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ESTRADIOL AND PROGESTERONE INFLUENCE ON THE KNEE JOINT EXTENSORS AND FLEXORS RELAXATION SPEED

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Abstract. The aim of the study was to find if a level of hormones influenced relaxation of skeletal muscle force during menstrual cycle. Fifteen physical education students having a regular menstruation without any use of contraceptive pills were tested in ovulatory and luteal phase of menstrual cycle. Relaxation from maximal voluntary contraction was measured during knee extension and flexion using Biodyna dynamometer. The level of estradiol and progesteron were assessed using cheminoluminescent method. The following rates were calculated: early (GWR), late (GPR), most late (GKR), and maximal relaxation ratę (MGR). The estradiol and progesteron level was higher in luteal phase than in ovulatory phase. None of the relaxation indices were statistically different between ovulatory and luteal phase. During knee flexion there was a positive correlation between GKR and estradiol level (r= 0.715), and a negative between GKR and progesterone (r= -0.91). Moreover, there was a negative correlation between MGR and progesterone level (r= -0.705). For knee extensors, there was not found any significant correlation. The result suggest that although there was no changes in relaxation indices between ovulatory and luteal phase of menstrual cycle, the level of progesterone and estradiol might influence the different phases of relaxation indices during knee flexion, but not extension.

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Key words: Sex hormones – Relaxation - Skeletal muscles

Introduction

Performance of some periodical movements i. e.: walk or run involves the alternate work of the knee joint flexors and extensors. The co-operation of those muscles is tightly connected with their relaxation. The most frequently used indices for the measurement of relaxation after voluntary or elicited (electrostimulation)

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contractions are the half relaxation time (PtR) and the maximal relaxation gradient [4,5,10]. Recently, Jaskólska and Jaskólski [12,13] determined also the early (GWR), late (GPR) and most late (GKR) relaxation rates as indices of the slow and fast relaxation after the voluntary contraction. The slow relaxation phase, called the early and encompassing the muscles tension decrease to about 80-70% of the maximal force, is determined by the rate of Ca^{2+} dissociation from a thin filaments and a re-uptake [Ca^{2+}] through a sarcoplasmic reticulum [19] which depends on the other hand on a calcic ATP-ase in a terminal cisterns [6,8] and speed of the calcium ions uptake through the sarcoplasmic reticulum and consequently the calcium pomp action. The fast relaxation phase is only partly depended on the Ca^{2+} removal rate and mostly depended on a cross-bridges speed initiated by the disconnection of Ca^{2+} from TnC [3,19], cross-bridges kinetics and especially on the rate of the detachment cross-bridges passing from the strong power state to week power state [1,7,8,9]. Considering the fact that the central nervous system takes part in the voluntary motions performance, the early relaxation depends on the speed of the bio-electric activity decrease in an agonist muscles and on the derecruitment of motor units. Next, the late and most late relaxation phased depend on the level of the antagonistic muscles activity (unpublished own results 2001).

The data regarding the muscles power during a menstrual cycle are not coherent in the accessible references [11,16,17]. However, there exist one report about the relaxation change during the menstrual cycle while stimulation of the quadriceps of thigh [18]. Authors stated that the rate of relaxation after the twitch and tetanic contraction is longer during the ovulation than during luteal phase. Taking into account the influence of the central nervous system on the relaxation rate after the voluntary twitch it seems that the influence of the hormones concentration on relaxation speed might be also higher than in the case of elicited contractions.

The aim of the study was to find out if the level of hormones influences the specific relaxation phases after the voluntary contraction of the knee joint extensors and flexors during the ovulatory and luteal phase of menstruation.

Materials and Methods

The methodology of the study was described precisely in an previous article thus only the most important issues will be described briefly in this paper [14]. Fifteen physical education female students aged from 20 to 24 years old (21.6±1.6) weighting – 60.8±5.8 kg and with height – 165.2±4.9 cm took part in the study. Examined students were having a regular menstruation from 26 to 35 days (average

29.8±3.2) and not using contraceptive pills. Examinations always begun at the same hour (±2h).

