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EVALUATION OF GLOVE SAFETY USING ALGOMETER

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ABSTRACT

The intent of this study was to use algometer principle to study the safetyness of gloves. An experiment was conducted to assess the discomfort threshold level at twelve zones on the palmar surface of the hand for five hand conditions - bare hand, single glove, double glove, and 2 prototype gloves. Prototype I consisted of a glove with an extra layer of glove material, applied selectively to critical areas of the hand, while Prototype II had up to four layers applied to critical areas. This design increases protection in critical areas without increasing bulk, provides performances comparable to single glove, and improves grip strength. The study was conducted using an Algometer device to apply pressure to each of the 12 zones, for all hand conditions. The results indicated that for pressure tolerance, Prototype II had the highest pressure-discomfort threshold, while Prototype I had a threshold similar to the Double layer glove. Pressure discomfort tolerance threshold is greatly increased by the use of gloves, and pressure-discomfort thresholds are raised by 25% to 65%. Algometer can be used to assess the safetyness of gloves from mechanical trauma. Hence generalizability of the results is somewhat restricted. The implications for the glove designers are discussed..

INTRODUCTION

In the modern industrial workplace, the use of power operated tools and other equipment is taken for granted. The physical stresses imposed on the body of the worker by the tools and equipment are often overlooked because in most cases, the use of such equipment is intermittent, and there is often a adequate rest period between stress-intensive periods.

However, in many situations where the hand/tool unit is the primary interface with the job, no part of the body is subjected to as much punishment as the hand. The job may involve prolonged periods where the worker is required to support the weight of the job or the tool awaiting the next phase of the job. The sustained pressure on the surface of the hand quickly gives rise to a sense of discomfort which rapidly turns into pain leading to the potential risk of dropped tools. Moreover, pain is a warning sign of impending tissue damage, and as such should not be ignored.

The sensation of pain in the hand due to high sustained external pressure has been cited as a limiting factor in the performance of work with hand held tools by Fraser (1980). The transfer of mechanical loads to flesh has been studied by several researchers, in an effort to determine the pressure-pain thresholds associated by different loads. Bennet (1971) modeled the transfer of load to flesh as a biomechanical model in order to determine the compressive stress experienced by a uniform fleshy mass squeezed between a external load and a bony foundation. The study, although purely theoretical, nevertheless was useful in demonstrating how compressive stresses at a point decay to low or negligible values at a distance of 2.5 to 3.0 inches from the point of loading. The subcutaneous fat in the hand acts as a pressure absorbent (Fransson-Hall and Kilbom, 1993), and in the parts of the hand that do not have a thick layer of fat, pressure is absorbed by the other structures and the palmar fascia. Brennum, Kjeldsen, Jensen and Jensen (1989) measured the human pressure pain thresholds on fingers and toes using a pressure algometer. Their study found that there were no significant changes in pressure-pain threshold for repeated stimulation. They found that the localized loading gave rise to inflammation and indentations that could last for hours

Fransson-Hall and Kilbom (1993) studied the sensitivity of the hand to surface pressure using controlled increases in externally applied surface pressure (EASP), to locate the point at which the feeling of pressure turned into pain. The found that the hand was most sensitive to EASP at the thenar area, the skin fold between thumb and index finger, and the area around the os pisiforme.

Gloves are the primary protective device for hands in the industrial world. Affording maximal protection with minimal performance compromise is often the aim of all glove designers and glove manufacturers. Almost all of the published literature on gloves have been on the performance aspect of gloves. Research on the safety aspect of gloves have been sparse, primarily due to wide range of protection function and difficulties in objective measurement of those protection function. For this reason, it was argued that the changes in pressure pain threshold with gloves would be a good measure of the safetyness of the glove. While almost all the previous research in the area of hand pressure have focused on the pressure-pain threshold of the barehand, it is very rare in actual working conditions that pressure is allowed to reach the level of pain. Accordingly , the objective of this study was to:

(i) Compare the pressure-discomfort threshold (PDT) levels for different hand conditions- barehand, single glove, double glove, and two prototype gloves for 12 areas of the hand, and

(ii) Use the pressure-discomfort threshold data to evaluate two prototype gloves that were designed as a part of another study.

