

# THE EFFECT OF INCREASED FEMALE SEX HORMONE CONCENTRATION ON MOVEMENT PROPRIOCEPTION

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## ABSTRACT

*Research background and hypothesis.* Over the last years, basic research on the effect of different hormones on tendons and ligaments has been initiated. Regarding oestrogen receptor localization in brain and their interaction with neurotransmitters (Maki et al., 2002; Friden et al., 2003; Farage et al., 2008), we speculate that the increase in the level of female sex hormone concentration will improve the sense of movement.

*Research aim* was to study the effect of increased female sex hormone concentration on movement proprioception.

*Research methods.* Subjects were healthy and physically active women (n = 15) with normal menstrual cycle, aged 19–23 years, body weight –  $58.2 \pm 6.1$  kg, height –  $168.4 \pm 5.6$  cm as well as female basketball players (n = 15) with normal menstrual cycle, aged 19–23 years, body weight –  $78.31 \pm 2.81$  kg, height –  $182.40 \pm 4.71$  cm. We performed three experiments with each participant: in follicular phase, ovulation and luteal phase. The samples of 5 ml venous blood were taken to establish the amount of estradiol $17\beta$ -estradiol and progesterone concentration. The sense of knee joint position was evaluated using isokinetic dynamometer (*System 3; Biodex Medical Systems, Shirley, New York, USA*). During a training session, a subject's right leg was flexed at the knee joint and fixed at the angle of  $90^\circ$ . Prior to each test, the researcher demonstrated the target angle of  $60^\circ$  by stretching subject's leg. In order to train the flexion of the knee joint, a subject's right leg was extended at the knee joint and fixed at the angle of  $0^\circ$ . The researcher demonstrated the target angle of  $50^\circ$  by flexing subject's leg. The subjects had to perform three tests at the velocity of  $2^\circ/s$ ,  $5^\circ/s$  and  $10^\circ/s$  with their eyes open and closed.

*Research results.* Females in the control group performed knee joint proprioception task better with an extended knee at velocity of  $2^\circ/s$  with open eyes during the follicular phase, but at the velocity of  $10^\circ/s$  the values were better during ovulation. Basketball players performed the same task better at velocity of  $5^\circ/s$  during ovulation, but at velocity of  $10^\circ/s$  the values were better during the luteal phase. Females in control group performed knee joint proprioception task with an extended knee at the velocity of  $5^\circ/s$  with closed eyes better during the luteal phase. No statistical difference between control group and basketball player indices of knee joint position proprioception task with a flexed knee at velocity of  $2^\circ/s$ ,  $5^\circ/s$  and  $10^\circ/s$  with closed eyes during the menstrual cycle was found.

*Discussion and conclusion.* Knee joint proprioception indices were better during ovulation phase in control group and basketball players.

**Keywords:** knee joint proprioception, follicular phase, ovulation, luteal phase.

## INTRODUCTION

Proprioception is related to the senses of position and movement of limbs. These senses are mediated through neural input from peripheral mechanoreceptors in the skin, muscles, tendons, ligaments and joint capsules (Friden et al., 2003). Over the last years, basic research on the effect

of different hormones on tendons and ligaments has been initiated. Estrogen and progesterone receptors have been identified on fibroblasts in the humans (Nakata et al., 2010). Estrogen has been shown to decrease the proliferation of fibroblasts and the synthesis of Type 1 procollagen (Nakata

