ORIGINAL ARTICLE

Diurnal changes of the postural control in young women without and with hormonal contraceptive treatment

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Submitted: 2014-04-11 *Accepted: 2014-05-05* *Published online: 2014-06-27*

Key words: **postural control; diurnal changes; time of day; hormonal contraception; women**

Neuroendocrinol Lett 2014; **35**(3):230–235 **PMID:** 24977974 NEL350314A05 © 2014 Neuroendocrinology Letters • **www.nel.edu**

Abstract

OBJECTIVES: The aim of this study was to investigate diurnal changes of the postural control in young women without and with hormonal contraceptive treatment.

METHODS: The postural activity was assessed during stance from two accelerometers positioned at the level of the lumbar (L5) and thoracic (Th4) vertebra in twenty healthy young women non-using (13) and using (7) hormonal contraception.

RESULTS: We observed a significant increase of trunk tilts in the morning in the group of women with hormonal contraception compared to control. Women with hormonal contraception showed the significant decrease of trunk tilts and their velocity in the evening in relation to increased morning data at the L5 in anterior-posterior direction during stance on foam. Measurements at Th4 showed higher variability of lateral trunk tilts in conditions with altered somatosensory inputs. Distinct reduction of velocity of lateral trunk tilts in the evening related to morning measurements were present in the control group at the L5 in conditions with altered somatosensory inputs and at the Th4 in all experimental conditions in both groups.

CONCLUSION: We demonstrated diurnal changes of the postural control in young women. Women using hormonal contraceptives showed a weakened postural stability compared with the control group in the morning and the normalization of postural stability in the evening to the values of the control group. These findings suggest that the time of day and the use of hormonal contraception affect postural stability of women.

INTRODUCTION

Postural control is defined as the control of the body's position in space for the purposes of balance and orientation (Shumway-Cook & Woollacott 2000a; Shumway-Cook & Woollacott 2000b; Woollacott & Shumway-Cook 2002). The control of postural system consists of 1) several sensory systems (visual, vestibular and somatosensory), 2) the motor system and 3) the integrating control system, which involves complex interactions among multiple neural systems (Horak & MacPherson 1996).

Sensory integration, enabling adequate muscle contraction in order to maintain balance, requires a high level of vigilance (Redfern *et al.* 2001). Since vigilance is mainly determined by both sleep deprivation and by circadian rhythmicity (Borbély 2009), the postural control may be affected by these two factors. Also Gribble & Hertel (2004) in their study focused on change in the postural control during a 48-hours sleep deprivation period and some other authors (Morad *et al.* 2007; Bougard *et al.* 2011) hypothesize that the repeated oscillations of the postural control exhibited a circadian pattern. However, there are only a few studies (Litvinenková 1970; Litvineková 1972; Gribble *et al.* 2007; Jorgensen *et al.* 2012; Deschamps *et al.* 2013) focused on temporal aspects of the postural control and results are rather ambiguous.

In fertile women the postural control can be affected by cyclic hormonal changes. There are data that the menstrual cycle, due to changes in the levels of estradiol and progesterone, significantly alters the postural stability (Naessen *et al.* 1997; Hayashi *et al.* 2004; Ekenros *et al.* 2011; Shahin *et al.* 2012) but other authors did not confirm the existence of this relationship (Abt *et al.* 2007).

Therefore, the purpose of our study was to investigate diurnal changes of the postural control in young healthy women. Hormonal contraceptives substantially affects natural hormonal milieu, therefore the second aim of our study was to identify effects of this treatment on postural control parameters during the daytime.

MATERIAL AND METHODS

Twenty young healthy women (mean age 21.3±0.3 years, mean height 165.9±1.1 cm, mean body weight 58.5±2.2 kg) participated in this study. None of the volunteers reported previous or present disease or injuries associated with gait and/or balance impairments. Thirteen control volunteers were without oral contraceptives or other hormonal treatment for at least three months before entering the study and seven volunteers had taken hormonal contraceptives. Both groups were matched regarding the age, height and body weight. All subjects signed informed consent prior to participation.

