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Gradient of clothing pressure for comfortable support wear

Abstract

We wear clothes that may restrict our movement, but at that time, clothing pressure will occur between our body surface and the clothes. The advantages and disadvantages of this clothing pressure were introduced and described the points to keep in mind to use it well for producing support wear. In addition, the merits and demerits of clothing pressure measuring methods from the past to the present are described, and the adequacy of current methods of use and future trends are also described. In order to make comfortable support wear using these measuring methods, it is important also to know the various functions of the human somatosensory and autonomic nervous system. Using this information, the support wear currently produced was also introduced.

Keywords: clothing pressure, direct and indirect method, support wear, respiratory movement, sensory evaluation, general medical device, swelling, body fat burning

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Introduction

What is clothing pressure? In daily life, our body movements are restricted by the clothes worn, and at that time, clothing pressure is generated between the body surface and the clothes. Clothing pressure is the component of force[1] in the direction normal to the stretching direction of stretched clothes and is the force that presses the body surface in the vertical direction. Clothing pressure experienced in daily life can be roughly classified into the following three conditions. When wearing a thick coat or outerwear in winter, it is the clothing pressure that occurs on the shoulders and waist due to the weight of the clothing. In addition, it is generated by the circumferential stress that holds the clothes such as skirts and pants belts on a part of the body so that they do not slide down. For example, even when wearing a belt, there is almost no clothing pressure in the standing position, but when the body bends down to pick up some objects, the circumference of the abdomen increases. It also occurs when a stretch material that has been stretched, such as a body-shaping foundation or swimsuit, tries to return to its original shape. This is the kind of clothing pressure that we experience very closely in our daily lives.[2] The strength of the clothing pressure is related not only to comfort but also to our health. Therefore, to help those who study clothing pressure in the future, the following explanation is provided.

Units of pressure include Pa, g/cm^2, and mmHg. In the past, g/cm^2 and mmHg were often used, but now "Pa" is used as the SI unit. "hPa" is convenient for displaying clothing pressure. Incidentally, 1hPa = 1.02g/cm^2 = 0.75mmHg.

Measuring method for clothing pressure[3]

Since the 1960s, clothing pressure has attracted worldwide attention as a means of expressing comfort. In other words, it is the "quantification of tightness sensation". The measuring methods for clothing pressure are roughly divided into indirect methods and direct methods. The former is a method proposed by Kirk et al., who applied Laplace's membrane equilibrium theory to cloth, to determine the clothing pressure from the tension of the cloth and the curvature radius of the measurement position.[4] The latter used the flat rubber ball method[5] and the semiconductor strain gauge method[6] in the past, but in recent years, the direct method, in which an airbag or water bag is directly inserted between the human body and the clothing, is the mainstream method for measurement. Both methods can examine the clothing pressure obtained by sensory evaluation while wearing, but the measuring equipment is expensive and not suitable for general use. In addition, the airbag method[7] is difficult to measure the pressure on the concave surface of the ankle when wearing socks because it is necessary to enclose compressed air so that the inner membrane of the pressure-receiving part of the airbag does not contact each other. On the other hand, the receiving part of water bag method[8] is soft and can handle various unevenness. Still, it is easy to tear because of the membrane thickness is 20 micrometer, so it is necessary to replace the pressure-receiving part. In addition, if many pressure-receiving parts are inserted between the skin and clothes, artifacts such as disturbance of wearing and weight of wired cables will be added, so both methods are unsuitable for simultaneous multi-point measurement.[9]

Recently, a method for simulating the clothing pressure distribution in the wearing condition has been studied. By three-dimensional analysis of the deformation of the circle grid printed on the surface of the clothing when worn, the clothing pressure is calculated by the indirect method[4] from the tension and curvature radius of the cloth. It has been reported that the obtained pressure distribution agrees well with the results of the direct method using an airbag.[10] A method has also been devised to calculate the relationship between the clothing pressure generated when an avatar wears various clothes and moves, but it is still a long way from being put to practical use. It will be a great method to include an avatar if he has the somatosensory presence at the proper position of the body. It has high hopes for future development.