et al., 2010). Previous studies have suggested that the variation of estradiol and progesterone during the menstrual cycle influences neurological and motor functions (Osterlund et al., 2001). Increased levels of progesterone metabolites during the luteal phase are known to affect various transmitters and hormone systems, for example in the cerebellum, resulting in effects on motor functions (Shen Yin-Chen, Franz, 2005). It was ascertained that oestrogen receptors (ER $\beta$ ) detected in cerebellum interact with neurotransmitter  $\gamma$ -aminobutyric acid (GABA) (Friden et al., 2003) and higher estradiol concentration improve procedural memory (Gur et al., 2000). However, the performance of right movements, movement coordination, and balance during ovulation are worse when comparing the indices during follicular and luteal phases (Friden et al., 2003). Several investigations have studied the relationship between menstrual cycle phase and the risk of anterior cruciate ligament (ACL) injuries. There are multiple indications that ACL laxity (Friden et al., 2003), neuromuscular factors (Friden et al., 2006), as well as athletic performance (Shen Yin-Chen, Franz, 2005), may fluctuate during the menstrual cycle. However, these findings have been equivocal and there is little consensus in research literature. Some studies suggested that pre-menstrual and menstrual symptoms affect the athletic performance and neuromuscular control, and may increase the risk of musculoskeletal injuries (Shultz et al., 2005). However, few studies have investigated the influences of these dysfunctions on noncontact ACL injuries (Eiling et al., 2007). The implications of these physiological changes during the menstrual cycle on ACL injury risk in female athletes have not been clarified yet. Regarding oestrogen receptor localization in brain and their interaction with neurotransmitters (Maki et al., 2002; Friden et al., 2003; Farage et al., 2008), we speculate that the increase in the level of female sex hormone concentration will improve the sense of movement. The aim of the study was to study the effect of increased female sex hormone concentration on movement proprioception.

## RESEARCH METHODS

**Subjects** were healthy and physically active women (n = 15) with normal menstrual cycle, aged 19–23 years, body weight –  $58.2 \pm 6.1$  kg, height –  $168.4 \pm 5.6$  cm as well as female basketball

players (n = 15) with normal menstrual cycle, aged 19–23 years, body weight –  $78.31 \pm 2.81$  kg, height –  $182.40 \pm 4.71$  cm. The healthy and physical active women (n = 15) were chosen as control group. All the participants had not been using oral contraceptives for six months and had regular (28 days) menstrual cycle. Ethical approval was obtained from Kaunas Regional Ethics Committee of Biomedical Research (report number BE-2-24). Written informed consent was obtained from the volunteers prior to their participation in this study. All the volunteers could be considered as physically active as they took part in recreational activities two or three times per week.

**Estimation of basal body temperature.** Basal body temperature (BBT) estimation is a method for identifying the approximate day of ovulation, and thus the relative length of follicular and luteal phases (Bauman, 1981). Each subject measured BBT every morning for three months before the experiment. BBT increased approximately by  $0.3^\circ\text{C}$  after ovulation, which sustained throughout the luteal phase. Using BBT method we chose subjects in the study on their early-follicular phase, when oestrogen and progesterone concentrations were low, and on ovulation, when estrogen concentrations were high (Bauman, 1981).

**Estimation of estrogen concentrations.** At the beginning of every study, 5 ml of venous blood sample was taken to establish estradiol (17 $\beta$ -estradiol) and progesterone concentration in blood. The enzyme immunoassay analysis ECLIA was used to establish estradiol (17 $\beta$ -estradiol) and progesterone concentration in blood in vitro with *Roche Elecsys 1010/2010 cobas e 411* (Roche Diagnostics GmbH, Germany) and *Modular Analytics E170* immunological analyzers (Roche Diagnostics GmbH, Germany). In our study we measured estradiol 17 $\beta$ -estradiol and progesterone concentration in blood on the second (follicular phase), fourteenth (ovulation) and twenty third day (luteal phase) of menstrual cycle.

**Estimation of knee joint position sense.** Knee joint position sense was evaluated using isokinetic dynamometer (*System 3; Biodex Medical Systems, Shirley, New York, USA*). During a training session, a subject's right leg was flexed at the knee joint and fixed at the angle of  $90^\circ$ . Prior to each test, the researcher demonstrated the target angle of  $60^\circ$  by extending subject's leg. A subject's right leg was extended at the knee joint and fixed at the angle

of  $0^\circ$ . The researcher demonstrated the target angle of  $50^\circ$  by flexing subject's leg (Figures 1 A, B). The same sequence of actions was used throughout the research while performing the test of the knee joint position sense. The subjects had to perform three tests at the velocity of 2°/s, 5°/s and 10°/s with their eyes open and closed (Hertel et al., 2006).

**Testing schedule.** Training tests were administered for the subjects to get used to the laboratory environment and learn how to perform joint position sense tests. Each study was conducted at least a week after the training tests. During the experiment, the room temperature was usual ( $20\text{--}22^\circ\text{C}$ ). The subjects were selected randomly, females were chosen according to the duration of their menstrual cycle and ovulation day. The day for the test was set in the early follicular phase (estradiol and progesterone in blood is low); on ovulation, estradiol in blood is peak during the menstrual cycle; during luteal phase, estradiol – medium, progesterone – peak during the menstrual cycle. At the beginning of the experiment, 5 ml of venous blood sample was taken to measure the concentration of female sex hormones: estradiol and progesterone. The knee joint position sense tests were conducted.

