

Study on the Anthropometric and Body Composition Indices for Prediction of Cold and Heat Pattern

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Objectives: Many symptoms of cold and heat patterns are related to the thermoregulation of the body. Thus, we aimed to study the association of cold and heat patterns with anthropometry/body composition.

Methods: The cold and heat patterns of 2000 individuals aged 30–55 years were evaluated using a self-administered questionnaire.

Results: Among the anthropometric and body composition variables, body mass index (-0.37, 0.39) and fat mass index (-0.35, 0.38) had the highest correlation coefficients with the cold and heat pattern scores after adjustment for age and sex in the cold-heat group, while the correlation coefficients were relatively lower in the non-cold-heat group. In the cold-heat group, the most parsimonious model for the cold pattern with the variables selected by the best subset method and Lasso included sex, body mass index, waist-hip ratio, and extracellular water/total body water (adjusted $R^2 = 0.324$), and the model for heat pattern additionally included age (adjusted $R^2 = 0.292$).

Conclusions: The variables related to obesity and water balance were the most useful for predicting cold and heat patterns. Further studies are required to improve the performance of prediction models.

Key Words : Pattern identification, Cold pattern, Heat pattern, Anthropometry, Body composition

Introduction

Cold and heat patterns are major components of pattern identification, which is an essential diagnostic process in Korean medicine. Approximately 85% of Korean medicine doctors consider cold and heat patterns when prescribing herbal treatment¹⁾. Cold and heat patterns have opposed symptoms and signs such as preferences for heat or cold, and hot or cold sensation; thus, the two have generally been understood as opposing concepts. However, several researchers have

suggested that they need to be understood as independent concepts, because there are individuals who have both cold and heat patterns (cold-heat complex) or none of those patterns (no cold-heat)²⁾.

The evaluation of cold and heat patterns has generally been conducted by listening to the expression of patients about their relevant symptoms and inspecting the relevant signs and palpation by Korean medicine doctors; thus, the subjectivity of the participants and doctors could not be ruled out. There have been efforts to

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develop objective and quantitative methods for cold and heat pattern evaluation, such as the quantitative examination of facial color³⁾, metabolic rate^{4,5)}, thyroid function^{6,7)}, glucose metabolism⁸⁾, and sympathetic nerve function⁸⁻¹⁰⁾.

Most symptoms and signs of cold and heat patterns are related to the thermoregulation of the body, such as cold or heat sensation, sensitivity to low or high temperature, preferable water temperature, facial color, and the quantity and color of the urine. Therefore, it is worth studying the association of cold and heat patterns with anthropometric and body composition indices that have been reported to be associated with thermogenesis or thermoregulation. Previous studies that focused only on anthropometric indices have reported that increased body mass index (BMI) and thorax circumference are related to the increased level of heat pattern^{11,12)}. Regarding body composition, one study reported that fat-free mass (FFM) and body fat mass (BFM) have a negative correlation with cold pattern score and a positive correlation with heat pattern score⁴⁾; however, useful variables for a prediction model were not selected. We previously conducted a study on the association of cold/heat patterns with both anthropometry and body composition indices in elderly individuals aged ≥ 50 years¹³⁾ and presented the selected indices for prediction models. However, it is not possible to generalize the results to younger adults, and the cold and heat patterns were not evaluated independently.

This study aimed to investigate the association between cold and heat patterns and anthropometry/body composition and select the most useful

variables for predicting such patterns using the best subset method and least absolute shrinkage and selection operator (Lasso) in adults aged 30–55 years.

Subject and Methods

1. Participants

This study analyzed 2000 adults aged 30–55 years who participated in the Korean Medicine Daejeon Citizen Cohort study (KDCC) and completed the baseline visit. The KDCC is a prospective cohort study of community-based populations and uses stratified cluster sampling according to region, sex, and age. The baseline survey has been completed, and follow-up survey is scheduled to be conducted every 2 years¹⁴⁾. This study was approved by the Institutional Review Board of the Dunsan Korean Medicine Hospital of Daejeon University (no. DJDSKH-17- BM-12) and the Korea Institute of Oriental Medicine Institutional Review Board (no. I-1703/002-002). All participants were included in the study after providing informed consent.

2. Evaluation of cold and heat patterns

Self-administered questionnaires on usual symptoms were used to evaluate the cold and heat patterns of the participants. The questionnaire consisted of 15 items (eight items on cold patterns and seven items on heat patterns). All items were rated on a five-point Likert scale. The score of the cold and heat patterns is the sum of responses to the relevant items, with a higher score indicating a higher level of cold or heat pattern. A previous study suggested the cutoff

point for cold pattern as 21.5 in both men and women, and reported an agreement rate of 87.1% and a kappa value of 0.741. The suggested cutoff points for heat pattern were 17.5 in men and 16.5 in women, with an agreement rate of 78.5% and kappa value of 0.570¹⁵⁾.

