HFD Human Factors in Design
PPGDESIGN UDESC

EVALUATION OF DISCOMFORT IN MANUAL ACTIVITIES USING HAND MAPPING: THE INFLUENCE OF AGE

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ABSTRACT

This study analyzes the method of hand mapping to assess the perceived discomfort during the use of hand tools by different age groups. The aim was to determine the influence of age and how it affects the perception of discomfort. Considering that, this was a study that involves subjective aspects, it seeks to analyze results by means of a comparative assessment among different areas of the hand. Hence, the hand palm was divided by both anatomical and interface criteria for the task. The manual activity consisted in a simulation of opening procedure for PET packaging of soft drinks. The results show differences in perception of discomfort among the ages analyzed. The adopted method contributes to the ergonomic design, as the perception of discomfort is an important parameter in the product design, providing more efficient and accessible products.

KEYWORDS

Design, ergonomics, discomfort, hand mapping, hand tools.

1. INTRODUCTION

The human being is surrounded by products in all his daily life places, whether at home, at his place of work or leisure occasion. However, many of those objects do not match their expectations in many aspects, including ergonomic ones.

As a science that deals with the interface between men and technology, ergonomics covers the aspects of human interaction with products and systems, and in this sense Kujit-Evers et al. (2004) point out that there is a lack of knowledge about the comfort (which is a major ergonomic criteria) in the use of objects, particularly on hand instruments.

Nowadays, there is a growing demand for subjective aspects of those interactions, particularly for comfort and/or discomfort. In this case, scales of perception were often used. These scales provide parameters on which users rely to assess perceived levels, and they can be pictorial or numerical based. Specifically for manual interfaces, the division of the hand in various regions (hand mapping), is gaining popularity and is a effective method, providing satisfactory results.

2. THEORETICAL REVIEW

2.1 Comfort and Discomfort

Most of the ergonomic design approaches depends on the user perception about the use of a particular product, and this perception is due to some evaluation criteria (PASCHOARELLI; MENEZES, 2009). According to Paschoarelli (2003), the main criteria used in the evaluation of a product is discomfort as negative, and comfort, as positive criterion. Iida (2005, p.248) states that "... comfort does not have a precise definition, and depends on the field of study where it is applied" and adds that comfort is an "... ergonomic quality of the product …" (p. 249), which is certainly valued by the user.

Kuijt-Evers (2006, p.22) denotes the term comfort according to Webster's dictionary, which defines comfort "... as a state or feeling of having relief, encouragement and pleasure..." and complements its meaning from other authors, as Slater (1985), which defines comfort as a "...pleasant state of physiological, psychological and physical harmony between a human being and his environment..." or Richards (1980), which states that "... comfort is a state of the person that involves a sense of subjective well-being in response to a situation or environment... ".

The same study states that, according to Looze et al. (2003) there is some consensus about its meaning: comfort is a construct of nature subjective and personal, and is affected by factors of diverse natures (physical, physiological, psychological) and, finally, is a reaction to the environment.

Vink (2012), exposes in his study other meanings and relations for comfort and discomfort. Citing Helander and Zhang (1997), which explain the absence of discomfort does not automatically result in comfort. Hence, the comfort is perceived only when the satisfaction is greater than expected. And discomfort, based on questionnaires, is associated with physical factors such as posture, stiffness and fatigue. In the absence of discomfort, nothing is experienced.

According to Vink (2012, p.271) "... comfort is seen as a state of pleasant feeling of a human being in reaction to its environment ..." and "... discomfort as an unpleasant state of the human body in response to their physical environment ...". Helander and Zhang (1997) argue that there is a split or discontinuity between comfort and discomfort.

At the same point of view, Looze et al. (2003, cited by Kong et al., 2012) suggested a theoretical model, which assumes that comfort and discomfort are independent entities, not two opposite ends of a continuous scale. In their model, the physical factors of a human product or environment can lead to discomfort.

But under the influence of emotional factors, the discomfort can be switched to comfort. Zhang et al. (1996, cited in KONG et al., 2012) presented the idea that comfort is associated with feelings of relaxation and well-being, while the discomfort is closely related to pain, numbness or fatigue.