Descriptive data is presented as means (SEM). The one-way analysis of variance (ANOVA) for repeated measures was used to determine the effect of menstrual cycle on the knee joint position sense values separately at different velocities. If significant effects were found, post hoc testing was performed, applying paired t-tests with a Bonferroni correction for multiple comparisons. Statistical significance of all tests was set at  $p < 0.05$ .

## RESEARCH RESULTS

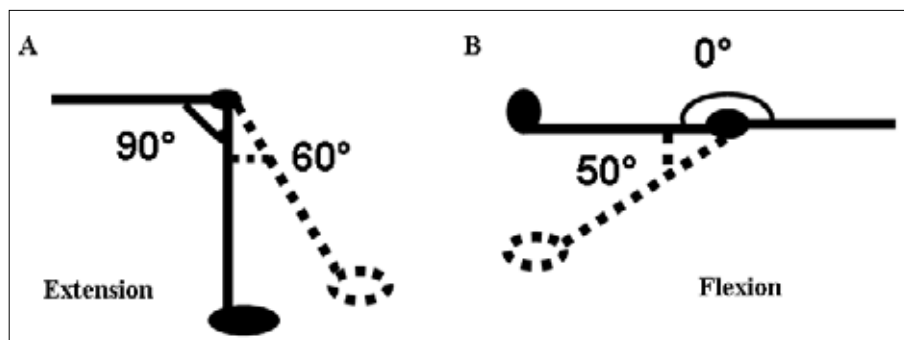
Control group values of estradiol and progesterone concentration in blood were higher during ovulation and luteal phases than in the follicular phase ( $p < 0.05$ ; Figures 2 A, B).

Female basketball players' values of estradiol and progesterone concentration in blood were higher during ovulation and luteal phases than in the follicular phase ( $p < 0.05$ ; Figures 3 A, B).

Females in control group performed knee joint position sense task better with an extended knee at the velocity of 2°/s with open eyes during the follicular phase ( $p < 0.05$ ; Figure 4 A), but at the velocity of 10°/s the values were better during ovulation ( $p < 0.05$ ; Figure 4 A). Basketball players performed the same task better at the velocity of 5°/s during ovulation ( $p < 0.05$ ; Figure 4 A), but at the velocity of 10°/s the values were better during the luteal phase ( $p < 0.05$ ; Figure 4 A). The females in control group performed knee joint position sense task with an extended knee at the velocity of 5°/s with closed eyes better during the luteal phase ( $p < 0.05$ ; Figure 4 B).

Females in control group and basketball players performed the knee joint position sense task better with a flexed knee at velocity of 10°/s with open eyes during ovulation ( $p < 0.05$ ; Figure 5A). No statistical difference between control group and basketball player indices of knee joint position sense task with a flexed knee at velocity of 2°/s, 5°/s and 10°/s with closed eyes during the menstrual cycle ( $p > 0.05$ ; Figure 5 B) was found.

