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Abuse of Empire style robe to thermal insulation and body discomfort

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Abstract

Purpose – Empire style fashion, Greek-Roman style robe with bare shoulder and chest and short sleeved with long gloves which created a slim silhouette, was worn even in winter season in Europe, where average temperature is 0-5°C. Most women suffered with catching cold and thousands caught flu and tuberculosis of the lungs, called muslin disease. The purpose of this paper is to find out clothing insulation of the robe by measuring the thermal resistance and to guess how cold they felt in this robe in winter time.

Design/methodology/approach – The authors performed the investigation on original robe shape with based on historical evidence and data, such as drawings, sketches, pattern books and sewing books, and reproduced a representative robe costume and tested its thermal insulation. The fabrics of robe were thin wool, silk and cotton following the literature evidence and preserved costume. Thermal insulation of the robes was measured using thermal manikin with the test method ISO 15831. The authors analyzed the thermal insulation of reconstructed robes with an inner cotton breech as for daily use and tested them wrapped with cashmere shawl on manikin shoulder as for severe cold weather.

Findings – The dress robes had the range of 0.61-0.67 clo regardless of the type of fabric materials, and 0.80-0.81 clo with the cashmere shawl. These values were not enough for women to keep body temperature or comfort in winter time.

Originality/value – This study combined fashion historic theory for costume reproduction with clothing science and technology for thermal insulation. Combination of costume history, construction technology and measurement engineering is the ingenious idea, and the combination of historical and scientific research evidences interdisciplinary originality.

Keywords Clothing insulation, Empire style robe, Thermal manikin

Paper type Research paper

Introduction

After the French Revolution, new types of clothing were introduced in early nineteenth century. At that time, Empire style fashion of clothing was fresh and bold, for it was similar to the ancient Greek-Roman style made with fine and sheer fabrics and high-waist robes to showcase the freedom of the body out of the corset, and the Greek-Roman style robe was adapted as a response to social oppression. The material was derived from ancient Greek chiton. Made of thin, soft cloth, such as Greek chiton, this was a new style that was welcomed and followed by many women. The clothing showed bare shoulders and chest with short sleeves and a slim silhouette, but this style was unsuitable for cold winters.

Western Europe has a typical oceanic climate with an annual range of temperature of 10-18°C and an average winter temperature of 0-5°C. The Eastern and Northern European climate, except for the coast of Norway is characterized typically by cold

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temperatures. Continents, particularly in winter, have many days with temperatures below freezing due to the expansion of the internal temperature in the Siberian High (January average $-5$ to $-20^\circ\text{C}$). Therefore, there are fairly heterogeneous weather patterns across Western Europe. The annual rainfall is approximately $750$ mm, and it rains more in the fall and winter (Wikipedia, 2013).

In cold weather, a large amount of heat flows from a warm body to the cold environment via conduction, convention and radiation, and the body temperature can decrease severely. In addition, more heat is transferred through the evaporation of body sweat from hard work or wet clothes by rain because latent heat is extracted from the wet surface (Havenith et al., 1990).

Empire style fashion, which was a giant trend in the fashion history, satisfied the eagerness for naturalism and freedom of the people at that time but might be harmful to women’s health in winter because of the inadequate thermal insulation. Women only wore a thin and sheer robe dress, even in winter, and put on large shawls or short spencer jackets over their robe for warmth in extremely cold weather. Dr Regnault (1816) published *Journal universal des sciences médicales* and asserted that most women suffered and even died from influenza and tuberculosis of the lungs, of which their thin dress even in winter time was one of the reasons. For the thin muslin material of women’s robe, influenza affected approximately $60,000$ women in the winter of $1803$ and was called muslin disease.

Although the clothing insulation of the robe of the Empire style has not been studied, and there is considerable insulation data about contemporary clothing and its combinations. Underwear, shirt, pants, socks, shoes in casual wear combination is approximately $0.7$ clo. The thermal characteristics of current-market garment were analyzed and each garment by clothing weight was investigated with the relationship of clothing insulation using the thermal manikin method (Choi and Lee, 2009). To develop an air force mechanic parka, the insulation was evaluated using thermal manikin method (Lee et al., 2012). When making changes in the parka patterns and designs to enhance mobility, it was necessary to maintain the insulation capacity. Sun et al. (2013) developed multilayer protective clothing with improved thermal insulation consisting of reflective nano-fibrous thin layers. The protective jacket filled with multilayer polyester battings and reflective nano-fibrous interlayers had better thermal insulation and a moisture permeability index than those filled with the same multilayer polyester battings.

