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The Effects of Different Tactile Sensations on Pinch Effort

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Abstract. Failure in proper design of ergonomic hand tools can lead to the prevalence of hand-related injuries. In order to improve the ergonomics of hand tools, numerous studies have been done on causal factors related to these injuries such as grip postures, grip forces and torque directions. Nevertheless, there appears to be limited studies concerning how pinch effort can change with different types of tactile sensations. Therefore this study aims to determine the effects of different tactile sensations on pinch effort. A total of 110 manual workers from the wooden pallets and furniture manufacturing firm participated in the study. The descriptive analyses were conducted in Microsoft Excel 2010 and the reliability of data was verified using Cronbach's alpha reliability analyses. The results show that individuals can produce a greater pinch effort while gripping objects that have a high friction coefficient between the fingers and the grip surface. This study improves our understanding on the implications of different tactile sensations and potentially decreases workplace hazards for eventual improvements on safety, health and medical costs.

Introduction

Many injuries in manufacturing firms involve hand-related injuries [1]. Researchers indicate that about 14.8% of employees in manufacturing firms suffer from carpal tunnel syndrome and 78% of them complain that their hand-related injuries are caused by the limitation of the hand tool's grip [2]. In association to this, numerous studies have been done on workers' grip postures, grip forces and torque [3-6]. However, there appears to be limited studies concerning how pinch effort can change with varying types of tactile sensations. Therefore, this study aims to determine the effects of different tactile sensations on pinch effort.

Pinch Grips and Tactile Sensation

Pinch grips are widely used in daily living activities such as writing, holding a toothbrush and picking up small objects. According to Long, et al. [7], a pinch grip is defined as a compression between the two fingers and thumb or a compression between the index finger and thumb.

Sensation can be defined as a physical feeling or perception resulting from something that happens to or comes into contact with the body [8]. Tanaka and Numazawa [9] describe sensation as an occurrence when a stimulus or something that causes a physical or mental response, is received by one of the various sensory organs of the body and is fed into the brain. Tactile sensation is a frequently used sensory perception to detect external stimuli outside the body [9].

Research Method

A survey was developed to collect the feedback from the test subjects who were required to participate in a simple experiment. The test subjects were healthy adult male workers, between the age of 18 and 65 years old. A total of 160 test subjects (the actual number of manual workers in the firm) were recruited from a wooden pallets manufacturing firm in Penang, Malaysia. The response rate was 68.75%, a satisfactory response rate in most research studies [10].

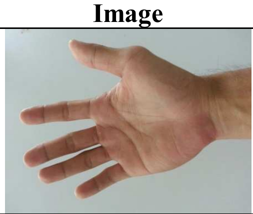
Subjects were tested in an upright standing position with their elbow flexed at a 90 degree angle [11]. Subjects were required to use only the right hand to pinch the knobs [11]. The Borg CR10 scale was used in the survey to define the pinch effort based on ratings from 1 to 10 [12]. A total of 6 industrial screw knobs with 3 different shapes (2 sizes for each shape) were developed. The 6 knobs were given labels of sample 1(a), 1(b), 2(a), 2(b), 3(a) and 3(b) as shown in Table 1.

Table 1: The Knob Labels

Shape (Size)	Sample
Round (Small)	1(a)
Round (Large)	1(b)
Ball (Small)	2(a)
Ball (Large)	2(b)
Star (Small)	3(a)
Star (Large)	3(b)

Subjects were requested to turn the knobs with their bare hands and rate the pinching effort using the Borg CR10 scale. Subjects were asked to repeat the test with cotton and latex gloves. Table 2 shows the list of utilized gloves. The data were descriptively analysed using mean, maximum, minimum and Cronbach's alpha reliability analyses [13].

Table 2: List of Glove Types and Testing Procedures

Glove Types	Image	Testing Procedure	Image	Thickness of the Glove
Bare Hands		Turning the models with bare hands		-
Cotton Gloves		Turning the models with cotton gloves		1.8 mm
Latex Gloves		Turning the models with latex gloves		0.5 mm

Results

Table 3 presents the Cronbach's alpha reliability test results. The Cronbach's alpha coefficient is 0.954 (a value which is adequately above 0.7). A Cronbach's alpha coefficient above 0.7 signifies high reliability and excellent internal consistency [14, 15].

Table 3: Results from the Cronbach's Alpha Reliability Test

Cronbach's Alpha Reliability Test	
Standard Deviation (SD)	24.480
Alpha	0.919
Standard Error of Mean (SEM)	6.96

Figure 1 shows that the mean grip effort for three kinds of sensations and three types of pinch techniques applied on sample 1(a) and 1(b).

