

Correlation between Abdominal Fat Distribution and Abdominal Temperature in Korean Premenopausal Obese Women

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Objectives: Considering that homeothermy is a major component of metabolic rate, body temperature might play a role in the pathophysiology of obesity. This study aimed to determine the relationship between abdominal fat distribution and abdominal temperature in Korean, premenopausal, obese women.

Methods: Weight and height were measured in 26 premenopausal, obese women to calculate body mass index (BMI). Obesity was defined as a BMI $\geq 25\text{kg/m}^2$. Waist circumference (WC) was also measured as well as abdominal fat by computed tomography (CT) and abdominal temperature by digital infrared thermographic imaging (DITI).

Results: Visceral abdominal fat area was found to have a significant negative correlation with the temperature of *Guanyuan* (CV4, lower abdomen acupoint). We also found the visceral-subcutaneous fat ratio had a significant negative correlation with the temperature of CV4 and Right *Tianshu* (RST25, lateral navel acupoint). Only visceral fat and its ratio to subcutaneous fat had a significant correlation with abdominal temperature. Subcutaneous fat area and total fat area were not correlated with abdominal temperature.

Conclusions: This study suggests that abdominal visceral fat has a significant negative correlation with abdominal temperature. Further study is needed to uncover the relationship between abdominal fat distribution and temperature regulation in obese individuals and to define the role of body temperature in the pathogenesis of obesity.

Key Words : Obesity, abdominal fat distribution, visceral abdominal fat, abdominal temperature, digital infrared thermographic image

Introduction

Although the global obesity epidemic and its associated health consequences have aroused interest in the root causes of excessive fat accumulation in adipose tissue¹, no definite mechanisms have been identified. The common explanation that obesity is the result of overeating or limited physical activity is time honoured, but this hypothesis oversimplifies the complexity of the problem², as it has been demonstrated that lean and obese individuals differ

in their metabolic efficiency³. Considering that metabolic rate is important in energy output and homeothermy is a major component of resting metabolic rate (RMR), body temperature may play a role in the pathophysiology of obesity⁴.

Currently, some data⁵⁻⁷ support an inverse association between core temperature and obesity, while other data do not⁸⁻⁹. Studies involving different populations have provided considerable evidences for significant variations in both RMR and core temperatures¹⁰⁻¹³. In one study on the

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relationship between adiposity and regional body temperature, core temperature did not differ significantly between lean and obese subjects. In another study, digital infrared thermographic imaging (DITI)-measured abdominal skin temperature was significantly lower and fingernail-bed temperature was significantly higher in obese subjects than in lean subjects, suggesting that greater subcutaneous abdominal fat in the obese may provide a significant insulating layer that blunts abdominal heat transfer, and that augmented heat release from the hands may offset heat retention¹⁴). However, most studies on DITI-measured abdominal temperature that simply compare obese and non-obese subjects do not reflect the extent and the distribution of subcutaneous and visceral (intra-abdominal) fat¹⁵⁻¹⁶).

The purpose of this study was to determine whether abdominal fat distribution affects abdominal temperature in Korean premenopausal obese women.

Methods

1. Participants

Participants were recruited through announcements and advertisements in newspapers and on hospital websites. 30 obese (BMI ≥ 25 kg/m²) Korean women between 18 and 55 years of age were enrolled in the study from 1 July to 30 October 2011, after providing written informed consent. Participants had to be ambulatory, 18 to 55 years old, and have a body-mass index (BMI) ≥ 25 kg/m². Participants were excluded if they previously or currently had heart disease, hypertension, diabetes mellitus, kidney disease, or malignant tumors. Also excluded were smokers and participants who had experienced weight changes over 3 kg within the past 2 months, who received any treatment for obesity in the past 6 months, who were or might be pregnant or who had given birth in the last 6 months. Based on these exclusion criteria, we excluded 4 women (1 for hypertension, 1 for hydronephrosis, 2 for

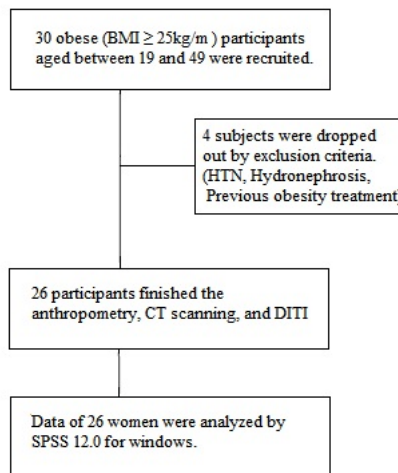


Fig. 1. Schematic diagram of study design.