METHOD

The study was conducted using a pressure algometer apparatus fabricated at the University of Nebraska-Lincoln. (Figure 2) The apparatus consisted of a frame capable of being raised or lowered by means of a spring and lever arrangement. The frame was modified from a drill press stand for portable power drills. The frame was modified to enable a Load Cell (Hottinger-Baldwin) connected to a digital display (National Controls) to be mounted on it, and a contact rod with a cross-section of 1 sq. cm was attached to the load cell. The tip of the contact rod was covered by a thin, rubbery membrane to cover the edges.

Safety stops were provided in order to prevent accidental excessive travel of the contact rod, eliminating the risk of injury. The operation of the apparatus was entirely manual and under the control of the subjects. A firm pad of expanded polyurethane was provided at the base of the apparatus to support the dorsal side of the subjects' hand.

SUBJECTS

The subjects consisted of 10 healthy male and 10 healthy female volunteers drawn from the population group 18 - 40 years. No prior experience was required of the subjects, and they were able to verify orally that they had no previous history of upper extremity muscular disorders, nerve damage or any limitation in the use of their hands.

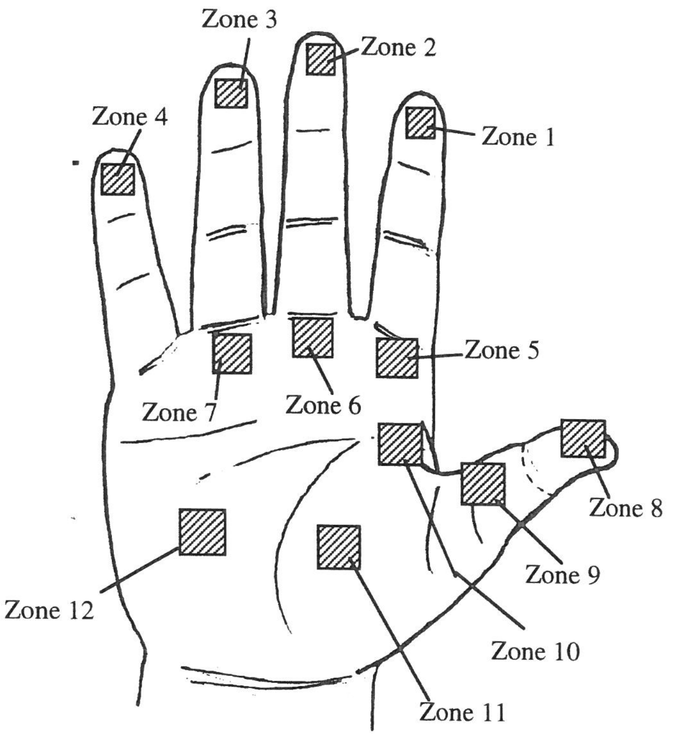

Figure 1: Test Zones

PROCEDURE

Twelve areas (Zones 1-12) on the palm were identified as the test zones (Figure 1). The subjects' dominant hand was placed with the palm facing upwards on the expanded polyurethane support pad, and the subject was asked to grasp the lever handle of the algometer apparatus with the other arm, and gently lower the contact rod onto the designated zones one by one . The entire test was carried out under the subjects' own control. The subject was asked to gently increase the pressure on his or her palm until the pressure on that zone became uncomfortable, and indicate the same to the investigator. The load at that point was recorded as the pressure-discomfort level for that zone. The test was performed twice for each hand condition - barehand, single glove, double glove, Prototype I (Contour glove) and Prototype II (Laminar glove) (Figures 3 and 4). Sufficient rest period was provided in between the trials to ensure that local inflammation was not caused due to repeated loading.

