Based on Upper Extremity Comfort ROM of Ergonomic Methods for Household Products Design

Fan Yang[1], Qianxiang Zhou[1,*], Aiping Yang[2],
Huimin Hu[3], Xin Zhang[3], and Zhongqi Liu[1]

[1] School of Biological Science and Medical Engineering, Beihang University,
Beijing 100029, China,
{buaa_yangfan,zqxg,liuzhongqi}@buaa.edu.cn
[2] School of Electronics and Mechanics, Beijing Union University, Beijing 100020, China
289442397@qq.com
[3] Ergonomics laboratory, China National Institute of Standardization, Beijing 100088, China
{huhm,zhangx}@cnis.gov.cn

Abstract. The structure of product demands a higher level of user performance and involves risk that may possibly negatively impact the user's safety and health. For this reason, the evaluation or design of new products requires extensive knowledge of human interaction, including the operation and comfort of motion. This paper presents a technique for assessment of the upper extremity comfortable ROM. The method is based on new experimental data from perceived discomfort of subjects, and uses digital human modeling (DHM) systems to verify the perceived discomfort rank. 55 participants participated in this experiment. They were required to extract and insert pegs from different panels. We get the comfort ROM of subjects according to subjective comfortable ratings and use digital DHM systems to verify the perceived discomfort rank. In this paper, comfortable motion range of the 50th percentile was shown only. Using DHM systems, we can supply upper limb comfortable motion range of different percentile Chinese people for household products ergonomics design.

Keywords: Comfort ROM, DHM, Product design, Ergonomics.

1 Introduction

In order to design household products, we generally need to consider the interaction between the various parts of the body and the product. Activity of joints of the human body is one of the most important factors [1]. We should consider the position of control components (e.g. panel and shelf) of products whether to fit the range of motion (ROM) of the human body. If within the range of motion, we also need to consider whether the joint angle of activity can make people feel uncomfortable.

Unfit and repetitive postures can increase the risk of musculoskeletal disorders. Therefore, the use of effective quantification of the magnitude for physical exposure

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[*] Corresponding author.

V.G. Duffy (Ed.): DHM 2014, LNCS 8529, pp. 167–173, 2014.
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to poor working postures is important and necessary, if the potential for injury as a result of postures is to be reduced [2]. Since development of the Posturegram, a technique for numerically defining a posture proposed by Priel (1974) [3], various postural classification methods have been developed to identify and quantify postural stress during work. More observation methods have been appliedto the postural classification schemes, such as OWAS (Karhuet al., 1977) [4], RULA (McAtamney and Corlett, 1993) [5], and PATH (Buchholz et al., 1996) [6].

Although the above methods have proved useful for assessment of postural stresses, and contributed to preventing work-related musculoskeletal disorders, they have some disadvantages. First, many of the observational classification schemes are not based on experimental data. In addition, the evaluation criteria was not based on experimental results, but rather relied on the rankings provided by ergonomists and occupational physiotherapists using the biomechanical and muscle function criteria.

A lot of scholars began to made explorations in comfortable ROM by large sample of the experimental data. Genaidy and Karwowski [7] examined the effects of postural dadeviations on perceived joint discomfort ratings assessed under similar working conditions. On the basis of these preliminary findings, Genaidy [8] and Dohyung Kee [9] further developed a ranking system for the stress of non-neutral postures around the joints of the upper extremity. This was based on the ratings of perceived discomfort.

This paper presents a new technique for assessment of the upper extremity comfortable ROM. The method is based on new experimental data from perceived discomfort of subjects, and uses digital human modeling (DHM) systems to verify the perceived discomfort rank.

The DHM is used in ergonomic analyses such as motion capture and simulation, performance measurement, reach-capability check, and visibility check. For example, in the product design, human factors such as positioning, comfort, visibility, reaching, grasping, ingress, and egress can all be evaluated [10].

The important role of the DHM in the design process is in the prototype phase; expensive physical mockups are replaced by virtual prototypes, which can quickly simulate the use of different types of manikins with different percentiles, 5th, 25th, 50th, 95th, etc., male and female. We can change the manikin's data (e.g., stature, weight, leg length, etc.) and build it from similar body dimensions of a real human being.

Meanwhile, digital human models simulating are becoming an effective tool for ergonomics analysis and design. Don B. Chaffin [11, 12] carried out human motion simulation for workplace design. Porter et al. (1998) [13] and Parkinson et al. (2006) [14] studied evaluation and design of driving comfort by DHM systems.

Based on the theory of human-computer interaction, the study of human-products compatibility was carried out. The main goal of the present study was to show human upper limb motion comfortable range and use DHM method for recommended range size of household products' structure.

2 Methods

2.1 Participants

55 participants (28 females, 27 males) participated in this experiment. The age range was between 21 and 70 years old (42±17.1). Participants are all physically active, without any pain or limitation in cubitus, the upper arm, wrist muscle or osteoarticular. Six of them were left handed. Twelve of 55 subjects participated in DHM research.

2.2 Different Heights and Distances Fetching Tasks

Instrument. The functional range of motion (FROM) pegboard (Fig. 1) of BTE-EvalTech assessment system (BTE, Hanove, Germany), operating at a sample frequency of 100Hz.