In this study, participants with scores higher than the cutoff points in either cold or heat pattern were defined as the cold-heat (CH) group, while those with scores higher than the cutoff points in both cold and heat patterns (cold-heat complex) and those with scores lower than the cutoff points in both cold and heat patterns (no cold heat) were defined as the non-cold-heat (NCH) group.

3. Anthropometry

To measure the height and weight of participants, a stadiometer (BSM370, Biospace, Seoul, South Korea) was used. To measure weight and hip circumferences, a tape measure was used; the waist circumference was measured at the navel level, and the hip circumference was measured at the widest part of the gluteal region. Measurements of the waist and hip were conducted twice, and the mean value was used for analysis. BMI was calculated as weight in kilograms divided by the squared height in meters. Waist-hip ratio (WHR) was calculated as waist circumference divided by hip circumference.

4. Body composition

A multifrequency bioelectrical impedance analysis (InBody770, InBody, Seoul, South Korea) was used to analyze body composition. Values of FFM, BFM, skeletal muscle mass (SMM), body

cell mass (BCM), total body water (TBW), extracellular water (ECW) were extracted from the device. Fat-free mass index (FFMI), fat mass index (FMI)^{16,17)}, skeletal muscle index (SMI)¹⁸⁾, body cell mass index (BCMI)^{19,20)} were calculated respectively as FFM, FM, SMM, and SCM divided by the squared height. $ECW/TBW^{21)}$ is the ECW divided by TBW.

5. Statistical analysis

Sample characteristics are presented as means and standard deviations according to the four groups that constituted the CH and NCH groups. Group comparisons were conducted using Student's *t*-test for those with normal distribution, or the Mann-Whitney *U* test for those with non-normal distribution. Correlations between cold/heat score and anthropometric/body composition indices were analyzed using Pearson's correlation according to the CH and NCH groups. Partial correlation analyses were also conducted, adjusting for age and sex.

In the CH group, the best subset method and Lasso were applied to select adequate variables to predict the cold and heat scores²²⁾. In the best subset method, Mallows's C_p , Bayesian information criterion, and adjusted R^2 were used to select the optimal model. Lasso minimizes the residual sum of squares subject to the sum of the absolute values of the coefficients being less than a constant. It performs variable selection by forcing some of the coefficient estimates to be exactly zero, producing interpretable models²³⁾. To select an adequate value for lambda, which is a tuning parameter of Lasso, 10-fold cross-validation was used. The value of lambda that gives the

minimum mean cross-validated error (λ_{\min}) and another value of λ that gives the most regularized model such that the error is within one standard error of the minimum (λ_{1se}) were used. The chosen models were examined for multicollinearity using the variance inflation factor (VIF). If the VIF was ≥ 10 , the variable with the smallest standardized regression coefficient was removed. The final models were presented with variables with regression coefficients and adjusted R^2 values. Statistical significance was set at $P < 0.05$. All analyses were performed in R (the R Foundation for Statistical Computing, Version 4.0.5) using the leaps package (Version 3.1) and the glmnet package (Version 4.1-1) for the best subset method and the Lasso, respectively.

Results

Of the 2000 participants, 1133 (56.7%) were in

the CH group, and 867 (43.3%) were in the NCH group. In the CH group, age, cold score, heat score, and anthropometric and body composition indices were significantly different between the cold and heat groups. In the NCH group, age, cold score, heat score, FFMI, SMI, and BCMI showed significant differences (Table 1).

Correlation analysis between cold/heat score and anthropometric/body composition variables showed a significant correlation in the CH group, even after the adjustment for age and sex ($P < 0.001$). The variables with the highest correlation with the cold score were BMI (-0.37), FMI (-0.35), and BCMI (-0.31), while the variables with the highest correlation with heat score were BMI (0.39), FMI (0.38), and WHR (0.30). In the NCH group, the correlation coefficients were generally lower than those in the CH group, and some variables showed no significance. The variable with the highest correlation with the cold

