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# Relationship between Thermal Insulation and the Combinations of Korean Women's Clothing by Season -Using a Thermal Manikin-

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# 한국 성인 여성의 계절별 의복조합과 보온력과의 관련성 -써멀마네킨 실험에 의한-

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## Abstract

The purpose of this study was to examine the correlation between the combination of women's clothing by season and thermal insulation using a thermal manikin. A total of 34 kinds of clothing ensembles were selected based on previous studies(8 types for spring/fall, 7 types for summer, and 19 types for winter). The results were as follows: The thermal insulation of clothing ensembles($I_{cle\_total}$) ranged from 0.34~0.60clo for spring/fall, 0.16~0.37clo for summer, and 0.89~1.35clo for winter. The correlation coefficient between the thermal insulation of clothing ensembles and thermal insulation accumulated by the individual garments composing of the clothing ensembles($I_{cle\_summed}$) was 0.982($p<0.001$). The correlation coefficient between the thermal insulation of clothing ensembles and total clothing layers for the upper body part was 0.750 ($p<0.001$), for the total clothing weight was 0.978($p<0.001$), and for the covering area was 0.776($p<0.001$). In conclusion, $I_{cle\_total}$ showed higher relationships to the $I_{cle\_summed}$ and total clothing weight than to the total clothing layers or surface area covered by clothing.

***Key words:*** Clothing combination, Thermal insulation, Clothing weight, Covering area, Clothing layers; 의복조합, 보온력, 의복중량, 피복면적, 착의매수

## I. Introduction

Clothing is the closest environment to the human body. Since we wear clothing almost all hours of the day, it is not questionable that clothing has effects on environmental adaptation, such as body temperature regulation and subjective perceptions. Also, clothing can have a considerable influence on health, performance, and work efficiency in sports activities and special work areas as well as in our daily lives. Hence the exact prediction of clothing insulation and the appropriate selection of daily clothing according to daily weather reports would enhance the quality of life.

In a modern life, requirements for the various kinds of clothing are increasing due to the particular situations/extreme environments. Thermal insulation is in-

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fluenced by both outer and inner garments, wearing the same clothing, and wearing habits(Morris, 1953; Tamura & Iwasaki, 1985). Furthermore, clothing insulation complexly is influenced by a number of factors, such as air content, heat/moisture transfer of materials, total clothing weight, total clothing layers, density/air permeability of fabric, opening of garments, and clothing allowances.

While the changes in fashion(new wearing habits/materials/designs, etc.) is fast, studies on clothing insulation has relatively been retarded. Moreover, studies using thermal manikins have been somewhat sporadic because of the restriction of the access to the thermal manikins. Until now, there has been reported about studies dealt with thermal insulation of textile materials, particular experimental garments, or the effect of layering on clothing insulation(Choi, 1989; Lee et al., 2007; McCullough et al., 1983; Son & Baek, 1999; Son & Char, 1998; Son & Choi, 1999; Sung, 1997). Comprehensive studies that try to quantify the thermal insulation of seasonal clothing ensembles are rare in Korea. Few studies have tried to investigate the relationship between total clothing insulation and various clothing factors with currently worn clothing. It is necessary that we examine the clothing insulation of garments recently worn clothing by season and we have an intention of getting the best prediction index of clothing insulation using a thermal manikin.

As a preliminary step for the present study, we surveyed 825 women about seasonal women's clothing ensembles using questionnaires(Choi et al., 2006) and from that survey, we selected a total of 34 types of representative clothing ensembles for this study. The aims of this study were 1) to quantify the clothing insulation of women's seasonal clothing ensembles; 2) to examine the change of clothing insulation according to addition/removal of the individual garments for upper/lower parts; 3) to elucidate relationships between total clothing insulation and various clothing factors.

## II. Methods

### 1. Experimental Clothing

As mentioned above, we surveyed 825 women about the layering of clothing and actual wear states of adult women using one-on-one interviews and questionnaires(Choi et al., 2006). The respondents were restricted to adult women who lived in Seoul and Gyeonggi province(January 2005~August 2005). We examined Korean women's wearing conditions(materials, designs, etc.) and the clothing layers in their daily lives by season, to select the clothing combination. Based on that survey, a total of 34 types of clothing ensembles were selected(8 types for spring/fall, 7 types for summer, and 19 types for winter). These ensembles were composed of a total of 43 individual garments(Table 1).