Despite the frequent use of the term, there is no widely accepted definition for both comfort and discomfort. However, one may notice that you feel comfortable, involves pleasure, either by physiological or psychological. We can conclude, therefore, that comfort is the interaction of these factors together, in a smoothly and enjoyable fashion. Still, it is susceptible to personal experiences and highly subjective, difficult to measure, moving beyond the expectations of users.

2.2 Comfort and Discomfort During the Use of Hand Tools

The frequent use of poorly designed hand tools can cause discomfort during occupational activities, reduces the efficiency and job satisfaction of employees (FELLOWS; FREIVALDS, 1991 apud KUIJT-EVERS et al., 2004).

In a study using different models of pliers, Dempsey et al. (2002) stated that an ergonomic instrument should offer health and safety standards, and acceptable levels of productivity. In this study, the authors assessed measures of discomfort and productivity levels, confirming a relation between increased discomfort and reduced productivity.

In the use of hand tools, comfort has been associated with positive feelings of reliability, security, ease of use and satisfaction, while discomfort is associated with negative feelings such as pain, pressure, hardening and irritation (VINK, 2005 apud KONG et al., 2012).

Several studies have reported that perceived comfort and discomfort during the use of hand tools are influenced by different factors, especially the size (COCHRAN; RILEY, 1986; MIRKA et al., 2009), the shape of the instruments (SHIH; WANG, 1996; PASCHOARELLI et al. 2003; KONG et al. 2007; 2008), the utilized materials (CHANG et al., 1999) weight distribution and center of gravity (BJÖRING; HÄGG, 2000), among others.

Kong et al. (2012) also highlight the lack of knowledge about the hand sectors that contribute to the general comfort and discomfort of the hand.

So comfort is not just an attachment to the design, but a determinant factor in productivity. In this sense, studies involving the assessment of comfort in hand interfaces are still scarce. Methods of analysis still have to be developed, evaluated and improved so we can compare different designs of hand tools of everyday use.

2.3 Methods for Evaluating Perceived Comfort and Discomfort During Manipulation of Hand Tools

Different methods were developed for evaluating perceived comfort/discomfort during manipulation of hand tools. Boyles et al. (2003) evaluated two models of scissors, a standard (STD) and an ergonomic (ETD) (Figure 1), with 44 hairdressers who used both models. They fulfilled a protocol with a hand mapping, indicating the anatomical regions in which they perceived discomfort during the use of such products. It was found that the conventional scissors caused more individual complaints about discomfort.

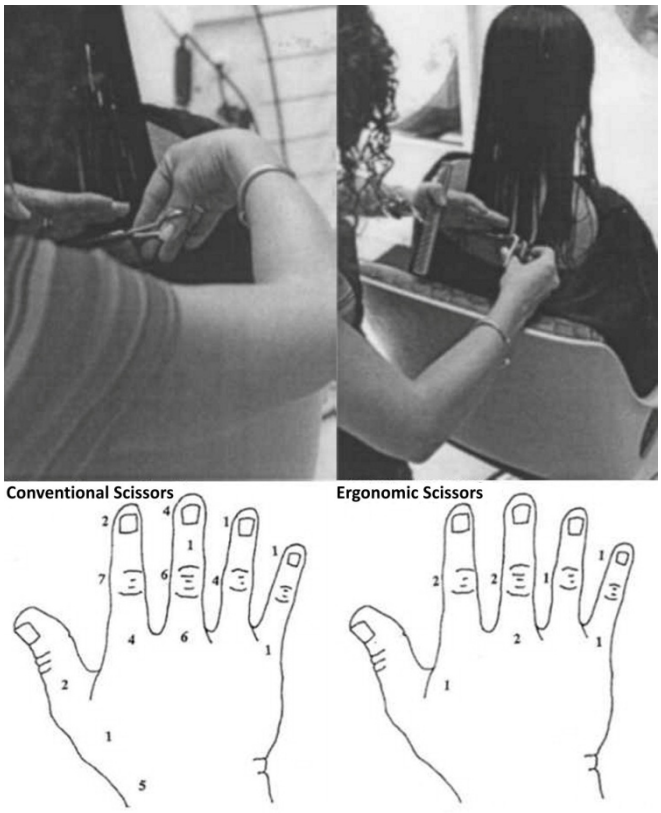

Figure 1. Simulation with two types of scissors, conventional (left) and ergonomic (right) and hand mapping with the number of individuals that perceived discomfort in each hand region. (Source: Boyle et al., 2003, p.201-5).