Table 1. Characteristics of Study Participants

	CH group		<i>P</i>	NCH group		<i>P</i>
	Cold (N=561)	Heat (N=572)		Cold-heat complex (N=634)	No cold-heat (N=233)	
Age	44.46 ± 6.19	42.82 ± 7.12	< 0.001	43.44 ± 6.97	46.00 ± 6.41	< 0.001
Cold score	28.10 ± 4.15	17.27 ± 3.09	< 0.001	25.76 ± 3.18	16.06 ± 3.28	< 0.001
Heat score	13.77 ± 2.54	22.89 ± 3.85	< 0.001	21.62 ± 3.09	13.60 ± 2.63	< 0.001
Height	160.07 ± 6.49	165.53 ± 8.73	< 0.001	162.41 ± 8.57	161.81 ± 7.73	0.565
Weight	58.36 ± 8.90	71.81 ± 13.35	< 0.001	64.14 ± 11.83	64.19 ± 10.84	0.385
BMI	22.72 ± 2.72	26.10 ± 3.78	< 0.001	24.24 ± 3.50	24.44 ± 3.26	0.182
WHR	0.83 ± 0.06	0.89 ± 0.06	< 0.001	0.86 ± 0.06	0.86 ± 0.06	0.356
FFMI	15.46 ± 1.51	17.81 ± 2.26	< 0.001	16.41 ± 2.03	16.80 ± 2.09	0.008
FMI	7.26 ± 2.04	8.29 ± 2.96	< 0.001	7.83 ± 2.73	7.64 ± 2.47	0.672
SMI	8.36 ± 0.96	9.89 ± 1.46	< 0.001	8.98 ± 1.31	9.21 ± 1.36	0.015
BCMI	10.04 ± 1.03	11.67 ± 1.55	< 0.001	10.70 ± 1.39	10.96 ± 1.45	0.013
ECW/TBW	0.38 ± 0.01	0.38 ± 0.01	< 0.001	0.38 ± 0.01	0.38 ± 0.01	0.256

Abbreviations: CH, cold heat; NCH, non-cold heat; BMI, body mass index; WHR, waist-hip ratio; FFMI, fat-free mass index; FMI, fat mass index; SMI, skeletal muscle index; BCMI, body mass index; ECW, extracellular water; TBW, total body water.

score was BCMI (-0.17), and the variable with the highest correlation with the heat score was WHR (0.11) (Table 2).

To select adequate variables, the best subset method and Lasso were applied in the CH group, which showed a significant correlation with the variables. The most parsimonious model for cold score was the one with sex, BMI, WHR, and ECW/TBW, with an adjusted R^2 of 0.324. In women, the most parsimonious model included BMI and WHR, with an adjusted R^2 of 0.183. ECW/TBW was not included in the most parsimonious model, but was included in the remaining four models. In men, the most parsimonious model included only BMI, with an adjusted R^2 of 0.079. In the final model by adjusted R^2 (FMR), FMI and SMI were included without anthropometric variables, but had comparable adjusted R^2 with the model with only BMI.

The final five models for the heat score all included sex, age, BMI, and WHR. The models that additionally included FMI or ECW/TBW

were the most parsimonious, with adjusted R^2 of 0.292 or 0.297, respectively. In women, the most parsimonious model included age, BMI, and WHR, with an adjusted R^2 of 0.204. In men, the most parsimonious model included age and FMI, with an adjusted R^2 of 0.118 (Table 3).

Discussion

This study used a questionnaire that evaluated cold and heat patterns independently and computed cold and heat scores separately. We divided the participants into the CH and NCH groups and performed a correlation analysis between cold and heat scores independently with anthropometric and body composition indices.

The results showed that all anthropometric and body composition indices were significantly correlated with cold and heat scores in the CH group. The correlations were in opposite directions for the cold and heat scores. In contrast, in the non-CH group, the correlations were remarkably weaker than in the CH group. Therefore, the

Table 2. Correlation Coefficients Between Cold Score, Heat Score, and Anthropometry/Body Composition Variables

	CH group				NCH group			
	Cold score		Heat score		Cold score		Heat score	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
BMI	-0.46**	-0.37**	0.47**	0.39**	-0.15**	-0.11*	0.06	0.09*
WHR	-0.43**	-0.30**	0.40**	0.30**	-0.15**	-0.07	0.05	0.11*
FFMI	-0.52**	-0.30**	0.46**	0.28**	-0.26**	-0.16**	-0.02	<0.01
FMI	-0.21**	-0.35**	0.26**	0.38**	< 0.01	-0.06	0.10*	0.12**
SMI	-0.52**	-0.30**	0.47**	0.29**	-0.25**	-0.16**	-0.02	0.01
BCMI	-0.52**	-0.31**	0.47**	0.29**	-0.26**	-0.17**	-0.02	0.01
ECW/TBW	0.40**	0.16**	-0.37**	-0.15**	0.14**	0.05	-0.06	-0.07*

Pearson's correlation and partial correlation analyses with adjustment for age and sex were conducted. *, $P < 0.05$; **, $P < 0.01$. Abbreviations: CH (cold-heat); NCH (non-cold-heat); BMI, body mass index; WHR, waist-hip ratio; FFMI, fat-free mass index; FMI, fat mass index; SMI, skeletal muscle index; BCMI, body cell mass index; ECW, extracellular water; TBW, total body water.

prediction for cold and heat patterns using anthropometric/body composition indices was not considered adequate in the non-CH group. The best subset method and Lasso were performed

only in the CH group.