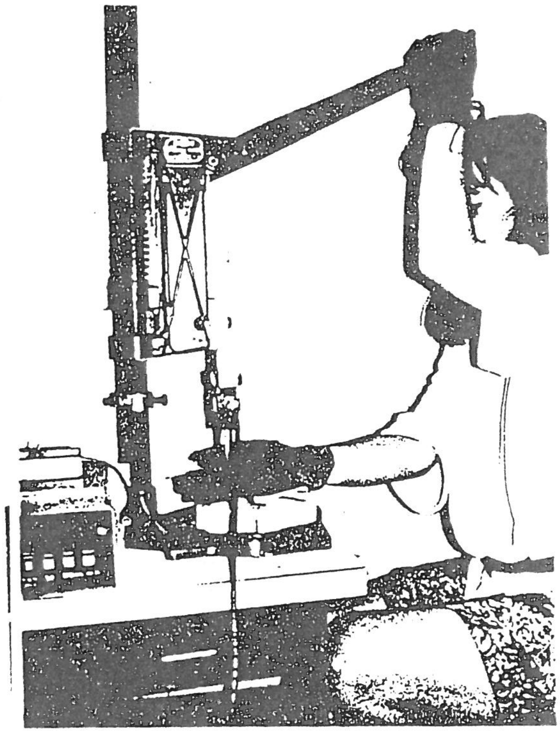

Figure 2: Algometer Apparatus.