In another study, Groenesteijn et al. (2004) compared two kind of pliers: two conventional and one multifunctional in both laboratory and field experiments (Figure 2). The palmar surface of the hand was divided into eight regions, to evaluate the intensity of discomfort in the interface areas.

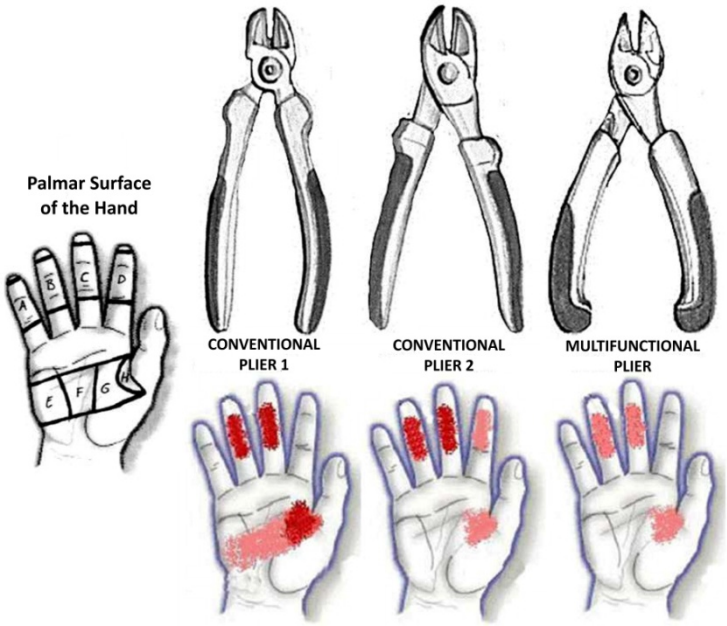

Figure 2. Conventional and multifunctional pliers, as well as the respective hand regions where subjects feel discomfort for each type of plier evaluated. (Adapted from Groenesteijn et al. 2004, p. 486-490).

The results indicated that the two models of conventional pliers exhibited more intense discomfort in comparison with the multifunctional model, which led to a reduction in discomfort, while productivity remained without significant changes.

Kong et al. (2012) comment on the method of division of the hand used in their previous study, in which there were four regions, one for each finger (except the thumb), and four others to the palm of the hand, including part of the thumb, middle and ring fingers. In this sense, the authors assumed that the palm is a dominant area for a general mapping, due its large contact area and intensity of force that can exert, although it may be limited to certain types of instruments and tasks.

These methods for evaluating perceived comfort/discomfort in the use of hand tools may also be used to investigate how different groups of users perceive the same product. These groups can be nested by some of the variables that can influence the perception and the use of hand tools, including: age, gender, dominance, etc.

3. OBJECTIVE

The aim of this study was to analyze the perception of discomfort in the palm of the human hand, for individuals of different ages, in simulated activities of opening packages with screw caps.

4. MATERIAL AND METHODS

This study was cross-sectional and was developed at the Laboratory of Ergonomics and Interfaces (FAAC - UNESP). The methodological procedures were approved by the Research Ethics Committee of Universidade do Sagrado Coração / Bauru - SP (Protocol 121/2009), in agreement with the Resolution 196/96-CNS-MS and the Brazilian regulation "ERG BR 1002", of the "Code of Ethics of Certified Ergonomist" (ABERGO, 2003).

4.1 Subjects

The definition of the sample was based on the theory of statistical inference, and a set of 198 subjects of both genders and equally distributed in age groups: 18 to 29 years old (mean 23.77 years old - SD 3.22); 30 to 55 years old (mean 42.84 years old- SD 7.26); over 55 years old (mean 66.41 years old - SD 9.22).

