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DERYA ÖZER KAYA

ŞEYDA TOPRAK ÇELENAY

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Fluctuations of state anxiety, spinal structure, and postural stability across the menstrual cycle in active women

Derya ÖZER KAYA¹, Şeyda TOPRAK ÇELENAY^{2,*}

¹Department of Physiotherapy and Rehabilitation, Health Sciences Faculty, İzmir Kâtip Çelebi University, İzmir, Turkey

²Department of Physiotherapy and Rehabilitation, Health Sciences Faculty, Yıldırım Beyazıt University, Ankara, Turkey

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Background/aim: To investigate differences in state anxiety, spinal posture and mobility, postural competency, and stability across the menstrual cycle in active women.

Materials and methods: Thirteen physically active women (18–25 years) with a regular menstrual cycle were recruited. Anxiety with the Spielberger State Trait Anxiety Inventory; spinal posture, mobility, and competency with a Spinal Mouse device (Idiag, Fehraltorf, Switzerland); and postural stability with a Biodex Balance System SD (Biodex Medical Systems, Inc., Shirley, NY, USA) were evaluated across phases of the menstrual cycle.

Results: No significant differences were observed between phases of the menstrual cycle for state anxiety, spinal posture, mobility, or competency ($P > 0.05$). No differences were found for static postural stability ($P > 0.05$); however, a significant difference was detected in dynamic postural stability within three phases of the menstrual cycle ($P < 0.05$). The highest values of overall stability, anterior–posterior and mediolateral indexes were at menses; the lowest values were at the midluteal phase.

Conclusion: State anxiety, spinal posture, mobility, and postural competence did not change across the menstrual cycle. However, dynamic stability declined in menses. Improving awareness of dynamic stability impairment during menses may be important toward injury prevention in active women.

Key words: Anxiety, menstrual cycle, postural stability, spine, posture

1. Introduction

The fluctuations of estrogen and progesterone throughout a menstrual cycle have long been known to play a dominant role in the physiological development and homeostasis of women (1). Lately, these effects of hormone fluctuations on brain function, cognition, emotional status, mood, perception, and state anxiety have become a matter of interest since more women have been active in professional work or in sports (2,3). In particular, the limbic system, a group of tightly interconnected forebrain areas controlling mood and emotion, is rich in estrogen receptors and plays a role in the regulation on serotonin mechanism (4). Thereby, a decreased estrogen level could reduce serotonin levels and cause impaired mood symptoms (5). In some studies, increased levels of progesterone in the luteal phase were related to increased intensity of premenstrual complaints (anxiety, tension, irritability) (6,7), while in other studies decreased progesterone levels were found to be related to more pronounced negative mood changes (8,9).

Moreover, the neuromusculoskeletal effects relating to muscle strength and stretch reflex (10), ligament laxity (11), biomechanical characteristics (12), and postural control (13,14) throughout the menstrual cycle have been investigated in the literature in order to determine the relationship between injury mechanisms in women and the differences between the sexes. Menarche itself was declared to be a risk factor in some sports and conditions (15). It was found that women had greater risk of knee injury than men, especially during the pre-ovulation stage of their cycle, when participating in either professional or recreational sports (16). One of the most striking effects related to the musculoskeletal system was shown in joint laxity (17,18). Increased joint motion may be related to decreased stability and neuromuscular control that may in turn lead to risk of injury in women (19–21). Although there are some studies on athletic women, women who are active in their social lives are underestimated. The effects of menstrual cycle on their mood, performance, posture, stability, life quality, or injury risk are unknown. Although

* Correspondence: sydtoprak@hotmail.com

women have faced problems in their daily lives as a result of menstrual fluctuations, it has not been recorded in the literature to date.