Physical properties of every garment were measured by the following methods: 1) surface area covered by clothing(covering area) was estimated using the photographic method(Lee, 2005), 2) for clothing weight, every garment was weighed three times with an electronic balance(Sartorius Company, Germany, Sensitivity 1g) and averaged, 3) clothing thickness was measured using a dial-gauge(No 2046S, Mitutoyo Company, Japan, Sensitivity 0.01 mm) according to KS K 0506, and 4) the air permeability of clothing was measured by an air permeability tester (FX 3300, Textest Instruments Company, Switzerland) based on the instruction of KS K 0570.

### 2. Measurement of Thermal Insulation using a Thermal Manikin

Thermal insulation values of clothing ensembles were determined using a thermal manikin with 20 parts controlled respectively(Newton, Measurement Technology NORTHWEST, USA, 1.7 of BSA). This experiment was tested in FTC(Fashion Textile Center) of the Seoul National University(March 2005~August 2005). The measurements were conducted two times for every clothing combination and the average was used. Mean skin temperature of the thermal manikin was maintained at $33.3 \pm 0.5^{\circ}C$. The air temperature of the chamber was set at $21.5 \pm 0.5^{\circ}C$, the relative humidity was $50 \pm 5\%RH$, and air velocity was limited to less than 0.1 m/s. Effective clothing insulation($I_{cle}$) designated at the value subtracted the insulation of surface air layer($I_a$) from total clothing

