Use of soft tissue properties for ergonomic product design

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Abstract. In order to achieve better comfort and fit for designed products it is important to understand the product and user interface and to analyze the interaction at the region of contact. Study of biomechanical properties of soft tissue can provide a good insight of this interface between user and the product. Biomechanical properties can help the designers in material selection which can improve the comfort and fit and help in serving the purpose of the designed product. A sample study soft tissue thickness of human head and face was conducted using an ultrasound indentation device at selected locations. Results showed the variation in soft tissue thickness levels, which was further used to discuss the role of soft tissue properties in the field of ergonomic product design.

Keywords: Biomechanical properties, soft tissues, comfort, fit, ergonomic product design

1 Introduction

Traditional anthropometric measurements acquired from tapes [1-2], scales, calipers [3-4] have been used by the product designers in past for designing products. However, due to the complex contour and surface geometry of the body surfaces it is very difficult to acquire accurate anthropometric measurements using traditional techniques [5]. Also measurements acquired from these conventional techniques are less reliable and have human errors involved in them [6-7]. With the advancement of 3D scanning and 3D modelling techniques it has been possible to acquire highly accurate and precise 3D anthropometric data [8] which can be used for designing of products. Many researchers have used 3D models developed from multiple images [9-10], medical imaging data like Computerized Tomography (CT) [11] and Magnetic Resonance Imaging (MRI) [12] or by using various 3D scanning techniques for acquiring 3D anthropometric data [13-14]. These 3D models have been further studied to understand the shape variance [15-16] of the surface morphology of the region of interest in order to develop products and to understand their sizing for a wider range of target population.

However, this 3D anthropometric data can only provide the surface dimensions for the designing of product but it fails to provide any valuable information regarding the actual interface between the product and the related body surface, which can be influential factor in understanding user comfort and fit.

2 Soft tissues properties and product design

Soft tissue properties vary depending on various parameters like the location of the tissue, age of the person and existence of any pathophysiological condition. In past may researchers have used this data in studying different medical conditions like edema [17], cancerous tissue [18], ulcers [19] muscle thickness changes [20] and corneal data [21].

Safety devices, wearable devices, medical devices and textile products are designed to carry out functions like protection, information transmission and for improving the aesthetics appearance. Some of these products cover the related body part partially or completely and in order for its proper functioning, they need to have a close fit, which leads to certain amount of pressure to the body. If the pressure is too high, it can lead to discomfort of pain. Also if the device is supposed to be worn for a continuous period for a long time duration even a small amount of pressure can lead to discomfort. Researchers have shown that continuous application of force in a specific region can lead to occurrence of marks on the skin, rashes, skin irritation or ulcers [22].

Researches have also been conducted studies to evaluate the impact of designed products like seats of wheelchairs [23] and bras [24] on the soft tissue of the contact region. At the same time researchers tried to use this data for optimizing and designing better comfort based products like prosthetics [25], undergarments [26] and footwear [27]. But still the application of soft tissue data in the field of ergonomic product designing has not widely been seen and there is a need of more exploration in this field of research. Xiong et al. [28] studied the effect of pressure on soft tissues and deduced a range of Pressure Discomfort Threshold and Pressure Pain Threshold for human foot. The pressure sensitivity map developed from such research can provide a wide range of useful information for ergonomic product design.

User experience as comfort and fit are considered to be the most important factors while buying products [29]. There is a need of studying the biomechanical properties of soft tissues in relation with the product interface. This paper tries to explore how these biomechanical properties of soft tissues can help in improving comfort and fit and lead to designing of better ergonomic products.

3 Experimental Study

In order to study the soft tissue thickness and understand how it varies in different regions, an experimental study was performed to collect soft tissue thickness data of head and face.

3.1 Participant

Ten Chinese adults (three males and seven females) participated in the study. They were provided information and explained the experimental protocol. Written consents were obtained from them before starting the experiment. Participants with no facial deformities or abnormalities were selected for the study.

3.2 Equipment

Artec Eva 3D scanner was used to capture 3D surface shape of head and face of the participants. Fourteen landmarks were selected on head and face corresponding to areas in contact with products related to head and face for the soft tissue study as shown in Fig.1. An ultrasound indentation system as shown in Fig.2. was used to measure soft tissue thickness at the selected landmarks. Ultrasound gel was used as the coupling medium.