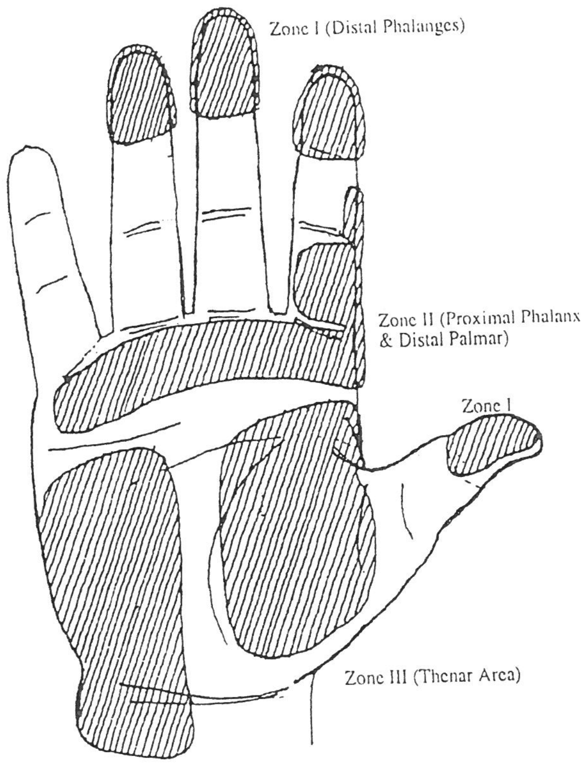

Figure 3: PROTOTYPE I

- CONTOUR GLOVE

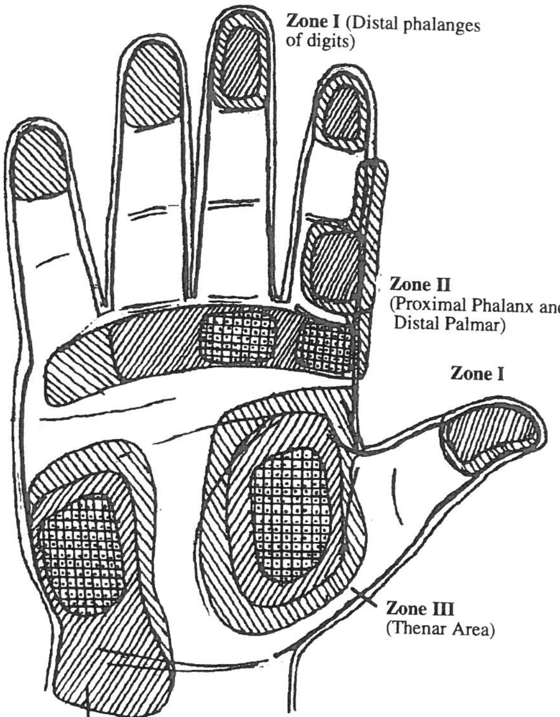

Figure 4: PROTOTYPE II - LAMINAR GLOVE

RESULTS

A multivariate analysis of variance (MANOVA) was performed, and the consolidated table for the effects of Gender, Glove, Trial and Zone and their interactions is presented as Table 1. It is seen that the Glove effect, Zone effect, and the Zone*Glove interaction effects are significant. Figure 5 shows the plot of the hand condition effect of pressure-discomfort threshold. It is seen that among the various hand conditions bare handed had the least PDT, while the laminated glove (one of two prototype developed here) had the highest PDT. Overall, the prototype gloves provide a greater measure of safety by raising the pressure tolerance threshold, allowing the hand to sustain a greater amount of pressure before discomfort becomes apparent. Figure 6 shows the plot of the pressure-discomfort threshold and performance of the various hand conditions (borrowed from an earlier study). It can be seen that the time taken for the task is lesser for the two prototype gloves than for the double glove, while the protection is comparable. Figure 7 shows the plot of PDT and grip strength for the various hand conditions.

Table 1 MANOVA for the effects of Gender, Glove, Trial and Zone.

Effect	Wilks Lambda	Pillai's Trace	Hotelling - Lawley Trace	Roy's greatest root
Gender	0.5655	0.5655	0.5655	0.5655
Glove	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Trial	0.1821	0.1821	0.1821	0.1821
Gender*Glove	0.5001	0.5001	0.5001	0.5001
Gender*Trial	0.1671	0.1671	0.1671	0.1671
Zone	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Gender*Zone	0.2127	0.2127	0.2127	0.2127
Zone*Glove	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Glove*Trial	0.4505	0.4505	0.4505	0.4505

Alpha = **0.05** for significance.

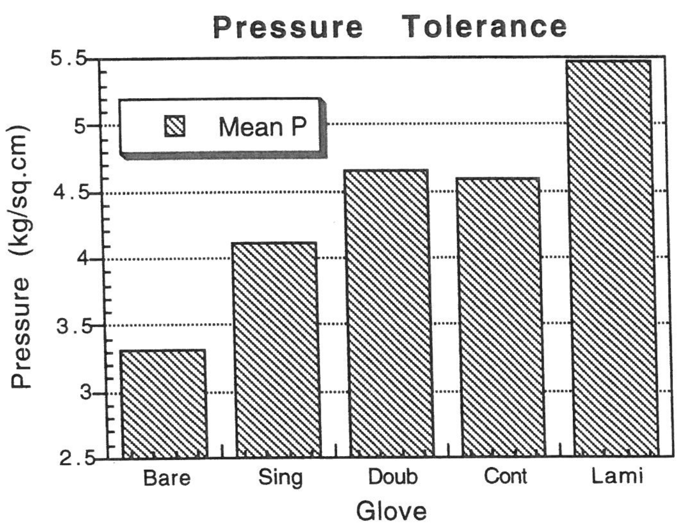

Figure 5: Discomfort Threshold Pressure by Glove

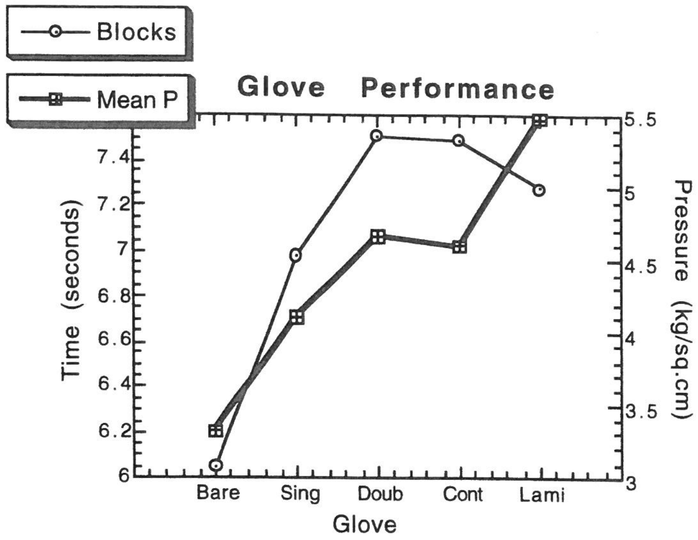

Figure 6: Comparison of Performance with respect to Pressure Threshold and Task Time