Experimental Protocol. The subjects were required to extract pegs from panel 2, and insert pegs to panel 3. Test was set up six with distances (based on arm length, AL) and 7 heights (based on shoulder height, SH), as shown in table 1. Participants repeated operation for 1 min, and then gave subjective comfortable ratings (9 scale). Subjects' operation process in different heights was shown in Fig 2.

Table 1. Six distances and seven heights

	1	2	3	4	5	6	7
Distance	1/4 AL	2/4 AL	3/4 AL	4/4 AL	5/4 AL	6/4 AL	/
Height	SH+45cm	SH+30cm	SH+15cm	SH	SH-15cm	SH-30cm	SH-45cm

Fig. 1. FROM Pegboard Attributes and Peg

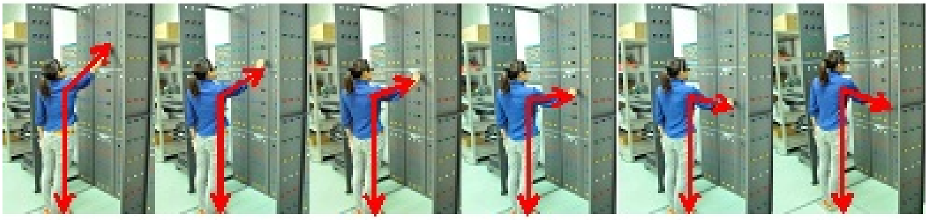

Fig. 2. Subjects' operation process in different heights

2.3 Fetching Tasks of Different Upper Limb Joint Angle

Instrument. Motion capture system (Vicon Motion Systems Ltd. UK) recorded users' actions data. Static Strength Prediction tool of Jack 6.0 (Siemens PLM Software, Germany) [15] analyzed satisfaction of operation action (Fig. 3).

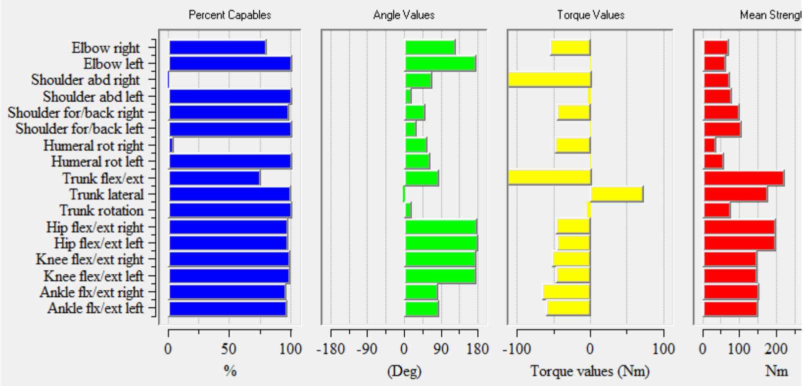

Fig. 3. Static Strength Prediction tool of JACK 6.0

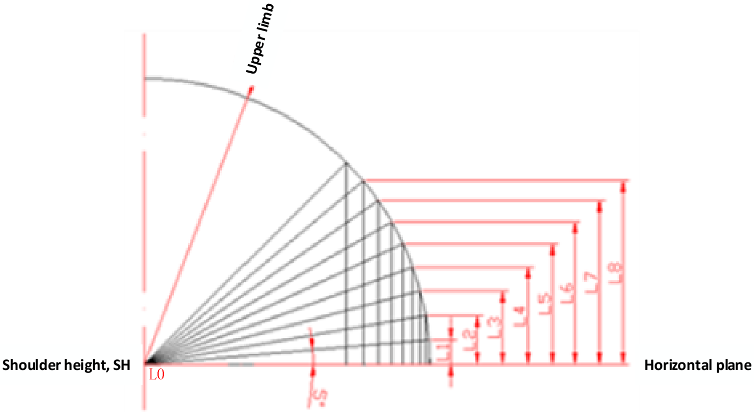

Fig. 4. Test heights

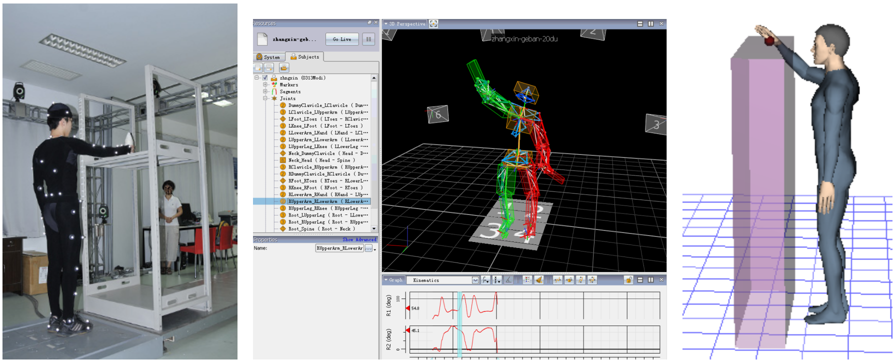

Fig. 5. Experimental schematic diagram

Experimental Protocol. The subjects were required to pick and place bottle (1-2kg) three times in different heights. The test heights was based on the angle of the upper arm in the horizontal plane, 5° intervals increasing (Fig.4). Experimental schematic diagram is shown in Fig.5.