Tests were conducted in two cycles though the hormones determination only in the second one (both in the luteal and ovulatory phase) in consideration of the fact that Sarwar *et al.* [18] obtained the highest differences among the relaxation indices between these two cycle phases. The examination was lead between 13th and 18th cycle day (ovulation) and 19th and 24th day (luteal phase) [11,18].

The relaxation indices measurement was taken using the BIODYNA dynamometer (Institute of Air Technics and Applied Mechanics by Engineering College of Warsaw) [15]. The trial was preceded by 5 min warm up. The examination was performed in a sitting position. The lower limb was placed on a lever in such a way that the circle axis in the knee joint was coherent with the lever turn axis. Subjects were to obtain as quick as they could the maximal muscle force and keep it up from one signal to another. The second signal was emitted randomly after 2 or 3 s. After this mark subjects ought to loosen working muscles. The result of the relaxation course was analysed in Fig. 1:

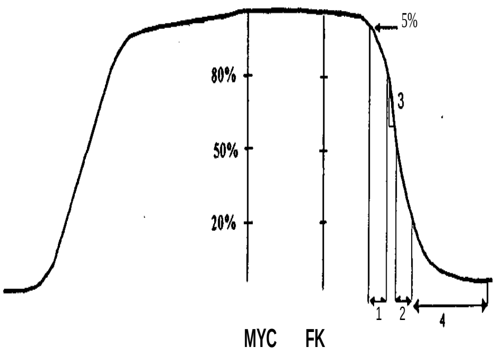

Fig. 1
Indices measured and calculated basing on the recording of force in time
MVC = maximal isometric strength; FK - final force;
1 - rate of early relaxation (GWR); 2 - rate of late relaxation (GPR); 3 - maximal relaxation rate (MGR); 4 - most late relaxation rate (GKR)

early relaxation rate (GWR) was calculated as a ratio of the force decrease from 90% to 80% of a final force (FK) i.e.: from the value registered during the emission of the second signal to the moment in which the fall occurred. It was presented in a relative values [%F/5 ms];

late relaxation rate (GPR) was calculated as the ratio of the force decrease from 50% to 20% FK [%F/5 ms];

most late relaxation rate (GKR) was calculated as the ratio of the force decrease ofthe last 20% FK [%F/5 ms];

maximal relaxation gradient (MGR) was accepted as the final force decrease (FK) in a 5 ms time period [%F/5 ms] [13].

The percentage difference between the ovulatory and luteal phase was calculated for the above indices. Next, it was correlated with the percentage changes of estradiol and progesterone in those phases.

Hormones concentration was measured in both phases. Ten millilitres of the vein blood was taken in the morning in fasting state and next centrifuged. Hormones were marked using a chemiluminescent method (Diagnostic Products Corporation, USA). Relaxation indices measurements were taken in the same day as blood was collected.

Results were compiled statistically. An arithmetic averages and standard deviation were calculated. The paired t- Student test was used for the comparison of ovulatory and luteal phases of mensurations [2]. The relation between the respective relaxation indices and hormones concentrations in the luteal and ovulatory phase were specified using the simple correlation of Pearson. The level of $p \le 0.05$ was accepted as statistically significant.

Results

Eleven of fifteen students finished the test. Two of them were excluded considering the irregular menstruation and next two regarding the state of health.

The estrogen level during the ovulatory phase equalled 83.6±31.3 pg/ml and in luteal 148.3±81.3 pg/ml. The progesterone level equalled respectively: 1.82±1.10 ng/ml and 7.20±6.70 ng/ml.

The knee joint flexors and extensors indices did not differ significantly in both menstrual phases (Fig. 2A, 2B). However, early (GWR), late (GPR) and most late (GKR) extensors relaxation rates displayed the diminishing tendency (Fig. 2A) and maximal relaxation rate (MGR) the increasing course in the luteal phase.

The knee joint flexors (Fig. 2B) manifested converse behaviour: early (GWR) and late (GPR) relaxation rates showed the increasing tendency, maximal relaxation rate (MGR) – the diminishing course and only most late relaxation (GKR) presented the same tendency as extensors (decrease).