Sample 1(a). For all three types of pinch techniques, subjects rated that they used more grip effort to turn the sample with reduced sensation (cotton gloves) as compared to the normal sensation (bare hands) and increased sensation (latex gloves). For every pinch technique, turning the sample using the latex gloves (increased sensation) required the least grip effort.

Sample 1(b). The mean grip effort for three kinds of sensations and three types of pinch techniques applied on sample 1(b) also shows that turning the sample using cotton gloves required more effort as compared to the two other sensations. In the similar way, turning the sample with latex gloves utilized the least grip effort.

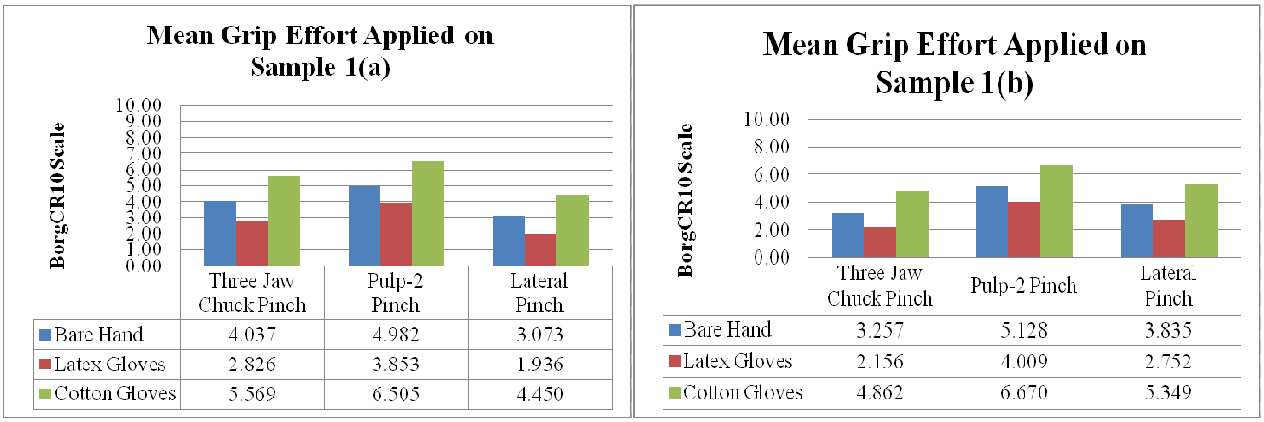


Figure 1: Mean Grip Effort Applied on Sample 1(a) and 1(b)

Figure 2 shows the mean grip effort for three kinds of sensations and three types of pinch techniques applied on sample 2(a) and 2(b).

Sample 2(a). Regardless of the type of pinch techniques, turning the sample using cotton gloves required more pinch effort as compared to the two other sensations. For every pinch technique, turning the sample with latex gloves utilized the least pinch effort.

Sample 2(b). Turning the sample using cotton gloves required more pinch effort as compared to the two other sensations. For every pinch technique, turning the sample with latex gloves utilized the least grip effort. It is observed that the overall pinch effort however is lower than sample 2(a).

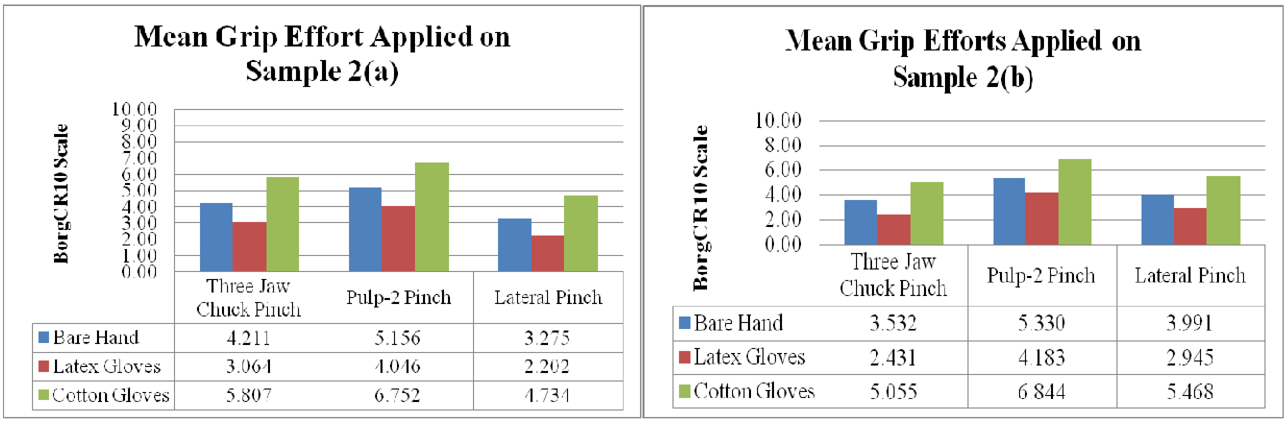


Figure 2: Mean Grip Efforts Applied on Sample 2(a) and 2(b)

Figure 3 shows the mean grip effort for three kinds of sensations and three types of pinch techniques applied on sample 3(a) and 3(b).