**Table 1. The characteristics of the individual garments composing of seasonal clothing ensembles**

| Season | No | Description | $I_{cle}$ | Covering Area (%) | Clothing weight (g) | Thickness (mm) | Air permeability ($cm^3/cm^2/sec$) |
|---|---|---|---|---|---|---|---|
| Spring/ Fall (SF) | 1 | Underwear-Bra | 0.02 | 4 | 47 | 4.15 | 61.0 |
| | 2 | Underwear-Sleeveless shirts | 0.07 | 26 | 71 | 0.63 | 124.0 |
| | 3 | T-Shirts(Long sleeves, Round N.) | 0.11 | 42 | 229 | 0.97 | 51.6 |
| | 4 | Jacket(Long sleeves) | 0.15 | 43 | 406 | 0.49 | 2.7 |
| | 5 | Underwear-Panty | 0.01 | 13 | 22 | 0.36 | 195.7 |
| | 6 | Skirt-Knee length, lined | 0.12 | 32 | 195 | 0.49 | 6.6 |
| | 7 | Trousers(Straight, Ankle L.) | 0.22 | 44 | 407 | 0.58 | 6.2 |
| | 8 | Pantyhose(Semi-transparent) | 0.03 | 53 | 24 | 0.27 | 349.3 |
| | 9 | Socks(Ankle L.) | 0.01 | 7 | 21 | 2.14 | 167.0 |
| | 10 | Shoes(Hard sole, Leather) | 0.04 | 7 | 511 | - | - |
| Summer (S) | 11 | Underwear-Bra | 0.02 | 4 | 36 | 0.87 | 305.0 |
| | 12 | Underwear(sleeveless, string top) | 0.03 | 23 | 58 | 0.60 | 125.7 |
| | 13 | T-Shirts(Sleeveless) | 0.06 | 26 | 120 | 0.95 | 67.1 |
| | 14 | T-Shirts(Half sleeves) | 0.09 | 34 | 141 | 0.70 | 84.7 |
| | 15 | Underwear-Panty | 0.01 | 13 | 22 | 0.36 | 195.7 |
| | 16 | Trousers(Semi-bell bottoms, Ankle L.) | 0.19 | 44 | 251 | 0.47 | 4.8 |
| | 17 | Skirt(Mini-length) | 0.09 | 21 | 227 | 0.64 | 9.1 |
| | 18 | Skirt(Knee L.) | 0.13 | 32 | 146 | 0.47 | 2.5 |
| | 19 | Dress(Sleeveless, Knee L.) | 0.19 | 51 | 287 | 0.47 | 4.8 |
| | 20 | Sandal | 0.02 | 3 | 552 | - | - |
| Winter (W) | 21 | Underwear-Bra | 0.02 | 4 | 47 | 4.15 | 61.0 |
| | 22 | Underwear-Sleeveless shirts | 0.07 | 26 | 71 | 0.63 | 124.0 |
| | 23 | Sweaters(Long sleeves, Turtle N.) | 0.14 | 37 | 214 | 1.31 | 135.7 |
| | 24 | T-Shirts(Long sleeves, Turtle N.) | 0.15 | 44 | 227 | 0.74 | 32.4 |
| | 25 | Sweater(Half sleeves, turtle N.) | 0.14 | 36 | 211 | 1.47 | 43.7 |
| | 26 | Sweater(Long sleeves, round N.) | 0.12 | 42 | 283 | 2.03 | 117.0 |
| | 27 | Underwear-Long johns(Upper) | 0.11 | 42 | 151 | 0.74 | 86.8 |
| | 28 | Cardigan(Round N.) | 0.16 | 42 | 259 | 1.32 | 87.8 |
| | 29 | Coat(Mid-calf L.) | 0.54 | 72 | 1310 | 2.54 | 8.5 |
| | 30 | Underwear-Panty | 0.02 | 15 | 28 | 0.55 | 57.4 |
| | 31 | Underwear-Long johns(Pants) | 0.10 | 43 | 139 | 1.50 | 86.8 |
| | 32 | Trousers(Straight, Wool, lined) | 0.25 | 44 | 527 | 1.51 | 9.9 |
| | 33 | Trousers(Straight, jean) | 0.16 | 44 | 657 | 1.08 | 2.5 |
| | 34 | Trousers(Straight, corduroy) | 0.20 | 43 | 402 | 1.20 | 7.7 |
| | 35 | Underwear(Tights, Ankle L.) | 0.07 | 46 | 140 | 0.68 | 17.9 |
| | 36 | Skirt(Knee L., Wool) | 0.17 | 34 | 357 | 1.64 | 10.5 |
| | 37 | Panty hose(Opacity) | 0.07 | 53 | 49 | 1.06 | 297.0 |
| | 38 | Socks(Ankle L.) | 0.01 | 7 | 21 | 2.14 | 167.0 |
| | 39 | Shoes(Hard sole, Leather) | 0.04 | 7 | 511 | - | - |
| | 40 | Gloves(Leather) | 0.02 | 5 | 42 | 0.84 | - |
| | 41 | Muffler(Wool) | 0.03 | 5 | 121 | 2.05 | 54.9 |
| | 42 | Hat(Knit) | 0.02 | 5 | 91 | 3.27 | 89.0 |
| | 43 | Boots(Knee L., Leather) | 0.11 | 23 | - | - | - |

insulation ($I_T$). Formulas to calculate $I_{cle}$ are as follow:

$I_{cle}=I_T-I_a$

$I_T=6.45(\frac{\overline{T}_{skin}-\overline{T}_{air}}{Q/A})$

$I_T=R_{ct}\cdot 6.45$

$I_T$=Total clothing insulation(clo)

$T_{skin}$=20 Zone average temperature(°C)

$T_{air}$=Ambient average temperature(°C)

A=Body surface area($m^2$), Q=Area weighted heat flux(W)

### 3. Statistical Analysis

For the total clothing weight, clothing layers, covering area, and thermal insulation accumulated by the individual garments of each clothing combination ($I_{cl\_summed}$), descriptive statistics were calculated using SPSS v. 12.0. Pearson's correlation coefficients were analyzed to investigate the relationship between clothing ensembles and various clothing factors, such as total clothing weight, clothing layers, covering area, and $I_{cle\_summed}$. To estimate total clothing insulation with various clothing factors as explanatory variables, regression analysis was conducted. Significant differences were set at $p<0.05$.

