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Electrodermal response to auditory stimuli in relation to menopausal transition period

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Abstract

Background: Menopause-associated estrogen deficiency results in climacteric symptoms like vasomotor, psychological and sleep disturbances that cause a decline in the quality of life. Electrodermal activity (EDA), a psychophysiological measure, reflects sympathetic activity, which provides information associated with individual's emotions, phobias, arousal, cognition and stress. The study compared electrodermal response to auditory stimuli between postmenopausal and perimenopausal women with and without symptoms and also correlated the association of scores of the menopausal transition symptoms with indices of EDA.

Methods: Seventy-five women volunteers in the age group of 45–60 years, 25 in each group who were postmenopausal, perimenopausal with symptoms and perimenopausal without symptoms, were recruited. Indices of EDA such as latency, amplitude, rise time and half recovery time for auditory stimuli were quantified using standard techniques. Symptoms of menopausal transition were assessed using Women Health Questionnaire.

Results: Analysis using one-way analysis of covariance after controlling for variables showed that mean skin conductance level of EDA was significantly higher among perimenopausal women with symptoms compared with perimenopausal women without symptoms and postmenopausal women. Perimenopausal women with symptoms had significantly lower latency of response when compared with other groups. Analysis using Pearson correlation test showed that latency of EDA had significant positive correlation and amplitude had significant negative correlation with menopausal transition symptom scores.

Conclusions: Perimenopausal women with symptoms exhibited increased sympathetic sudomotor activity when compared with perimenopausal women without symptoms and postmenopausal women as measured by EDA. Further, select measures of EDA exhibited significant association with the symptoms of menopausal transition.

Keywords: electrodermal activity; menopause; perimenopause.

Introduction

Menopause is a normal aging phenomenon among women, when there is a gradual transition from the reproductive to nonreproductive phase [1]. Increase in life expectancy as well as earlier average age of attainment of menopause, especially in developing countries, may result in greater risk of health hazards among women during this phase of life [2]. The reproductive period of women gradually transcends into a stage of perimenopause followed by menopause after a couple of years [3]. The hormonal changes during this transition period, mainly estrogen, have potent and long-lasting influence on the functions of vital organ systems [2]. In addition to cardiovascular risk, substantial fluctuations in estrogen (perimenopause) or estrogen deficiency (postmenopause) may also cause climacteric symptoms like vasomotor, psychological or musculoskeletal disturbances that may lead to decline in the quality of life [4].

Electrodermal activity (EDA) is a noninvasive psychophysiological measure used to describe changes in the skin's ability to conduct electricity. EDA is quantified depending upon activity of eccrine sweat glands that release the cholinergic neurotransmitter acetylcholine upon sympathetic stimulation and also by the activity of myoepithelial cells controlled by epinephrine levels in the blood stream. Since EDA is controlled by the sympathetic nervous system, it provides information about a person's "internal state" associated with emotions, phobias, arousal, cognition and stress [5]. Therefore, EDA can be used as a simple measure to assess the sympathetic autonomic function that can be an insight into the cardiovascular status of an individual. In addition, EDA being a psychophysiological measure can also assess the personal stress level. Based on this fact, the aim of the study is to evaluate electrodermal response in middle-aged women during menopausal transition and its association with transition symptoms during this period.

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Materials and methods

This is a cross-sectional study conducted among 75 women volunteers (postmenopausal women, perimenopausal women with and without symptoms = 25 in each group) in the age group of 45–60 years. Volunteers were recruited from the staff community after obtaining written informed consent. The study was approved by the Institutional Ethics Committee.

Perimenopausal women (with and without symptoms) and postmenopausal women (both surgical and natural menopause) were included in the study. Those subjects with the history of diabetes mellitus, hypertension or any other chronic medical illness, hormone replacement therapy, deafness or hearing abnormalities were excluded from the study.

