integr med res 4 (2015) 189–194

Available online at www.sciencedirect.com

Integrative Medicine Research

journal homepage: www.imr-journal.com

Review Article

Body temperature regulation: Sasang typology-based perspective

*Duong Duc Pham, Chae Hun Leem**

Department of Physiology, Ulsan College of Medicine, Seoul, Korea

ARTICLE INFO

Article history:
Received 15 July 2015
Received in revised form
24 July 2015
Accepted 1 August 2015
Available online 17 August 2015

Keywords:
heat balance
Sasang medicine
temperature load
thermoregulation

ABSTRACT

Global warming induces a dramatic elevation of heat-related morbidity and mortality worldwide. Individual variation of heat stress vulnerability depends on various factors such as age, gender, living area and conditions, health status, and individual innate characteristics. Sasang typology is a unique form of Korean traditional medicine, which is based on the hypothesis that constitution-specific traits of an individual determine the particular distinctive tendency in various aspects, including responses to the external environment. Recent scientific evidence shows that Sasang types differ in body composition, metabolic profile, susceptibility to certain disease patterns, and perspiration. This review aims to interpret these findings under the context of heat balance consisting of heat production (H_{prod}), heat loss (H_{loss}), and heat load (H_{load}). Based on the published data, at a given body mass, the TaeEum type tended to have a lower H_{prod} at rest and at the exhaustion state, which may indicate the lower metabolic efficiency of this type. Meanwhile, the surface-to-mass ratio and heat capacity of the TaeEum type appear to be lower, implying a lower heat dissipation capacity and heat storage tolerance. Thus, because of these characteristics, the TaeEum type seems to be more vulnerable to heat stress than the other constitutions. Differences in temperature regulation across constitutional types should be taken into account in daily physical activity, health management, and medical research.

1. Introduction

Over the past several decades, climate change has become an emerging global threat to our planet and has induced a remarkable increase in morbidity and mortality by affecting the human health. According to an estimation by the World Health Organization, between 2030 and 2050, climate change may cause approximately 38,000 heat stress-related deaths annually.[1] It has been demonstrated that some populations are at a higher risk of heat-related illness and damage than others. Elderly persons and children are most vulnerable to heat stress[2–4] due to degeneration and immaturity in heat acclimation, respectively. Physical and mental illnesses also affect how the body responses to heat stress. Those who suffer from obesity, diabetes, hypertension, cardiovascular, and/or respiratory diseases have a higher incidence of heat-related disorders than healthy individuals of the same age and

* *Corresponding author.* Department of Physiology, Ulsan College of Medicine, 388-1 Poongnap-dong, Songpa-gu, Seoul, Republic of Korea.
E-mail address: leemch@amc.seoul.kr (C.H. Leem).

http://dx.doi.org/10.1016/j.imr.2015.08.001

gender.[4] Although population-based factors related to heat stress have been reported, far too little attention has been paid to physiological traits as determinants of heat stress vulnerability.

Investigation on the impact of physiology traits on health could be dated back to the ancient time, with the "Four Humor" theory of Hippocrates and Galen[5] in the West and constitution-based medicine, Ayurveda, in the East.[6] Recently, there has been an emerging interest in body type and constitution-based approach in the fields of individualized and tailored medicine. The somatotype theory of Sheldon[7] and Sasang constitutional medicine of Lee[8] have been investigated thoroughly. Among these four available constitution-based approaches, Sasang constitutional medicine appeared to be a well-structured theory that provided not only a type classification, but also a comprehensive theory related to medical practice.

According to Sasang constitutional medicine, human beings can be classified into four constitutional types: the Taeyang, TaeEum (TE), SoEum (SE), and SoYang (SY) types. Scientific evidence revealed that these four body types have distinct genetic bases[9–11] and differ in physical appearance,[12,13] body composition,[14] temperament traits,[15] hormonal regulations,[16,17] and vulnerability to particular diseases patterns.[18–20] In terms of thermoregulation, a few investigations suggested constitution-specific traits in skin structure,[21,22] sweating capacity,[21,23] and energy expenditure profile.[24]

The current review aims to describe the constitution-specific characteristics of Sasang types in heat stress regulation capacity and discuss the factors need to be taken into account in the studies of thermoregulation in Sasang typology.