There appears to be a linear correlation between physical activity and health status, such that a further increase in physical activity and fitness will lead to additional improvements in health status (22). The evidence indicates that physical activity and structured exercise may improve the maintenance of postural stability, strength, endurance, bone density, and functional ability (23). Many studies have investigated changes in knee structure and function during the menstrual cycle (24,25) and suggested that anterior cruciate ligament injury may specifically be related to knee laxity (26,27). Although musculoskeletal spinal disorders are major health problems in terms of their high prevalence in women who are physically active in daily life, there was no study investigating spinal structures, postural stability, or anxiety, which were directly in relation to physical activity across the cycle.

Therefore, the current study aimed to investigate differences in state anxiety, spinal posture and mobility, postural competency, and stability across the menstrual cycle in active women. The following hypothesis was investigated: state anxiety, spinal structure, and postural stability were affected across the menstrual cycle in active women.

2. Materials and methods

2.1. Subjects

Forty-seven female university students, aged 18–25 years, volunteered to participate in the study. They all had a regular menstrual cycle and were physically active, by means of sports, recreational activity, or simply an active lifestyle. The activity level criterion assessed by the International Physical Activity Questionnaire (IPAQ) was used to standardize the group. The exclusion criteria were as follows: being pregnant; taking hormonal supplements or any type of medications or contraceptive pills; having had an irregular menstrual cycle or a regular cycle of less than 26 days or longer than 33 days; having had any neurological, rheumatologic, orthopedic, or a vestibular dysfunction; having musculoskeletal injury related to spine and extremities in the last 6 months; having had a total physical activity score of less than 600 METs-min/week; smoking; and drinking alcohol. Thirteen physically active women (age 21.00 ± 1.25 years) with 28.15 ± 0.77 days length of menstrual cycle were included in this study.

This study was conducted in accordance with the rules of the Declaration of Helsinki. Written informed consent was obtained from each of the subjects. It was approved by the Human Research Ethics Committee of the University (Approval number = 12/12-1).

2.2. Assessments

Data were collected throughout the three phases of the menstrual cycle: onset of menses (early-follicular phase), midfollicular phase (the 7th–9th days of the cycle), and midluteal phase (20th–23rd days of the cycle) (25,28). All subjects started their participation in the study during the follicular phase. All assessments were conducted by the same physiotherapist (STC).

The physical characteristics including age, weight, and height were recorded. Body composition was evaluated by the Bodystat1500 Bio-impedance Analyzer (Bodystat Ltd, Douglas, Isle of Man, UK). The menstrual pain intensity was evaluated with a 0 to 10 cm visual analogue scale (VAS); “0” indicated “no pain” and “10” indicated “the worst imaginable pain” (29).

Physical activity levels were assessed by the International Physical Activity Questionnaire (IPAQ): short last 7 days self-administered format. The IPAQ has been used worldwide for physical activity surveillance and international validation for the questionnaire has been previously reported (30). In addition, the reliability and validity of the IPAQ Turkish version have been established (31). The short IPAQ form is composed of separate domain scores for walking, moderate-intensity activities, and vigorous-intensity activities, as well as sedentary behavior including work, transportation, gardening, and leisure-time. The intensity of self-reported physical activity lasting 10 min per bout was measured in metabolic equivalent (MET), which is defined as the ratio of a working metabolic rate to a standard resting metabolic rate (32). MET-min/week was computed by multiplying the MET score of an activity (3.3 for walking, 4.0 for moderate-intensity, and 8.0 for vigorous-intensity) by the minutes and days performed. The summation of walking, moderate, and vigorous METs-min/week enabled the computation of the total physical activity performed by an individual. An individual who performed any combination of walking, moderate-intensity, or vigorous-intensity activity in the previous 7 days with at least a total physical activity score of 600 METs-min/week was classified as active.

The Turkish version (33) of the state part of the Spielberger State Trait Anxiety Inventory (STAI) was used to evaluate levels of anxiety. The state part of the STAI is a 20-item self-report inventory designed to measure state anxiety (current feelings of apprehension, worry, etc.). The STAI state scale is scored on four levels of anxiety intensity from 1 = ‘not at all’ to 4 = ‘very much’ and with a total score between 20 and 80. A higher total score indicates a more severe anxiety level. The STAI has been shown to have high internal consistency as well as adequate validity (34).

