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Core body temperature is lower in postmenopausal women than premenopausal women: potential implications for energy metabolism and midlife weight gain

Lisa M. Neff, MD, MS[a,b,*], **Mindy E. Hoffmann, MD, MA**[a,b,*], **Dinah M. Zeiss, MS**[a], **Katherine Lowry**[c], **Monica Edwards, MD, MPH**[a], **Sarah M. Rodriguez, MD**[b], **Kelley N. Wachsberg, MD**[b], **Robert Kushner, MD**[a,b], and **Lewis Landsberg, MD**[a,b]

[a]Northwestern Comprehensive Center on Obesity, Northwestern University, Feinberg School of Medicine, Chicago, IL

[b]Department of Medicine, Northwestern University, Feinberg School of Medicine, Chicago, IL

[c]Department of Medicine, Southern Illinois University School of Medicine, Springfield, IL

Abstract

Objective—Weight gain during the menopausal transition is common. Although studies have suggested that weight gain is more likely related to aging than menopause, there is a reduction in resting energy expenditure with surgical or natural menopause which is independent of age and changes in body composition. The underlying mechanisms could include a reduction in core body temperature.

Methods—Data were obtained from two related studies. Sample size was 23 men and 25 women (12 premenopausal,13 postmenopausal). In the Clinical Research Unit, core temperature was measured every minute for 24 hours (CorTemp System,HQ Inc.).

Results—Mean 24-hour core body temperature was 0.25 ± 0.06 °C lower in postmenopausal than premenopausal women (p=0.001). Mean 24-hour core temperature was 0.34 ± 0.05 °C lower in men than in premenopausal women (p<0.001).

Conclusions—Postmenopausal women, like men, had lower core body temperatures than premenopausal women. This may have implications for midlife weight gain.

Keywords

temperature; menopause; women; obesity; metabolism; weight

Corresponding Author: Lisa Neff, MD, MS, Assistant Professor of Medicine-Endocrinology, Feinberg School of Medicine, 645 N. Michigan Ave., Suite 530-30, Chicago IL, 60611, Phone: 312-503-3267, Fax: 312-926-8693, lneff@nm.org.

*LMN and MEH contributed equally as first authors.

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Introduction

Weight gain during the menopausal transition is a common symptom. Controversy exists as to whether perimenopausal weight gain is due to changes in energy metabolism related to aging or changes in sex hormones related to menopause. Many studies have suggested that aging is the primary driver of weight gain in perimenopausal women, rather than menopause per se.[1-4] However, there is a reduction in resting energy expenditure at menopause which has been shown to be independent of changes in body composition.[5] In a rodent model, this decreased energy expenditure occurs as a result of the surgical loss of ovarian function rather than aging.[6] In premenopausal women, acute sex hormone suppression with GnRH antagonist therapy reduces resting energy expenditure below baseline follicular phase levels.[7]

The mechanisms underlying changes in energy expenditure at menopause could include a reduction in core body temperature. Indeed, body temperature is an understudied variable linked to energy metabolism.[8] It has been estimated that 40-80% of a typical mammal's basal metabolic rate is spent in the cost of maintaining homeothermy.[9] In addition, small decreases in body temperature coincide with large decreases in energy expenditure, as seen in previous studies of caloric restriction in humans.[10, 11] Therefore, a small decrease in core temperature with menopause could lead to significantly decreased energy expenditure and weight gain over time.

Body temperature has long been known to decline with extremes of age in men. However, recent data suggest that women may also experience a decrease in body temperature around ages 40-60.[12] The more abrupt decline in body temperature observed in women could be due to menopause. In contrast, the gradual decline in temperature that occurs in men could correlate with the more gradual sex hormone changes of andropause.

Prior studies have measured core body temperature in postmenopausal women. Using an ingested core temperature sensor (the CorTemp sensor), Freedman et. al. found that core body temperature is significantly lower over 24 hours and during sleep in postmenopausal women who experience hot flashes than in asymptomatic postmenopausal women.[13] Freedman and Subramanian assessed core temperature in premenopausal women and postmenopausal women with and without hot flashes using a rectal probe over 2-4 sessions lasting 5 hours each.[14] The mean rectal temperature was significantly lower in postmenopausal women with hot flashes than in asymptomatic postmenopausal and premenopausal women.

Our study is the first known study to assess 24-hour core body temperature in premenopausal versus postmenopausal women using the ingested CorTemp sensor. We hypothesized that 24-hour core temperature would be lower in postmenopausal women than in premenopausal women, which could have implications for energy metabolism in midlife.