Figure 1. Estimation of knee joint position sense



**Note.** A – knee joint extension till  $60^\circ$  angle; B – knee joint flexion till  $50^\circ$  angle.

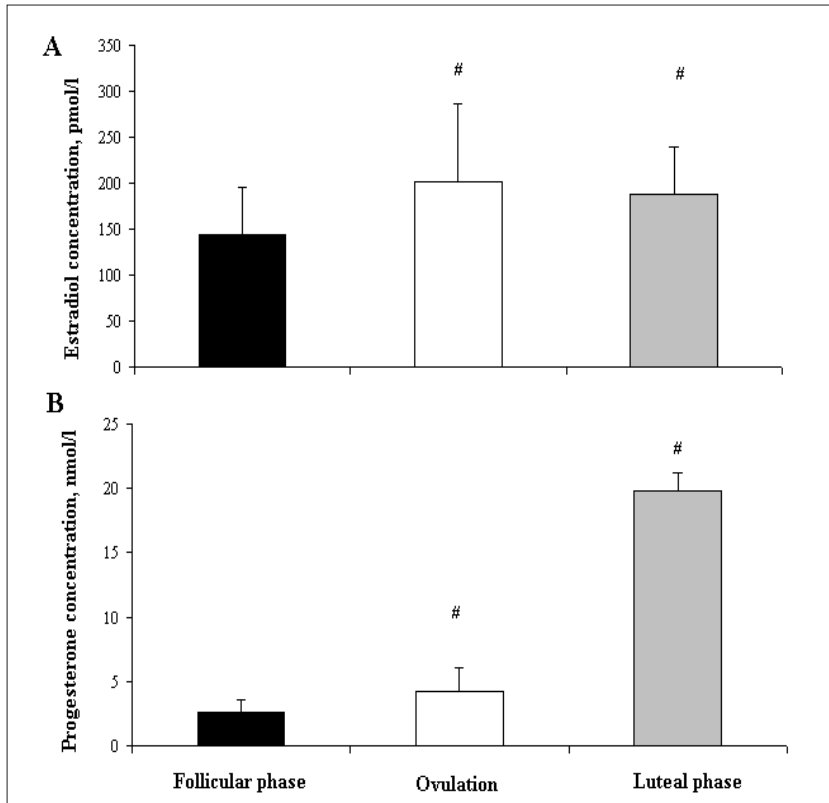


Figure 2. Control group women's estradiol (A) and progesterone (B) concentration in blood during follicular, ovulation and luteal phases

Note: # – compared to the follicular phase indices ( $p < 0.05$ ).

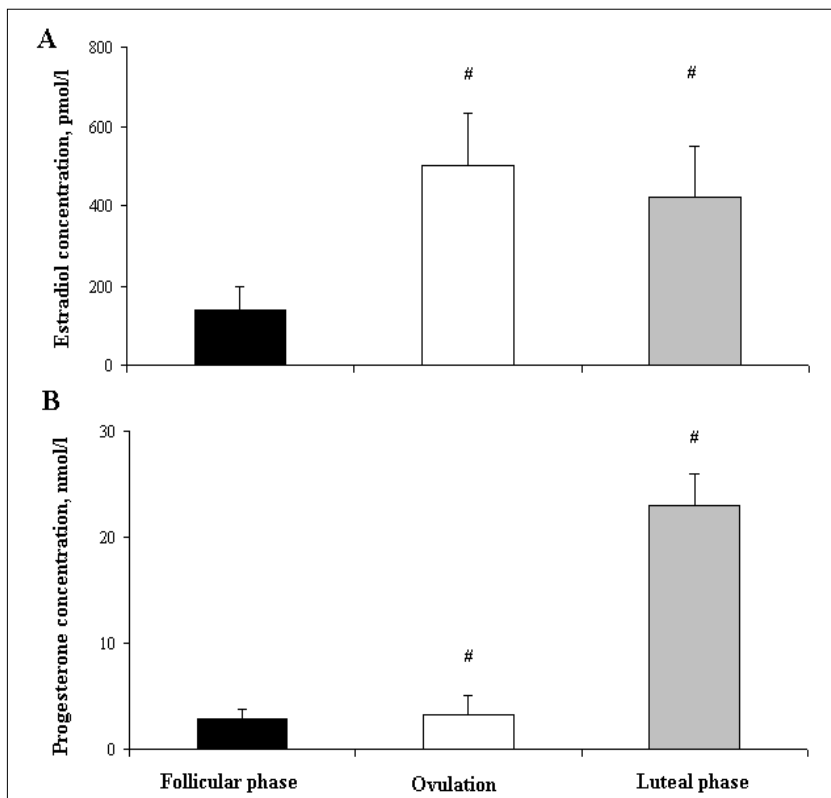
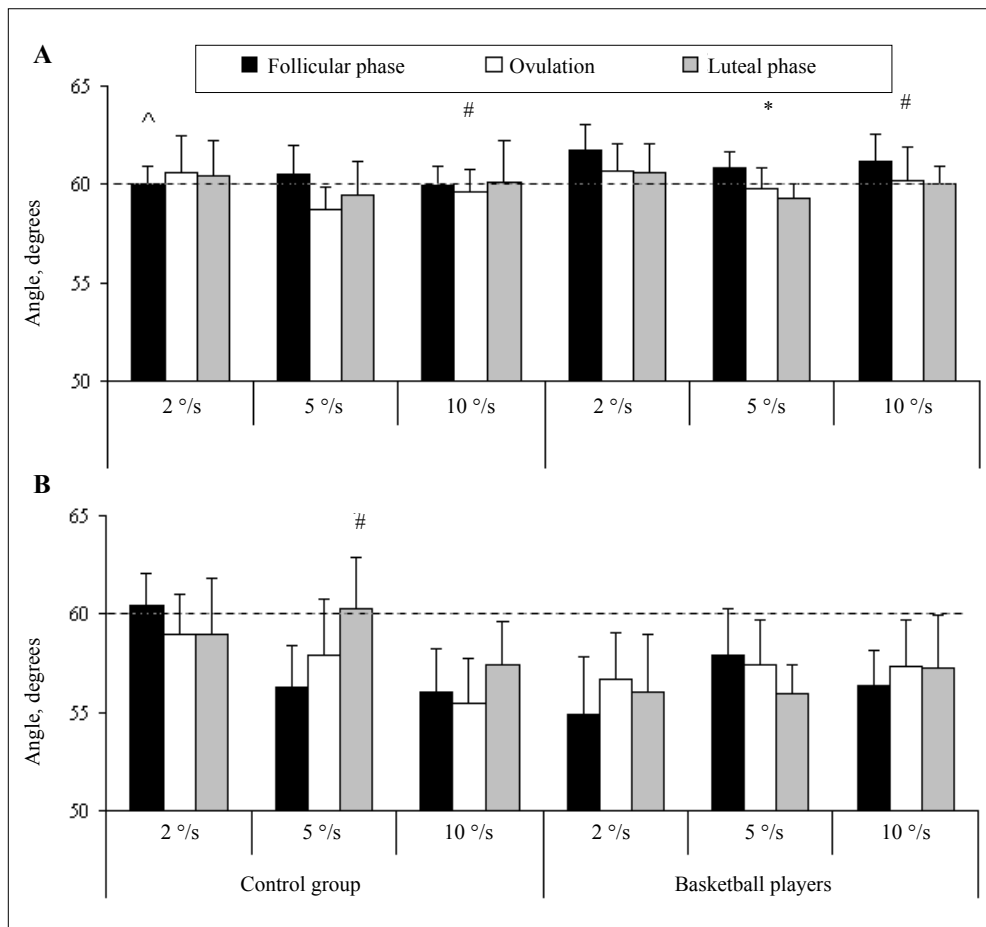