Spinal alignment was evaluated using a Spinal Mouse (Idiag, Volkenswill, Switzerland), a computer-assisted and noninvasive device (35–37). The intraclass coefficients

for curvature measurement with the Spinal Mouse were declared to be 0.92–0.95 (35). The demographic information of the subjects was recorded on the software of the computer. The spinal processes of the vertebra from C7 to S3 were marked. The device was slid along the spine, starting from the top and moving to the bottom to complete measurement. We evaluated the subjects while they were standing in an upright position for spinal posture, maximum forward flexion position for spine mobility, and raising her stretched-out arms to shoulder height with weights, designed according to the body weight, in each hand for postural competency. The scores (Spine-check-Score) were calculated by the software. They provided weighted scores for the spinal functions (posture, mobility, and postural competence) ranging between 0 and 100. “0” indicated “fair” and “100” indicated “excellent” scores.

Postural stability of participants was evaluated with the Biodex Balance System SD (Biodex Medical Systems, Inc., Shirley, NY, USA) with Postural Stability mode while the eyes were open (bilateral). Measurements were repeated three times for each mode on barefoot. The base was set ‘12-1’ for dynamic modes. In this system, the base becomes more unstable while the number decreases; thus mode ‘1’ is the most unstable mode. All subjects completed the following modes: static mode (SM) and dynamic mode (DM). As a result, overall stability, anterior–posterior, and mediolateral indexes were taken into account for measurement purposes. For these indexes, a low value indicated high stability.

2.3. Statistical analyses

The G’Power software package (G’Power, Version 3.0.10, Franz Faul, Universität Kiel, Germany) was used to determine the sample size. It was calculated that a sample consisting of 13 subjects was needed to obtain 80% power with $f = 0.38$ effect range, $\alpha = 0.05$ type I error, and $\beta = 0.20$ type II error. SPSS 20.0 for Windows (SPSS Inc. Chicago, IL, USA) was used for the outcomes. The variables were investigated using visual (histograms, probability plots)

and analytical methods (Shapiro–Wilk test) to determine whether or not they were normally distributed. Descriptive analyses were presented using mean and standard deviation (SD) for the normally distributed variables. All data were analyzed using analyses of variance (ANOVAs) with repeated measures on time and Tukey post-hoc tests. Level of significance was set at $P < 0.05$.

3. Results

The physical characteristics, body composition, and IPAQ scores of the participants are displayed in Table 1. The menstrual pain intensity was evaluated at 2.89 ± 2.61 cm.

No significant differences existed between phases of the menstrual cycle for state anxiety ($P = 0.626$), spinal posture ($P = 0.901$), mobility ($P = 0.401$), or postural competency ($P = 0.590$) (Table 2). No differences were found for SM overall ($P = 0.841$), anterior–posterior ($P = 0.352$) or mediolateral indexes ($P = 0.577$) of postural stability (Table 2). However, a significant difference was observed within three phases of menstrual cycle in DM overall ($P = 0.013$), anterior–posterior ($P = 0.003$) and mediolateral indexes ($P < 0.001$) of postural stability (Table 3). The highest values of overall stability, anterior–

Table 1. Physical characteristics of the subjects.

Physical characteristics (n = 13)	X ± SD
Age (year)	21.00 ± 1.25
Fat mass (kg)	13.07 ± 3.04
Lean mass (kg)	41.93 ± 4.47
Body mass index (kg/m ²)	21.03 ± 1.61
Waist/hip ratio	0.77 ± 0.04
IPAQ (METs-min/week)	1376.07 ± 679.40

IPAQ: International Physical Activity Questionnaire

Table 2. State anxiety and spine structure variables across the three phases of the menstrual cycle.