## III. Results and Discussion

### 1. Thermal Insulation of Clothing Ensembles by Season

Thermal insulations of a total of 34 clothing ensembles were measured using a thermal manikin. The insulation showed ranging from 0.34~0.60clo for spring/fall wear, 0.16~0.37clo for summer, and 0.89~1.35clo for winter. For the spring/fall wear, the thermal insulation of clothing ensembles had a mean of 0.46clo, and this is the same as that of SF6. The mean of $I_{cle}$ were 0.26clo and 1.08clo for summer and winter, respectively. Among our clothing combinations, S5 and W7 were corresponding to these values for summer and winter(Table 2).

Regarding the thermal insulation of clothing ensembles according to the type of the individual garments, we maintained upper wears identically but the combinations of lower wears were changed(SF1, SF3, SF5, SF2, SF4, SF7). In these cases, the increase of clothing insulation was higher in wearing pants and socks than in skirts and pantyhose, when comparing the values predicted from the thermal insulation of the individual garment. Conversely, when we kept the lower wear be identical and the upper wear changed(SF5, SF6, SF7, SF8), the increase of thermal insulation due to adding the individual garments was a little lower than we expected from the thermal insulation of the individual garments.

For winter wear, when we kept the upper wear be identical and the lower wear changed(W1, W4, W5, W6, W7, W8, W9), the thermal insulation of clothing ensembles showed a little higher value than values predicted from thermal insulation of the individual garments. When wearing long john and woolen pants, the increase of thermal insulation was highest among various combinations of lower wears. Interestingly, clothing insulation for this combination was higher than the combination of panty hose+woolen pants or the combination of undertights+woolen pants.

In the case of wearing identical lower wear but changing upper wears(W2, W3, W4, W10, W11), thermal insulation was highest in wearing the combination of "bra+sleeveless underwear+sweater". The clothing insulation in this case represented a higher value than the values we predicted using the thermal insulation of the individual garment. Among all combinations, W11 was predicted as showing the highest thermal insulation, but the value was not high as we expected. This indicated that, if clothing layers are in excess to a certain extent, total clothing insulation is decreased due to the compression of the still-air layer that exists between clothing layers.

### 2. Comparisons Between Thermal Insulation of Clothing Ensembles($I_{cle\text{-}total}$) and Thermal Insulation Accumulated by the Individual Garments Composing of the Clothing ensembles($I_{cle\text{-}summed}$)

We compared thermal insulation of clothing ensembles with thermal insulation accumulated by the indi-

**Table 2. Total clothing layers, total clothing weight, covering area and thermal insulation of clothing ensembles using a thermal manikin**