2. Thermoregulatory response at rest and during exercise

Under basal condition (e.g., resting, thermoneutral, and fasting states), energy consumed for maintaining basal functional activities and body core temperature is the so-called basal metabolic rate (BMR). To some extent, BMR refers to the resting energy expenditure (REE), energy expenditure measured at the resting state.[25] Most of the energy consumed under basal condition comes from heat generation and needs to be released into the environment via various heat loss (H_{loss}) pathways such as conduction, radiation, convection, respiration, and evaporation. At rest, 54–60% of total H_{loss} occurs by radiation, 25% by convection and conduction, 14% by respiration, and <7% by sweating.[26] When heat production (H_{prod}) and H_{loss} are balanced, body core temperature can be maintained at nearly a constant level of 37 °C.

In daily life, energy used for digestion and absorption of food and for muscle contraction accounts for 30% of total energy expenditure. During exercise, 40% of total body energy expenditure is used to produce adenosine triphosphate for functional activities, whereas >60% is converted to heat. During heat exposure, when the ambient temperature is higher than the skin temperature, the gradient results in a heat load (H_{load}) to the body.[26] The increment in the body core temperature induced by H_{load} consequently initiates a negative feedback loop that stimulates cutaneous vasodilation, promoting skin blood flow and enhancing the heat dissipating function, particularly via evaporation. When the core temperature returns to normal, this thermoregulation process terminates and sweating stops. In case the heat dissipation process is insufficient to compensate for the H_{load}, the heat stored inside the body elevates the body core temperature to a thermal threshold at which heat-related illnesses such as heat stroke, heat cramp, and eventually death occur.[27]

Heat flow can be described as $H_{prod} = H_{loss} + H_{load}$, in which H_{prod} is the heat converted from energy expenditure and refers to metabolic heat production, H_{loss} is the heat dissipated to the environment, and H_{load} is the heat stored in the body. The next section describes constitution-specific characteristics of Sasang types according to these three factors.

3. Metabolic heat production and Sasang typology

Metabolic heat production (H_{prod}) strongly determines heat dissipation, and heat storage at rest and during exercise.[28] An equilibrium between the rates of H_{prod} and H_{loss} should be maintained in every thermal condition. Since H_{prod} is mainly determined by the body mass, particularly fat-free mass (FFM), comparative studies on thermoregulation response among groups of different body size should take into account the proportional relationship between H_{prod} and body size.[29]

Recently, there has been more attention on the metabolic basis of Sasang types. Based on the original text of Lee JeMa[8], Kim and Pham[30] raised a hypothesis that the physical principles of Sasang types may be interpreted under a context of two major seesaw processes, anabolic/catabolic seesaw and intake/discharge seesaw. Shim et al[31] then developed a more specific assumption that the distinction in metabolic profiles of the TE and other Sasang types may be due to a reduction of the mitochondrial metabolism of the TE type, which consequently results in a low REE per unit of body mass and a higher risk of weight gain in the TE type. Using an estimated equation, Chae et al[14] calculated BMR for Sasang types using simple anthropometric indices, such as weight, height, age, and gender, and reported that the TE type has a higher BMR than other Sasang types. Shim et al[32] calculated the BMR using weight and height, and then normalized it to the body mass to calculated the so-called cellular metabolic rate. They reported a lower cellular metabolic rate in the TE type in comparison with other Sasang types. However, as BMR or REE mainly originates from non-fat tissue, normalizing BMR or REE to the whole body mass may underestimate the real cellular metabolic rate. Data based on indirect calorimeter revealed that REE adjusted for FFM was identical among Sasang types, whereas the correlation between REE adjusted for FFM and body mass index was positively significant in the SY types only. However, these findings were of a study involving a relatively small sample size of young men only.[24] In our recent study on 304 males and females aged 20–50 years, REE was higher in the TE type. However, when normalized to FFM, REE was identical across Sasang types. Normalization of REE to weight showed a significantly low REE only in men of the TE type (Fig. 1).[23] These