4.2 Material and Equipments

The following materials were used:

- Informed Consent (IC);
- Recruitment Protocol / Identification (PRI) of the subjects;
- Text marker with a round tip.
- The objects used in this analysis were five models of soft drinks packaging (PET bottles) with a capacity of 2 liters (Figure 3). These products are widely used by the soft drink industry. Brazil is characterized as a large consumer of this product, ranking 3rd in the consumption of this type of beverage in 2006 (GUBOLINO, 2007).

Figure 3. Packaging models used in this study.

- Protocols for evaluating the perception of discomfort in manual interfaces of everyday use, based on Kuijt-Evers et al. (2004), with the representation of the palmar surface for the right and left hands.

4.2.1 Protocol of Perceived Discomfort

In order to detect and analyze the regions where each subject indicated discomfort, the hand was divided into 33 regions, using a map to better understanding and systematizes the data. For each region was assigned a letter (A-Z), the side regions from the distal phalanx for both index and thumb fingers received apostrophe, separating them from their larger areas (Figure 4).

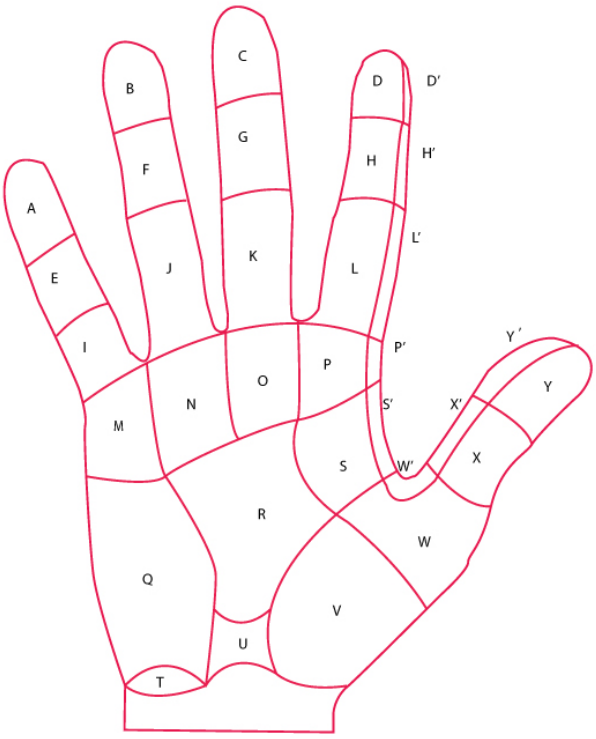

Figure 4. Hand mapping for the right hand with letters indicating the palmar region.

5. PROCEDURES

All procedures took place in the Campus of UNESP - Bauru, or at Retirees and Pensioners Association of Bauru and Region, or at Vila Vicentina - Shelter for Elderly, in Bauru – SP, Brazil.

All subjects were approached individually and invited to participate in the study. After an explanation of goals and procedures to be adopted during the activity, the individual read, filled and signed the Informed Consent and the PRI.

Further, the subjects performed the simulation opening packages using alternate hands, either on the body of the package, and on the cap, according to a specified prehension and then twisting, for both hands (Figure 5).

Figure 5. On the left, one individual performing the procedure. On the right, detail of prehension used in opening soft drinks bottle.

It is important to say that the caps were fixed to a torque transducer in the packaging and therefore the subjects wouldn't be able to open it under any circumstances.

That was necessary since it had the necessity of subject exert his maximum strength, thus understand the discomfort level reached in the activity.

After the simulation, it was offered the Protocol of Perceived Discomfort and, with the marker, the subject marked dots on the regions of the hand where he perceived discomfort (Figure 6).

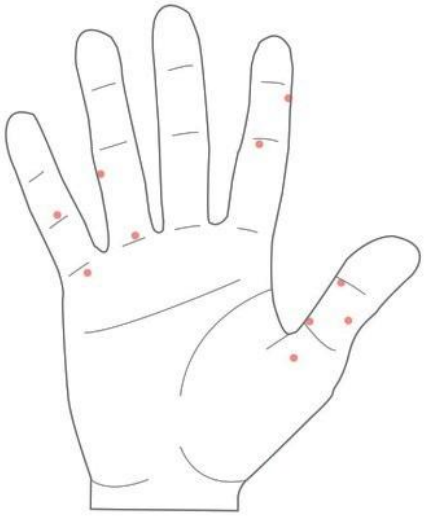

Figure 6. Example of dots marked by a subject.