Methods

Subjects

Subjects' data were obtained from two separate but related studies of core temperature conducted by the same investigators using the same methods. The first study, conducted in 2009-2010, was designed to explore potential differences in core body temperature between lean (BMI: 18.5-24.9 kg/m^2) and obese (BMI: 30.0-39.9 kg/m^2) men and women, ages 25-40.[15] Subjects were lean men (n = 6), lean women (n = 6), obese men (n = 6) and obese women (n = 6). All subjects were weight stable, with no weight change of > 2% for at least 2 months. The second study, conducted in 2011-2013, was primarily designed to examine changes in core body temperature with weight loss. This study included overweight and obese (BMI: 27 to 39.9 kg/m^2) men (n = 11) and postmenopausal women (n = 13), ages 18-65. For this report, only baseline data were included. Subjects were weight stable; they had no weight change of > 2% in the 2 months prior to study enrollment and were within 3% of their maximal body weights. The sample size drawn from the combined studies was 23 men and 25 women, ages 23-64 (See Table 1). A wide range of ethnic backgrounds was represented.

Potential volunteers were excluded if they had a medical condition or took medications which might affect core temperature or the use of the CorTemp System. Premenopausal women had a history of regular menstrual cycles (25-30 days duration) and were admitted during days 1-7 of their menstrual cycle (follicular phase). Both studies were approved by Northwestern's institutional review board.

Procedure

Detailed procedures have been published previously.[15] In brief, subjects were admitted for a 24-hour stay at the Northwestern Clinical Research Unit (CRU). Participants were asked to wear light clothing and a comfortable room-temperature (~ 70° F) environment was maintained. At 9 a.m., each subject swallowed a pill-sized CorTemp sensor (CorTemp H.Q. Inc., Palmetto, FL). The sensor passed through the subject's gastrointestinal tract and sent a core temperature reading every minute to an external monitor worn at the waist. The monitor recorded the subjects' temperatures during standardized activities including rest, sleep, and meals. Participants also exercised on a stationary bicycle for 20 minutes, with a goal of achieving at least 10 consecutive minutes between a level of 5 (hard) and 7 (very hard) on the Rate of Perceived Exertion scale.

The Institute of Medicine (IOM) predictive equations were utilized to estimate each subject's total energy expenditure, which was provided in the form of three meals, each containing 15% protein, 35% fat, and 50% carbohydrate.[16]

Body composition was measured using the QDR 4500 Acclaim Series Elite DEXA scan (Hologic Europe, Bedford, MA).

Data analysis

Outlier temperature data points due to incorrect signals from CorTemp monitors were excluded if they were greater than two standard deviations from the mean. Mean temperature and standard deviation were calculated for each subject during four time intervals: exercise (20 minutes), during dinner (30 minutes), sleep (excluding the first and last half hour), and 24 hours (excluding the first 4 hours after the pill was swallowed to ensure passage into the small intestine). Data analyses were conducted using SPSS v. 22 (IBM). Means and standard error of the mean (SEM) were calculated for subject characteristics (Table 1). Independent samples t-tests were performed to assess for significant differences between study groups. Pearson's correlations were utilized to explore relationships between continuous variables. Significance was taken as $p < 0.05$.

Results

Mean (± SEM) 24-hour core body temperature was 0.25 ± 0.06 °C lower in postmenopausal women than in premenopausal women ($p = 0.001$) (See Fig. 1). Mean core temperature during sleep was 0.28 ± 0.08 °C lower in postmenopausal women than premenopausal women ($p = 0.002$), and similar differences were found during dinner and exercise (both p's < 0.05) (See Fig. 1). Similarly, mean core body temperature was significantly lower at all timepoints (all p's < 0.05) among our postmenopausal women (mean BMI 34.8 ± 1.1) than among the subset of obese premenopausal women (mean BMI 33.9 ± 0.2). Mean 24-hour core temperature was 0.34 ± 0.05 °C lower in men than premenopausal women ($p < 0.001$), with similar differences found during sleep, dinner, and exercise (all p's < 0.01) (See Fig. 1). Mean core temperature was not significantly different between postmenopausal women and men (See Fig. 1). There was a significant correlation between age and 24-hour core body temperature for women ($r = 0.615$, $p = 0.001$) (See Fig. 2) but not men in our cohort of individuals under age 65.

Discussion

In this post-hoc analysis, we observed that postmenopausal women, like men, have lower core body temperatures than premenopausal women. Postmenopausal women were on average 0.25°C cooler, which is equivalent to a 3.25% reduction in energy expenditure, or 65 fewer kilocalories burned per day. For a typical postmenopausal woman, 50 years old, 150 lbs. (68 kg) and 5 ft. 4 in. (162.5 cm) tall, this would lead to 6.7 lbs. (3.04 kg) of weight gain in one year, assuming no metabolic adaptation to weight gain. On the other hand, it is well known that energy expenditure increases in response to weight gain; thus the amount of weight accumulated over time may be more modest.[17] If confirmed in future studies, however, our findings are likely to have important implications for cardiometabolic health. Relatively small weight gains of 5 kg or less in adulthood have been associated with an increased risk of type 2 diabetes, cardiovascular disease, and stroke in women as well as men. [18-21]

Importantly, the differences in core temperature in this study cannot be attributed to differences in body composition or size. The regulation of core body temperature is a

function of the hypothalamic set-point, and as such it is thought to be independent of body surface area, fat mass, and lean mass.[22]

Our findings add to what has already been reported by Freedman and Subramanian, who found that postmenopausal women with hot flashes had significantly lower core temperatures than asymptomatic postmenopausal and premenopausal women.[14] Notably, we did not assess for the presence of hot flashes in our subjects.