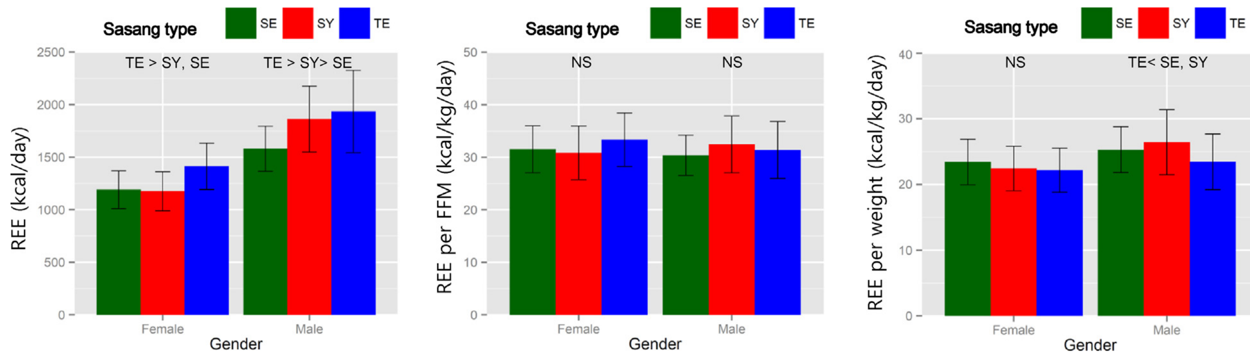

Fig. 1 – REE and REE normalized to fat-free mass and body weight across Sasang types.
***Note.* Data were extracted from Pham et al.[23]**
FFM, fat-free mass; NS, not significant; REE, resting energy expenditure; SE, SoEum type; SY, SoYang type; TE, TaeEum type.

findings therefore underline the need to investigate H_{prod} of Sasang types by a real measurement approach, and not by estimation.

Very few studies have been conducted to visualize the energy expenditure of Sasang types during exercise. Almost all the studies were focused on maximal oxygen uptake (VO_{2max}), the highest level of oxygen consumption during exercise. Pham et al[24] reported no difference in the VO_{2max} normalized to body weight among Sasang types in young men. However, in a larger sample size with age ranges from 20 years to 50 years, the VO_{2max} normalized to the body weight of the TE type was the lowest among Sasang types in men and women.[23] In addition, the TE type had a tendency to reach the stage of VO_{2max} earlier than the other types. From those results, we assume that the H_{load} threshold of the TE type during heat stress is lower than that of other Sasang types.

4. Heat dissipation capacity and Sasang typology

Heat exchange between the body and environment at rest contributes mostly to dry H_{loss}, whereas evaporation accounts for a major proportion of the total H_{loss} during exercise.[26] Although the dry H_{loss} and evaporation are body surface area (BSA)-dependent factors, it has been revealed that high BSA-to-mass ratio is a favorable condition for heat dissipation.[33] It has consistently been described in various studies that the TE type has a larger BSA than other types. However, when normalized to body weight, the TE type had the smallest ratio of BSA to body mass, whereas that in the SE type was the highest.[23] Since it has consistently been reported that the TE type has a higher percentage of fat,[14,20,23,24,34–36] a higher body mass index,[14] and a higher risk of being obese,[18] it is reasonable to assume that the subcutaneous adipose tissue, which functions as a thermal insulating layer inhibiting heat transfer from the body core to the skin when skin blood flow is low, is thicker in the TE type. Kim et al[22] found that the skin of the TE type has higher viscoelasticity, which may be due to a thick subcutaneous fat layer of this Sasang type. Several studies indicate that the TE type tends to have a higher rate of evaporation.[21,23] In our recent study, we found that the TE type has an elevation in sweating rate only in the middle of exercise, when confounding factors such as work load, H_{prod}, and temperature load, are taken into account.[23] Work-load-dependent evaporation in the TE type needs to be investigated in future studies. Moreover, other determinants of the heat dissipating capacity, such as skin blood flow, sweat gland function, and biochemical response during heat stress, have not yet been explored.