Menopausal status of women

Female volunteers were interviewed regarding bleeding pattern, duration of cycle, last date of menstruation and their menopausal stage. The menopausal status was classified according to STRAW (Stages of Reproductive Aging Workshop) [6, 7] classification, which divided menopause staging into (a) postmenopausal: no menstrual bleeding in the last 12 months; (b) late perimenopause: had menstruation in the last 2–12 months but not in the last 2 months; and (c) early perimenopause: had increasing irregularity of menses without skipping periods. However, in this study, early and late menopause stages were considered as perimenopause group.

After explaining the procedure in detail and obtaining a written informed consent, the subjects were enrolled in the study. All the participants were instructed to refrain from food, caffeinated or cocoa-containing beverages at least for 2 h prior the experimental protocol. They were also instructed not to consume alcohol or tobacco 12 h prior to recording. All recordings were performed in a single session at controlled room temperature at least 6 days after the last menstrual period (for perimenopausal group). Anthropometric measurements such as height and weight were measured. Height was measured to the nearest 0.01 m using a stadiometer. Weight was measured to the nearest 0.1 kg using an electronic weighing machine. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared.

Measurement of electrodermal activity

EDA was measured using a bioamplifier and digitized at a sampling rate of 1000 Hz (PowerLab 26T, AD Instruments, Australia). The electrodes of the galvanic skin response (GSR) unit for recording electrodermal response was placed on the middle phalanges of the index and the ring finger on the dominant hand, and EDA was measured as skin conductance changes between volar surface of the middle phalanges of the index and ring fingers of the subject's hands. Electrodermal signals travel first to the PowerLab GSR amplifier module, then to the A-D converter, and finally to a computer that records and displays the data. The parameters related to EDA that were quantified were amplitude in μS, latency, rise time and half recovery time in s for a standardized auditory stimulus. The professionally recorded auditory stimulus (fire engine siren) was delivered at an intensity of 90 dB [8]. After recording a baseline skin conductance for 1 min in sitting posture, the auditory stimulus was delivered through a "macro" program. During recording, a marker was introduced for each stimulus through the macro program to identify the timings of the stimuli. Five stimulation events were delivered, each auditory stimuli was standardized for 3-s duration, at an interval of 12 s from the beginning of the preceding stimulation event (Figure 1). Data obtained were analyzed offline for parameters such as latent period, amplitude, rise time and half recovery time using the Lab chart software. Tonic conductance level was defined as mean amplitude of baseline recording for the duration of 60 s. Latency period was considered to be the time between the stimulus and the onset of the event related to GSR. The difference between the tonic skin conductance levels at the time response evoked and skin conductance at the peak of the response

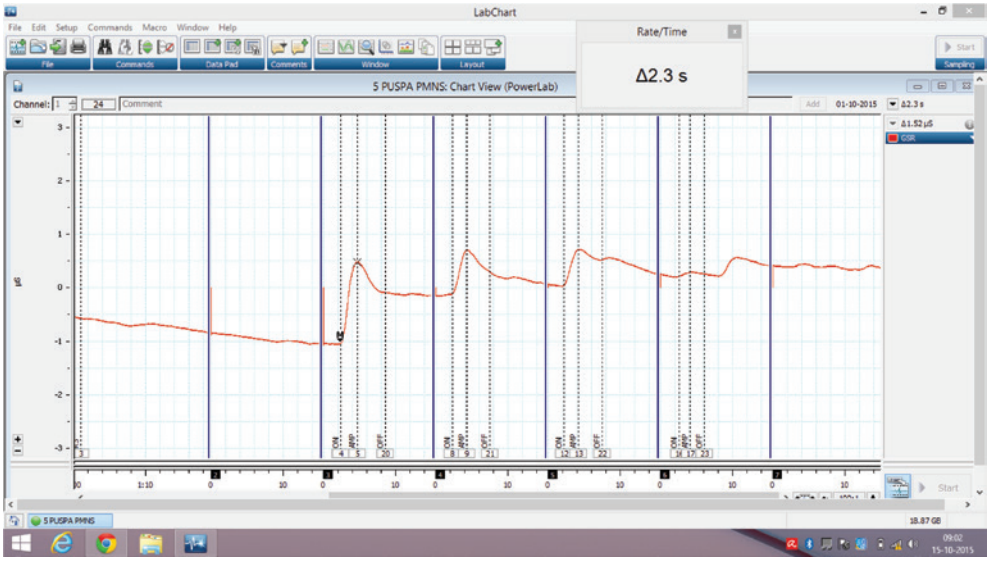

Figure 1: Recording of electrodermal response to auditory stimulus.