All protocols were scanned and then overlayed with the hand map with aid of a digital graphic software (Adobe Illustrator CS5©) in order to identify each of the regions. Finally, the data were tabulated and descriptive statistics were applied to understand the results.

6. RESULTS

The results of perceived discomfort in different regions of the palm for the left hand side of young (18-29 years old) as well as the number of individuals who mentioned each region are shown in Figure 7.

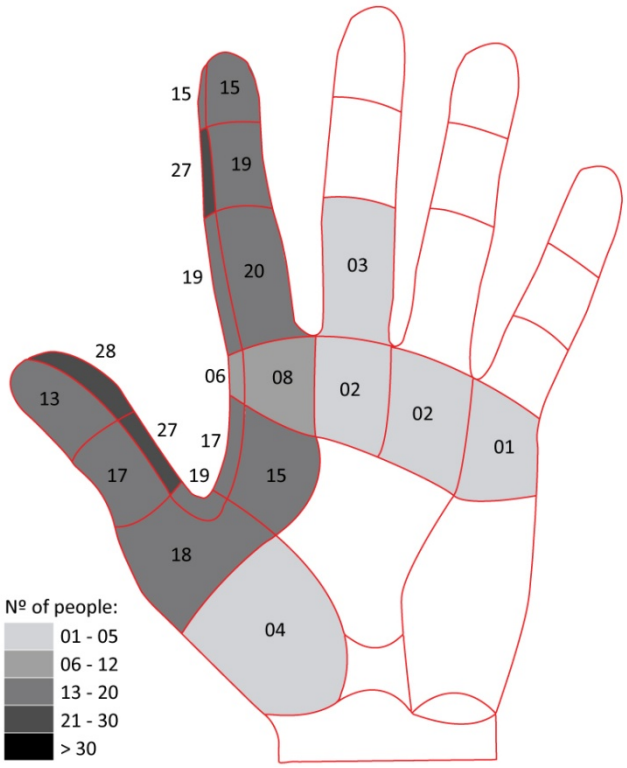

Figure 7. Map of the palmar aspect of the left hand of young individuals, aged 18 - 29 years old.

It was found that 63.63% of the regions presented were pointed out to have some level of discomfort, with the exception of the regions of the medial and distal phalanges of the middle finger, and all phalanges of minimal and ring fingers, as well as in central metacarpal and hypothenar areas. On the other hand, all regions of the index and thumb fingers, also all the metacarpal regions, and thenar region were indicated with some discomfort. The maximum of subjects who indicated the same region was 28 individuals, particularly in the lateral region of the distal phalanx of the thumb (Y').

The results of perceived discomfort in different regions of the palmar surface for the right hand of young subjects (18-29 years old) as well as the number of individuals who mentioned each region can be observed in Figure 8.

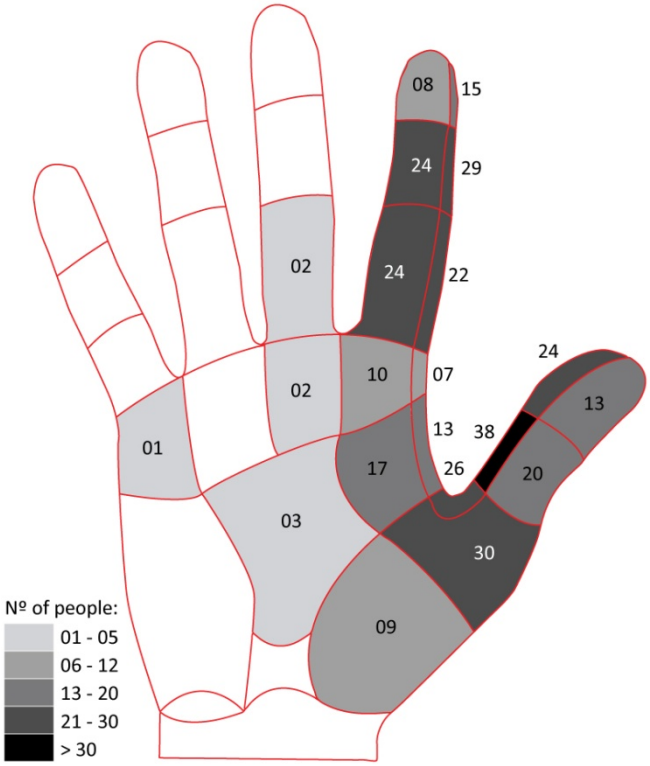

Figure 8. Map of the palmar aspect of the right hand of young individuals, aged 18 - 29 years old.