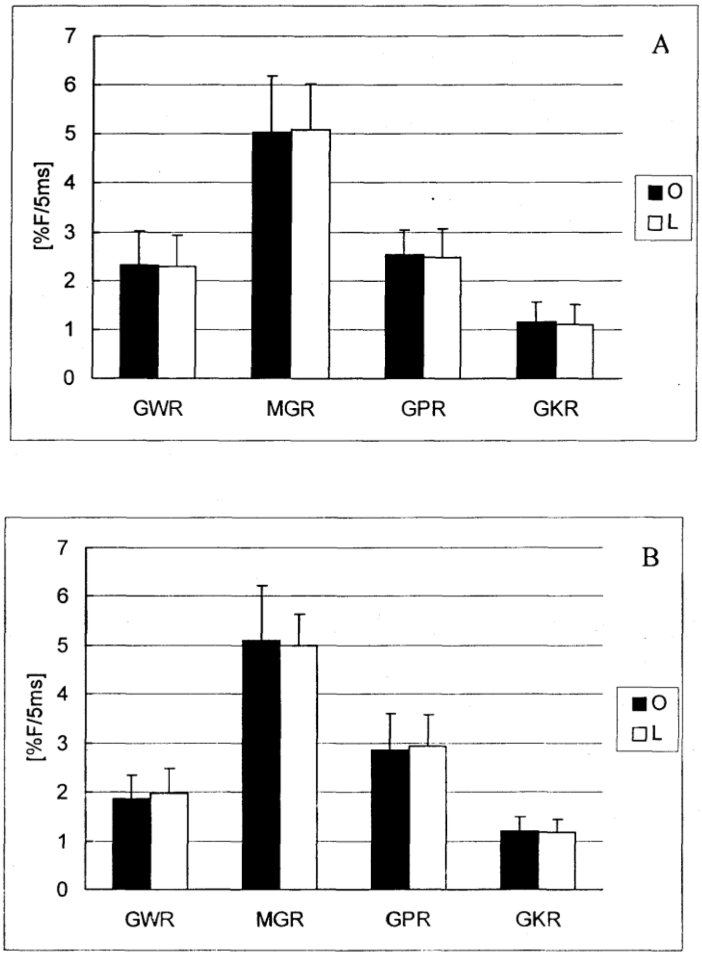

Fig. 2
Average values and standard deviation of early (GWR), maximal (MGR), late (GPR) and most late (GKR) relaxation rate in the ovulatory (O) and luteal (L) phase for the knee joint extensors (A) and flexors (B); n=11; $^*p \leq 0.05$

Some correlations between the percentage relaxation changes and hormones concentrations in luteal and ovulatory phase were calculated (Table 1). The positive relation between GKR of the knee joint flexors and estradiol level was stated. The negative correlation was observed between GKR and the progesterone concentration. The negative and statistically significant dependence was stated also between MGR of the knee joint flexors and the level of progesterone. As regards extensors the respective correlations were inverse. Nevertheless, none of them exceeded the value of 0.400 and reached the level of statistical significance (Table 1).

Table 1
Correlation coefficients (r) between the percentage changes of the estradiol and progesterone and the early (GWR), late (GPR), most late (GKR) and maximal (MGR) relaxation rate of the knee joint extensors and flexors in 11 students

Index		Estradiol		Progesteron	
		r	p	r	p
Extensors	GWR	-0.231	NS	0.205	NS
	GPR	0.173	NS	0.216	NS
	GKR	-0.041	NS	0.352	NS
	MGR	-0.169	NS	0.249	NS
Flexors	GWR	0.327	NS	-0.135	NS
	GPR	-0.164	NS	-0.410	NS
	GKR	0.715	0.03	-0.910	0.001
	MGR	0.053	NS	-0.705	0.034

p - level of the statistical significance

Discussion

The new interesting notice flowing from conducted research is the fact that in spite of the statistically significant difference of the knee joint extensors and flexors relaxation rate in ovulatory and luteal phase some positive influence of estradiol and negative of progesterone on the most late relaxation rate as well as the negative influence of progesterone on flexors maximal relaxation rate was noticed. However, no significant correlations were seen as considering progesterone and extensors.