To develop a product with a comfortable feeling of pressure, it is necessary to measure the pressure applied to the body using sewn clothes and repeat sewing and measurement until the desired comfortable pressure is reached. To efficiently design clothing with appropriate clothing pressure distribution, a prediction formula for obtaining clothing pressure and its distribution from unstitched fabric and pattern paper has been proposed and has begun to be applied in practice.[11] Thus, at this stage, the measurement and prediction methods for clothing pressure have not yet been unified. When clothing pressure is generated, it is related to the stretchability and

bending stiffness of the cloth, the hardness and curvature of the body measuring part, and the tension of the cloth and skin. In addition, the pressure sensation on the human body surface differs depending on the body part. Therefore, not only the measuring method for clothing pressure but also the measuring conditions are not controlled, so consumers cannot accept the clothing pressure attached to commercial products without thinking. Further research should be carried out to examine the validity and consistency of these measurement methods and prediction methods, and eventually, it will be necessary to unify them.

Effective clothing pressure

In Japan, many students want to wear kimonos for their graduation ceremony. The kimono is usually worn with three cords, one for the inner undergarment and the others for the outer kimono. Young people feel sick during the graduation ceremonies, or the parties were often shown, because they tied the kimono's cords tightly because they were worried about the unfamiliar kimono coming loose. This is the "demerit" part of the effect of the clothing pressure. Clothing pressure related to this demerit has been reported many times in daily life. According to Kikufuji,[12] the menstrual cycle is 44 days when wearing a tight bra and girdle, and 30 days when no tight underwear is worn. That is, wearing a tight foundation significantly delays the menstrual cycle by 14 days. According to Solomon,[13] those with a menstrual cycle of 40 days or longer reported a significantly higher incidence of diabetes compared to those supplemented with 30-day cycles. For this reason, tightening our body more than necessary is harmful to our health.

Therefore, it is necessary to know the comfortable pressure of human clothing, as well as the basic pressure distribution and its characteristics when wearing clothes.

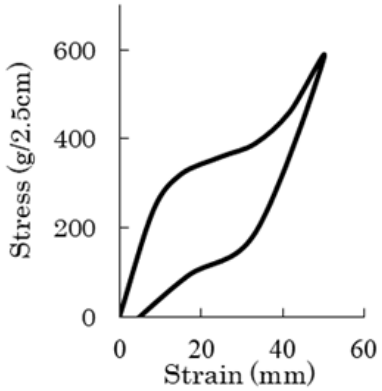

Figure 1 Stress and strain of an experimental band.[14]

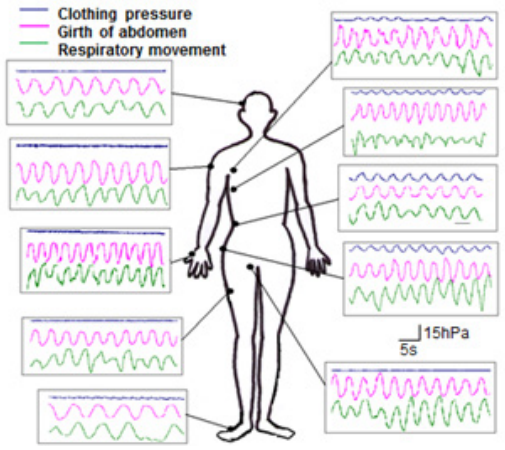

Figure 2 Simultaneous records of clothing pressure, girth of abdomen, and respiratory movement.[14]

Clothing pressure and respiratory movements

Since the clothing pressure is generated between the body surface and the clothes, it is affected by both side factors. As a daily experience of wearing clothing pressure, we used a 2.5 cm wide elastic band (Figure 1)[14] and tightened the 10 girths of the body (head, upper chest, top bust, waist, hip, leg, thigh, arm, hand, and foot girths). The clothing pressure generated on the right half of the body, the changes in the abdominal girth, and respiratory movement obtained from a thermistor taped near the nostrils were simultaneously recorded using a measuring system for clothing pressure based on the hydrostatic pressure balanced method (Figure 2),[14] when straight standing position).[8] The set of three wave patterns at each measuring position shows clothing pressure, abdominal girth change, and respiratory movement from the top to the bottom. These figures show that the clothing pressure obtained from the chest, waist, hip, and groin area fluctuates in synchronism with respiratory movements and changes in abdominal girths, but other parts are not affected by respiratory movements if they are stationary. In other words, when compressing the muscles related to respiratory movements, it is necessary to determine the pressure level that does not interfere with respiratory movement.