| No | Composition of clothing ensembles | clothing layers | | Total clothing layers | Total clothing weight(g) | Covering Area(%) | accumulated $I_{cle}$ | $I_{cle}$ |
|---|---|---|---|---|---|---|---|---|
| | | upper -wear | lower-wear | | | | | |
| SF1 | (1+3)+(5+6)+10 | 2 | 2 | 4 | 493 | 72 | 0.28 | 0.34 |
| SF2 | (1+3+4)+(5+6)+10 | 3 | 2 | 5 | 899 | 72 | 0.43 | 0.41 |
| SF3 | (1+3)+(5+6)+8+10 | 2 | 3 | 5 | 517 | 86 | 0.31 | 0.36 |
| SF4 | (1+3+4)+(5+6)+8+10 | 3 | 3 | 6 | 923 | 86 | 0.46 | 0.44 |
| SF5 | (1+3)+(5+7)+9+10 | 2 | 2 | 4 | 726 | 86 | 0.38 | 0.48 |
| SF6 | (1+2+3)+(5+7)+9+10 | 3 | 2 | 5 | 797 | 86 | 0.45 | 0.47 |
| SF7 | (1+3+4)+(5+7)+9+10 | 3 | 2 | 5 | 1132 | 86 | 0.53 | 0.56 |
| SF8 | (1+2+3+4)+(5+7)+9+10 | 4 | 2 | 6 | 1203 | 86 | 0.60 | 0.60 |
| S1 | (11+13)+(15+17)+20 | 2 | 2 | 4 | 405 | 45 | 0.20 | 0.16 |
| S2 | (11+14)+(15+17)+20 | 2 | 2 | 4 | 426 | 51 | 0.23 | 0.22 |
| S3 | (11)+(15+19)+20 | 2 | 2 | 4 | 345 | 54 | 0.24 | 0.23 |
| S4 | (11+14)+(15+18)+20 | 2 | 2 | 4 | 345 | 64 | 0.27 | 0.24 |
| S5 | (11+12+14)+(15+18)+20 | 3 | 2 | 5 | 403 | 64 | 0.30 | 0.27 |
| S6 | (11+14)+(15+16)+20 | 2 | 2 | 4 | 450 | 78 | 0.33 | 0.32 |
| S7 | (11+12+14)+(15+16)+20 | 3 | 2 | 5 | 508 | 78 | 0.36 | 0.37 |
| W1 | (21+23+29)+(30+33)+38+39 | 3 | 2 | 5 | 2271 | 88 | 0.89 | 0.89 |
| W2 | (21+26+29)+(30+32)+38+39 | 3 | 2 | 5 | 2210 | 86 | 0.93 | 0.94 |
| W3 | (21+25+29)+(30+32)+38+39 | 3 | 2 | 5 | 2138 | 88 | 0.95 | 0.97 |
| W4 | (21+23+29)+(30+32)+38+39 | 3 | 2 | 5 | 2141 | 88 | 0.95 | 0.98 |
| W5 | (21+23+29)+(30+31+32)+38+39 | 3 | 3 | 6 | 2280 | 88 | 1.05 | 1.16 |
| W6 | (21+23+29)+(30+34)+38+39 | 3 | 2 | 5 | 2016 | 88 | 0.93 | 1.00 |
| W7 | (21+23+29)+(30+36)+37+43 | 3 | 2 | 5 | 1999 | 88 | 1.04 | 1.07 |
| W8 | (21+23+29)+(30+32)+37+39 | 3 | 3 | 6 | 2169 | 88 | 1.02 | 1.11 |
| W9 | (21+23+29)+(30+35+32)+38+39 | 3 | 3 | 6 | 2281 | 88 | 1.02 | 1.10 |
| W10 | (21+22+23+29)+(30+32)+38+39 | 4 | 2 | 6 | 2212 | 88 | 1.02 | 1.11 |
| W11 | (21+27+23+29)+(30+32)+38+39 | 4 | 2 | 6 | 2292 | 88 | 1.06 | 0.97 |
| W12 | (21+22+23+29)+(30+3132)+38+39 | 4 | 3 | 7 | 2351 | 88 | 1.12 | 1.16 |
| W13 | (21+22+23+28+29)+(30+32)+38+39 | 5 | 2 | 7 | 2471 | 88 | 1.18 | 1.16 |
| W14 | (21+22+23+28+29)+(30+31+32)+38+39 | 5 | 3 | 8 | 2610 | 88 | 1.28 | 1.22 |
| W15 | (21+22+24+29)+(30+32)+38+39 | 4 | 2 | 6 | 2225 | 88 | 1.03 | 1.02 |
| W16 | (21+24+28+29)+(30+32)+38+39 | 4 | 2 | 6 | 2413 | 88 | 1.12 | 1.11 |
| W17 | (21+22+23+29)+(30+36)+37+39 | 4 | 3 | 7 | 2070 | 88 | 1.00 | 0.91 |
| W18 | (21+22+23+29)+(30+32)+38+39+40+41 | 4 | 2 | 6 | 2375 | 93 | 1.07 | 1.30 |
| W19 | (21+22+23+29)+(30+32)+38+39+40+41+42 | 4 | 2 | 6 | 2466 | 98 | 1.09 | 1.35 |

number of composition of clothing ensembles mean the individual garment of <Table 1>

vidual garments composing of the clothing ensembles ($I_{cle\_summed}$). As a result, the correlation coefficient was 0.982($p<0.001$). However, there showed a little difference by seasonal clothing. For spring/fall wear, $I_{cle\_summed}$ were close to the $I_{cle\_total}$. For summer wear, $I_{cle\_summed}$ showed a slightly higher value than the $I_{cle\_total}$. For winter clothing, the results showed a reverse tendency to summer wear $I_{cle\_summed}$ was a little lower(or similar) than $I_{cle\_total}$. In particular, for the cases of W18 and W19 adding gloves, a muffler, or a