The lack of changes of early relaxation speed in both phases of menstrual cycle for the knee joint flexors is contradictory to data of Sarwar *et al.* [18] who stated the slow down of the half of relaxation and force relaxation from 75% to 38% in the ovulatory phase in comparison to the luteal phase. Authors suggest that changes of the relaxation time may be connected with changes of the myosin ATP-ase activity and calcium uptake by the sarcoplasmic reticulum. It should be noticed that in the case of our research the relaxation was measured after the voluntary contraction while in work of Sarwar *et al*. [18] during the muscles stimulation (the tetanic and individual twitch). It means that the knee joint flexors and extensors were analysed in our work as a group of muscles while Sarwar *et al*. [18] treated it as a singular muscle [quadriceps of thigh].

Regarding the fact that the central nervous system takes part in the performance of voluntary movements the speed of relaxation depends additionally on the bio-electrical activity disappearance in the agonist and antagonist muscles, the co-activation degree and de-recruitment of motor units. It is probably the cause, among others, of the lack of differences between the ovulatory and luteal phase regarding the relaxation speed after the voluntary contraction.

In our research, despite of statistically insignificant differences between the luteal and ovulatory phase considering the speed of relaxation of the knee joint flexors, some positive correlation of percentage GKR changes and the estradiol level as well as the negative with the level of progesterone was stated. The conclusion flows out that the higher is the level of estradiol the higher GKR index is and the higher is the progesterone concentration the GKR is lower. Thus, the estradiol seems to have a restraining influence on GKR speed and progesterone – the inverse. This opposition between GKR and estradiol/progesterone is probably the effect of progesterone being the estrogen inhibitor [18]. In our research also the negative correlation of MGR changes and progesterone level in luteal and ovulatory phase was found. It means that along with the growth of progesterone level between phases the MGR decrease goes smaller. Hence, similarly as in the case of GKR, progesterone averts in a way the MGR slow down. Changes of other relaxation indices did not display significant relationship with hormones level. The above results show that mechanisms responsible for the final relaxation phase and maximal relaxation gradient in a more sensitive way respond to hormones changes than mechanisms of early and late relaxation phase.

The early relaxation phase depends on the agonist muscles bio-electric action decrease (unpublished own results 2001), the Ca^{2+} dissociation from thin filaments and the [Ca^{2+}] re-uptake through the sarcoplasmic reticulum [19] which depends on the other hand on the calcium ATP-ase in terminal cisterns [6,8] as well on the speed of the calcium ions uptake through the sarcoplasmic reticulum and consequently the calcic pomp action. The fast relaxation, encompassing late and most late phase, depends on the level of the antagonistic muscles bio-electric action (late phase especially – own research 2001) as well as on the rate of the bridges passing from the strong power state to the week power [1,7,8,9] and their separation speed initiated by the disconnection of Ca^{2+} from TnC [3,19]. It is only partly depended on the Ca^{2+} removal rate. Considering the fact that all relaxation rates showed negative correlations towards the progesterone level changes (early was small: r= -0.135; late was bigger: r= -0.410 and MGR and GKR were the biggest) it seems that progesterone may influence the cross-bridges kinetics. On the other hand, the respective correlations for the knee joint extensors were statistically significant (both phases) and positive. Therefore, if the progesterone has some influence on the cross-bridges kinetics, why it is different in flexors and extensors? It appears that the progesterone changes in the ovulatory and luteal phase may prevent the relaxation slow down through the mediation of OUN which influences the level of co-activation of agonic and antagonistic muscles during relaxation. In addition, the knee extensors are antigravity muscles, control our posture and any changes in their activity would be disadvantageous.

Conclusions

Findings of our research stated that hormones influence on the relaxation rate after the voluntary contraction is relatively low albeit:
1/ the estradiol influence is inverse to progesterone what flows probably from the progesterone role as the estrogen inhibitor,
2/ the influence depends on the examined group of muscles (knee joint extensors or flexors) and the relaxation phase,
3/ mechanisms responsible for the most late relaxation and the maximal relaxation gradient are the most docile on hormones influence during the ovulatory and luteal phase.