The test task was a quiet stance during which we recorded trunk tilts in anterior-posterior (AP) and medial-lateral (ML) direction by inertial measurement device (Xsens Technologies B.V, Enschede, NL). The device senses an acceleration by 3D accelerometer (± 1.7 g range). The accelerometer sensors were positioned at the spinal column of the upper trunk at the level of the fourth thoracic vertebra (Th4) (Hlavačka *et al.* 2011) and the lower trunk at the level of the fifth lumbar vertebra (L5), near the body center of mass (Hlavačka *et al.* 2011; Mancini *et al.* 2011; Mancini *et al.* 2012; Spain *et al.* 2012). The sensors were fixed on the body, using a special jacket made of elastic material and belts with velcro, MVN Mountings Straps (Xsens Technologies B.V, Enschede, NL). Wires from the sensors were connected to a portable data-receiver on a belt that transmitted obtained data wireless to a laptop.

Two postural measurements were performed per day, one in the morning (8.00±30 min) and another in the evening (18.00±30 min), in regular weekly intervals, within one month (eight postural measurements). For each measurement, the postural test consisted of four conditions of quiet stance: EO – stance on a firm surface with eyes opened; EC – stance on firm surface with eyes closed; FEO – stance on a foam surface with eyes opened and FEC – stance on foam surface with eyes closed. The participants were asked to stand upright and relaxed, barefoot with their feet side by side and arms along the body. During conditions with open eyes, the subjects were instructed to look at a black point (with a diameter 2 cm) placed at the eye level on the white wall in a distance 1.5–2 meters. During the subsequent test closed eyes, the subjects had eyes closed. For posture measurement on the soft base volunteers stood on the foam thickness of 10 cm. The beginning and the end of each trial was notified. Each measurement took 50 seconds, during which the subjects were not allowed to talk and rotate. If needed a short rest period between trials was allowed, when subjects could remain standing or sitting.

The trunk tilts were recorded using the Xsens MT Manager (Xsens Technologies B.V, Enschede, NL), that performs an analysis of accelerometer signals. These signals from the trunk AP and ML directions were collected with a 100 Hz sampling frequency, transformed to a horizontal-vertical coordinate system (Moe-Nilssen & Helbostad 2002) and low-pass filtered with cut-off frequency of 10 Hz. Obtained data were converted to the body tilts in degrees and evaluated with MATLAB program (Matlab R2011b, The MathWorks Inc., Natick, MA). After processing data, the trunk tilts were visualized on a monitor in the form of time and vector records, from which we obtained the following parameters of posture: A_{AP}, A_{ML} [°] – amplitude of trunk tilts in the anterior-posterior and medial-lateral direction; V_{AP}, V_{ML} [°/s] – velocity of trunk tilts in the anterior-posterior and medial-lateral direction.

Statistical processing of data was performed in the program Statistica 7.0 (StatSoft Inc., USA) and we used non-parametric the Wilcoxon test and Mann-Whitney U test. The *p*-values <0.05 were considered as significant.

RESULTS

Monitoring of posture with the accelerometer sensors located at L5 and Th4 in two time intervals during day revealed a reduction of trunk tilts in the evening compared to the morning measurements in both groups of women. However postural stability women using hormonal contraception was weakened compared to the control group of women.

At the area L5, we observed a significant increase in the amplitude of trunk tilts (A_{AP}) in the anterior-posterior direction ($p<0.05$) the morning as compared to the evening in the group of women with contraception in conditions altered somatosensory inputs during stance on foam (Figure 1). Moreover, we demonstrated a significant increase in the amplitude of trunk tilts in the anterior-posterior direction ($p<0.05$) in the group of women with hormonal contraception compared with the control group in the morning measurements under FEO condition (Figure 1).

We observed a significant increase in the velocity of trunk tilts (V_{AP}) in the anterior-posterior direction ($p<0.05$) the morning as compared to the evening in the group of women with contraception. The significant differences were demonstrated in conditions with altered somatosensory inputs (Figure 2).