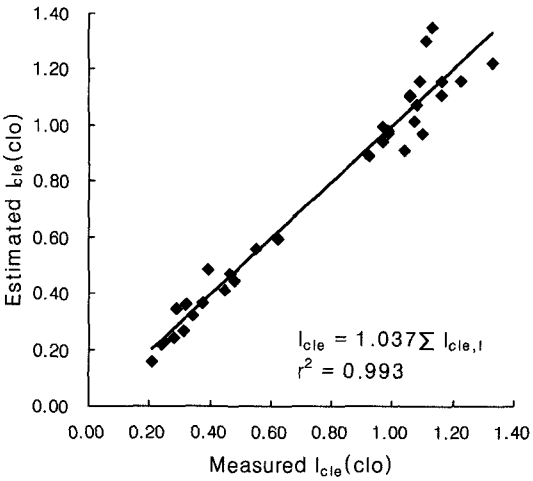


**Fig. 1. A scatter plot of $I_{cle}$ measured using a thermal manikin and $I_{cle}$ estimated by the thermal insulation accumulated by the individual garments($I_{cle\_summed}$).**

hat, increases in thermal insulation was higher than $I_{cle\_summed}$ by 0.23~0.26clo. It can be interpreted that blocking the openings around the periphery are a more effective way of keeping the body warm than adding insulation on other body parts.

For the case of estimating/predicting thermal insulation of clothing ensembles using the thermal insulation of the individual garments, we derived the following equation(Eq. 1). Explanatory power of <Eq. 1> was 99.3%(Fig. 1).

$$I_{cle} = 1.037\Sigma I_{cle,i} \ (r^2 = 0.993, p < 0.001) \qquad \text{<Eq. 1>}$$

**Table 3. Correlation coefficients between thermal insulation and clothing factors**

| Clothing factor | r |
|---|---|
| Clothing layers of upper-wear | 0.750*** |
| Clothing layers of lower-wear | 0.247 |
| Total of clothing layers | 0.738*** |
| Total clothing weight | 0.978*** |
| Covering Area | 0.776*** |
| Accumulated $I_{cle}$ (individual garment composing of the clothing ensembles) | 0.982*** |

***$p$<.001

### 3. Relationship between Thermal Insulation of Clothing Ensembles and Other Clothing Factors(Clothing layers, clothing weight, and covering area)

Regarding clothing layers, upper wear layers means the layers covered over the breast and lower wear layers means the layers covered over the pelvis and hip. In the cases where linings are included, we counted the lining to the total clothing layers as a piece. According to our previous study(Choi et al., 2006), the most worn clothing layers were three upper layers and two lower layers for spring/fall outwears, and total clothing layers were 4~6 layers Two upper layers and two lower layers(total 4~5 layers) for summer; four upper layers and two lower layers (total 5~8 layers) for winter. Shim(1985) reported higher numbers for the clothing layers. This is because she included a muffler, gloves, and socks in the total clothing layers. Correlation coefficient between $I_{cle\_total}$ and total clothing layers was 0.738 ($p$<0.001).

Regarding clothing weight, the total mass of clothing ensembles had a range of 493~1,203 g, 345~508 g and 1,999~2,610 g for spring/fall, summer, and winter wear, respectively. We did not include shoes to the total clothing mass. Correlation coefficient between $I_{cle\_total}$ and total clothing weight was 0.978($p$<0.001).

The surface area covered by clothing showed ranges from 72~86% for spring/fall, 45~78% for summer, and 86~98% for winter wear. The correlation coefficient between $I_{cle\_total}$ and covering area was 0.776($p$<0.001).