References

1. Allen D.G., J.A.Lee, H.Westerblad (1989) Intracellular calcium and tension during fatigue in isolated single muscle fibers from Xenopus Laevis. *J.Physiol.* 415:433-458

2. Baumgarten T.A., A.S.Jackson (1987) Measurements for Evaluation in Physical Education and Exercise Science. Wm. C. Brown, Dubuque, Iowa, pp. 92-97

3. Caputo C., K.A.P.Edman, F.Lou, Y-B.Sun (1994) Variation in myoplasmic Ca^{2+} concentration during contraction and relaxation studied by the indicator flu-3 in frog muscle fibres. *J.Physiol.* 478:137-148

4. Duchateau J., K.Hainaut (1985) Electrical and mechanical failure during sustained and intermittent contractions in humans. *J.Appl.Physiol.* 58:942-947

5. Duchateau J., L. de Montigny, K.Hainaut (1987) Electromechanical failures and lactate production during fatigue. *Eur.J.Appl.Physiol.* 56:287-291

6. Dulhunty A.F. (1990) The rate of tetanic relaxation is correlated with the density of calcium ATPase in the terminal cisterns of thyrotoxic skeletal muscle. *Pflügers Arch.* 415:433-439

7. Edwards R.H.T., D.K.Hill, D.A.Jones (1975) Metabolic changes associated with the slowing of relaxation in fatigued mouse muscle. *J.Physiol.* 251:287-301

8. Fryer M.W., I.R.Neering (1986) Relationship between intracellular calcium concentration and relaxation of rat fast and slow muscles. *Neurosci.Lett.* 64:231-235

9. Gillis J.M. (1985) Relaxation of vertebrate skeletal muscle. A synthesis of the biochemical and physiological approaches. *Bioch.Biophys. Acta* 811:97-145

10. Gollnick P.D., P.Körge, J.Karpakka, B.Saltin (1991) Elongation of skeletal muscle relaxation during exercise is linked to reduced calcium uptake by the sarcoplasmatic reticulum in man. *Acta Physiol.Scand.* 142:135-136

11. Gur H. (1997) Concentric and eccentric isokinetic measurements in knee muscles during the menstrual cycle: A special reference to reciprocal moment ratios. *Arch.Phys.Med.Rehabil.* 78:501-505

12. Jaskólska A., A.Jaskólski (1997) The influence of intermittent fatigue exercise on early and late phases of relaxation from maximal voluntary contraction. *Can.J.Appl.Physiol.* 22:573-584

13. Jaskólska A. (1998) Przebieg zmian narastania siły i relaksacji u ludzi po wysiłkach o różnej charakterystyce. AWF Poznań, Monografie 326

14. Jaskólska A., K.Kisiel, Z.Adach, A.Jaskólski (2005) The influence of elbow joint angle on different phases of relaxation from amximal voluntary contraction. *Biol.Sport* 22:89-104

15. Kędzior K., E.Kotwicki, W.Niwiński (1987) Testing module for static and dynamic measurements of muscle group characteristics. W: B.Jonsson (ed.) Biomechanics X-B. Human Kinetics Publ. Champaign,. IL, pp 1127-1130

16. Phillips S.K., J.Gopinathan, K.Meehan, S.A.Bruce, R.C.Woledge (1993) Muscle strength changes during the menstrual cycle in human adductor pollicis. *J.Physiol.* 473:125P

17. Reis E., U.Frick, D.Schmidtbleicher (1995) Frequency variations of strength training sessions triggered by the phases of the menstrual cycle. *Int.J.Sports Med.* 16:545-550

18. Sarwar R., B.Beltran Nicols, M.Ruthherford (1996) Changes in muscle strength, relaxation rate and fatigability during the human menstrual cycle.

J.Physiol. 493:267-272

19. Wahr P.A. (1994) Determinants of the kinetics of force development and relaxation in skeletal muscle. Doctoral thesis. The Ohio State University

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