was considered as amplitude of response. Rise time was taken to be the time between the onset of the event related to GSR and the peak of response. The half recovery time referred to the time between the peak of the response and the point after the peak when conductance returns to an amplitude that is one half of the amplitude of the peak [9, 10]. For the analysis, average responses of each of the above variables for five stimuli were considered (Figure 1).

Assessment of menopause-associated symptoms

This was performed using the Women's Health Questionnaire (WHQ): The WHQ is a 23-item self-reported health-related quality of life scale that was designed to assess a wide range of physical and emotional symptoms, or sensations, experienced by middle-aged women [11, 12]. There are four response options for each item, ranging from 1 to 4, where 1 means "yes definitely" and 4 means "no, not at all." This provides scores on six factors: anxiety and depressed mood, well-being, somatic symptoms, memory and concentration, vasomotor symptoms and sleep problems. Two optional factors are available: sexual dysfunction and menstrual symptoms. Raw scores can be calculated for each scale. Transformed scores can be obtained from raw scores. Scores vary from 0, which indicates a "poor health status" (women experience symptoms), to 100, which indicates a "good health status" (not symptomatic).

Statistical analysis

Continuous data were expressed as mean ± SE (standard error). Intergroup comparison of the parameters of EDA, psychological stress scores between the three groups (perimenopausal women with and without symptoms, postmenopausal women), was done by one-way analysis of covariance controlling for age and systolic blood pressure (SBP) among the study groups. Pearson's correlation test after Bonferroni correction for multiple tests was used for correlation between EDA parameters and menopause transition symptom scores. A p-value ≤ 0.05 was considered as statistically significant.

Results

Table 1 shows subject characteristics, anthropometric parameters and blood pressure parameters among the three study groups. The postmenopausal women were of higher age when compared with perimenopausal women without symptoms and perimenopausal women with symptoms with p = 0.001 and p = 0.006, respectively. There was no significant difference in height, weight and BMI among the three groups. SBP was higher among postmenopausal women, and it was significant when compared with perimenopausal women without symptoms and perimenopausal women with symptoms (p = 0.001, p = 0.008, respectively). Heart rate was not significantly different between the three study groups.

Table 1: Subject characteristics, anthropometric parameters and blood pressure parameters among the three study groups (n = 75).

Variables	PMNS	PMS	PM
Age, years	46 ± 3[a]	46 ± 3[a]	51 ± 4
Weight, kg	59.51 ± 1.90	58.39 ± 1.96	56.84 ± 1.93
Height, m	1.55 ± 0.12	1.55 ± 0.12	1.55 ± 0.02
BMI, kg/m^2	24.76 ± 0.60	24.24 ± 0.57	23.68 ± 0.60
SBP, mmHg	115.79 ± 15.90[a]	119.33 ± 19.94[a]	133.63 ± 5.78
DBP, mmHg	75.90 ± 13.45	78 ± 12.40	95 ± 12.39
Basal heart rate	73.74 ± 7.94	72.80 ± 8.20	71.83 ± 7.56

Data are expressed as mean ± SD. PMNS, perimenopausal no symptoms; PMS, perimenopausal with symptoms; PM, postmenopausal; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. [a]Significantly different from postmenopausal women, statistical significance at p < 0.01.

Table 2 shows variables of electrodermal responses to auditory stimuli among perimenopausal without symptoms, perimenopausal with symptoms and postmenopausal women. After controlling for age and SBP, mean skin conductance level was significantly higher among perimenopausal women with symptoms when compared with perimenopausal women without symptoms (p = 0.04). Also, perimenopausal women with symptoms had a significantly higher mean skin conductance level when compared with postmenopausal women (p = 0.02). Significantly lower latency of electrodermal response to auditory stimuli was observed among perimenopausal women with symptoms when compared with perimenopausal women without symptoms (p = 0.02) and postmenopausal women (p = 0.01). There was no significant difference in amplitude, rise time and half recovery time among the three groups.