Clothing pressure of "Just right feeling"

Everyone wants to know the clothing pressure that humans feel is just the right feeling, but it is not easy to find it. The degree of pressure preferred by humans is influenced not only by the clothing material (belts in this case), but also by various factors such as age, gender, experience, and preferences specific to humans. The pressure values that young adult women feel are "just right feeling" are shown below. Although it does not apply to all conditions, the characteristics of the pressure distribution are well preserved. By the way, Figure 3[14] shows the elastic band pressure (mean value of 15 women in their 20s) evaluated as "just right feeling" by the participants using the belt in Figure 1. The fan shape indicates clothing pressure. In this way, the preferred band clothing pressure generated in the extremities is generally higher than that of the trunk, and the preferred clothing pressure increases toward the toes and hands. In other words, the clothing pressure cannot be explained only by the body surface curvature (curvature radius) and clothing tension. Perhaps, the number of pressure-sensitive sensors per unit area of the living body is different depending on the body part, or the threshold value is not equal. In addition, the clothing pressure on the trunk and in the midline are low and high on the sidelines. This is related to the depression of the relief along the spinal column, the radius of curvature of the body surface, and the position of the bone. Especially, the clothing pressure on the ventral side is low from the dovetail to the waist and the lower abdomen, which is due to the presence of nerve plexuses of the autonomic nervous system and the absence of bones to protect them. Recently, we often see simulations of clothing pressure obtained from the tension of cloth and surface curvature of the human body.[13] If the distribution of nerves and blood vessels that emerge from the deep layers could be considered in the clothing pressure simulation obtained from the surface curvature of the human body, it would be possible to design truly comfortable clothes. In other words, support wear products should not apply pressure to the locations that cross superficial nerves and blood vessels near the body surface. In addition,

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this pressure value is the result obtained when a non-pressurized human body is pressurized with one rubber belt. If the area to be tightened at the same time increases even in the same part, the value divided by that area will be the comfortable pressure.[14–16]

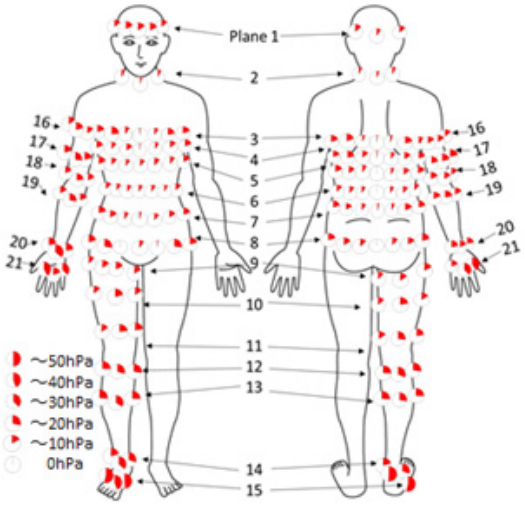

Figure 3 Distribution of clothing pressure over the whole body when tightening an elastic-band at standing posture.[14]

The order from plane 1 to the 21; Head, Neck, Chest, Top bust, Under bust, Waist, Lower waist, Hip, Groin, Thigh, Upper knee, Lower knee, Calf, Ankle, Foot, Upper arm, Upper elbow, Lower elbow, Wrist, Hand girths.

Sensory evaluation that is not always correct[2,3]

Various method[3] have been used to quantify pressure sensation, but if sensory evaluation is to be believed, there is clothing pressure that causes physiological damage. To know whether the degree of pressure is comfortable or not, it is necessary to examine not only the sensory evaluation but also the physiological response to pressure. That is thermoregulatory functions (metabolism, core body temperature, skin temperature, perspiration rate, wetness rate, blood flow), respiratory/circulatory functions (spiritual capacity, respiratory rate, ventilation, heart rate, blood pressure, electrocardiogram, blood flow), motor/sensory functions (muscular strength, electromyogram, a center of gravity sway, muscle blood flow, sensory discrimination threshold, sensory threshold), autonomic/central nervous system reactions (electroencephalogram, cerebral blood flow, electroencephalogram, heart rate variability, respiratory variability, blood pressure variability), endocrine system reactions (blood, sebum, urine, By examining changes such as sweat and various trace component analyzes in saliva, it is possible to clarify the burden on the human body without subjective symptoms. Currently, EEG is used as a response of the central nervous system to evaluate the sleeping environment (including bedding and night clothes) and clothing,[17,18] skin temperature[19] and salivary secretion[20] as indicators of the autonomic nervous system, and electromyography, which is the response of the somatic nerves, to evaluate various wearing comforts, and is also applied to product development.[21] In addition, by deriving the ratio of sympathetic and parasympathetic nerve activity from the heartbeat R-R interval and measuring the load on the body,[22] we have developed a conductive material that expands and contracts, and we are beginning to realize biological information measurement wear that is naturally comfortable to wear.[23]