Exactly the opposite we found a significant increase in the velocity of trunk tilts (V_{ML}) in the medial-lateral direction ($p<0.05$) the morning

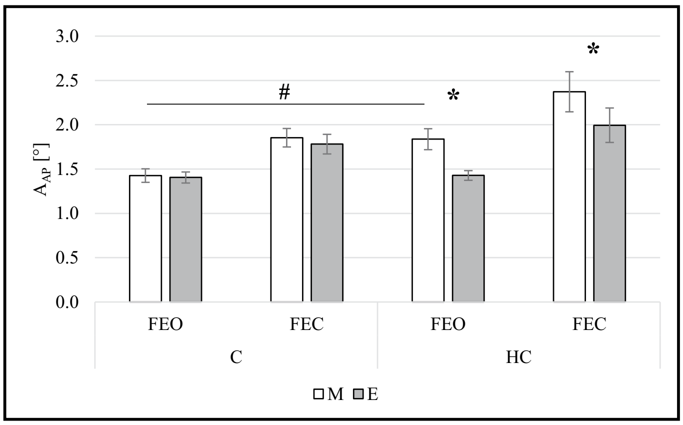

Fig. 1. Comparison of amplitude of trunk tilts in the anterior-posterior direction (A_{AP}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental conditions: FEO – stance on foam surface with eyes opened, FEC – stance on foam surface with eyes closed. Sensor was located at the fifth lumbar vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$), # significant difference between the control and contraceptive group ($p<0.05$).

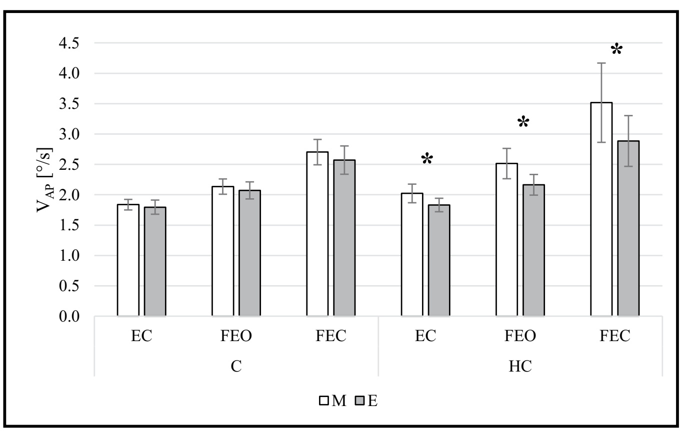

Fig. 2. Comparison of velocity of trunk tilts in the anterior-posterior direction (V_{AP}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental conditions: EC – stance on firm surface with eyes closed, FEO – stance on foam surface with eyes opened, FEC – stance on foam surface with eyes closed. Sensor was located at the fifth lumbar vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$).

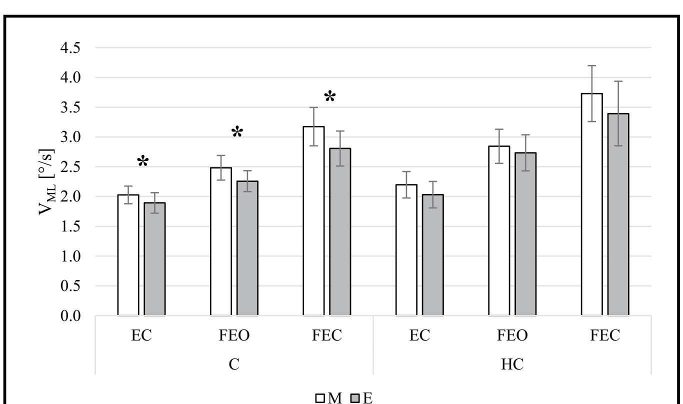

Fig. 3. Comparison of velocity of trunk tilts in the medial-lateral direction (V_{ML}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental conditions: EC – stance on firm surface with eyes closed, FEO – stance on foam surface with eyes opened, FEC – stance on firm surface with eyes closed. Sensor was located at the fifth lumbar vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$).

as compared to the evening in the control group of women. The significant differences were also demonstrated in conditions with altered somatosensory inputs (Figure 3).

