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Testing methods of pressure distribution of bra cups on breasts soft tissue

B Musilova[1], R Nemcokova[2] and M Svoboda[3]

[1,2]Technical University of Liberec, Faculty of Textile Engineering, Department of Clothing Technology, Studentská 1402/2, 461 17, Liberec, Czech Republic
[3]Technical University of Liberec, Faculty of Mechatronics, Informatics and Interdisciplinary Studies, Institute of Mechatronics and Computer Engineering Studentská 1402/2, 461 17, Liberec, Czech Republic

E-mail: blazena.musilova@tul.cz

Abstract. Objective of this study is to evaluate testing methods of pressure distribution of bra cups on breasts soft tissue, the system which do not affect the space between the wearer's body surface and bra cups and thus do not influence the geometry of the measured body surface and thus investigate the functional performance of brassieres. Two measuring systems were used for the pressure comfort evaluating: 1) The pressure distribution of a wearing bra during 20 minutes on women's breasts has been directly measured using pressure sensor, a dielectricum which is elastic polyurethane foam bra cups. Twelve points were measured in bra cups. 2) Simultaneously the change of temperature in the same points bra was tested with the help of noncontact system the thermal imager. The results indicate that both of those systems can identify different pressure distribution at different points. The same size of bra designing features bra cups made from the same material and which is define by the help of same standardised body dimensions (bust and underbust) can cause different value of a compression on different shape of a woman´s breast soft tissue.

1. Introduction

Most brassieres are designed to beautify the figure of a woman by compression on human soft tissue to the required shapes of breasts. The evaluation of clothing pressure using direct or indirect methods is important to investigate the functional performance of brassieres. In direct sensing methods, the clothing pressure is measured directly using sensors or gauges while the clothing pressure is derived from measurements of independent variables [1]. Indirect methods are favoured in some circumstances as they are suitable for measuring the pressure ranges normally exerted by garments during wear. Factors like the changes in human body temperature depending on the uneven distribution of pressure on the sensing region can be measured as well as. The characteristics of bra include its cup shape being skin-tight with the breasts, its pattern making and production techniques as complicated, and usage of many materials. All of these characteristics bring on many problems of wearing bras and its research value is the highest in daily clothes [2]. As a new way of measuring can introduce method of measuring clamping effects of clothes on the surface of human body at points of mutual contact [3].We must also consider fit of bra, therefore we should also deal with matching of appropriate body measurements as input pattern construction parameters for a particular size of bra as well as being interested in the results of anthropometric survey of target female population [4, 5].

Range of bra cup pressure we can also evaluate and visualize of bra models using 3D computer programme to show in the current display of the pressure, strain, compression, tension and the elongation related to the selected material of bra [6]. Thermography can be a very useful technique in different applications of textile research as indicated in review of literature by Banerjee et.al. Many researchers in the field of application in comfort of clothing have investigated thermal comfort and change in temperature due to interaction of human body with clothing. Ishikura studied the effect of skin-reflex of clothing pressure upon skin temperature by using a thermography. In this study, the physiological effects of the compression of the lower-limbs upon the changes in skin temperature were investigated on subjects wearing different kinds of elastic support knitwear and the skin temperature was measured using thermography [7]. The skin temperatures measured by infrared thermography are used for various studies. Values of mean skin temperature were computed by 18 different techniques were compared with the mean of skin temperatures measured by infrared thermography. In conclusion, this study indicates that an accurate estimation of mean skin temperatures in a resting nude subject is dependent on the location and number of skin temperature measurements [8]. The temperature (ie, radiation) measured by the infrared camera does not solely depend on the temperature of the skin surface but is also a function of the radiation emissivity of the skin, which is ≈ 0.98 for human skin.

2. Subjects and bra type

Commercial bra of the size 75E of the examined effective design features has been tested on two females with different shape of a human soft tissue. Two measured subjects were healthy women of the same value of bust and underbust body dimension, but with a different shape type of breasts. Subject 1 aged 55 years of moderate sagging shape of breast. Subject 2 aged of 23 years of normal shape of breasts. The commercial bra of one brand was used that the size of it is defined with the help of standardised body dimensions: Bust = 96cm, Underbust = 75cm. The style of bra and points of test are shown in Figure 1.

a) b)

Figure 1. a) Contact points on human body; b) Corresponding positions of the sensors.