Schematic diagram of study design. Thirty participants were recruited, and 4 subjects were excluded by exclusion criteria. Results of 26 women were analyzed.

previous obesity treatment), resulting in a sample population of 26 women (Fig.1). To avoid the effect of menopause on abdominal fat and body temperature, we included only premenopausal women. This study was approved by the Institutional Review Board of Kyung Hee University Hospital at Gang-dong.

2. Evaluation

1) Anthropometry

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. Waist circumference (WC) was measured by one observer, using the same tapeline, and was performed three times according to the World Health Organization (WHO) method, at mid-point between the lower end of the rib cage and top of the iliac crest in a standing position, which is usually 3 cm above the anterior superior iliac spine¹⁷.

2) Abdominal Fat Computed Tomography (CT) Scanning

Abdominal fat area was measured by CT scanning (Gemini 16 Power CT, Phillips Medical Systems, Cleveland, OH, USA) between the L4 and L5 vertebrae levels in a standing position¹⁸. Cross-sectional total fat area (TFA) and visceral fat

area (VFA) were estimated by delineating the regions and calculated at an attenuation range of -190 to -30 Hounsfield units (HU).

3) Digital Infrared Thermographic Imaging (DITI)

Abdominal temperature was measured by DITI (IRCT-510, Dong Seo Corporation, Su-won, Korea) at a consistent room temperature (25 °C) and humidity, with light and heat blocked from the outside.

To rule out other factors that may affect the thermographic image, 24 hours prior to measurement, irritations that could change body temperature, such as other treatments, medications, caffeine, alcohol, and exercise, were restricted. To improve measurement accuracy, participants waited 15 minutes in a quiet room at room temperature before the measurements began. A thermographic image was taken in a standing position. To minimize the effect of circadian rhythm, the DITI was performed during the afternoon for all participants¹⁹⁻²⁰.

Temperature measurement sites were chosen among acupuncture points cited in other studies²¹⁻²², and we designated 1cm² square test locations in the upper abdomen (*Zhongwan*, CV12), lower abdomen (*Guanyuan*, CV4), and lateral abdomen (*Tianshu*, RST25 and LST25) (Fig.2). The temperature inside

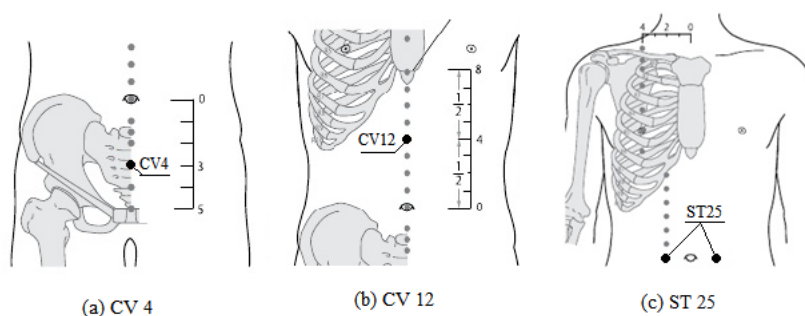


Fig. 2. Acupuncture point locations.

Acupuncture point locations. (a) CV 4, *Guanyuan*, (b) CV 12, *Zhongwan*, (c) ST 25, *Tianshu*. This figure originated from the World Health Organization Standard Acupuncture Point Locations.