Also in this case, the percentage of regions pointed with some level of discomfort was 63.63% of the total. Exceptions are the regions of the medial and distal phalanges of the middle finger, and all the phalanges of the fingers and minimum ring and the hypothenar region. The regions with some indication of discomfort were similar to those of the left hand, including the central area of metacarpal region. The maximum of subjects who indicated the same area was 38 individuals, particularly in the region of the lateral face of the proximal phalanx of the thumb.

By analyzing comparatively the left and right hand, one could note that both have similar characteristics of coverage areas, however, the right hand has a higher number of indications (in general). Possibly this is due most young subjects were right-handed (90.9%) and hence the right hand was the one that exerted greater strength, particularly on the cap of the bottle, which may explain the higher level of discomfort in that hand.

The results of perceived discomfort in different regions of the palmar surface for the left hand of adults (30-55 years old) as well as the number of individuals who mentioned each region can be observed in Figure 09.

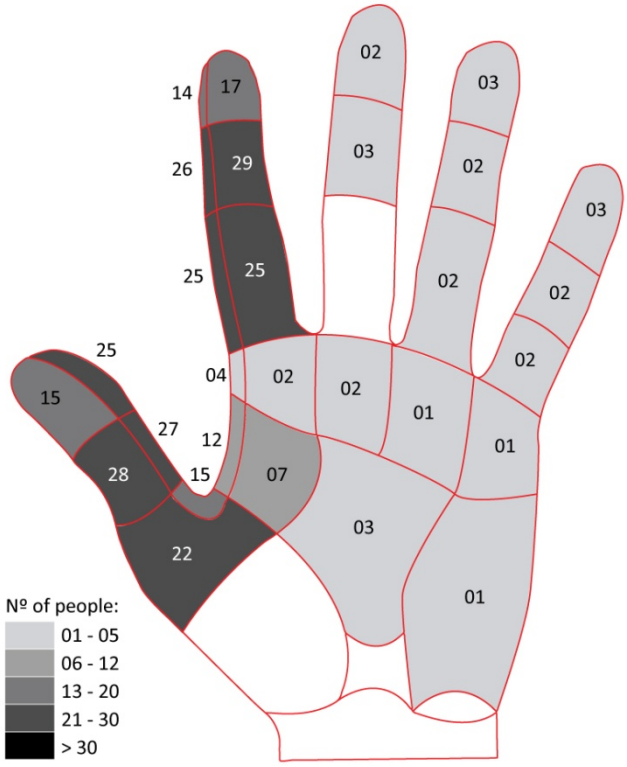

Figure 9. Map of the palmar aspect of the left hand of adult individuals, aged 30 - 55 years old.

In this case, one could note that only 12.90% of the regions do not have any level of discomfort. The regions of the middle, ring, and minimum fingers; the hypothenar; and the central portion of metacarpal region showed little or no indication (at most 03).

In general, the regions with higher numbers of perceived discomfort were the whole palmar face of the index finger and the thumb. The maximum of 29 individuals indicated the same region, particularly in the palmar face of the medial phalanx of the index finger.

In the case of the right hand of adult individuals, the percentage of regions indicated with some level of discomfort was 66.66%. The exceptions are the regions of the distal phalanges of the middle, and ring, and minimum fingers as well as the hypothenar region.

The results of perceived discomfort for the various regions of the palmar face for the right hand of adults (30-55 years old) as well as the number of individuals who mentioned each region can be observed in Figure 10.