Measurements with the accelerometer sensor located at Th4 showed a significant increase in the amplitude of trunk tilts (A_{AP}) in the anterior-posterior direction ($p<0.05$) the morning as compared to the evening in women using hormonal contraception during stance on firm surface with eyes opened (Figure 4).

We observed a significant increase in the amplitude of trunk tilts (A_{ML}) in the medial-lateral direction ($p<0.05$) the morning as compared to the evening in the group of women with contraception. The significant differences were demonstrated in conditions with altered somatosensory inputs (Figure 5). Moreover, we demonstrated a significant increase of trunk tilts in the medial-lateral direction ($p<0.05$) in the group of women with hormonal contraception compared with the control group in the morning measurements under EC and FEO conditions (Figure 5).

We observed a significant increase in the velocity of trunk tilts (V_{ML}) in the medial-lateral direction ($p<0.05$) the morning as compared to the evening in the both groups of women. The significant differences were demonstrated in all tested conditions (Figure 6).

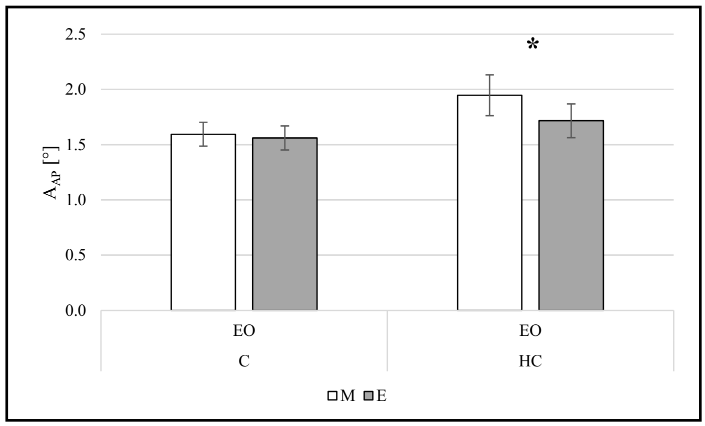

Fig. 4. Comparison of amplitude of trunk tilts in the anterior-posterior direction (A_{AP}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental condition: EO – stance on firm surface with eyes opened. Sensor was located at the fourth thoracic vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$).

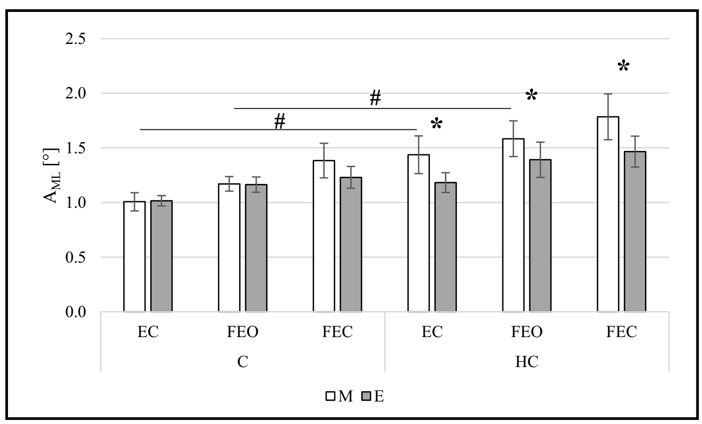

Fig. 5. Comparison of amplitude of trunk tilts in the medial-lateral direction (A_{ML}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental conditions: EC – stance on firm surface with eyes closed, FEO – stance on foam surface with eyes opened, FEC – stance on foam surface with eyes closed. Sensor was located at the fourth thoracic vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$), # significant difference between the control and contraceptive group ($p<0.05$).

