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Research on Ease of Protective Clothing Based on Three-dimensional Human Body Scanning*

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Abstract

The experiment recruited 18 young healthy males as the subjects. Four postures with a limited range of movement during outdoor activity were captured by the mean of a 3D scanning system. The grids of rows and columns were made on the skin surface before scanning. The grids' distance in terms of skin stretch was measured between the static posture and the four experimental postures. A paired sample T-test was conducted to test that the variation in skin length change for each part of the body. Among them, there were more significant changes in the horizontal direction for the small shoulder width, back width, bust, hip, thigh circumference, knee circumference, big arm circumference and elbow circumference. In the vertical direction, except for the inner lines of the legs, all measured sizes changed significantly. Through further analysis, it was found that the back length and the back width were relatively active factors that affected the entire upper limb movement. Finally, according to the changes in the measured sizes, it is necessary to explore protective clothing in terms of ease.

Keywords: Protective Clothing; 3D Scanning System; Skin Stretch; Ease Design

1 Introduction

A special type of clothing, protective clothing, is highly important in the field of life-saving and safety protection. But, in addition to comfort, the mobility of protective clothing should meet the wearer's need. However, there are some problems in the structure and size of clothing [1], which affect the wearing comfort, but also the safety of the wearer. Therefore, it is necessary to study the ease of protective clothing.

Current research emphasizes the structure design of the protective clothing. Xiang-Hui Zhang [2] proposed the method of "concurrent engineering" to design the structure of protective clothing. Huck [3] studied the crotch of one-piece protective clothing. He added ease at the waist to satisfy

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the minimum amount during squatting. Mullet [4] found that the structure of a protective suit influences the movement function of the human body, but also the clothing thermal comfort. But there is no research on the overall structure of protective clothing [5-12]. This paper used 3D scanning [13] technology to discuss the skin stretching of different postures and provided some suggestions for ease design [14] in terms of protective clothing.

2 Experiment

2.1 Experimental Subjects

The subjects of the experiment were 18 young healthy males aged 20-25 years, with a height of 170-180 cm and a BMI of 18 to 25.

Table 1: Basic information on experimental subjects

Subject Number	Height (cm)	Weight (kg)	BMI (kg/m^2)	Bust (cm)	Waist (cm)	Hip (cm)
No. 1	173.4	63.3	20.1	90.2	73.4	92.2
No. 2	179.7	60.2	19.9	91.9	70.1	90.0
No. 3	175.0	65.4	21.4	98.4	73.5	90.6
No. 4	175.1	68.3	22.3	90.9	77.2	97.0
No. 5	177.8	57.5	19.6	85.4	70.2	87.3
No. 6	171.5	55.1	18.7	87.0	71.7	90.2
No. 7	175.1	60.9	19.0	91.3	73.9	93.5
No. 8	174.8	62.6	20.3	96.8	76.0	93.1
No. 9	172.8	71.1	22.0	96.9	80.1	98.4
No. 10	177.1	62.4	20.8	86.8	73.5	90.6
No. 11	174.0	63.9	20.8	89.5	75.3	89.6
No. 12	179.1	65.6	21.4	96.1	77.2	101.0
No. 13	177.3	63.7	21.3	92.5	77.1	96.1
No. 14	177.0	67.2	22.9	93.7	80.6	93.4
No. 15	175.8	68.0	23.2	89.1	78.9	98.8
No. 16	171.2	64.6	20.6	97.2	74.4	92.7
No. 17	171.2	66.2	20.9	93.3	79.6	93.7
No. 18	171.3	67.1	22.9	94.9	75.3	94.0
Mean.	174.9	64.1	21.0	92.3	75.4	93.5
St. dev.	2.7	3.9	1.3	3.9	3.2	3.6

2.2 Experimental Environment

The experiment was carried out in the Ergonomics Centre of the Beijing Institute of Fashion Technology. The laboratory temperature was controlled at $22 \pm 2.5\,^{\circ}\mathrm{C}$, and relative the humidity was controlled at 50±2.5%. Each subject needed to put on lab pants and adapt to the laboratory