Table 3 shows the parameters of menopausal transition expressed as symptom scores among perimenopausal

Table 2: Variables of electrodermal responses to auditory stimuli among perimenopausal without symptoms, perimenopausal with symptoms and postmenopausal women (n = 75).

Variables	PMNS	PMS	PM
MSCL, μSi	3.15 ± 0.67[a]	5.05 ± 0.49[b]	3.01 ± 0.38
Latency, s	2.15 ± 0.16[a]	1.62 ± 0.10[b]	2.18 ± 0.12
Amplitude, μSi	0.84 ± 0.13	1.61 ± 0.31	1 ± 0.16
Rise time, s	1.97 ± 0.14	1.78 ± 0.16	1.84 ± 0.13
Half recovery time, s	1.81 ± 0.16	1.38 ± 0.16	1.78 ± 0.18

Data are expressed as mean ± SE. PMNS, perimenopausal no symptoms; PMS, perimenopausal with symptoms; PM, postmenopausal; MSCL, mean skin conductance level. [a]Varies significantly from perimenopausal with symptoms, p < 0.05 considered to be statistically significant. [b]Varies significantly from postmenopausal women.

Table 3: Menopausal transition symptom scores among perimenopausal without symptoms, perimenopausal with symptoms and postmenopausal women (n = 75).

Variables	PMNS	PMS	PM
ADM	93.33 ± 2.62[a]	43.33 ± 3.89[b]	89.09 ± 3.38
VSM	96.67 ± 1.95[a]	52.5 ± 7.58[b]	86.11 ± 5.82
WLB	97.08 ± 1.25[a]	64.67 ± 3.63[b]	95.83 ± 2.24
MEM	86.67 ± 3.28[a]	55.56 ± 3.95[b]	85.19 ± 3.82
SLE	88.33 ± 4.20[a]	34.17 ± 5.86[b]	86.11 ± 5.08
SOM	84 ± 4.03[a]	41 ± 3.36[b]	83.89 ± 4.56

PMNS, perimenopausal no symptoms; PMS, perimenopausal with symptoms; PM, postmenopausal; ADM, anxiety depression mood; VSM, vasomotor symptoms; WLB, well-being; MEM, memory disturbances; SLE, sleep disturbances; SOM, somatic symptoms. [a]Varies significantly from perimenopausal with symptoms. [b]Varies significantly from postmenopausal women.

without symptoms, perimenopausal with symptoms and postmenopausal women. There was a significant difference in the menopausal transition symptom scores for anxiety depression mood, vasomotor symptoms, well-being, memory disturbances, sleep disturbances and somatic symptoms among perimenopausal women with and without symptoms. Also, there was a significant difference in the symptoms of menopausal transition scores among perimenopausal women with symptoms and postmenopausal women.

Table 4 shows the correlation of electrodermal responses to auditory stimuli with menopausal transition symptom scores. Latency of electrodermal response showed significant positive correlation with scores of well-being (p = 0.02) among perimenopausal women with and without symptoms (Figure 2). However, there is no significant correlation between latency of electrodermal response and other symptoms of menopausal transition. Also, there was significant negative correlation between amplitude of electrodermal response to auditory stimulus and scores of well-being (p = 0.03) (Figure 3). Amplitude of electrodermal response also showed negative correlation with anxiety mood depression scores, scores of memory disturbances, vasomotor symptoms and somatic symptoms; however, this was not significant. There was no significant correlation between rise time and half recovery time of electrodermal activity with the symptoms of menopausal transition.