On the other hand, there is little data on the thermal insulation of the garments in the past. In the present study, the historical costume of a dress robe was reconstructed and its thermal insulation was tested. In addition, the data showing how the people at that time felt physiological comfort during winter was added to the database of clothing insulation.

**Research method**

*Selection and production of the robe*

The style of robe was selected among those that best represent the preserved clothes of the period (Arnould, 1964) and the popular fashion types of nineteenth century Europe (Boucher, 1965; Waugh, 1968). The robe design in Figure 1 was shown in the resource “Costume in detail 1730-1930” (Bradfield, 1968). An analysis of the historical data included the robe form, fabric materials and pattern construction (Grivel, 1982; Musée nationale de techniques, 1989). The historical investigation was performed based on the data and evidence, such as drawings, pattern books and sewing books, and the
robe costume was reproduced using historical methods (Arnould, 1964). The pattern pictures and silhouette were first analyzed and then re-sized to fit the size of the thermal manikin, and the details of the sewing methods were determined afterwards. Information of the conserved costume assisted in the process of pattern construction, reproduction and sewing techniques in detail.

The dress comprised of two large pieces of linear panels for the skirt part and seven small pieces for bodices and half sleeves. Each panel of the skirt was directed in the warp direction, following a bottom curve for back-trail floor. After input and printing of the final pattern using a CAD program, the robe was completed by adjusting the pattern panels and sewing a margin to the seam following the investigation results. Figure 2 shows the CAD pattern.
At that time, women sought garment form, color and originality of the fabric pattern rather than the practicality and durability of clothes. Therefore, the use of light and delicate cotton or fine silk material rather than thick wool or hemp fabric increased. Women’s underwear, lingerie fabric was too thin to cover (Boucher, 1965). From 1804 to 1806, there was an embroidery muslin robe with a pineapple pattern. In 1805, a grape pattern with the embroidered hemp of a wedding robe was popular (Musée nationale de techniques, 1989). Therefore, thin and light fabrics with wool, silk and cotton fibers were selected and three robes were made using the above production methods. Table I lists the specifications of the robe and fabrics.

**Measurements of thermal insulation**

The thermal insulation was tested using the thermal manikin method. The thermal insulation of the historical reconstruction robe was measured in units of clo. The unit of clothing insulation “clo” was first coined by Gagge et al. (1941). One clo is defined as the amount of clothing required by a resting sedentary person to be definitely comfortable at ambient conditions where the temperature is 21°C (70°F), the relative humidity is less than 50 percent, and wind velocity is 0.25 m/sec. The lowest clo value (0) is that of a
naked person, and the highest practical clo value (4) is that of Eskimo clothing (fur pants, coat, hood, gloves, etc.). The overall clo value is the summation of the clo value of the individual garments. A thick jacket of 0.49 clo, thick pants of 0.32 clo, shirt of 0.25 clo, and with underwear, socks, shoes of 0.18 clo are summed to 1.24 clo, and the effective value of combination are 1.0 clo after a 25 percent correction, which is appropriate for men to feel comfort in a 21°C indoor environment (ISO 11079, 2007).

For clothing insulation, the objective insulation value was measured using the thermal manikin method (Sweating thermal manikin, MTNW American, Newton four, signal acquisition and monitoring for computer, electrode/sensor and cable, ISO 15831, 2004) (Table II). The conditions of the climate chamber were a temperature of 20°C, relative humidity of 50 percent and air flow of 0.38 m/sec. The mean data of heat transfer on a skin surface of 35°C was collected from the manikin by parts in terms of the steady-state average data and the experimental pictures were taken, as shown in Figure 3.