3. Experimental methods

The pressure distribution of a wearing bra during 20 minutes on women's breasts has been directly measured using pressure sensor. Twelve points were measured in bra cups, see Figure 1. Two methods and systems are used. The first is direct sensing method using capacity sensor and its dielectric material is the elastic polyurethane foam of bra cups. The second is indirect sensing method using the thermography system FLIR SC6540. Was measured the difference between the temperature before and after 20 minutes wearing bra. Both of those systems do not affect the space between the wearer's soft tissue and bra cups. Thus geometry of a soft tissue during measurement is not changed.

3.1. Principle of measurement pressure

Twelve capacity sensors for compression measuring were used. For the first time it was used method of measuring clamping effects of clothes on the surface of human body at points of mutual contact [3].

3.2. Measurement by using a thermography

The measurement was carried out in an air-conditioned room under constant conditions at a relative humidity of 65 % and the temperature of 21 °C. The experiment took place in a measurement cabin with dimensions of 130 × 100 × 155 cm. This cabin was chosen because there was a requirement to perform the measurement in a dark chamber, in order to eliminate external environment influences and to ensure stable conditions. Change of temperature on the body was tested with the help of noncontact system the thermal imager. On the skin were glued labels for accurate reading of temperature. The location of labels corresponds to position of the sensors on the bra. The position of labels is shown in Figure 2, 3. Measured object was wearing bra for 20 minutes and then was relaxing. The aim was to determine whether the applied pressure increases regional surface temperatures of the breast.

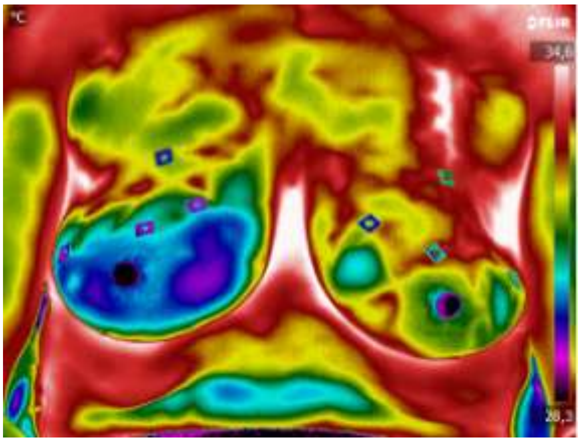

Figure 2. The position of labels on body of women 1 (Subject 1).

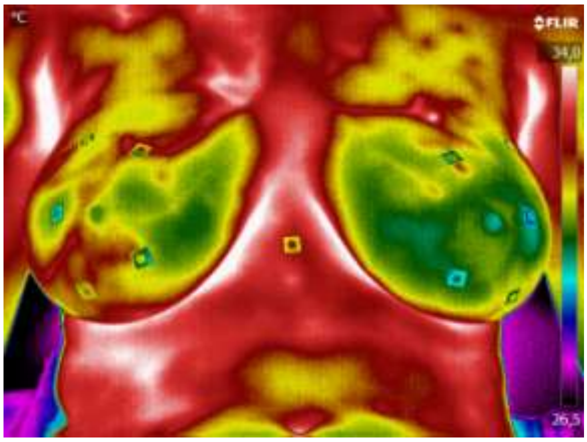

Figure 3. The position of labels on body of women 2 (Subject 2).

4. Results and discussion

The aim was to determine whether a pressure distribution of bra cups on breasts soft tissue increases temperatures of the breast surface in specific points during 20 minutes wearing the bra. In the Table 1 there are the results which represent an average value of 12 measurements at 12 points on the surface of the breast.

Table 1. Pressure and temperature changing. Temperature (Temper.) means the difference between the temperature before and after 20 minutes wearing bra.

Point on body right side	Subject 1 Temper. (^{0}C)	Subject 1 Pressure (kPa)	Subject 2 Temper. (^{0}C)	Subject 2 Pressure (kPa)	Point on body left side	Subject 1 Temper. (^{0}C)	Subject 1 Pressure (kPa)	Subject 2 Temper. (^{0}C)	Subject 2 Pressure (kPa)
R0	0.3	0.7	0.8	1.6	**L0**	-0.1	0.7	0.7	1.5
R1	0.7	0.3	0.7	0.4	**L1**	0.8	0.3	0.5	0.3
R2	0.4	0.5	0.8	1.4	**L2**	-0.1	0.5	0.7	1.4
R3	0.4	0.3	0.9	0.2	**L3**	0.6	0.6	0.7	0.3
R4	0.4	0.3	0.4	1.4	**L4**	0.5	0.3	0.3	1.2
R5	0.9	0.5	0.7	0.9	**L5**	0.7	0.4	0.9	0.9

Figure 4, 5 shows a graphical representation of the measurement results. The points are arranged in the graph symmetrically (right versus left side of breast).