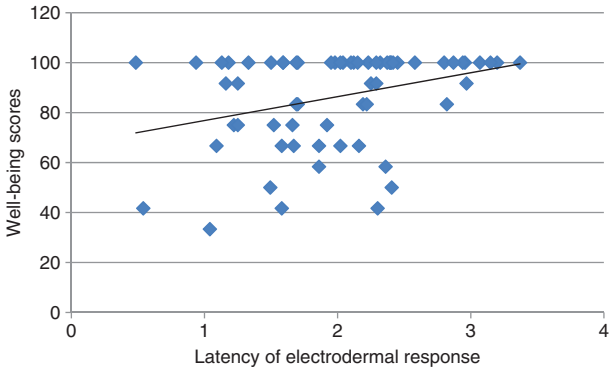

Figure 2: Correlation between latency of electrodermal response and well-being scores.

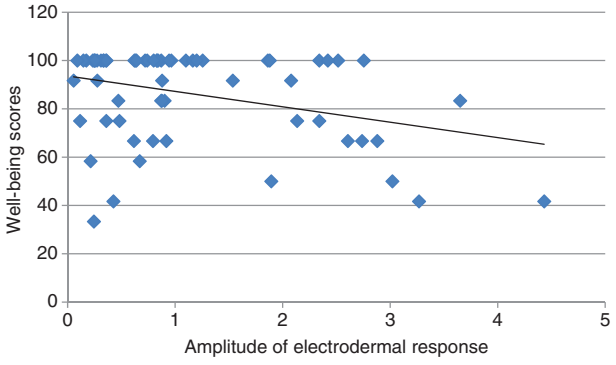

Figure 3: Correlation between amplitude of electrodermal response and well-being scores.

Table 4: Correlation of electrodermal responses to auditory stimuli with menopausal transition symptoms scores (Pearson's correlation test with Holm-Bonferroni correction).

Variables	ADM	WLB	SOM	MEM	VAS	SLE
Latency, s						
p-Value	0.18	0.02[a]	0.6	1	1	0.24
r Value	0.27	0.32	0.2	0.16	0.15	0.24
Rise time, s						
p-Value	1	0.66	1	1	1	1
r Value	0.03	0.19	0.02	0.11	0.09	0.09
Amplitude, μSi						
p-Value	0.36	0.03[a]	0.18[a]	0.48	1	0.12
r Value	−0.23	−0.34	−0.27	−0.21	−0.03	−0.27
Half recovery time, s						
p-Value	0.3	0.66	0.72	1	0.3	0.48
r Value	0.24	0.2	0.19	0.1	0.24	0.21

ADM, anxiety mood depression; WLB, well-being; SOM, somatic symptoms; MEM, memory disturbances; VAS, vasomotor symptoms; SLE, sleep disturbances. [a]Statistically significant at p < 0.00083.

Discussion

The study assessed electrodermal responses among middle-aged women during the period of menopausal transition. Due to hormonal, social and psychological

alterations, middle-aged women experience more age-related health changes and complications, the most important of which is menopause and subsequent infertility, which negatively affects women's self-concept and self-esteem [13]. However, in addition, there is substantial evidence for positive experiences associated with menopause such as cessation of menstrual cycle as well as positive psychological changes [14]. Perimenopausal phase of women's life lasts for several years, and changes that take place during this transition period can be debilitating. However, studies evaluating and quantifying the symptoms of menopausal transition as well as the health of perimenopausal women are limited; moreover, most studies focus on health issues related to postmenopausal period. This study mainly evaluated the sympathetic sudomotor response among women during the period of menopausal transition and correlation of changes in these electrodermal response parameters with symptoms of menopausal transition.

In the present study, SBP was significantly higher among postmenopausal women. A similar cross-sectional study that focused on the relative influence of menopausal status, age and BMI on blood pressure levels of healthy women aged 35–60 years showed that both SBP and diastolic blood pressure (DBP) changed with menopausal status. However, the same study also concluded that DBP was higher only among women who attained surgical menopause, which was attributed to abrupt withdrawal of ovarian function that would lead to hormonal imbalance [15]. In the present study, there was no significant difference in DBP, but SBP was significantly higher among postmenopausal women when compared with perimenopausal women. Studies have shown that premenstrual estrogen levels inhibit progression of atherosclerotic process, hence reducing risk of cardiovascular disease (CVD). With the decline in endogenous estrogen production after 40 years of age, risk of CVD increases [16]. Estrogen is known to have direct protective effects on the arterial wall like vasodilatation and inhibition of smooth cell proliferation, thereby modulating response to injury. Estrogen deprivation seems to be a major determinant of higher prevalence of hypertension in postmenopausal women [17]. Further, sympathetic activity is higher in postmenopausal women than in an age-matched man, which is attributed to the decline in estrogen that in turn increases the SBP [18]. However, rise in SBP with ageing may also be due to an increase in vascular stiffness of great arteries in combination with atherosclerotic changes in vessel walls [16].

