasks. Our study reveals an explanation why women report more pronounced higher pain rating and higher number pain feeling than men.

Through Tekscan software, it was seen that major contact force occurs on the distal phalanges and middle phalanges. This compares well looks like similar what response feels on online survey regards pain location when doing the comparison data regarding the pain location between online survey and distribution grip force applied to a vacuum handle was measured using.

However, if we look at the proportion of the hand under high pressure when undertaking the hoovering task it can be seen that the female hand is under a higher proportion of the load than males for both grip styles used. This suggests that the prevalence of discomfort in female cleaners could be due to more of the hand under these higher pressures more often.

Further work is underway to look at which hoovering tasks produce the highest levels of pressure over the hand. The eventual aim would be to aid in the more ergonomic design of these types of appliances, reducing instances of pain and discomfort and hence the likelihood of the onset of any more serious illness.

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