**Results and discussion**

*Thermal insulation of reconstruction robes*

Table III lists each of the thermal insulation (clo) and thermal resistance (m² °C/W) of the three robes. The insulation value of the robe was in the range, 0.61-0.67 clo, and 0.80-0.81 clo with a cashmere shawl. The insulation of the silk robe (B) was slightly higher than that of a cotton robe (C) and wool robe (A). Interestingly, the thermal insulation of a wool robe (A: 0.61 clo) was low compared to a silk robe (B: 0.67 clo), but this difference was as big as compared with an additional underwear (0.06 clo) (Choi and Lee, 2009). The high value of the silk robe was similar to the previous result in that fabrics made from fine microfibers show lower heat conductance and higher thermal insulation properties than those of conventional fibers (Schacher et al., 2000).

The weather in Western Europe is humid and windy in winter and once the robe is wet, the wearer may feel uncomfortable and have difficulty in maintaining their body temperature. In this case, a wool robe might be better than silk or cotton robes for the wearer to maintain their body temperature and physiological comfort.

Each garment category’s thermal insulation and garment weight were averaged as follows: under garment (0.06 clo, 89 g), blouse/shirt/t-shirt (0.13 clo, 200 g), cardigan/sweater/vest (0.14 clo, 287 g), coat/jacket/jumper (0.41 clo, 890 g), skirt (0.16 clo, 276 g),
trousers (0.20 clo, 438 g), headgear (0.03 clo, 102 g), gloves/footwear (0.03 clo, 33 g) (Choi and Lee, 2009). The clothing combination of 0.6-0.7 clo is underwear, half sleeve shirt and thin pants and socks and shoes for men, and underwear, stocking, dress and shoes for women. The half sleeve and light dress is 0.20 clo, long sleeve and winter dress is 0.40 clo, boiler suits 0.55 clo, and inner cotton breech 0.05 clo from the database of the effective clothing insulation values (ISO 9920, 1995). The 0.61-0.67 clo of the robe insulation from this study was slightly higher than 0.45 clo – winter dress of 0.40 clo with an inner cotton breech of 0.05 clo.

The robes made from sheer and thin materials are believed to have a low value in clothing insulation. On the other hand, the experimental test results of insulation showed 0.61-0.67 clo, which is higher than expected. Clothing insulation of the Empire style dress robe was similar with thermal insulation of boiler suits (0.55 clo) with underwear (0.05 clo). This appears to be because there are many air spaces under the waist-part gathering of the dress skirt.

The thermal insulation values of the robes were similar according to the material type of robes. The order of the air permeability of the fabric (C > B > A) did not match the order of the clothing insulation of robes (B > C > A), probably because the dress width was too wide and there was considerable air space volume under the garment. This still air gap around the waist is believed to contribute to the high level of clothing

Table II. Characteristics of the thermal manikin

<table>
<thead>
<tr>
<th>Thermal manikin</th>
<th>parts</th>
<th>Name of parts</th>
<th>Surface area(㎡)</th>
<th>Surface temperature(℃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>1</td>
<td>0.04569</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>2</td>
<td>0.09687</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Upper arm</td>
<td>3</td>
<td>0.08356</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Upper arm</td>
<td>4</td>
<td>0.08356</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Forearm</td>
<td>5</td>
<td>0.06483</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Forearm</td>
<td>6</td>
<td>0.06483</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Hand</td>
<td>7</td>
<td>0.04604</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Hand</td>
<td>8</td>
<td>0.04604</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>9</td>
<td>0.12006</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Shoulders</td>
<td>10</td>
<td>0.10089</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>11</td>
<td>0.11915</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>12</td>
<td>0.09395</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Hip</td>
<td>13</td>
<td>0.07604</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Hip</td>
<td>14</td>
<td>0.07604</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Thigh</td>
<td>15</td>
<td>0.15193</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Thigh</td>
<td>16</td>
<td>0.15193</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R Calf</td>
<td>17</td>
<td>0.1351</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L Calf</td>
<td>18</td>
<td>0.1351</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>R foot</td>
<td>19</td>
<td>0.05965</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>L foot</td>
<td>20</td>
<td>0.05965</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.81091</td>
<td>Mean. 35</td>
<td></td>
</tr>
</tbody>
</table>
insulation. An important factor of thermal insulation is the still air gap in the clothing rather than the type of fiber (Fourt and Hollies, 1970).