Our study had several other limitations. We may not have observed a decline in core temperature with increasing age in men because our cohort included few men above age 50 and none above age 65, when we would expect to see the greatest decreases in core temperature in men. Another limitation is that all the female subjects ages 41 and older were postmenopausal, so we were not able to differentiate the effects of age and menopausal status on core temperature. Finally, season was not standardized in this study; all volunteers were studied in a research unit under thermoneutral conditions, however, to minimize any potential environmental effect on core body temperature.

Conclusions

Although exploratory in nature, our post-hoc analyses of two of our previous studies suggest that postmenopausal women have lower core body temperatures than premenopausal women and their temperatures are more similar to the temperatures of men. These preliminary observations may have implications for energy metabolism, perimenopausal weight gain, and cardiometabolic risk and thus merit further study.

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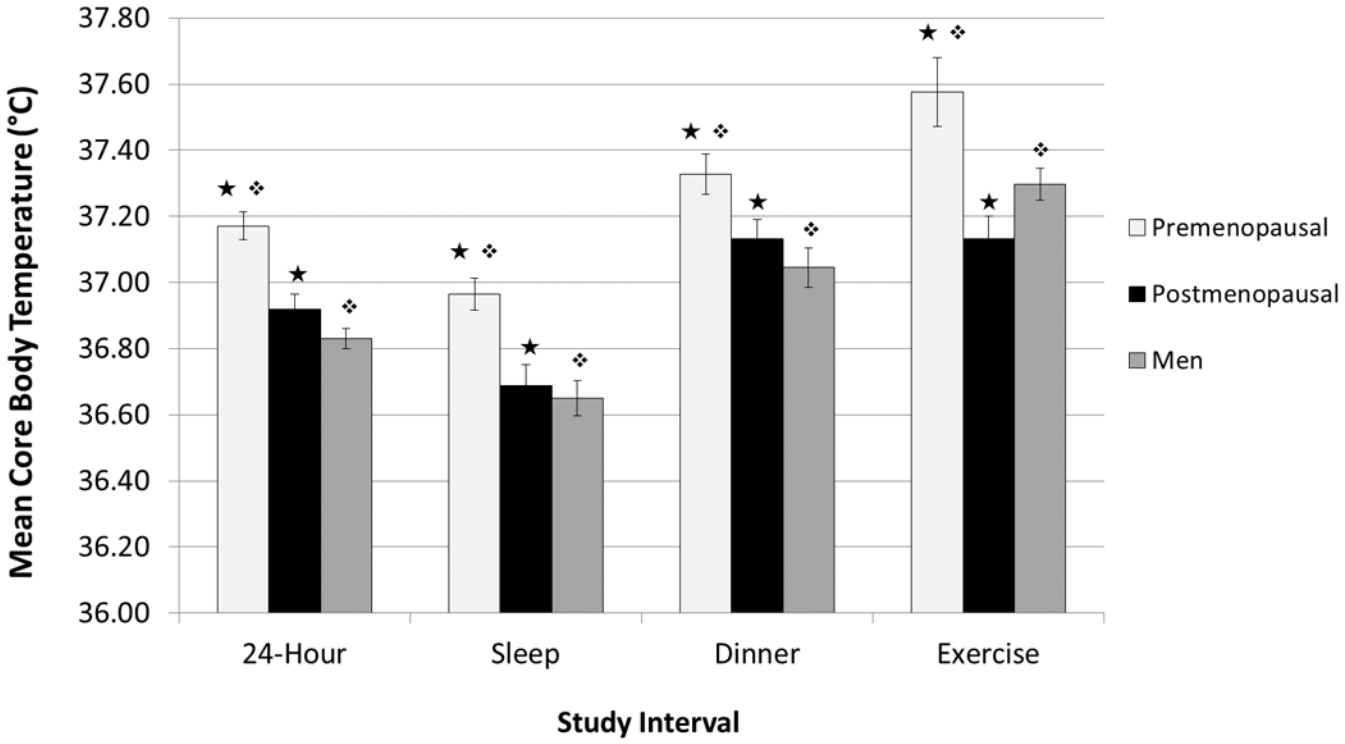

Figure 1.