Figure 3. Female basketball players' estradiol (A) and progesterone (B) concentration in blood during follicular, ovulation and luteal phases

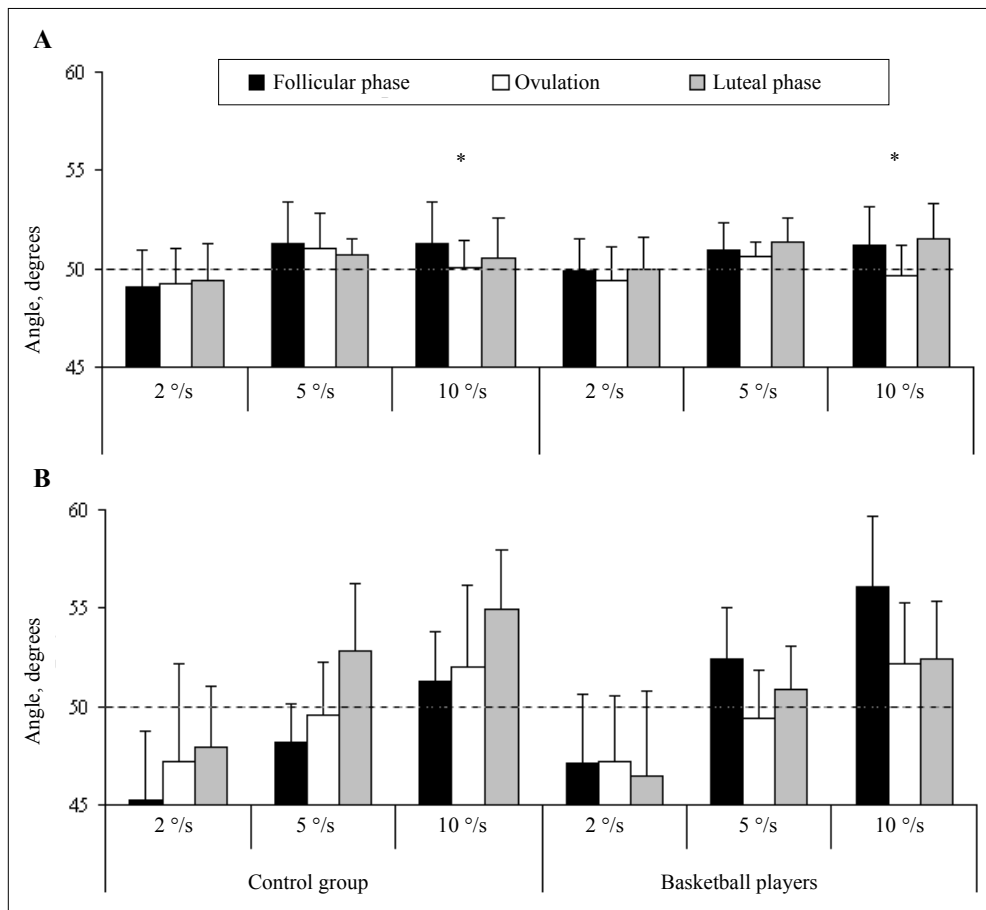
Note: # – compared to the follicular phase indices ( $p < 0.05$ ).