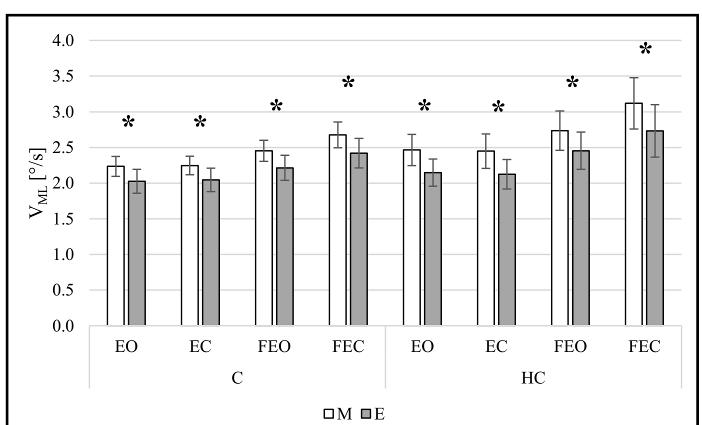

Fig. 6 (right). Comparison of velocity of trunk tilts in the medial-lateral direction (V_{ML}) between the morning (M) and evening (E) measurements in the control group (C, n=13) and group of women using hormonal contraceptives (HC, n=7). Experimental conditions: EO – stance on firm surface with eyes opened, EC – stance on firm surface with eyes closed, FEO – stance on foam surface with eyes opened, FEC – stance on foam surface with eyes closed. Sensor was located at the fourth thoracic vertebra. Value are presented as means±SEM. * significant difference between the morning and evening measurements in the postural parameter ($p<0.05$).

DISCUSSION

Information about diurnal changes in the postural control are limited and results are ambiguous. Our results support findings, that the time of day can influence the postural control in young women regardless of the use of hormonal contraception.

In young women without hormonal contraception monitoring of posture with the accelerometer sensor located at L5 revealed a significant increase, i.e. worsening postural stability in the morning compared to the evening in one postural parameter – V_{ML} under EC, FEO and FEC conditions. Monitoring of posture with the sensor located at the Th4 region, showed a significant evening improvement of V_{ML} parameter under all tested conditions.

A similar trend of stability improvement in the evening was observed in studies using stabilometry in groups of young men (Litvinenková 1970; 1972) in which measurements were performed in regular 4-hour intervals (8.00, 12.00, 16.00, 20.00, 00.00 and 4.00 over 24-hour cycle). In the first study Litvinenková (1970) observed sagittal deviations – amplitude in the anterior-posterior direction, which corresponds to A_{AP} in our study. In that study the best sagittal deviations were observed in the evening at 20.00, followed by a deterioration and peak of postural instability at 4.00. Posture in the morning (at 8.00) was more stable than at 4.00, but worse compared with the evening measurement at 20.00. In the next study Litvinenková (1972) observed circadian rhythms in the regulation of posture control in relation to the change of light stimulus field. Daily amplitude of body sway reached minimum in the afternoon at 16.00 and maximum at 4.00, similarly as in the previous study.

A shift in acrophase of postural stability in a group of elderly people during the day was observed at 9.00, 12.30 and 16.00 using forceplate (Jorgensen *et al.* 2012). Significant daily changes in sway velocity-movement, confidence ellipse area, total sway area and total sway length were observed and the best results were showed at the midday. Our results obtained in women differed partially from those found in elderly people since we observed the better stability in the evening. It is possible that increased sleepiness and fatigue in elderly people may explain the worse results in comparison with young women.

Controversial results were obtained by Gribble *et al.* (2007) in young people of both sexes. They assessed center of pressure velocity in the anterior-posterior and medial-lateral directions (similarly in our V_{AP} and V_{ML}), using forceplate during two consecutive days. During the first day, the postural control in both directions was significantly better in the morning (10.00) as compared to 15.00 and 20.00, with the best results at 20.00 than at 15.00. On the second day, the postural control in both directions was significantly better in the evening (20.00) as compared to 15.00 and 10.00. The authors explain these differences between two days by learning effects. Results from the second day are in accord with our data. However we did not detect any learning effect, although we performed the measurement in regular weekly intervals.