In the best subset selection and Lasso in the CH group, BMI and WHR were found to be critical in the prediction of both cold and heat

Table 3. Regression Coefficients and Adjusted R² of Regression Models for Cold Score by Anthropometry and Body Composition Variables in the CH group

	Best subset method			Lasso	
	FMM	FMB	FMR	FMLm	FML1
< All >					
Sex	3.29***	3.29***	3.34***	3.08***	3.10***
Age			0.04	0.02	
BMI	-0.48***	-0.48***		-0.45***	-0.46***
WHR	-12.01***	-12.01***	-13.72***	-12.92***	-12.25***
FFMI					
FMI			-0.43***		
SMI				-0.11	-0.1
BCMI			-0.98***		
ECW/TBW	122.3***	122.3***		112.34**	118.99***
Adjusted R ²	0.324	0.324	0.319	0.323	0.323
< Female >					
Age			0.04	0.04	
BMI	-0.53***	-0.53***	-0.53***	-0.48***	-0.57***
WHR	-15.75***	-15.75***	-16.68***	-17.07***	-16.29***
FFMI					
FMI					
SMI				-0.25	
BCMI					
ECW/TBW	143.32**	143.32**	134.91**	127.51**	
Adjusted R ²	0.183	0.183	0.184	0.183	0.173
< Male >					
Age					
BMI	-0.39***	-0.39***		-0.39***	-0.39***
WHR					
FFMI					
FMI			-0.36***		
SMI			-0.74**		
BCMI					
ECW/TBW					
Adjusted R ²	0.079	0.079	0.079	0.079	0.079

**, $P < 0.001$; *, $P < 0.01$; †, $P < 0.05$. Abbreviations: CH, cold-heat; FMM, Final model by Mallow's Cp; FMB, Final model by BIC; FMR, Final model by adjusted R²; FMLm, Final model using lambda.min; FML1, Final model using lambda.1se; BMI, body mass index; WHR, waist-hip ratio; FFMI, fat-free mass index; FMI, fat mass index; SMI, skeletal muscle index; BCMI, body cell mass index; ECW, extracellular water; TBW, total body water.

scores. This is consistent with previous studies that investigated the association between BMI and cold and heat patterns¹¹⁻¹³). In obese individuals,

heat production is increased and greater subcutaneous adipose tissue provides a significant insulating effect; however, their core temperature did not

Table 4. Regression Coefficients and Adjusted R² of Regression Models for Heat Score by Anthropometry and Body Composition Variables in the CH group

	Best subset method			Lasso	
	FMM	FMB	FMR	FMLm	FML1
< All >					
Sex	-3.03***	-1.86***	-3.03***	-1.86***	-2.63***
Age	-0.11***	-0.10***	-0.11***	-0.10***	-0.09***
BMI	0.37**	0.45***	0.37**	0.45***	0.54***
WHR	10.53**	10.75***	10.53**	10.75***	9.76**
FFMI					
FMI	0.16		0.16		
SMI					-0.42
BCMI					
ECW/TBW		-88.56**		-88.56**	-102.44**
Adjusted R ²	0.292	0.297	0.292	0.297	0.298
< Female >					
Age	-0.10***	-0.09**	-0.10***	-0.09**	
BMI	0.53***	0.51***	0.53***		0.52***
WHR	12.79***	12.19***	12.79***	11.98**	10.42**
FFMI					
FMI				0.53***	
SMI					
BCMI				0.71**	
ECW/TBW		-102.75**		-94.41*	-118.93**
Adjusted R ²	0.204	0.210	0.204	0.210	0.201
< Male >					
Age	-0.13***	-0.13***	-0.13***	-0.12***	-0.13***
BMI			0.11	0.06	0.11
WHR				3.76	
FFMI					
FMI	0.56***	0.56***	0.42	0.43	0.42
SMI					
BCMI					
ECW/TBW				-58.27	
Adjusted R ²	0.118	0.118	0.116	0.116	0.116

**, $P < 0.001$; *, $P < 0.01$; †, $P < 0.05$. Abbreviations: CH, cold-heat; FMM, Final model by Mallow's Cp; FMB, Final model by BIC; FMR, Final model by adjusted R²; FMLm, Final model using lambda.min; FML1, Final model using lambda.1se; BMI, body mass index; WHR, waist-hip ratio; FFMI, fat-free mass index; FMI, fat mass index; SMI, skeletal muscle index; BCMI, body cell mass index; ECW, extracellular water; TBW, total body water.

differ from that of non-obese individuals because of heat dissipation through some body parts such as hands is increased²⁴⁻²⁷). Thus, obese people seemed to have increased sensitivity to higher ambient temperature and warmer sensation, especially in the hands, by these mechanisms.