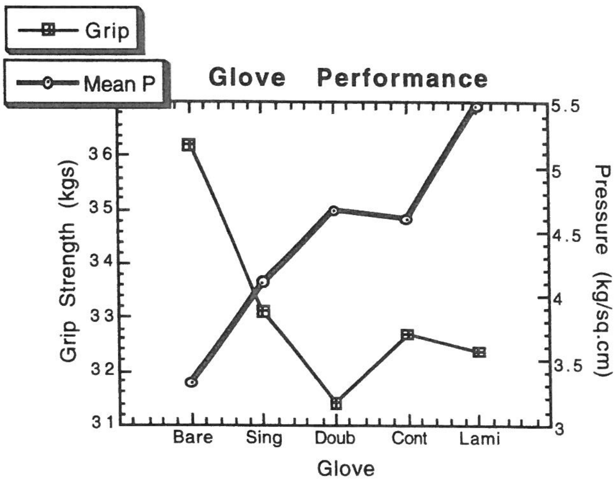

Figure 7: Grip Strength Performance as compared to Pressure-Discomfort Threshold.

Figure 8 shows the plot of the zone effect on PDT. It is seen that the Laminar glove is the best and the Bare hand condition is the worst. The pressure threshold for the gloved hand conditions is in all cases greater than that of the bare hand, and that Zones 4, 7 and 10 exhibit the lowest tolerance levels to pressure.

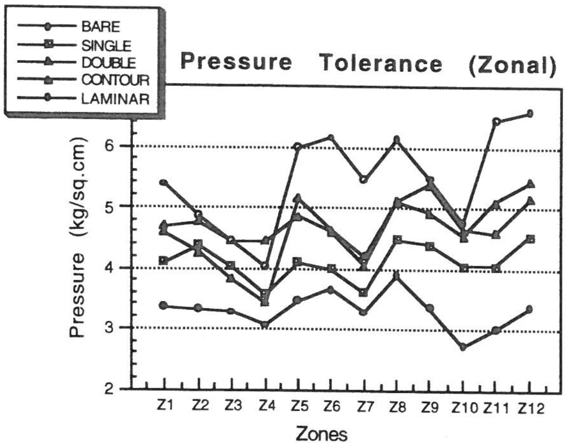

Figure 8: Pressure - Discomfort Threshold across Zones.

CONCLUSIONS

The primary intent of this study was to use Algometer to study the safetyness of gloves. To that extent the intent has been served. It is seen that the use of gloves raises the pressure-discomfort threshold, and increases pressure tolerance to a considerable extent. The relative differences in PDT can be assumed to be an indicator of the protective ability of the gloves. As compared to bare hand, even a single layer of glove material imposed between the pressure source and the hand raises the threshold values significantly.

Both the prototype gloves tested raised the discomfort threshold to a level that was comparable with the double glove. Prototype I (Contour glove) had threshold levels that was almost equal to that of the double glove, whereas the Laminar glove by virtue of additional layers of material at critical zones, raised the discomfort threshold by approximately 25% over the Double glove threshold. The use of selective protection, using varying levels of protection targeted at specific parts of the hand , therefore, increases the protective ability of the gloves. It is seen that selective protection, while increasing the protection, does not reduce the performance as seen from Figures 6 and 7 above. The distribution of PDT across the 12 zones on the palmar surface of the hand was not uniform. This finding is consistent with those reported by Fransson-Hall and Kilboum (1993).

A caveat is in order here. Protection against environment is far more complex than protection against mechanical trauma addressed in this study. Therefore, the generalizability of this finding is somewhat suspect. However, the method of selective protection without compromising performance appears to be promising and is definitely worth pursuing by glove designers.

REFERENCES

Bennet, L., (1975). Transferring Load to Flesh, Part II. Analysis of Compressive Stress. Bulletin of Prosthetics Research **BPR 10-16** (Fall) 45-63

Brennum, J., Kjeldsen M., Jensen, K. and Staehelin Jensen, T. (1989) Measurement of Human Pain Threshold on Fingers and Toes. Pain, **38**, 211-217.

Fransson-Hall, C. and Kilbom, A. (1993) Sensitivity of the Hand to Surface Pressure. Applied Ergonomics, **24**(3), 181-189.

Srinivasan, M. A., (1989). Surface Deflection of Primate Fingertip under Line Load. Journal of Biomechanics, **22**(4) pp. 343-349.