It is known that the basic cause of menopausal symptoms is the complex relationship of estrogen metabolism and autonomic nervous system (ANS). Therefore, imbalance of the ANS may also indicate the onset of symptoms of menopausal transition [19]. Research studies that have evaluated sympathovagal balance by studying cardiac autonomic functions via assessment of heart rate variability (HRV) are many. Moreover, most of the research is concentrated among postmenopausal group. Very few data are available on the assessment of sympathetic sudomotor function by evaluating electrodermal responses among perimenopausal women.

EDA is the most sensitive index of sympathetic function, as it is the only autonomic psychophysiological variable that is not contaminated by parasympathetic activity. EDA is an easily obtainable index of sudomotor function and is a sensitive index of bodily arousal related to emotion, attention and altered thermoregulation [20].

Studies by Lee et al. showed an increase in sympathetic activity among perimenopausal women with symptoms. However, they evaluated sympathetic functions by assessing HRV [19]. After, the study groups were matched for age and SBP, the present study shows lower latency of electrodermal response to auditory stimuli among perimenopausal women with symptoms, which implies that they have increased sympathetic activity.

Also, there was a significant positive correlation of latency of electrodermal response with menopausal transition symptoms. This shows that symptomatic women (with lower scores) have lower latency of response and, henceforth, higher sympathetic activity. Correlation statistics between electrodermal response and menopausal transition symptom scores also showed significant negative correlation of amplitude of electrodermal response with symptoms of menopausal transition, implying that symptomatic women have higher amplitude of response and higher sympathetic activity. Electrodermal activity, being controlled by the sympathetic nervous system, provides information about a person's "internal state" associated with emotions, phobias, arousal, cognition and stress [5].

Previous studies have indicated that mild intensity exercise suppresses the sympathetic nervous system activity and increases the parasympathetic activity even during menopausal transition period. Therefore, causes of physical and psychological changes during perimenopausal period can be attributed to be a disorder of ANS, apart from decline in estradiol levels [21]. Apart from this, ANS markers like norepinephrine and epinephrine were reported as correlates of symptom severity clusters that women experience during menopausal transition period [22].

Vasomotor symptoms (hot flushes and night sweats) are the most debilitating symptoms of menopausal transition

experienced by 60–70% of women, having profound effect on quality of life [2]. Perimenopausal women with vasomotor symptoms are 4 times more likely to develop depression than are those without symptoms [22]. However, in the present study, there was no significant association between electrodermal activity and vasomotor symptoms [23].

Increased sympathetic activity during menopausal transition may be attributed to gradual withdrawal of estrogen. Studies have shown that during early perimenopause, midcycle estrogen concentrations have been observed to be normal or increased. This is owing to the fact that estradiol levels do not gradually decrease but instead fluctuate greatly around the normal range until menopause, when no more responsive follicles are available [24].

Diagnostic accuracy of various biochemical markers such as estimation of follicle stimulating hormone, estradiol or inhibin to determine menopausal status is widely studied. However, menopausal transition symptoms modulated by autonomic changes using a simple assessment technique such as recording electrodermal responses may be of clinical use. Owing to the fact that the risk of CVD increases among postmenopausal women, a study of sympathetic autonomic function during perimenopausal period itself may result in the assessment of risk even before attainment of menopause. Apart from cost-effectiveness, it may help in the early diagnosis of menopausal transition symptoms and in improved management as well as outcomes.

Conclusions

The study concludes that perimenopausal women with symptoms have increased sympathetic sudomotor activity when compared with perimenopausal women without symptoms and postmenopausal women.

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