Mean core body temperatures in premenopausal women, postmenopausal women, and men during the activities of the study. Mean core body temperature was lower in postmenopausal women than premenopausal women and more similar to the temperature of men. Symbols denote significantly different groups ($p < 0.05$).

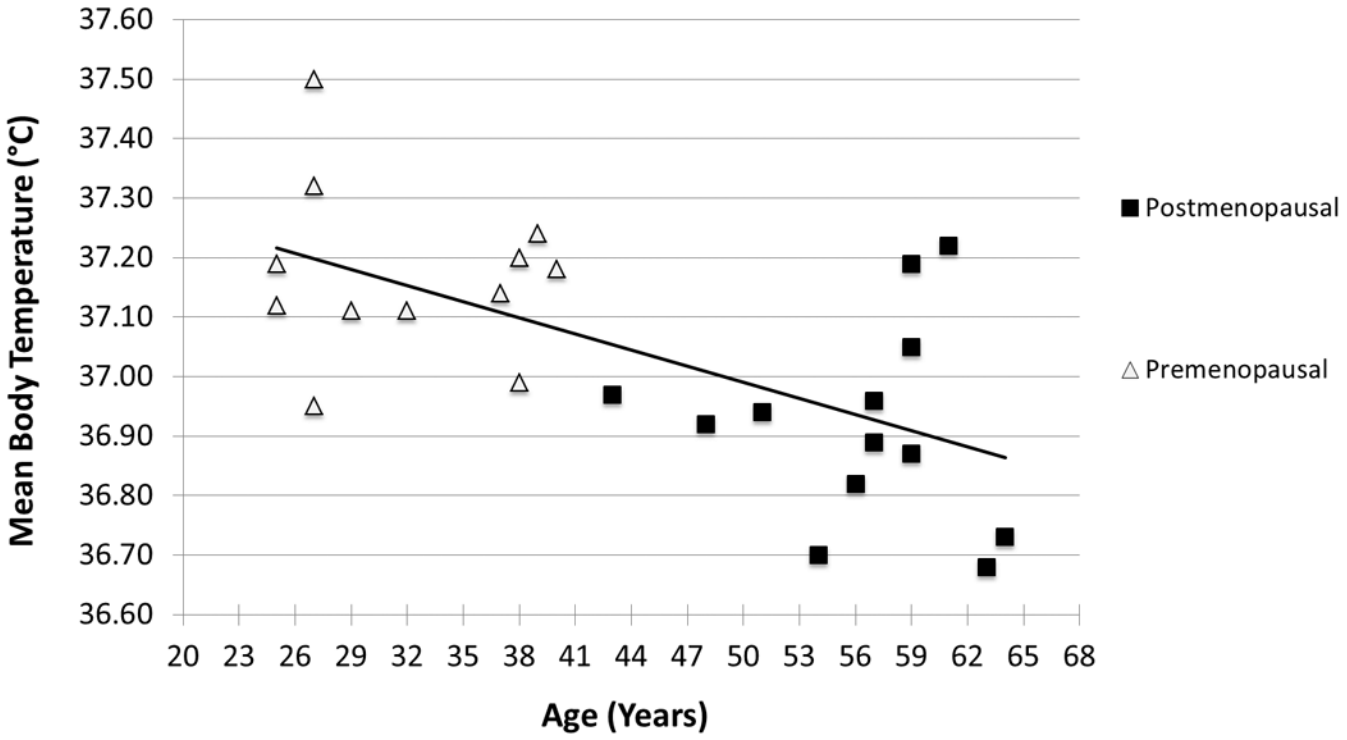

Figure 2.
There was a significant correlation between age and 24-hour core body temperature for women ($r = 0.615$, $p = 0.001$).

Table 1
Characteristics of the study population, mean and (SEM)

Characteristic	Premenopausal Women (n=12)	Postmenopausal Women (n=13)	Men (n=23)
Age (years)	32.0 (1.7) ¥€	56.2 (1.6) ¥♣	37.6 (2.1)♣€
BMI (kg/m^2)	28.3 (1.7) ¥	34.8 (1.1) ¥	31.9 (1.3)
Mass (kg)	76.2 (5.4)♣€	92.8 (3.3)¥	101.5 (19.9)€
Lean Mass (kg)	48.7 (1.2)€	46.7 (1.5)♣	68.9 (1.5)♣€
Fat Mass (kg)	27.4 (3.4)¥	44.5 (2.5)¥	31.3 (2.8)
Race/Ethnicity	5W; 2H; 3B; 1A;1U	6W;2H;4B;1A	14W;4H;4B;1U

¥For p < 0.05 between pre- and post-menopausal women

♣For p < 0.05 between postmenopausal women and men.

€For p < 0.05 between premenopausal women and men. For race/ethnicity of study subjects: W, white non-Hispanic; H, white Hispanic; B, black or African American; A, Asian; U, declined to identify.