Variable	Menses	Midfollicular	Midluteal	Δ1	Δ2	Δ3	P1	P2	P3	F
State anxiety	40.58 ± 7.06	39.61 ± 9.26	37.50 ± 7.12	0.96 (–6.81, 8.74)	3.08 (–4.85, 11.01)	2.11 (–5.66, 9.89)	0.950	0.612	0.784	0.475
Spine structure										
Posture	63.08 ± 21.52	64.53 ± 19.67	61.00 ± 16.51	–1.45 (–20.44, 17.53)	2.08 (–17.28, 21.44)	3.53 (–15.45, 22.52)	0.981	0.962	0.892	0.105
Mobility	43.08 ± 18.53	52.07 ± 20.26	44.33 ± 13.95	–8.99 (–26.51, 8.52)	–1.25 (–19.11, 16.61)	7.74 (–9.77, 25.26)	0.428	0.984	0.531	0.940
Postural competence	29.83 ± 9.32	34.69 ± 11.81	33.25 ± 14.28	–4.85 (–16.60, 6.88)	–3.41 (–15.39, 8.56)	1.44 (–10.30, 13.18)	0.573	0.766	0.951	0.536

Δ1: Change in outcome variables from menses and to midfollicular, Δ2: Change in outcome variables from menses and to midluteal, Δ3: Change in outcome variables from midfollicular and to midluteal, P1: Comparison of changes between menses and midfollicular, P2: Comparison of changes between menses and midluteal, P3: Comparison of changes between midfollicular and midluteal

Table 3. Postural stability variables across the three phases of the menstrual cycle.

Variable	Menses	Midfollicular	Midluteal	Δ1	Δ1	Δ1	P1	P2	P3	F
Postural stability										
SM										
Overall	0.91 ± 0.79	1.00 ± 0.92	0.81 ± 0.55	-0.08 (-0.84, 0.67)	0.10 (-0.67, 0.87)	0.18 (-0.57, 0.94)	0.961	0.947	0.827	0.174
Anterior-posterior	0.57 ± 0.36	0.71 ± 0.71	0.41 ± 0.32	-0.14 (-0.63, 0.35)	0.15 (-0.35, 0.66)	0.29 (-0.20, 0.79)	0.771	0.728	0.319	1.076
Mediolateral	0.53 ± 0.30	0.53 ± 0.67	0.75 ± 0.72	0.00 (-0.59, 0.58)	-0.22 (-0.82, 0.37)	0.21 (-0.80, 0.36)	1.000	0.632	0.634	0.558
DM										
Overall	1.59 ± 1.15	0.82 ± 0.48	0.74 ± 0.27	0.76 (0.04, 1.48)	0.85 (0.11, 1.58)	0.08 (-0.63, 0.80)	0.034*	0.020*	0.958	4.962
Anterior-posterior	1.28 ± 0.87	0.57 ± 0.48	0.46 ± 0.22	0.70 (0.13, 1.28)	0.81 (0.22, 1.40)	0.11 (-0.46, 0.68)	0.013*	0.005*	0.886	6.887
Mediolateral	1.54 ± 1.09	0.40 ± 0.38	0.36 ± 0.26	1.14 (0.47, 1.80)	1.17 (0.49, 1.85)	0.03 (-0.63, 0.69)	0.001*	<0.001*	0.992	11.852

*P < 0.05, SM: Static mode, DM: Dynamic mode, Δ1: Change in outcome variables from menses and to midfollicular, Δ2: Change in outcome variables from menses and to midluteal, Δ3: Change in outcome variables from midfollicular and to midluteal, P1: Comparison of changes between menses and midfollicular, P2: Comparison of changes between menses and midluteal, P3: Comparison of changes between midfollicular and midluteal

posterior, and mediolateral indexes were at menses, and the lowest level was at the midluteal phase.