Table 1. Participants Characteristics (n=26)

Characteristics	Mean \pm S.D.
Age (years)	36.0 \pm 10.9
Height (cm)	159.6 \pm 5.6
Weight (kg)	74.1 \pm 9.5
BMI (Kg/m ²)*	29.0 \pm 3.20
WC (cm) [†]	90.7 \pm 8.10
TFA (cm ²) [‡]	366.3 \pm 85.6
VFA (cm ²) [§]	103.7 \pm 33.8
SFA (cm ²)	262.8 \pm 90.2
VSR [¶]	0.48 \pm 0.33

Values are mean \pm standard deviation

*BMI, Body mass index

[†]WC, Waist circumference

[‡]TFA, Total fat area

[§]VFA, Visceral fat area

^{||}SFA, Subcutaneous fat area

[¶]VSR, VFA/SFA ratio

Table 2. Mean Abdominal Temperature by DITI (n=26)

Acupoint	Temperature (°C)
<i>Zhongwan</i> (CV*12)	31.3 \pm 1.5
<i>Guanyuan</i> (CV4)	31.0 \pm 1.4
Right <i>Tianshu</i> (RST [†] 25)	31.1 \pm 1.3
Left <i>Tianshu</i> (LST [‡] 25)	31.2 \pm 1.2

Values are mean \pm standard deviation

*CV, Conception vessel

[†]RST, Right stomach meridian

[‡]LST, Left stomach meridian

each square was measured three times and a mean value was calculated.

Guanyuan (CV4), the 4th meridian point of the conception vessel (CV), is located on the lower abdomen, at a point 3/5 down the ventral midline connecting the umbilicus to the pubic tubercle. *Zhongwan* (CV12), the 12th meridian point of the CV, is located on the upper abdomen, at the midpoint of the line connecting the xiphisternal junction and the center of the umbilicus. *Tianshu* (ST25), the 25th meridian point of the stomach meridian (ST), is located at 2 B-cun, lateral to the center of the umbilicus²³⁾.

4) Data analysis

All values are expressed as mean \pm SD.

Correlation between fat area and abdominal temperature was analysed by Spearman's correlation using the Statistical Package for the Social Sciences (SPSS) version 12.0 program for windows. A p-value less than 0.05 was considered statistically significant.

Results

1. Demographic characteristics of participants

The 26 women were aged from 18 to 49 years and had a BMI range of 25.4 to 35.5 kg/m². Participant demographics, anthropometric characteristics, and mean abdominal fat areas are

Table 3. Correlation between Abdominal Fat Area and Abdominal Temperature (n=26)

Fat area	Zhongwan (CV [‡] 12)	Guanyuan (CV4)	Right Tianshu (RST ^{**} 25)	Left Tianshu (LST ^{††} 25)
TFA [†] (cm ²)	0.19	0.14	0.26	0.22
VFA [‡] (cm ²)	-0.32	-0.42*	-0.31	-0.32
SFA [§] (cm ²)	0.25	0.23	0.31	0.27
VSR	-0.36	-0.45*	-0.41*	-0.37

Values are Spearman's correlation coefficient

*: significant at $p < 0.05$

†TFA, total fat area

‡VFA, visceral fat area

§SFA, subcutaneous fat area

||VSR, VFA/SFA ratio

‡CV, Conception vessel

**RST, Right stomach meridian

††LST, Left stomach meridian

summarized in Table 1. Mean abdominal temperatures by DITI are summarized in Table 2.

2. Abdominal fat and abdominal temperature correlation

Visceral fat area (VFA) was negatively correlated with the temperature at CV4 ($R = -0.420$, $p = 0.033$). There were no significant correlations between VFA and the other temperature locations (CV12, RST25, LST25). Visceral-subcutaneous ratio (VSR) was negatively correlated with the temperature of CV4 ($R = -0.450$, $p = 0.021$) and RST25 ($R = -0.413$, $p = 0.036$). There were no significant correlations between VSR and the other temperature locations (CV12, LST25). Total fat area (TFA) and subcutaneous fat area (SFA) were not significantly correlated with any of the abdominal temperatures. Correlations between abdominal fat and abdominal temperature by DITI are summarized in Table 3. and Fig.3.

Discussion

The aim of this study was to achieve a better understanding of body temperature in the pathophysiology of obesity by evaluating the relationships between the distribution of

abdominal fat and abdominal temperature under the thermoneutral conditions in Korean premenopausal obese women. Several studies have found that obesity is associated with lower body temperature. In previous studies, obese subjects classified by BMI or fat mass had significantly low temperatures in the trunk or belly, and blunted cold-induced thermogenesis^{4,15-16,24-25}, suggesting that the fat tissue has lower thermal conductivity and that the adipose tissue of obese individuals has lower blood flow²⁶. These results also suggest that the low temperature may cause obesity by lowering metabolic rate or changing lipid metabolism^{4,27}. However, these studies had limited discussion on the extent and the distribution of adipose tissue, and on whether abdominal temperature is more related to visceral or subcutaneous fat. Therefore, we conducted CT scanning to classify abdominal fat as visceral or subcutaneous fat. To our knowledge, this is the first study to demonstrate the relationship between the visceral abdominal fat and the abdominal temperature.