By establishing an accurate and simple evaluation method for pressure stimulus and by using an index of autonomic nervous system response that can accurately measure changes in the physiological state of the human body without being deceived by the brain, it will be possible to identify and consider the unconscious load on the human body, making it possible to design more comfortable support wear.

Examples of application of support wear

Recently, "support wear products" that effectively use compression have begun to appear on the market. As mentioned above, it is difficult to actively apply clothing pressure to the muscles involved in respiratory movements, so many research focus on the extremities, especially the legs. Among them, the Pharmaceuticals and Medical Devices Agency has given pharmaceutical approval for elastic stockings as "general medical device class I". Under the "Act on Securing Quality, Efficacy, and Safety of Pharmaceuticals and Medical Devices", "elastic stockings" (physical therapy equipment and instruments 31724000)[24] are "medical elastic stockings (including elastic sleeves for arms) used for the purpose of promoting venous return, such as reducing or preventing venous blood and lymphatic stasis in the extremities. It has the function of applying pressure in a gradually decreasing direction". Such products use a design drawing different from general compression socks and are manufactured using a production line dedicated to medical device manufacturing at a medical device manufacturer-certified factory. Of course, in terms of sales strategy, some products do not dare to obtain pharmaceutical approval, that is, are not described as promoting blood circulation, but consumers who expect such effects may choose medical device notification numbers as a reference.

Now, to promote blood circulation, hoop tension should not be applied inside the joint, since this is the part where blood vessels and nerves are exposed from the deep layers of the body. However, if it is necessary to apply pressure for some reason, devise some ways to apply pressure to the body so that thin belts and string-like clothes (including the wrinkles that bite when bending and stretching) do not bite into the body. The conventional method of tightening the leg from the surroundings to prevent edema should not be selected.

About 17 liters of the 20 liters of blood pumped out from the heart per day on average return to the heart through the blood vessels. However, the remaining 3 liters become lymph and fill every corner of the tissue.[4] Lymph that does not return well to the heart causes edema, so the key to development is how to return this to the heart. Structurally, lymph vessels do not have a clear return path to the heart as do blood vessels. If the return path of the lymph fluid is blocked in the middle, the volume of the tip will inevitably increase, that is, edema will occur. Based on the above law of edema, we created spiral compression high socks[25] based on the seemingly contradictory concept of "not tight, removes edema, keeps us warm, makes our feet look neat and beautiful, and leaves fewer pressure marks". At present, elastic socks to reduce fatigue, stockings to reduce the impact on the foot depending on the direction, lower clothing to support knee joint movement, and socks to prevent stumbling to improve the QOL of seniors are designed and have already been commercialized.[26] We also proved the validity of the pressure gradient of the clothing pressure of pantyhose that prevents fatigue even when wearing high heels.[27]

Now, I mentioned that the pressurization of muscle groups related to respiratory movement should be avoided. However, if there are bones that protect the internal organs even in these body parts, there is some freedom. Body fat can be moved freely by keeping the position of the partition wall that wraps it. However, the pressure value of such compression products is also affected by age.[28,29] If we used clothing pressure well, it can also be used to create clothing that helps us burn fat preferentially. In the future, to supply healthy and comfortable

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support wears to the market, we believe that steady basic research, joint development with companies that apply this research, and warning to the world should be continued.

Conclusion

We wear clothes that may restrict our movement, but at that time, clothing pressure will occur between our body surface and the clothes. The advantages and disadvantages of this clothing pressure were introduced and described the points to keep in mind to use it well for producing support wear. In addition, the merits and demerits of clothing pressure measuring methods from the past to the present are described, and the adequacy of current methods of use and future trends are also described. In order to make comfortable support wear using these measuring methods, it is important also to know the various functions of the human somatosensory and autonomic nervous system. Using this information, the support wear currently produced was also introduced.

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Conflicts of interest

Declare if any conflict of interest exists.

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