In the present study, the robe weight ranges from 257 to 593 g. Dividing this by the body surface area of 1.8 m², the robe weight is approximately 143-329 g/m², and this clothing weight is for summer clothes. The outdoor clothing weighs 1,363 g/m² in

### Table III.
Thermal insulation of three robes and with shawl

<table>
<thead>
<tr>
<th>Robe</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A + shawl</th>
<th>B + shawl</th>
<th>C + shawl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clo</td>
<td>0.61 (± 0.009)</td>
<td>0.67 (± 0.005)</td>
<td>0.62 (± 0.005)</td>
<td>0.81 (± 0.000)</td>
<td>0.81 (± 0.009)</td>
<td>0.80 (± 0.000)</td>
</tr>
<tr>
<td>Rct</td>
<td>0.09 (± 0.001)</td>
<td>0.10 (± 0.001)</td>
<td>0.10 (± 0.001)</td>
<td>0.13 (± 0.000)</td>
<td>0.13 (± 0.001)</td>
<td>0.12 (± 0.000)</td>
</tr>
</tbody>
</table>

Figure 3.
Thermal insulation test of the robe (up-robe, down-with shawl)
winter and 341 g/m² in summer. In winter, they normally wear about four times heavier clothes than in summer (Lee et al., 2011). The air temperature and relative humidity of the physiological comfort zone were at least 15-18°C and 48 ± 9 percent RH in winter indoors if wearing a clothing weight of 240-1,076 g/m² for a combination of overall/skirt/dress (Lee et al., 2011).

If wearing 0.6 clo, for 80 percent of subjects to feel comfortable in a normal office environment according to ASHRAE’s new standard (Standard Effective Temperature of American Society of Heating, Refrigerating, Air-Conditioning Engineers, when sitting on chair in standard state of air flow, relative humidity, light work of 58-70 W/m² (1.0-1.2 MET, where 1 MET = 58 W/m²), the air temperature of the comfort zone should be 22.2-25.6°C. In the same case of wearing 0.8 clo, the air temperature should be 21-24°C (McCullough and Hong, 1994).

Effect of additional shawl on thermal insulation by body parts
If a shawl was placed on the manikin shoulder, the combinatory insulation of historical dress robe increased by approximately 33 percent, from 0.61-0.67 to 0.80-0.81 clo. On the other hand, the clothing insulation of the robe with the shawl is lower than required insulation level for body comfort in a European winter. The value is even under 1.0 clo, which is the thermal insulation of men’s spring/fall business suit in comfort status.

Figure 4 shows the differences in the effective thermal resistance (m² °C/W) between the robe and shawl combination according to the body parts. First, the thermal resistance of the robe was analyzed according to the body part. Each body part showed different thermal resistance values. The value of the up-thigh parts was highest and the values of the face, hand and forearm was lowest. These data showed that the exposed parts had a low-thermal resistance and the middle of the covered part showed a high value. The next highest were the back and stomach, and these torso and thigh parts could play important roles in thermal comfort because they cover more than 60 percent of the skin surface area. The parts around the waist are surrounded by a thick still air layer in the high-waist skirt gathering of the robe, giving them warmth.

By the additional shawl, the increase in thermal resistance is slightly different according to the robe type. In the C cotton robe only, there was no increase in thermal resistance in the thigh part by adding the shawl. In common, there are increases in thermal resistance in most parts, such as the upper arm, chest, shoulders and stomach, which are covered by the shawl.

The position of the robe’s clo in the IREQ and \( D_{\text{lim}} \)
IREQ is defined as the required clothing insulation for preserving the body heat balance at the defined levels of physiological strain, i.e. the resulting clothing insulation required in the actual environmental conditions to maintain the body in a state of thermal equilibrium at acceptable levels of body and skin temperature (ISO 11079, 2007).

When the robe insulation was made, as 0.6 clo for the day of 5°C and 0.8 clo for 0°C, to determine its position in the IREQ diagram of Figure 5, the two dots are shown on the line, 175 W/m² of the activity level. This means that the clothing insulation of the robe is appropriate for body heat equilibrium only in a very hard working environment. When looking for proper clothing insulation for 0-5°C with light working activity every day, at least 2.5 clo was found to be required from the line of 70 W/m².