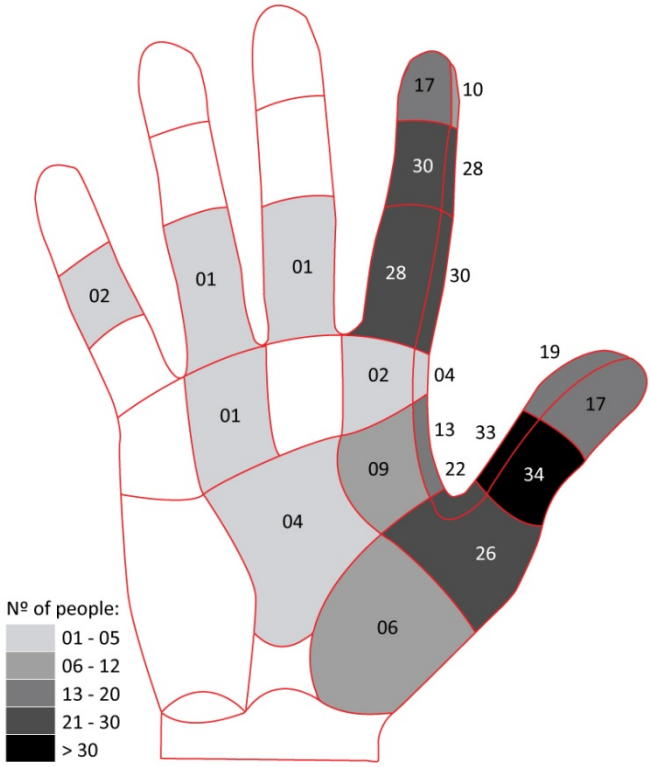

Figure 10. Map of the palmar aspect of the right hand of adult individuals, aged 30 - 55 years old.

The regions with some indication of discomfort were similar for the right hand of the young subjects (18-29 years old). On the other hand, the maximum of subjects who indicated the same region was 34 individuals, particularly in the region of the palmar surface of the proximal phalanx of the thumb.

A comparison between the left and right hands of adults reveals that for the first one there is a greater distribution of points, with a higher concentration in metacarpals, while in the right hand, the concentration occurs similarly for the right and left hands of young individuals.

In the case of the left hand of the elderly, it was noted that all regions were indicated with some level of discomfort. However, compared to the results of adults and young people, the number of individuals is more sparse.

The results of perceived discomfort in different regions of the palmar surface for the right hand of the elderly (> 55 years old) as well as the number of individuals who indicated each region can be observed in Figure 11

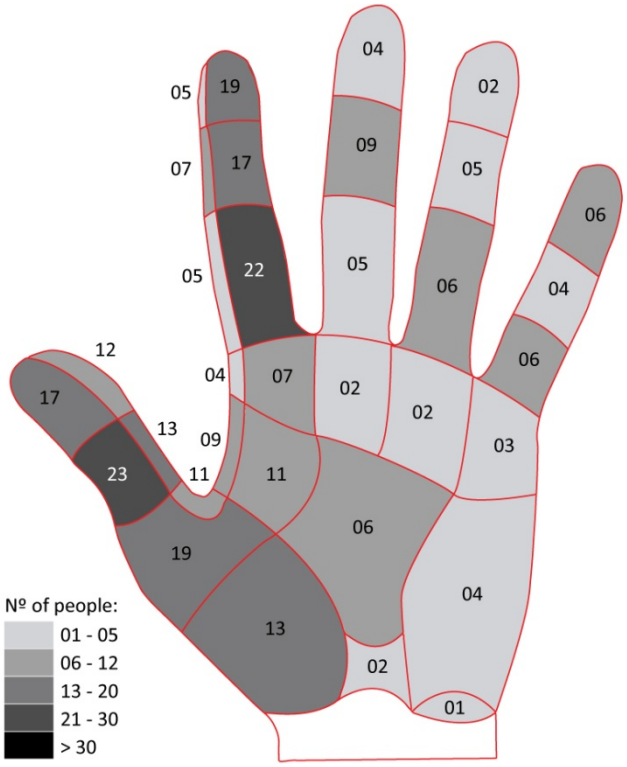

Figure 11. Map of the palmar aspect of the left hand of elderly, aged over 55 years old.