Sample 3(a). Regardless of the type of pinch techniques, turning the sample using cotton gloves required more effort as compared to the two other sensations. For every pinch technique, turning the sample with latex gloves utilized the least grip effort.

Sample 3(b). Turning the sample using cotton gloves required more pinch effort as compared to the two other sensations. In the similar way, for every pinch technique, turning the sample with latex gloves utilized the least grip effort.

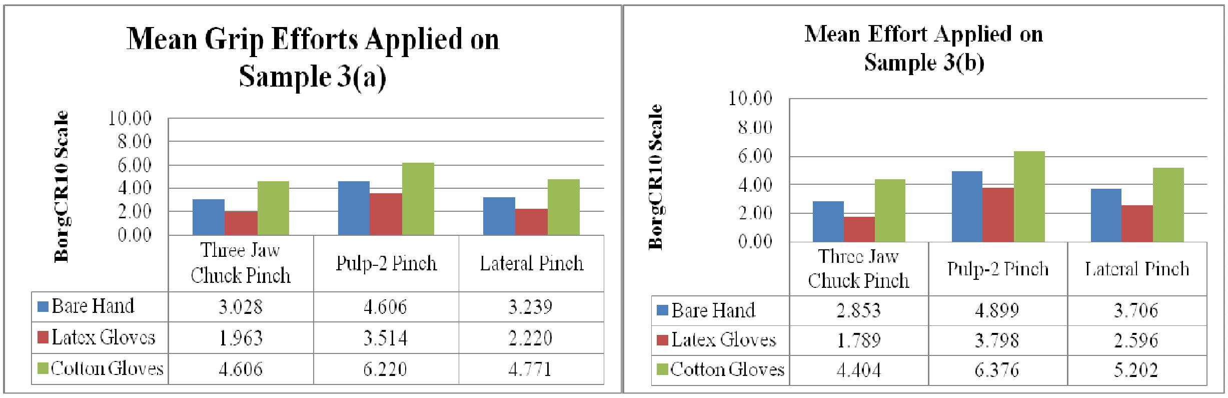


Figure 3: Mean Grip Efforts Applied on Sample 3(a) and 3(b)

Discussion

Similar characteristics can be observed in the mean grip effort of different tactile sensations. Wearing latex gloves has the effect of decreasing the effort to pinch and turn the knobs. On the other hand, wearing cotton gloves continually makes the turning action harder due to slippages between the fingers and the pinched object [13]. Assuming that the pinch efforts reflect the grip strength of the user, an increase in pinch effort may lead to an increase in grip strength [16-18].

The coefficient of friction between the surface of the knobs and the fingers is a very important factor that can influence the pinch forces used to twist the samples. As observed from the analysis, different types of sensations are capable of altering the pinch effort. The coefficient of friction for different sensations can be summarized in Table 4.

Table 4: The Coefficient of Friction for Different Sensations

Sensation	Thickness of the Gloves	Coefficient of Friction between the Grip and Aluminum Surface
Bare Hands	-	0.56 [19]
Latex Gloves	0.5mm	1.1 [19]
Cotton Gloves	1.8mm	0.373 - 0.453 [20]

By relating the friction coefficient of the materials to the results analyzed, pinch effort appears to be affected by the friction coefficient of the glove contact with the surface of knobs. By wearing a latex glove which has the highest friction coefficient, the pinching and turning effort will decrease.

On the other hand, wearing cotton gloves (lowest friction coefficient) seems to deter the implementation of a secure grip and causes slippages to occur. Therefore, the subjects tend to exert more effort to pinch the knobs in order to not give in to these slippages [3].

Conclusion

This study shows that different types of tactile sensations can alter pinch effort. It provides preliminary results for researchers to better understand the effects of different tactile sensations on pinch effort. It also serves as an effective prevention strategy to address the problems related to pinch effort. Design guidelines can be developed to improve the design of manual tools to reduce muscle strains that can potentially lead to injuries. To improve the findings, this research can be done using a design of experiment and biomechanical contact pressure sensors for direct pinch force measurement.

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