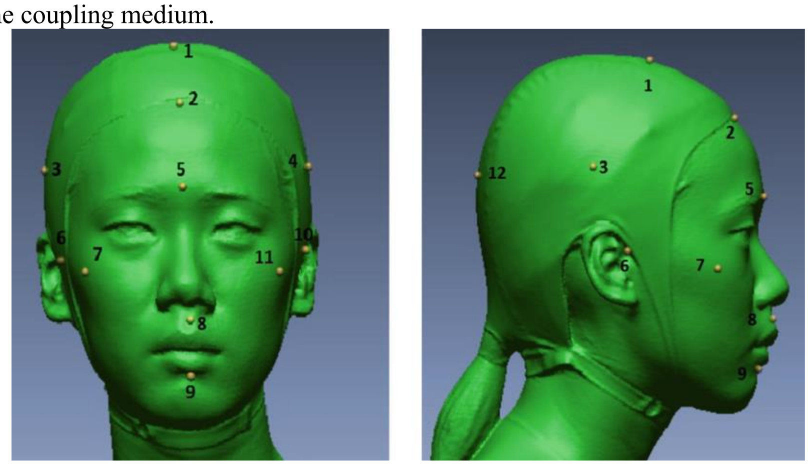

Fig. 1. Position of landmarks selected for the study in (a) front view and (b) side view

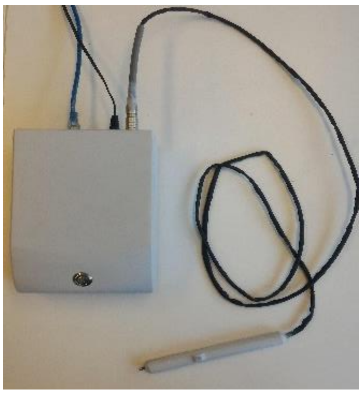

Fig.2. Ultrasound indentation device

3.3 Procedure

3D scanning was performed first. The participants were made to wear a cap for 3D scanning in order to compress the hair and get head data. The cap used while scanning was removed during the experiment for measuring soft tissue thickness. The participants were informed about the experimental protocol and then trained to understand the ultrasound indentation device for five minutes. Ultrasound echo signals were recorded at all the individual landmarks in order to evaluate the soft tissue thickness.

3.4 Results

The ultrasound data acquired during the study was post processed using the software developed in Microsoft C++ for the ultrasound indentation device. The time of flight of the ultrasound wave was used to measure soft tissue thickness at different landmarks. The mean values of soft tissue thickness for all the 10 participants are shown in Table 1.

Table 1. Mean values soft tissue thickness for ten participants at selected landmarks

Landmark	Mean soft tissue thickness (mm)
1	5.76
2	4.66
3	5.04
4	5.18
5	4.64
6	2.75
7	6.24
8	7.03
9	5.30
10	2.81
11	6.31
12	5.98

4 Conclusion and Discussion

Current techniques used for product design tend to focus on using 3D anthropometric data which provides valuable information about the anatomical contour and surface measurements. However, the point of interaction of the product and the user, which can be influential in understanding the user comfort and fit parameters is not explored. With the use of soft tissue thickness data, further biomechanical properties can be analysed which can help in understanding this relation more prominently and can help in designing of better ergonomic product.

The results acquired in the experiment help us understand the variation in the soft tissue thickness in different areas of head and face. The skull region (landmarks 1, 2, 3, 4, 12) and the area near the ears (landmark 6 and 10) have a thinner soft tissue layer. At the facial region (landmarks 7 and 11) the thickness is higher as compared to areas near the skull region. The philtrum region (landmark 8) is the thickest region compared to all the other selected landmarks. The area with thinner soft tissue thickness like the skull or region near the ears would be less deformable as compared to facial region. Designer can hence use this soft tissue thickness values to evaluate the potential product material, size and weight and the amount of force it should create on the soft tissue surface so that the deformation is not too large and does not lead to discomfort or pain.

Products with better effectiveness and efficiency can be designed using the above collected soft tissue thickness data. Further calculation of soft tissue deformation limits and Young's modulus can help in deciding the material requirement for different regions in order to make sure the corresponding regions are compensated while designing of protective devices. Soft tissue deformation data can help in understanding of fit, which is very important for designing of wearable devices, garment manufacturing and also for designing of products used for protection purpose which need a close fit.

This study provides a good insight of how the soft tissue thickness varies on the head and face in order to help the designers to design ergonomic products with better comfort and good fit. A better understanding of the role of biomechanical properties of soft tissue like Young's Modulus and maximum deformation at areas of interest is needed in further studies.

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