The results of perceived discomfort in different regions of the palmar surface for the right hand of the elderly (> 55 years) as well as the number of individuals who indicated each region can be observed in Figure 12.

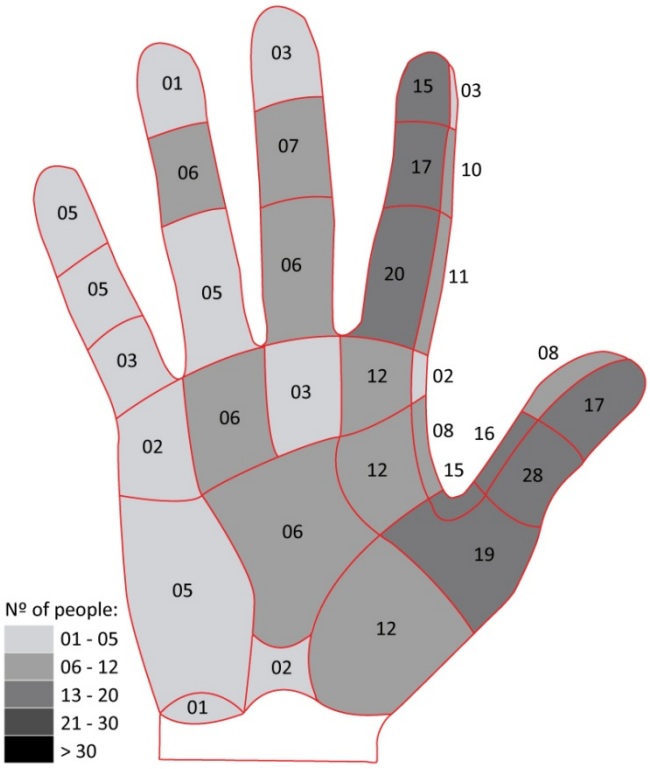

Figure 12. Map of the palmar aspect of the right hand of elderly, aged over 55 years old.

Also the right hand of the elderly, it can be noted that all regions were indicated with some level of discomfort. However, when compared to left hand of such individuals, one can observe a sparse indication, although among the elderly, both hands generally have a sparse distribution when compared to the results of adults and young individuals.

The greater distribution of points observed in elderly individuals can be interpreted from the perspective of biomechanical strategies adopted by them when compared to young and adults. The elderly, due to their loss of muscle strength, end up using the whole hand to reach their goal: opening the package. In this sense, it is expected that more regions of the palmar surface have been employed at the interface, which would cause the perception of discomfort in several regions.

Another aspect that may explain this sparse distribution refers to physiological changes, but in a neurological context. With aging, there are substantial changes in neurological motor patterns in order to compensate deficiencies in specific anatomical structures and the drop in the coordination of movements. In their study, Carus et al. (2006) point out that the elderly applied forces erratically, and the moment of force applied varied according to the group analyzed.

7. DISCUSSION

The influence of age on the biomechanical capabilities is a topic widely studied. However, the perception associated with tasks that require determined effort is still a relatively new topic. The initial hypothesis of this study was that, besides the biomechanical aspects, the perception of discomfort would be affected by the age of the subjects. The results confirm that hypothesis, but only for the group over 55 years when compared to any other, since between the groups of young individuals and adults, there were no significant differences.

As mentioned, older subjects tended to score several regions along the hand, in a less concentrated fashion. Thus, in this study there were situations in which an elderly individual attributed discomfort to a region rarely indicated by others. However that area should not be overlooked since it can indicate certain biomechanical strategies, which in its turn influences the perception of use of the interface.

Finally, it is noteworthy that the usability of hand tools depends on methodologies of evaluation of those interfaces, among which we can highlight the use of protocols based on maps for perceived discomfort of palmar surface of human hand. As for Tichauer and Gage (1977), it is emphasized here that the use of the hand mapping technique is feasible and, based on its results, one can prioritize the distribution of pressure on the use of hand tools.

Thus, it can be argued that the perceived discomfort can be used as a parameter for evaluation of various manual activities of daily life. Other studies involving the intensity level of discomfort are needed and should be developed in order to improve the methodologies of evaluation for hand tools, which are highly valuable for the development of ergonomic design.

8. ACKNOWLEDGEMENTS

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