Figure 4. Knee joint position sense for control group and basketball players with extended knee with open (A) and closed (B) eyes during the menstrual cycle.



Note: \* – compared to the ovulation phase ( $p < 0.05$ ); # – compared to the luteal phase ( $p < 0.05$ ); ^ – compared to the follicular phase ( $p < 0.05$ ).

Figure 5. Knee joint position sense for control group and basketball players with extended knee with open (A) and closed (B) eyes during the menstrual cycle



Note. \* – compared to the ovulation phase ( $p < 0.05$ ); # – compared to the luteal phase ( $p < 0.05$ ); ^ – compared to the follicular phase ( $p < 0.05$ ).

## DISCUSSION

The aim of the study was to investigate the effect of increased female sex hormone concentration on movement proprioception. The present results showed that subjects were in proper menstrual cycle phase. The estradiol concentration was higher in ovulation than in follicular and luteal phases, and progesterone concentration was higher in luteal phase than in follicular phase and ovulation, when ovulation day was counted as day 14, follicular phase – day 2 for female participants. By the classical terminology of menstrual cycle phase with corresponding days of 28-day, ovulation occurring on day 14, follicular phase – on the 1<sup>st</sup>–13<sup>th</sup> days (Janse de Jonge, 2003). The indication of corresponding hormone concentrations on ovulation day – estradiol is high, on the day of follicular phase estradiol is low (Janse de Jonge, 2003). Knee joint proprioception indices were better during follicular and ovulation phases. When investigating female kinaesthesia indices during the menstrual cycle, no statistically significant difference between the indices of control and basketball players' groups was determined. Yet both control group women and basketball players indicated knee joint position angles when flexing and extending their leg more precisely during the luteal phase. Kinaesthesia comprises a complex of functions related to nervous and muscular systems; therefore scientists wonder whether sex hormones affect the functions through peripheral or central

mechanisms. Increased level of estradiol and progesterone concentration in blood during the luteal phase affects neurotransmitters in cerebellum, which is responsible for motor functions (McEwen, 2002). The impact of changes in sex hormone concentration in blood on female bone system components, soft and connective tissues was also revealed (Wojtys et al., 2002). When estimating kinaesthetic indices, no statistically significant differences were found between movement rates. The indices varied, yet better results were recorded when performing a task at the velocities of 2°/s and 10°/s. It is possible to make assumption that when position sense velocity is low (2°/s) and the task is performed accurately, adaptation of CNS increases from I  $\alpha$  muscle spindles and receptors in joints to peripheral signals; and when position sense velocity is high (10°/s) and the task is performed accurately, CNS adaptation to peripheral signals increases from type II or dynamic muscle spindles during the movement (Brindle et al., 2009). Movement sense at the velocity of 5°/s encompasses information of I  $\alpha$  and II type muscle spindles; thus the plane for mistakes increases.