4. Discussion

This study presented the following outstanding findings: (i) the state anxiety was slightly high during menses in comparison to follicular and luteal phases; however, no significant difference was detected, (ii) no fluctuations were found for spinal posture and mobility or postural competency across the menstrual cycle, and (iii) dynamic stability was better in follicular and luteal phases in comparison to menses in active women.

The effects of the sophisticated interdependent fluctuations of the hormones progesterone and estrogen over the course of the female menstrual cycle have long been studied. Psychological effects have gained importance recently because more women are working in difficult conditions. Specifically, significant symptoms have been linked to decreased productivity at work (38) as well as relationship impairments, which are comparable to impairments associated with depression and other physical health conditions. In addition, perceptual changes, mood fluctuations, anxiety, depression, and hostility were thought to be the characteristics of certain periods (39).

It was shown that negative changes in mood occurred at the premenstrual stage, as both estrogen and progesterone levels decline and symptoms extend typically into the menses phase (2,40). The highest levels of well-being and self-esteem were reported during midcycle (2). Kiesner (41) also suggested that women with strong premenstrual symptoms might actually benefit from a midcycle sense of wellness. Rossi et al. (42) declared positive moods peaked

in the ovulatory phase and on weekends, while negative moods peaked in the luteal phase of the menstrual cycle. An individual difference analysis showed that women whose moods are responsive to the menstrual cycle are physically active, socially assertive, and sexually orgasmic for whom the maternal role is important (42). Miller et al. (43) concluded that the times of reproductive transition represented times of high risk for the onset or exacerbation of depressive symptoms. They pointed out the ability of the female brain to adapt the fluctuations of hormones that affect neurotransmitter functioning. They associated the difficulty of this adaptation with stresses related to social role transitions (43). However, in their review, Romans et al. (40) declared that approximately 40% of the studies could not find any link between mood and menstrual cycle phase. Nillni et al. (39) also declared that there were no interactive effects of anxiety sensitivity and menstrual cycle phase in predicting menstrual-related symptoms when measured by either the Menstrual Distress Questionnaire or the Daily Record of Severity of Problems. In other words, women did not prospectively report differences in menstrual symptom severity across the follicular and premenstrual cycle phases. However, they pointed out that the degree of anxiety was a significant independent predictor of menstrual symptom severity, regardless of cycle phase of assessment (39). Moreover, the findings reported by Schwartz et al. (44) demonstrated that, compared to stress and physical health, ovarian hormones are responsible for only a small contribution to daily mood. Thus, fluctuations in ovarian hormones do not contribute significantly to daily mood in healthy women (44). Our results showed similarities to these studies. The change

of the state anxiety was too slight to make any significant difference as it may be related to the adaptation of the condition. Another explanation might be related to pain or pain perception (45). Our subjects reported mild pain only during the menstrual phase. Veldhuijzen et al. (46) found lower pressure pain thresholds during the follicular phase compared with other phases. Their results showed that pain-related cerebral activation varied significantly across the menstrual cycle, even when perceived pain intensity and unpleasantness remain constant. The pain intensity, body awareness and cognitive perception, life and working conditions, social environment, and the appearance of severe physical symptoms might affect anxiety and well-being. Therefore, these conditions should be taken into account for further studies in order to conclude anxiety changes.

The effects of estrogen and progesterone on neuromuscular/biomechanical characteristics have been another focus of research. It was declared that hormonal changes acted on the central nervous system, resulting in changes in autonomic nerve activity. Increased parasympathetic activity in the follicular phase was described. Moreover, researchers concluded that baroreflex regulation of autonomic functions induced by changing positions was modified during the menstrual cycle (47). These autonomic changes and any impairment in neural control system, together with various symptoms such as abdominal or back pain, especially in the first few days of menstrual bleeding (48), encouraged us to investigate body posture, mobility, and postural competency. To the best of our knowledge, it is the first study to investigate posture in relation to anxiety and postural competency during menstrual phases. No differences for the components were observed throughout the cycle. Janse de Jonge et al. (49) studied skeletal muscle contractile characteristics in regularly menstruating women in different phases. They could not show any differences for contractile properties of muscles. Similarly, Burgess et al. (50) could not find any differences for tendon mechanical properties. Moreover, Abt et al. (28) declared that all neuromuscular and biomechanical characteristics remained invariable despite concentration changes in estrogen and progesterone through the phases. Similar to these studies, we could not detect any changes for the parameters since overall body posture, mobility, and postural competency were maintained by muscle contraction, tendon properties, biomechanical characteristics, and neural mechanisms.