5. Heat load and Sasang typology

During heat stress, the increment of H_{loss} should proportionally match the elevation of H_{prod} to minimize H_{load} to maintain a normal body core temperature. When the increase of H_{prod} is larger than H_{loss}, H_{load} ascends rapidly to raise the body temperature. At a given H_{load}, the temperature increment of an object is conversely correlated with its heat capacity (HC). The HC of the body was defined as the energy required to increase the body temperature by 1 °C. Since the HC of fat (1.88 kJ/kg/°C) is lower than that in fat-free tissues (3.72 kJ/kg/°C),[37] 200 kJ of H_{load} after 90 minutes of intensive exercise[38] induces a temperature increment of 0.83 °C in a body of 70 kg weight with 15% fat, whereas the increment is 0.90 °C in the same weight of body with 30% fat.

It has been demonstrated that Sasang types differ in body mass index and body composition. The very first investigation on body composition of Sasang typology using bioelectric impedance analysis indicated a relatively higher fat mass, a larger body size, and a higher body mass index in the TE type.[14] Since then, various studies employed advanced body composition analysis such as multifrequency bioelectric impedance analysis[23,36] or dual energy X-ray absorptiometry.[39] According to the recently published studies by Cho et al[20] and Pham et al,[23] the average body fat varied between 28.6% and 28.7% for the TE type, between 20.2% and 22.2% for the SE type, and between 22.1% and 26.2% for the SY type (Table 1). As the body of TE individuals contains more fat, the HC at a given body mass of this body type is consequently lower than that in other Sasang types. Thus, a given H_{load} induces a higher temperature increment in the TE type than in other Sasang types.

Table 1 – Percent of body fat across Sasang types based on the studies of Cho et al[20] and Pham et al[23]

Authors	Measuring method	Population	TE	SE	SY
Cho et al (2013)[20]	BIA	$n = 2460$ (M = 1100; F = 1360) Age: 40–69 y	28.7 ± 6.8	22.2 ± 7.0	26.2 ± 6.4
Pham et al (2015)[23]	Multifrequency BIA	$n = 304$ (M = 178; F = 126) Age: 20–49 y	28.6 ± 6.8	20.2 ± 6.4	22.1 ± 6.3

BIA, bioelectrical impedance analysis; F, female; M, male; SE, SoEum type; SY, SoYang type; TE, TaeEum type.

6. Heat balance in Sasang typology and future studies

In the original text, Lee,[8] the founder of Sasang typology, described that the TE type has a relatively weak lung function and profuse perspiration indicates a healthy state in the TE type. It has been hypothesized that the lung function resembles catabolism,[30] and pathogenesis of the TE type is related to a relatively low H_{prod}.[32] It has also been demonstrated that the evaporation H_{loss} of this type is higher than that of other Sasang types.[23] However, no concrete explanation has been established so far. System investigations on the balance between H_{prod}, H_{loss}, and H_{load} may shed light not only on the thermoregulation response, but also on the metabolic function and pathological aspects of Sasang types.