Based on a calculation of the body heat exchange, the IREQ for maintaining thermal equilibrium and the insulation provided by clothing ensemble in use or to be used could be found easily from the diagrams. If worn insulation was less than required, a duration
limited exposure ($D_{lim}$) was calculated based on the acceptable levels of body cooling (Figure 6, ISO 11079, 2007).

In this test, the robe clothing ensemble did not provide adequate insulation to prevent body cooling. There is an increasing risk of hypothermia with progressive exposure, and the time limited exposure can be selected and $D_{lim}$ found from the diagram. When
the robe value is made, as 0.6 clo for a day at 5°C and 0.8 clo for 0°C, to find its position in the $D_{lim}$ diagram, 90 W/m² in Figure 6, two dots were found near the curves of 0.5 and 1.0 clo. The two dots were on a vertical line of 45 min. Therefore, women wearing this robe must not stay over 45 min in an air temperature of 0-5°C.

This study had some limitations. The effects of other clothing items, such as underwear, head coverings, acclimatization and lifestyle, on comfort and body temperature were not included. The soft thin white lawn, muslin or batiste dresses clung to the body showing the natural body geometry. Hence, underwear, such as stays, drawers and knickers, were unpopular but they wore warm men’s pantaloons as undergarment when needed. They were made of a light stockinet in a flesh toned color and reached the ankles or just below the knee. The ladies wore a finely hand-embroidered fancy tulle cap, trimmed in ruffled lace (www.fashion-era.com). At that time, the heating systems comparable to current systems was lacking. People would have already adapted to the cold environment and high tolerance or endurance. Therefore, they would be expected to have less discomfort compared to current. Upper-class ladies did not have a lot of work with lower energy level, such as embroidery and music, than women today, whereas ladies in the lower classes would have more work and feel less cold.

**Figure 5.**
Clo position of the robe in the $IREQ_{neutral}$ and $IREQ_{min}$ neutral at four levels of metabolic rates
Conclusions
This study examined the thermal insulation of the robe of historical costume to determine how cold the women normally felt in the robe dress in winter time or what was their thermo physiological comfort in their fashion outfit. Through historical research of the data in the early nineteenth century, the Empire style robe was reconstructed precisely and thermal insulation of the robe was measured objectively. Historical research was performed by analyzing drawings, pattern books, and sewing books as well as the preserved costumes, and through previous studies, dress fabric was found to be made of various thin materials.

The thermal insulation values were measured using the thermal manikin method. The results are follows. Women’s clothing combination at that time in Europe was not comfort or suitable for their winter weather with an average temperature of 0-5°C. The thermal insulation of the robe combination was 0.61-0.67 clo, and 0.8-0.81 clo with an additional cashmere shawl. These insulation values are suitable for moderate indoor temperatures or spring/fall environments. Therefore, if the wearing situation is not strenuous exercise or very high-activity level, it is difficult for women to maintain their body temperature, which can lead to diseases or hypothermia excluding the feeling of discomfort. The value of clothing insulation 0.61-0.81 clo allows 80 percent of people to feel comfort at an ambient temperature of 21-25.6°C.

ISO 11079 (2007) suggested that when the air temperature is 0-5°C and light activity is 70 W/m², at least 2.5 clo is needed for IREQ min of clothing insulation. Therefore,
0.6-0.8 clo is very uncomfortable in winter, and the women at that time would have felt uncomfortable. The recommended duration limited exposure (D_{lim}) for neutral at an activity of 90 W/m\(^2\) of this robe wearing was less than 45 min.

In this study, the database with the results that thermal insulation of Empire style dress robe was 0.6-0.8 clo was added. Empire style dress has a rich gathering in the middle, giving the more warmth than other types of dresses and the thermal insulation was high relatively to the other dresses of thin and sheer materials. Thermal insulation had less to do with the type of clothing material in the case of the robe because there is a large air layer around the stomach and thigh similar to multiple layering clothing. Compared to the typical dress of 0.4 clo, the Empire style robe's thermal insulation was relatively high at 0.6 clo due to the still air space in the waist part.

References


**Further reading**


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