Although the overall postural changes were underestimated in the literature, knee and lower extremity alignment (51), knee joint position sense (25), knee joint laxity and loading (12), gait parameters (52), postural control, kinesthesia, and balance (13,14) have all been relevant since the menstrual cycle might be a potential

risk factor for anterior cruciate ligament injuries in active women. Postural stability parameters were assessed in our study. Our aim was to further analyze the postural stability in static and dynamic conditions related to body posture and overall stability. No differences were observed for static stability results. However, there were differences for the dynamic stability results in that they were better in follicular and luteal phases compared with menses. Anteroposterior, mediolateral, and overall postural sway were greater (dynamic stability was worse) at menses. Fridén et al. (14) only evaluated static stability with the two-legged and one-legged stance with eyes open. They could not find significant differences in the two-legged stance between the phases. However, in one-legged stance, there was a significant increase in postural displacement in the midluteal phase. In another study by Fridén et al. (13), a tendency towards greater postural sway in the midluteal phase was detected among women with premenstrual syndrome. Darlington et al. (53) found that the menstrual cycle phase had no significant effect on anterior-posterior sway, but it did significantly affect lateral sway. They further declared that sway on day 5 was significantly greater than on days 12 and 21, and that sway was significantly greater on day 25 than on day 21. Recent studies have indicated an increased incidence of female athletic injuries during the luteal phase and the first days of the menstrual period (26,54). Wojths et al. (54) emphasized the increase in injuries in the ovulatory phase of the cycle. Slaughterbeck et al. (26) declared that 10 of 27 athletes who reported their cycle day at time of injury sustained the injuries immediately before the onset of menses or 1 to 2 days after the onset of menses. Our findings may be related to the previously reported increased injury rate on or around the day of menses that the dynamic balance impairments might occur in active women.

When physiological or behavioral function during the menstrual cycle was investigated, one cycle might be divided into different phases (2, 3, 5, or more) depending on the researchers' purposes (47). In our study, we divided a menstrual cycle into three phases depending on the characteristics of hormonal concentrations and outcome parameters. We took some previous studies into consideration (25,28). This may cause a limitation, especially when comparing one study to another. However, mostly three main phases were relevant for most studies. The phases were explained according to hormone fluctuations. Female reproductive hormone concentrations would be expected to fluctuate differently (55). Most of the studies measured the hormone concentration levels to identify the exact phase. We did not measure hormone concentrations; however, we assumed the dates according to previous studies. This could be considered a limitation; nevertheless, taking the standardized study group with

regular 28-day cycle and similar physical characteristics enabled us to assume the timing in previous studies. Another limitation might be that the study was conducted in active women. Previous studies related to menstrual cycle and neuromusculoskeletal characteristics were generally conducted in athletes. Therefore, we think that we standardized the active women group and eliminated some associated factors. However, our results might be a very good base for further studies on different populations and athletes.

In conclusion, we observed that phases of the menstrual cycle could not be factors in fluctuations on state anxiety, spinal posture, mobility, or postural competence. However,

the results of the study suggest that active women have dynamic stability differences across a menstrual cycle. Moreover, dynamic stability declines in menses. Therefore, physically active women might be at higher risk of injury at menses and improving their awareness regarding the injury risk factors may be an essential step toward preventing injuries.

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