Our findings reveal that visceral fat has a correlation with lower abdominal temperature, while subcutaneous and total fat are not correlated with abdominal temperature. These results cast

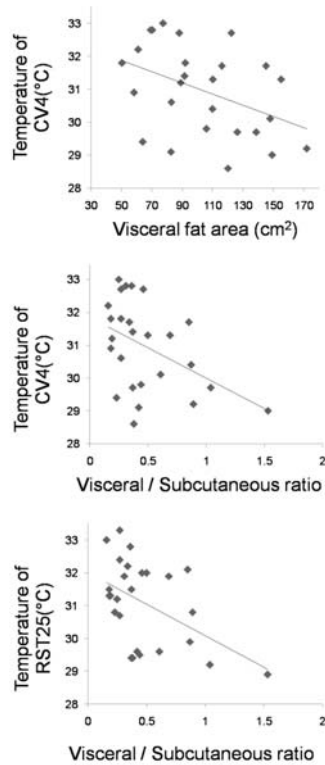


Fig. 3. Scatter graphs of correlation between abdominal fat and abdominal temperature.

Scatter graphs of correlation between abdominal fat and abdominal temperature. Visceral Fat Area (VFA) is negatively correlated with the temperature of CV4 ($R=-0.420$, $p=0.033$). Visceral-Subcutaneous Ratio (VSR) is negatively correlated with the temperature of CV4 ($R=-0.450$, $p=0.021$) and RST25 ($R=-0.413$, $p=0.036$).

doubt on the assumption that the low thermal conductivity of fat is responsible for the low abdominal temperatures. If this assumption is correct, TFA and SFA would correlate with the abdominal temperature, however our results indicate that only visceral fat or its ratio is significantly correlated with abdominal temperature.

The primary role of adipose tissue is as a passive energy reservoir. The main function of white adipose tissue (WAT) is energy storage, whereas brown adipose tissue (BAT) produces heat. In all mammals including humans, most fat tissue is WAT located in various organs and parts

of the body²⁸⁻²⁹). WAT is the main reservoir in mammals, and it serves as thermal and mechanical insulation. Recently, adipose tissue has been recognized as a dynamic endocrine organ, involved in broad metabolic processes. WAT secretes several major hormones, such as leptin and adiponectin, protein signals, and factors, such as adipokines, and is finally being recognized as an endocrine organ³⁰).

The location and distribution of adipose tissue reveals its function. Subcutaneous adipose tissue is located underneath the skin and reserve body fat or acts as thermal insulation. Visceral adipose tissue is located between organs and secretes

endocrine hormones such as leptin. It also releases non-esterified fatty acid (NEFA) directly into the portal system, thus increasing oxidative stress and insulin resistance. Hence, visceral adipose tissue has a greater effect on hepatic metabolic function than subcutaneous fat, and in turn, on systematic metabolism. In addition, it also secretes several unique adipokines and proinflammatory factors causing a chronic inflammatory state³⁰⁻³². Visceral fat likely play a greater metabolic role that affects skin temperature than subcutaneous fat, as the latter serves merely as insulation.

Guanyuan (CV4), which showed a negative correlation with VFA and VSR in our study, is located at a point 3/5 down the ventral midline connecting the umbilicus to the pubic tubercle²³. CV4 is reportedly related to gynaecological disorders and abdominal obesity. In Korean medicine, the conception vessel nourishes the uterus to adjust the body functions and CV4 is an important acupoint that reinforces qi and blood. In treatment, indications of CV4 include genitourinary and gynaecological disorders, and several deficiency syndromes³³⁻³⁴. As a main point that reflects the essential energy of the body, we expected that CV4 would correlate with metabolic visceral fat. Thus temperature of CV4 could be a possible tool for assessment of the visceral fat.