In terms of H_{prod}, although REE (H_{prod} at the resting state) and VO_{2max} (the maximal physical endurance determinant) are higher in the TE type, normalization of these values to the unit of body mass reverses the pattern. In terms of H_{loss}, because BSA per unit of body mass is lower in the TE type, dry H_{loss} seems to be not favorably performed and then compensated by the functional excess in evaporation. In terms of H_{load}, because the HC per unit of body mass is lower in the TE type, this type appears to be more sensitive to temperature increment than other Sasang types. Fig. 2 shows a three-dimensional relation between H_{prod} with proxy as REE per unit of body mass, H_{loss} with proxy as BSA per unit of body mass, and H_{load} endurance capacity with proxy as HC per unit of body mass. There is a clear pattern in men and women that the TE individuals are distributed toward the region where REE per unit of body mass, BSA per unit of body mass, and HC per unit of body mass are the lowest, whereas the SE individuals are distributed in the opposite direction; the SY individuals are distributed in the region between the TE and SE individuals. Taken together, the TE type has metabolic and anthropometric characteristics that are not favorable to dealing with heat stress. Evidence also revealed that patients with obesity, diabetes, and hypertension are vulnerable to heat stress,[4] while these illnesses belong to the constitution-specific disease pattern in the TE type. However, whether the heat control characteristics of the TE type are related to those diseases has not been explored.

Although several explanations have been given to interpret the pathological principles of the TE type, such as two see-saws of catabolism/anabolism and intake/discharge[30] and a hypofunctional mitochondria activity,[32], a concrete theoretical model based on the flow and balance of heat/energy should be established. To investigate H_{prod} and H_{loss}, the whole-body energy expenditure should be measured,[38] and the comparison should take into account the difference in body size and surface area[29] of Sasang groups.

In the modern era, climate change and global warming contribute to an extremely high risk of heat-related illnesses in vulnerable individuals. Some well-known factors of heat stress vulnerability such as age, gender, living condition, diseases, and individual variation of heat stress tolerance can be explained partially by the constitutional approach. As

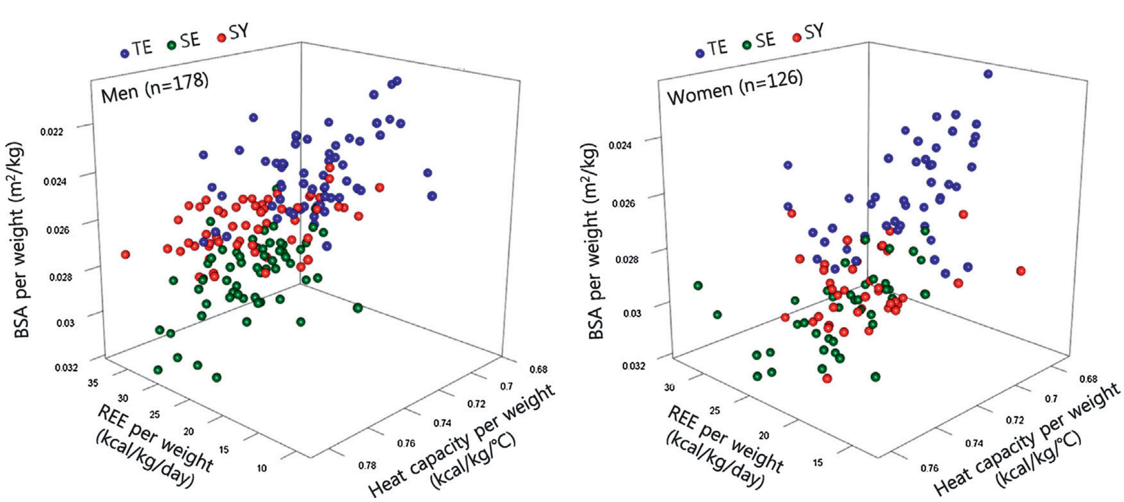

Fig. 2 – Three-dimensional relation between resting energy expenditure, body surface area, and heat capacity in 1 kg of body weight across Sasang types.
***Note*. Data were extracted from Pham et al.**
BSA, body surface area; REE, resting energy expenditure; SE, SoEum type; SY, SoYang type; TE, TaeEum type.

research on the thermoregulation response in Sasang typology is in infancy, well-designed and long-term experiments focusing on this issue should be performed.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

This work was supported by the Biomedical Technology Development Program of the National Research Foundation and funded by the Ministry of Science, ICT & Future Planning (Grant No. 2012-0009829).