3 Results

3.1 Upper Limb Comfortable Motion Range

By statistical analysis of subjective score after 1 min fetching tasks, the 9 subjective ratings were divided into three grades, from 1-3 (easy), 4-6 (moderate) to 7-9 (hard).

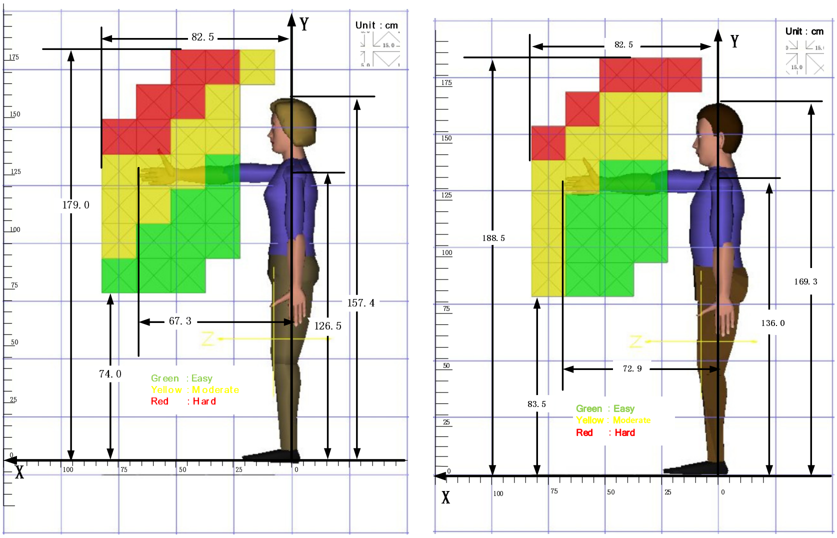

Fig. 6. Upper limb comfortable motion range of P_{50} female and male

Base on Chinese population P_{50} stature (Anthropometric data from the China National Institute of Standardization, 2009) and experimental data, we got the recommended figure of upper limb comfortable motion range of Chinese man and women, as shown in Fig.6.

3.2 DHM Results

The results showed that the participants felt more comfort, when they pick and place bottle in ≤L3 height. By Jack 6.0 ergonomics analysis, when the height is equal or greater than L3, the main body joints and segmental motion satisfaction showed a trend of decline, as shown in Fig.7.

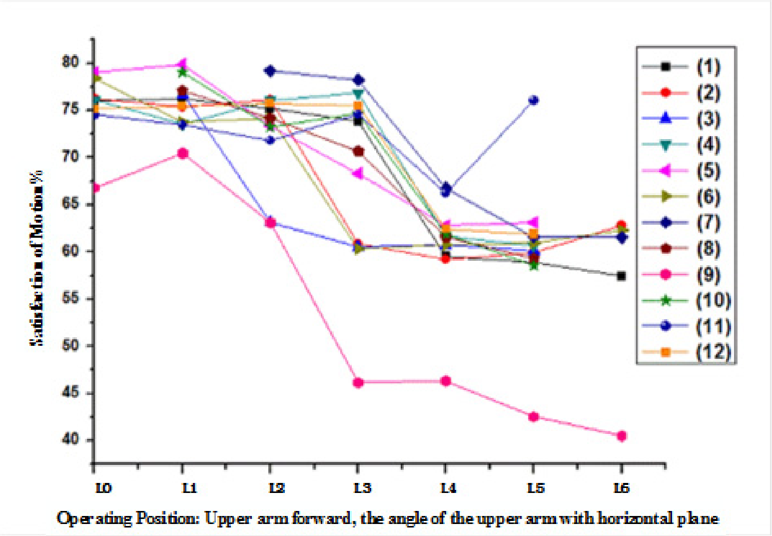

Fig. 7. Satisfaction curve of Fetching tasks of different upper limb joint angle

4 Discussion and Conclusion

The aim of the current study was to provide human upper limb comfortable motion range, which can guide human-computer interaction design of household products structure (e.g. panel, shelf, etc.).

When Manufacturing Process, designers and manufacturer can find reference data base on recommended figure of upper limb comfortable motion range of Chinese man and women, designers should household products. In this paper, comfortable motion range of the 50th percentile was shown only. Using DHM systems, we can supply upper limb comfortable motion range of different percentile Chinese people.

The results strongly indicate that DHM is a very effective method to assess human-machine matching of household products. DHM can also guide products ergonomics design for the recommended and limit value of top shelf height.

Acknowledgments. This work is supported by the Technology Foundation of National Science (A0920132003), the Natural Science Foundation of China (31170895), the opening foundation of the Science and Technology on Human Factors Engineering Laboratory, Chinese Astronaut Research and Training Center (HF2013-K-06), and the basic scientific research project of China National Institute of Standardization (522013Y-3055).

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