In contrast with all above mentioned findings, no specific effect of time of day on the static postural control was demonstrated by Deschamps *et al.* (2013). Their postural test consisted of the same four (EO, EC, FEO, FEC) conditions of quite stance. Measurements was performed at 8.00, 12.00 and 17.00±30 minute, using the forceplate. They evaluated the center of pressure (CoP) parameters – amplitude and velocity in anterior-posterior and medial-lateral directions, mean velocity and confidence ellipse area.

In young women using hormonal contraceptives, monitoring posture with sensor located at L5, we observed a significant evening improvement of two parameters – A_{AP} in FEO and FEC conditions and V_{AP} in EC, FEO and FEC conditions. Monitoring posture with sensor located at Th4, showed the significant evening improvement of three parameters – A_{AP} in EO condition, A_{ML} in EC, FEO and FEC conditions, V_{ML} in all tested conditions.

The postural control can be affected by cyclic production of sex hormones. Several studies have reported that postural control was positively influenced by increased levels of plasma estrogens (Naessen *et al.* 1997; Naessen *et al.* 2007). Moreover, estrogens secretion follows a diurnal pattern with elevated plasma levels in the morning and a gradual decrease throughout the day (Bao *et al.* 2003). If estrogens are able to improve postural stability their evening decline may worse postural stability and this prediction is not in line with our data. We observed significant differences in the postural control over the day in young healthy women, in velocity of lateral trunk tilts (V_{ML}) and a trend to improving stability during the daytime was observed. However, we did not record changes in posture control during 4-week measurements covering the menstrual cycle and our results are in accord with published data (Abt *et al.* 2007) suggesting that postural stability is not influence by the variation in hormonal levels between phases of the menstrual cycle.

We found a significant morning decrease in postural stability in women taking hormonal contraceptives in comparison with women without hormonal treatment. This difference was found in measurement at both the area L5 in parameter A_{AP} during stance on foam and at the level of Th4 in parameter A_{ML} in EC and FEO conditions. Since hormonal contraceptives depress production of natural estrogens and eliminate their rhythmicity (Aden *et al.* 1998) our results point on an importance of physiological rhythms in female sex hormones for different physiological processes including posture control.

The results of our study demonstrated differences in diurnal changes of postural stability between young women non-using and using hormonal contraceptives. These findings imply that time of day and using hormonal contraception should be controlled when assessing and evaluating postural balance in young healthy women.

ACKNOWLEDGEMENTS

This work was supported by grants VEGA 2/0138/13, 2/0107/12 and APVV 0291/12.