## CONCLUSIONS AND PERSPECTIVES

Knee joint proprioception indices were better in control and basketball players groups during ovulation phase.

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## PADIDĖJUSIOS MOTERIŠKŲJŲ LYTINIŲ HORMONŲ KONCENTRACIJOS POVEIKIS JUDESIO PROPRIORECEPCIJAI

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### SANTRAUKA

*Tyrimo pagrindimas ir hipotezė.* Paskutinių metų žmonių tyrimų rezultatai rodo hormonų poveikį sausgyslių ir raiščių dariniams. Dėl estrogenų receptorių lokalizacijos galvos smegenyse ir jų sąveikos su neurotransmiteriais (Maki et al., 2002; Friden et al., 2003; Farage et al., 2008) spėjama, kad moteriškųjų lytinių hormono koncentracijos padidėjimas pagerins judesio jutimo rodiklius.

*Tikslas* – ištirti padidėjusios moteriškųjų lytinių hormonų koncentracijos poveikį judesio propriorepcijai.

*Metodai.* Tiriamosios – sveikos nespportuojančios, turinčios natūralų mėnesinių ciklą, fiziškai aktyvios merginos (n = 15), kurių amžius – 19–23 m., kūno masė –  $58,2 \pm 6,1$  kg, ūgis –  $168,4 \pm 5,6$  cm. Taip pat moterys krepšininkės (n = 15), turinčios natūralų mėnesinių ciklą, kurių amžius – 19–23 m., kūno masė –  $78,31 \pm 2,81$  kg, ūgis –  $18,40 \pm 4,71$  cm. Kiekvieno eksperimento pradžioje buvo paimamas 5 ml veninio kraujo mėginys menstruacinio ciklo fazėms (folikulinei, ovuliacinei ir liuteininei) nustatyti. Tyrimo metu estradiolio ir progesterono koncentracija kraujyje nustatyta antrą dieną nuo menstruacinio ciklo pradžios (folikulinėje fazėje), 14-ą dieną nuo menstruacinio ciklo pradžios (ovuliacijos metu) ir 23-ią dieną nuo menstruacinio ciklo pradžios (liuteininėje fazėje). Kelio sąnario padėties jutimas buvo vertinamas naudojant izokinetinį dinamometrą (*System 3; Biodex Medical Systems, Shirley, New York, USA*). Mokantis tiesti kelio sąnarį, tiriamųjų dešinė koja buvo sulenkama per kelį ir fiksuojama 90° kampu. Tyrėjas prieš kiekvieną bandymą parodydavo, kaip tiesti koją 60° kampu. Mokantis kelio sąnarį lenkti, tiriamųjų dešinė koja buvo ištiesiama per kelį ir fiksuojama 0° kampu. Tyrėjas prieš kiekvieną bandymą parodydavo, kaip lenkti koją 50° kampu. Tiriamosios atliko tris bandymus: lenkė kojas 2°/s, 5°/s ir 10°/s greičiu atmerktomis ir užmerktomis akimis.

*Rezultatai.* Kontrolinės grupėje moterys užduotį geriau atliko atmerktomis akimis kelio sąnarį tiesdamos 2°/s greičiu folikulinės fazės metu, tačiau tą pačią užduotį atlikdamos 10°/s greičiu geresnių rezultatų pasiekė ovuliacijos fazėje. Krepšininkės tą pačią užduotį geriau atliko 5°/s greičiu ovuliacijos fazėje, o kai greitis siekė 10°/s, užduotį geriau atliko liuteininėje fazėje. Nebuvo nustatytas statistiškai patikimas skirtumas lyginant kontrolinės grupės ir krepšininkių kelio sąnario lenkimo užduoties rodiklius užmerktomis akimis, kai kelio sąnario lenkimo greitis 2°/s, 5°/s ir 10°/s menstruacinio ciklo metu.

*Aptarimas ir išvados.* Kontrolinės grupės krepšininkių kelio sąnario propriorepcijos rodikliai buvo geresni ovuliacijos fazėje.

**Raktažodžiai:** kelio sąnario propriorepcija, folikulinė fazė, ovuliacija, liuteininė fazė.

Gauta 2012 m. birželio 21 d.  
Received on June 21, 2012

Priimta 2012 m. rugsėjo 7 d.  
Accepted on September 7, 2012

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