Among the body composition indices, ECW/TBW was the most commonly selected in the final models. As ECW/TBW increased, cold score increased, and as ECW/TBW decreased, the heat score increased. Previous studies reported that ECW/TBW increased with age and in people with sarcopenia, obesity, edema, acute heart failure, kidney disease, and hepatic diseases, and reflects the inflammation and nutritional status of patients²⁸⁻³⁰). ECW/TBW, which showed the smallest correlation coefficients, was included in the final model possibly because it provided additional information that the included anthropometric variables could not. FMI was also selected as an important variable in several models for both cold and heat patterns. In men, FMI was included in the final models more commonly, and for the heat score in men, all the final models included FMI. Further studies are needed regarding the association of these variables with cold and heat patterns.

In men, the adjusted R^2 of the final models was generally lower, almost half of that in women. Previous studies reported that the neutral temperature did not differ between men and women; however, women reported more discomfort about ambient temperature because they are more sensitive to deviations from the neutral temperature³¹). These sex differences in sensitivity or discomfort on temperature might affect the

cold and heat scores and might cause different adjusted R^2 values in the models.

In a previous study that included the elderly aged ≥ 50 years, we reported that the model that included only sex and BMI showed a comparable adjusted R^2 of 0.12, with other models that included body composition indices. However, in this study, we analyzed relatively younger adults aged 30-55 years, and the most parsimonious model among the final models included ECW/TBW with sex, BMI, and WHR, and had a relatively higher adjusted R^2 of 0.30. The differences in the methods of those two studies were as follows: (1) age of participants, (2) inclusion or exclusion of the NCH group, (3) the type of questionnaire for cold and heat patterns, and (4) standardization of indices of body composition by height. We performed additional analyses to investigate the causes of the different results. The results showed that (1) when we analyzed the participants of this study in the same manner as the previous study (using the cold-heat score of the previous study, including the NCH group), the most parsimonious model included sex, BMI, and ECW/TBW, and the adjusted R^2 was 0.22. (2) When we excluded the NCH group, the most parsimonious model was the same, with an increased adjusted R^2 of 0.31. (3) These results were similar to those of the present study (Table 3). (4) When we analyzed the participants of the previous study with the standardized body composition indices by height, the adjusted R^2 did not change from the previous study, and the most parsimonious model still included only sex and BMI. Overall, we can assume that the standardization of body composition indices and the questionnaire

for cold/heat pattern did not affect the adjusted R^2 ; however, the characteristics of participants, that is, age and inclusion/exclusion of the NCH group, largely affected the adjusted R^2 . Therefore, prediction of cold and heat patterns based on anthropometric and body composition indices seems more adequate in younger adults than in the elderly, and more accurately predicted values can be expected in the CH group, excluding the NCH group.

Several limitations of this study should be considered when interpreting the results. First, we analyzed the data of healthy adults aged 30–55 years; thus, the results cannot be generalized to individuals older or younger than the age range, or to patients with diseases. Second, in the variable selection for prediction of cold/heat pattern score based on anthropometric/body composition, we included only the CH group, which showed significant correlations between these indices. However, the NCH group comprised 43.3% of all participants. Further studies are needed to investigate the characteristics and adequate predictive variables in the NCH group.

Conclusion

This study investigated the association of cold and heat patterns with anthropometric/body composition variables and aimed to select the most useful variables for predicting cold and heat pattern scores. The results showed that BMI, WHR, ECW/TBW, and FMI were the most useful. The adjusted R^2 of the final models was approximately 0.30, which was higher than that in a previous study, although still not sufficiently

high, especially in men. Cold and heat patterns were significantly associated with anthropometry and body composition. However, various physiopathological mechanisms are thought to be related to cold and heat patterns, including metabolic rate, thyroid function, glucose metabolism, and sympathetic functions, as suggested by previous studies. This result is important because, among the relevant factors, factors regarding anthropometric and body composition were investigated in depth. Further studies are needed to improve the predictive models for cold and heat patterns.

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