This study had several limitations. First, the sample size was too small to generalize our findings. Second, body temperature can vary by person, and even in one individual, results may vary depending on the season or other external factors. In future studies, assessment of body temperature should be done for a prolonged period, and mediating factors, such as fasting or low energy intake, should be assessed on both obese and lean individuals. Third, other factors that could affect body temperature such as basal metabolic rate (BMR), autonomic nervous system (ANS) activity, and body surface area were not

considered in this study.

Other temperature sites, such as core temperature and distal skin temperature, should also be measured. Also, instead of simply comparing the subjects' temperatures, a gap of temperatures between different sites (e.g. between anal and abdominal temperature) in one person, or the ability to control one's temperature in different conditions could help explain homeothermy in the pathogenesis of obesity. Other diagnostic methods, such as blood tests or heart rate variability (HRV) testing, would also help us understand body temperature mechanisms (e.g. chronic inflammation state or imbalance of ANS) in the obese.

Conclusion

In order to study the correlation between the abdominal fat distribution and abdominal temperature, we conducted anthropometry, abdominal fat CT scanning, and DITI in 26 Korean premenopausal obese women aged from 18 to 49, BMI range from 25.4 to 35.5 kg/m². We analyzed the correlation between abdominal fat distribution and abdominal temperature at 4 sites (CV4, CV12, RST25, LST25) using Spearman's correlation, and the results are shown below.

1. VFA and the temperature of CV4 had a significant negative correlation. VFA and temperature of other points (CV12, RST25, LST25) had no significant correlation.
2. VSR and the temperature of CV4 and RST25 had a significant negative correlation. VSR and temperature of other parts (CV12, LST25) had no significant correlation.
3. Neither SFA and TFA had any significant correlation with abdominal temperature.

Our study suggests that lower abdominal temperature has a significant negative correlation with abdominal visceral fat. Lower abdominal temperature could be a tool for assessment of the visceral fat. Further studies are necessary to uncover relationships between abdominal fat distribution and temperature regulation in obese subjects.

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References

1. WHO. Obesity and Overweight. Fact sheet 311 Geneva, Switzerland:World Health Organization: 2006.
2. Flier JS, Maratos-Flier E. What fuels fat. *Sci Am*. 2007;297(3):72-81.
3. Bouchard C, Tremblay A, Despres JP, Nadeau A, Lupien PJ, Theriault G, et al. The response to long-term overfeeding in identical twins. *N Engl J Med*. 1990;322(21):1477-82.
4. Landsberg L, Young JB, Leonard WR, Linsenmeier RA, Turek FW. Is obesity associated with lower body temperatures? Core temperature: a forgotten variable in energy balance. *Metabolism*. 2009;58(6):871-6.
5. Rising R, Keys A, Ravussin E, Bogardus C. Concomitant interindividual variation in body temperature and metabolic rate. *Am J Physiol*. 1992;263(4 Pt 1):E730-4.
6. Adam K. Human body temperature is inversely correlated with body mass. *Eur J Appl Physiol Occup Physiol*. 1989;58(5):471-5.
7. Kim H, Richardson C, Roberts J, Gren L, Lyon JL. Cold hands, warm heart. *Lancet*. 1998;351(9114):1492.
8. Rising R, Fontvieille AM, Larson DE, Spraul M, Bogardus C, Ravussin E. Racial difference in body core temperature between Pima Indian and Caucasian men. *Int J Obes Relat Metab Disord*. 1995;19(1):1-5.
9. Eriksson H, Svardsudd K, Larsson B, Welin L, Ohlson LO, Wilhelmsen L. Body temperature in general population samples. The study of men born in 1913 and 1923. *Acta Med Scand*. 1985;217(4):347-52.
10. Roberts DF. Climate and human variability. 2nd edition. Menlo Park, California:Cummings Pub. Co. 1978:169-83.
11. Henry CJ, Rees DG. New predictive equations for the estimation of basal metabolic rate in tropical peoples. *Eur J Clin Nutr*. 1991;45(4):177-85.
12. Soares MJ, Francis DG, Shetty PS. Predictive equations for basal metabolic rates of Indian males. *Eur J Clin Nutr*. 1993;47(6):389-94.
13. Leonard WR, Sorensen MV, Galloway VA, Spencer GJ, Mosher MJ, Osipova L, et al. Climatic influences on basal metabolic rates among circumpolar populations. *Am J Hum Biol*. 2002;14(5):609-20.
14. Savastano DM, Gorbach AM, Eden HS, Brady SM, Reynolds JC, Yanovski JA. Adiposity and human regional body temperature. *Am J Clin Nutr*. 2009;90(5):1124-31.
15. Ha JY, Joe JH, Jang JB, Lee KS. DITI of the Obesity Patients Compared with Non Obesity Group. *J Oriental Medical Thermology*. 2003;2:43-48.
16. Choi EM, Cho JH, Jang JB, Lee KS. The relations between Waist-to-Hip Ratio (WHR) and the abdominal temperature. *J Oriental Medical Thermology*. 2003;2.
17. WHO. Waist Circumference and Waist-Hip