In cases where we only have information about clothing pictures, not clothing layers, total clothing weight, or thermal insulation of the individual garments, we derived another formula based on covering area. When estimating the thermal insulation of clothing ensembles with the clothing pictures, the following equation would be useful for the estimation. Explanatory power of <Eq. 2> was 98.9%(Fig. 2).

$$I_{cle} = 0.0004825 \times \text{clothing weight(g)} \ (r^2 = 0.989, p < 0.001) \qquad \text{<Eq. 2>}$$

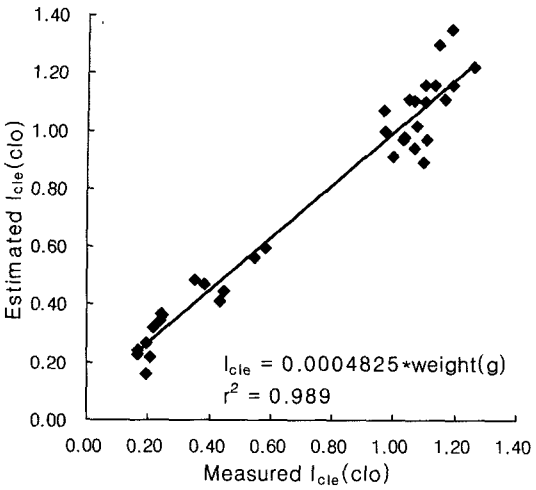


**Fig. 2. A scatter plot of $I_{cle}$ measured using a thermal manikin and $I_{cle}$ estimated total clothing weight.**

## IV. Summary and Conclusions

The purpose of this study was to investigate relationships between thermal insulation of clothing ensembles and clothing factors, such as the sum of thermal insulation of the individual garments, clothing layers, clothing mass, and covering area. To fulfill our goals, we surveyed first women's clothing with questionnaires by season. Based on the preliminary survey, we selected a total of 34 types of clothing ensembles. After setting the combinations and the individual garment, we measured directly clothing insulation using a thermal manikin, with the physical characteristics of the individual garments.

The results showed that 1) the thermal insulation of clothing ensembles had a range from 0.34~0.60clo (8 types) for spring/fall, 0.16~0.37clo(7 types) for summer, and 0.89~1.35clo(19 types) for winter 2) correlation coefficient between thermal insulation of clothing ensembles($I_{cle\_total}$) and thermal insulation accumulated by the individual garments composing of the clothing ensembles($I_{cle\_summed}$) was 0.982($p<$ 0.001). To estimate $I_{cle\_total}$ with $I_{cle\_summed}$, we derived the following equation: $I_{cle}=1.037I_{cle,i}$($r^2=0.993, p<0.001$) 3) the correlation coefficient between upper wear layers and $I_{cle\_total}$ was 0.750($p<0.001$), for the total clothing was 0.978, and for the covering area was 0.776($p<0.001$). All clothing factors involved in this study showed the significant relationships to $I_{cle\_total}$. Among those clothing factors, $I_{cle\_summed}$ had the strongest relationship to $I_{cle\_total}$.

In conclusion, we confirmed the possibility to estimate the thermal insulation of clothing ensembles using various clothing factors, with the high validity. Also, insulation-data obtained from both of the individual garments and clothing ensembles can be applied in quantification of the thermal insulation of commercial clothing products. Future studies concerning various accessories having relatively higher thermal insulation are required. Also, we need to compare the clothing insulation obtained from a thermal manikin and wearing trials of human subjects.

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## 요 약

본 연구에서는 한국 성인여성의 각 계절별 실제 착용하는 한 벌 의복조합과 보온력간의 상관관계를 알아보고자 하였다. 설문조사한 결과를 토대로, 총 34벌의 한 벌 의복과 이를 구성하는 단일의복 43종을 선정하여 써멀 마네킨을 이용하여 보온력을 측정하였고, 다음과 같은 결과를 얻었다.

한 벌 의복의 보온력은 봄가을(8벌) 0.34~0.60clo, 여름(7벌) 0.16~0.37clo, 겨울(19벌) 0.89~1.35clo였다. 단일의복 보온력의 단순가산치와 한 벌 의복의 보온력간의 상관계수는 0.982($p<0.001$)이며, 써멀 마네킨에 의해 측정된 한 벌 의복의 보온력과 상의 착의 매수간의 상관계수는 0.750($p<0.001$)이고 의복총중량과의 상관계수는 0.978($p<0.001$), 피복면적과의 상관계수는 0.776($p<0.001$)이었다. 한 벌 의복의 보온력과 의복요인과의 상관관계에서 단일의복 보온력의 단순가산치와 의복총중량이 가장 높은 상관을 보였다.