REFERENCES

1. WHO. *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*. Geneva: WHO; 2014.
2. Na W, Jang JY, Lee KE, Kim H, Jun B, Kwon JW, et al. The effects of temperature on heat-related illness according to the characteristics of patients during the summer of 2012 in the Republic of Korea. *J Prev Med Public Health* 2013;46:19–27.
3. Rowland T. Thermoregulation during exercise in the heat in children: old concepts revisited. *J Appl Physiol* 2008;105:718–24.
4. Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O. Heat stress in older individuals and patients with common chronic diseases. *CMAJ* 2010;182:1053–60.
5. Jouanna J. Hippocrates as Galen's teacher. *Stud Anc Med* 2010;35:1–21.
6. Chatterjee B, Pancholi J. Prakriti-based medicine: a step towards personalized medicine. *Ayu* 2011;32:141–6.
7. Sheldon WH. The somatotype, the morphophenotype and the morphogenotype. *Cold Spring Harb Symp Quant Biol* 1950;15:373–82.
8. Lee JM. *Longevity and life reservation in eastern medicine*. 2nd ed. Translated by Choi SH. Seoul: Kyung Hee University Press; 2009.
9. Won HH, Lee S, Jang E, Kim KK, Park YK, Kim YJ, et al. A genome-wide scan for the Sasang constitution in a Korean family suggests significant linkage at chromosomes 8q11.22-23 and 11q22.1-3. *J Altern Complement Med* 2009;15:765–9.
10. Kim BY, Jin HJ, Kim JY. Genome-wide association analysis of Sasang constitution in the Korean population. *J Altern Complement Med* 2012;18:262–9.
11. Cha S, Yu H, Park AY, Oh SA, Kim JY. The obesity-risk variant of FTO is inversely related with the So-Eum constitutional type: genome-wide association and replication analyses. *BMC Complement Altern Med* 2015;15:120.
12. Pham DD, Do JH, Ku B, Lee HJ, Kim H, Kim JY. Body mass index and facial cues in Sasang typology for young and elderly persons. *Evid Based Complement Alternat Med* 2011;2011:749209.
13. Jang E, Do JH, Jin H, Park K, Ku B, Lee S, et al. Predicting Sasang constitution using body-shape information. *Evid Based Complement Alternat Med* 2012;2012:398759.
14. Chae H, Lyoo IK, Lee SJ, Cho S, Bae H, Hong M, et al. An alternative way to individualized medicine: psychological and physical traits of Sasang typology. *J Altern Complement Med* 2003;9:519–28.
15. Chae H, Park SH, Lee SJ, Kim MG, Wedding D, Kwon YK, et al. Psychological profile of Sasang typology: a systematic review. *Evid Based Complement Alternat Med* 2009;6(Suppl 1):21–9.
16. Lee J, Lee J, Shin H, Kim KS, Lee E, Koh B, et al. Suggestion of new possibilities in approaching individual variability in appetite through constitutional typology: a pilot study. *BMC Complement Altern Med* 2012;12:122.
17. Ahn SY, Park SH, Han SR, Ahn YM, Lee BC. Association between subclinical hypothyroidism and Sasang constitution in a Korean population. *Exp Ther Med* 2012;3:740–4.
18. Jang E, Baek Y, Park K, Lee S. Could the Sasang constitution itself be a risk factor of abdominal obesity? *BMC Complement Altern Med* 2013;13:72.
19. Lee J, Lee J, Lee E, Yoo J, Kim Y, Koh B. The Sasang constitutional types can act as a risk factor for hypertension. *Clin Exp Hypertens* 2011;33:525–32.
20. Cho NH, Kim JY, Kim SS, Lee SK, Shin C. Predicting type 2 diabetes using Sasang constitutional medicine. *J Diabetes Investig* 2014;5:525–32.
21. Jung SO, Park SJ, Chae H, Park SH, Hwang M, Kim SH, et al. Analysis of skin humidity variation between Sasang types. *Evid Based Complement Alternat Med* 2009;6(Suppl 1): 87–92.