- Ratio. Report of a WHO Expert Consultation. Geneva, 8-11 December 2008. Geneva, Switzerland. WHO: 2011:5-7.
18. Yoshizumi T, Nakamura T, Yamane M, Islam AH, Menju M, Yamasaki K, et al. Abdominal fat: standardized technique for measurement at CT. *Radiology*. 1999;211(1):283-6.
 19. Kim JM. Clinical application of infrared thermotherapy-focusing onto practical aspects. *J Korea Inst of Oriental medical diagnostics*. 2000;4:32-42.
 20. Ring EFJ, Ammer K. The Technique of Infra-red Imaging in Medicine *Thermology International*. 2000;10:7-14.
 21. Hwang DS, Cho JH, Lee Ch, Lee JH, Jang JB, Lee KS. A Study of DITI in Women with Premenstrual Syndrome. *J Oriental Obstetrics & Gynecology*. 2008;21:111-20.
 22. Kim HW, Kim YS, Lee KS. DITI of the Abdomen on twenties` Dysmenorrhea Patients. *J Oriental Obstetrics & Gynecology*. 2001;14:311-18.
 23. WHO. WHO Standard Acupuncture Point Locations in the West Pacific Region. Geneva, Switzerland:WHO WPRO. 2008:58,221,225.
 24. Yeo JD, Jeon JB. Analysis of CT, MRI, DITI for the Diagnosis of Abdominal Obesity and Clinical Usefulness. *J Kor Contents Asso*. 2011;11:252-59.
 25. Claessens-van Ooijen AM, Westerterp KR, Wouters L, Schoffelen PF, van Steenhoven AA, van Marken Lichtenbelt WD. Heat production and body temperature during cooling and rewarming in overweight and lean men. *Obesity*. (Silver Spring) 2006;14(11):1914-20.
 26. Jansson PA, Larsson A, Smith U, Lonnroth P. Glycerol production in subcutaneous adipose tissue in lean and obese humans. *J Clin Invest*. 1992;89(5):1610-7.
 27. Kahn HS. The accumulation of visceral adipose tissue may be influenced by intra-abdominal temperature. *Obes Res*. 1996;4(3):297-9.
 28. Trayhurn P, Wood IS. Adipokines: inflammation and the pleiotropic role of white adipose tissue. *Br J Nutr*. 2004;92(3):347-55.
 29. Cinti S. Between brown and white: novel aspects of adipocyte differentiation. *Ann Med*. 2011;43(2):104-15.
 30. Vázquez-Vela M, Torres N, Tovar A. White adipose tissue as endocrine organ and its role in obesity. *Arch Med Res*. 2008;39:715-28.
 31. Erin EK, Jefferey SF. Adipose tissue as an endocrine organ. *J Clin Endocrinol Metab*. 2004;89:2548-56.
 32. Monteiro R, Azevedo I. Chronic inflammation in obesity and the metabolic syndrome. *Mediators Inflamm*. 2010;2010:1-10.
 33. Fu H, He Y, Gao Y, Man Y, Liu W, Hao H. Acupuncture on the Endometrial Morphology, the Serum Estradiol and Progesterone Levels, and the Expression of Endometrial Leukaemia-inhibitor Factor and Osteopontin in Rats. *Evid Based Complement Alternat Med*. 2011;2011:1-9.
 34. Zhou J, Qu F, Sang X, Wang X, Nan R. Acupuncture and auricular acupressure in relieving menopausal hot flashes of bilaterally ovariectomized Chinese women: a randomized controlled trial. *Evid Based Complement Alternat Med*. 2009;2011:1-8.