The value of the detected pressure and temperature indicate a asymmetry in the right and the left side of breast shape of the Subject 1 – moderate sagging shape of breasts, see Figure 4,5. Distribution of pressure is symmetrical on the right versus left side of breast of the Subject 2 – normal shape of breasts. We can see a visible difference between the normal and moderate sagging shape of breasts although there are of the same size.

The identified pressure range is from 0.2 kPa to 1.6 kPa. In the same point the recorded pressure of Subject 1 was 0.7 kPa and 1.6 kPa in case of Subject 2, see Figure 4.

There are recorded a different temperature changes around the measured points in the bottom part of breast and in the upper part bust points, see Figure 5. Subject 2 (normal shape of breast) shows greater change in temperature in the points in the bottom part than in the upper part bust points. The distribution is almost symmetrical. Temperature results of Subject 1 are disorderly. The difference between the temperature before and after 20 minutes wearing bra was varied from -0.2 ^{0}C to 0.9 ^{0}C. Measurement was done in a room with low temperature, it is recommended to raise the temperature, thereby ensuring better comfort during measurement.

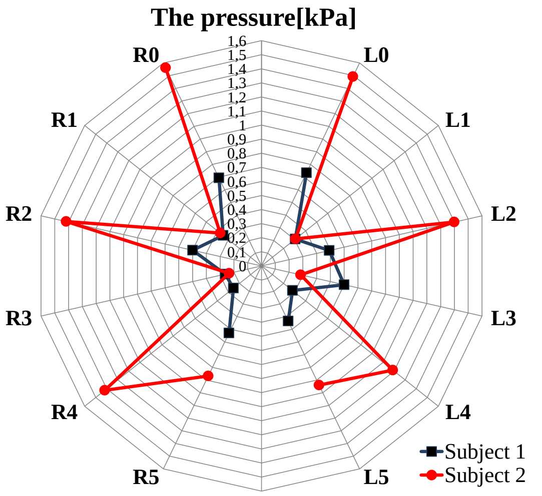

Figure 4. The pressure (kPa) - right (R) and left (L) side of breast - symmetrical view of points.

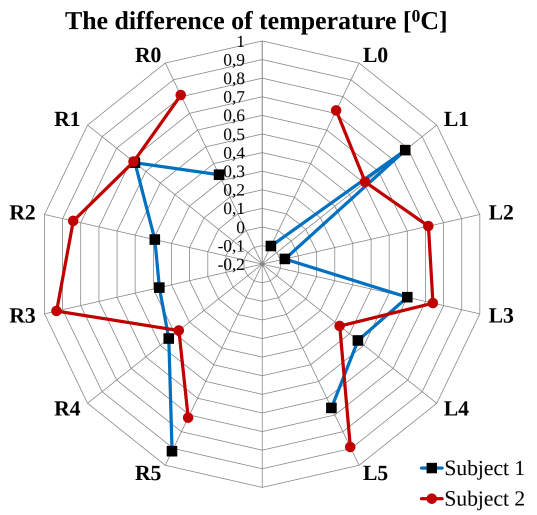

Figure 5. The difference of temperature (^{0}C) - right (R) and left (L) side of breast - symmetrical view of points.

5. Conclusion

The first, the direct sensing method is more objective than the second one. The value of the pressure distribution of bra cups on breasts soft tissue depends on a shape type of breast.

The results indicate that both of those systems can identify different pressure distribution at different points. The same size of bra designing features bra cups made from the same material and which is define by the help of same standardised body dimensions (bust and underbust) can cause different value of a compression on different shape of a woman´s breast soft tissue.

Correlation between the applied pressure and temperature change was to find out as well as for Subject 2. These results relate to the fullness of the breast, the same shape of the right and left breast and normal breast shape.

Infrared camera is good as non-contact tool in this experiment but environmental temperature can be critical in the formation of the skin temperature. We have to try to create a neutral environment. It means we must to procure optimal conditions which do not stimulate the self-regulating mechanisms of human organism. Neutral environment for the nude human body (in the rest position) is 30 °C and the air flow is less than $1ms^{-1}$.

Next research activities can be aimed to use those methods for evaluation a pressure distribution on the other parts on human body where we can propose bigger value of the compression.

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