22. Kim YM, Ku B, Jung CJ, Kim JU, Jeon YJ, Kim KH, et al. Constitution-specific features of perspiration and skin visco-elasticity in SCM. *BMC Complement Altern Med* 2014;14:24.
23. Pham DD, Lee JH, Park ES, Baek HS, Kim GY, Lee YB, et al. Thermoregulatory responses to graded exercise differ among Sasang types. *Evid Based Complement Alternat Med* 2015;2015:879272.
24. Pham DD, Lee JC, Ku BC, Kim YY, Kim JY. Relation between body mass index and resting metabolic rate, cardiorespiratory fitness and insulin sensitivity in Sasang typology for young male persons: an observational study. *Eur J Integr Med* 2012;4:E159–67.
25. Hulbert AJ, Else PL. Basal metabolic rate: history, composition, regulation, and usefulness. *Physiol Biochem Zool* 2004;77:869–76.
26. Irving PH. *Physics of the human body. Chapter 6: metabolism: energy, heat, work, and power of the body*. New York, USA: Springer; 2007:319–84.
27. Charkoudian N. Skin blood flow in adult human thermoregulation: how it works, when it does not, and why. *Mayo Clin Proc* 2003;78:603–12.
28. Gagnon D, Jay O, Lemire B, Kenny GP. Sex-related differences in evaporative heat loss: the importance of metabolic heat production. *Eur J Appl Physiol* 2008;104:821–9.
29. Cramer MN, Jay O. Selecting the correct exercise intensity for unbiased comparisons of thermoregulatory responses between groups of different mass and surface area. *J Appl Physiol* 2014;116:1123–32.
30. Kim JY, Pham DD. Sasang constitutional medicine as a holistic tailored medicine. *Evid Based Complement Alternat Med* 2009;6(Suppl 1):11–9.
31. Shim EB, Lee SW, Kim JY, Leem CH, Earm EY. TaeEum-type people in Sasang constitutional medicine have a reduced mitochondrial metabolism. *Integr Med Res* 2012;1:41–5.
32. Shim EB, Lee SW, Kim SJ, Leem CH, Kown KY, Baik YS, et al. Mitochondria hypothesis on the obesity-prone tendency in Tae-Eum people. *Kor J Ori Physiol Pathol* 2009;23:1241–6.
33. Epstein Y, Shapiro Y, Brill S. Role of surface area-to-mass ratio and work efficiency in heat intolerance. *J Appl Physiol Respir Environ Exerc Physiol* 1983;54:831–6.
34. Kim BS, Bae HS, Lim CY, Kim MJ, Seo JG, Kim JY, et al. Comparison of gut microbiota between Sasang

constitutions. *Evid Based Complement Alternat Med* 2013;2013:171643.

35. Hong JM, Yoon YS, Choi SM. A study of the difference in body composition, eating habits and dietary intake in three Sasang constitutions among elementary school children. *Korean J Commun Nutr* 2002;7:67–75 [In Korean].
36. Ko YS, You SE. Comparisons of physical fitness and body composition among Sasang types with and without body mass index as covariate. *Integr Med Res* 2015;4:41–7.
37. Havenith G, Coenen JM, Kistemaker L, Kenney WL. Relevance of individual characteristics for human heat stress response is dependent on exercise intensity and climate type. *Eur J Appl Physiol Occup Physiol* 1998;77:231–41.
38. Kenny GP, Gagnon D, Dorman LE, Hardcastle SG, Jay O. Heat balance and cumulative heat storage during exercise performed in the heat in physically active younger and middle-aged men. *Eur J Appl Physiol* 2010;109:81–92.
39. Song JS, Jeong HJ, Kim SJ, Son MS, Na HJ, Song YS, et al. Interleukin-1alpha polymorphism –889C/T related to obesity in Korean Taeumin women. *Am J Chin Med* 2008;36: 71–80.