REFERENCES

1 Abt JP, Sell TC, Laudner KG, McCrory JL, Loucks TL, Berga SL, *et al.* (2007). Neuromuscular and biomechanical characteristics do not vary across the menstrual cycle. Knee Surg Sports Traumatol Arthrosc. **15:** 901–907.
2 Aden U, Jung-Hoffmann C, Kuhl H (1998). A randomized crossover study on various hormonal parameters of two triphasic oral contraceptives. Contraception. **58:** 75–81.
3 Bao AM, Liu RY, van Someren EJ, Hofman MA, Cao YX, Zhou JN (2003). Diurnal rhythm of free estradiol during the menstrual cycle. Eur J Endocrinol. **148:** 227–232.
4 Borbély AA (2009). Refining sleep homeostasis in the two-process model. J Sleep Res. **18:** 1–2.
5 Bougard C, Lepelley MC, Davenne D (2011). The influence of time-of-day and sleep deprivation on postural control. Exp Brain Res. **209:** 109–115.
6 Deschamps T, Magnard J, Cornu C (2013). Postural control as a function of time-of-day: influence of a prior strenuous running exercise or demanding sustained-attention task. J Neuroeng Rehabil. **10:** 26.
7 Ekenros L, Hirschberg AL, Bäckström T, Fridén C (2011). Postural control in women with premenstrual symptoms during oral contraceptive treatment. Acta Obstet Gynecol Scand. **90:** 97–102.
8 Gribble PA, Hertel J (2004). Changes in postural control during a 48-hr. sleep deprivation period. Percept Mot Skills. **99:** 1035–1045.
9 Gribble PA, Tucker WS, White PA (2007). Time-of-day influences on static and dynamic postural control. J Athl Train. **42:** 35–41.
10 Hayashi C, Ikeda M, Aizawa K, Murai F, Mesaki N (2004). Change in dynamic and static balance ability during menstrual cycle among women. Jpn J Phys Fitness Sports Med. **53:** 197–204.
11 Hlavačka F, Bzdúšková D, Halická Z, Lobotková J, Szathmáry V (2011). Assessment of human balance during stance using accelerometer sensors. 8th International Conference; April 27–30, 2011; Smolenice, Slovak Republic.
12 Horak FB, Macpherson JM (1996). Postural orientation and equilibrium. In: Rowell LB, Shepard JT, editors. Handbook of physiology. Volume Section 12: Exercise: Regulation and integration of multiple systems. New York: Oxford University Press. p. 255–292.
13 Jorgensen MG, Rathleff MS, Laessoe U, Caserotti P, Nielsen OB, Aagaard P (2012). Time-of-day influences postural balance in older adults. Gait Posture. **35:** 653–657.
14 Litvinenková V (1970). 24-hour upright posture regulation in man. Acta Nerv Super (Praha). **12:** 147–148.
15 Litvinenková V (1972). Circadian rhythm in the regulation of posture in relation to the changes of light stimulus field. Československá hygiena. **17:** 264–268.
16 Mancini M, Carlson-Kuhta P, Zampieri C, Nutt JG, Chiari L, Horak FB (2012). Postural sway as a marker of progression in Parkinson's disease: a pilot longitudinal study. Gait Posture. **36:** 471–476.
17 Mancini M, Horak FB, Zampieri C, Carlson-Kuhta P, Nutt JG, Chiari L (2011). Trunk accelerometry reveals postural instability in untreated Parkinson's disease. Parkinsonism Relat Disord. **17:** 557–562.
18 Moe-Nilssen R, Helbostad JL (2002). Trunk accelerometry as a measure of balance control during quiet standing. Gait Posture. **16:** 60–68.
19 Morad Y, Azaria B, Avni I, Barkana Y, Zadok D, Kohen-Raz R, *et al.* (2007). Posturography as an indicator of fatigue due to sleep deprivation. Aviat Space Environ Med. **78:** 859–863.
20 Naessen T, Lindmark B, Larsen HC (1997). Better postural balance in elderly women receiving estrogens. Am J Obstet Gynecol. **177:** 412–416.
21 Naessen T, Lindmark B, Larsen HC (2007). Hormone therapy and postural balance in elderly women. Menopause. **14:** 1020–1024.
22 Redfern MS, Yardley L, Bronstein AM (2001). Visual influences on balance. J Anxiety Disord. **15:** 81–94.
23 Shahin A, Ulas YH, Deniz E (2012). Effects of menstrual periods on postural stability in eumenorrheic female group. Sci Res Essays. **7:** 3053–3057.
24 Shumway-Cook A, Woollacott M (2000a). Attentional demands and postural control: the effect of sensory context. J Gerontol A Biol Sci Med Sci. **55:** 10–16.
25 Shumway-Cook A, Woollacott M (2000b). Motor control: Theory and practical applications. 2nd ed. Baltimore (MD): Lippincott, Williams and Wilkens.
26 Spain RI, St George RJ, Salarian A, Mancini M, Wagner JM, Horak FB, *et al.* (2012). Body-worn motion sensors detect balance and gait deficits in people with multiple sclerosis who have normal walking speed. Gait Posture. **35**: 573–578.
27 Woollacott M, Shumway-Cook A (2002). Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture. **16**: 1–14.