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Original Article

Physical performance during the menstrual cycle of female athletes who specialize in 800 m and 1500 m running

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Abstract:
Due to increasing rivalry during the competitions women specializing in the 800m and 1500m running are subjected to high training loads. It often leads to overtraining and injuries. That's why it is necessary to plan the training process for female athletes taking into consideration the adaptation mechanisms of their organism to specific loads. The purpose of this study is to determine the dynamics of the physical performance and functional capacity of the women who specialize in the 800m and 1500m running during the menstrual cycle. 13 women (3 – Candidates for Master of Sports (CMS), 5 – category I athletes, 5 – category II athletes), aged 17 to 24 years, agreed to participate in a study. All the female athletes had normal menstrual function. The study was conducted during 5 phases of the menstrual cycle: phase I – menstrual (the 1^{st}–5^{th} day of the cycle); phase II – postmenstrual (6^{th}–12^{th} day of the cycle); phase III – ovulatory (the 13^{th}–15^{th} day of the cycle); phase IV – postovulatory (the 16^{th}–24^{th} day of the cycle); phase V – premenstrual (the 25^{th}–27^{th} day of the cycle). The physical performance was evaluated on the basis of the standard bicycle ergometer test Physical Working Capacity, the 4x400m running, the heart rate and lactate concentration in blood. We have found that the hormonal status changes that occur during the menstrual cycle significantly influence the special performance of female athletes, which was the highest in the postmenstrual and postovulatory phases, compared to the menstrual, ovulatory and premenstrual ones.
Keywords: special performance, functional capacity, heart rate, lactate, women, menstrual cycle**.**

Introduction

The evaluation of the physical performance is of great importance for solving the training process tasks (B. Bergier, A. Tsos, J. Bergier, 2014). Most researchers believe that physical performance is an integral indicator of the organism functioning, which depends on the morphological and functional parameters of the main life support systems and, first of all, on the state of the cardiorespiratory system (L.P. Matveev, 2010, A. Tsos, L. Sushchenko, N. Bielikova, S. Indyka, 2016).

According to the leading experts on the theory and methodology of sports training, it is always necessary to apply functional control over the degree of athletes' organism adaptation to the means and methods of their training process in order to enhance athletic performance and maintain the health of athletes (V.M. Platonov, 2004).

The activity of the functional systems and adaptive processes in the women's organism differ from those in men. It is due to the one of the main biological peculiarities of the women's organism, which is related to the reproductive function, – the cycle of functions of the hypothalamic-pituitary-ovarian-adrenal system (A. J. Anderson (2008), M. Burrows (2005)). A number of studies (A. R. Radzievskiy, L.G. Shakhlina, Z. R. Yatsenko, T. P. Stepanova, 1990) have been devoted to the influence of sex hormones in the system of the women sports training. The scientists have determined the dependence of the performance manifestation of the female athletes of different sports specializations and the reaction of their organism according to the change of sex hormones concentration during the MC (O. Roda (2014), S. V. Kalitka, L.G. Shakhlina (2002)).

Modern training of the track female athletes who specialize in the 800m and 1500m running is characterized by a significant increase in the intensity of the load because of the growing rivalry during the competition (V. M. Platonov, 2004, S. V. Kalitka, 2002). The problem of improving training efficiency in female athletes who specialize in middle distance running according to the functional state during different phases of the MC has not been studied enough. At present there arises the necessity of planning the training process for female athletes with a more detailed study of the mechanisms of their organism's adaptation to large amounts of special loads.

The aim of the research was to study the dynamics of the physical performance and functional capacity of the women who specialize in the 800m and 1500m running during the MC.

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Materials and methods

Reviewing scientific and methodical literature on athletic training, special attention has been paid to the studies of anatomical and physiological characteristics of the women's organism and the special working capacity dynamics during the different phases of the menstrual cycle of the female athletes of different specializations.

13 women (3 – candidates for master of sports (CMS), 5 – category I athletes, 5 – category II athletes), aged 17 to 24 years, who specialize in middle distance running, agreed to participate in a study. All the female athletes didn't take any birth control pills and had normal menstrual function. The study was conducted during each phase of the MC. The menstrual cycle (MC) is a complex physiological process of functions changes of a woman's reproductive system manifested by regular uterine bleeding (menses) (ed. by G. M. Saveleva, V. G. Breusenko (2007)). The main regulatory role of MC belongs to the cerebral cortex, pituitary, hypothalamus and other structures of the central nervous system. The onset of ovulation, adequacy of the luteal phase was determined by recording female athletes' basal body temperature (a test based on the hyperthermal influence of progesterone on the hypothalamic thermoregulatory center) measured daily by each female athlete with the same thermometer, the analysis of saliva crystallization (the "fern" phenomenon) based on the principle of changes of the physical properties of saliva depending on the estrogen and salts contents in it, connected with the presence of sex hormones in females (V. B. Faynberg, U. Y. Podar, S. F. Sibul, A. A. Siarg (1970)). The daily measurements of basal temperature have made it possible to distinguish five phases of the MC, which are divided as follows: phase I – menstrual (the 1^{st}–5^{th} day of the cycle); phase II – postmenstrual (6^{th}–12^{th} day of the cycle); phase III – ovulatory (the 13^{th}–15^{th} day of the cycle); phase IV – postovulatory (the 16^{th}–24^{th} day of the cycle); phase V – premenstrual (the 25^{th}–27^{th} day of the cycle) (Shakhlina L. (2000)). The study lasted two months.

The physical performance of female athletes was evaluated on the basis of the results of the standard bicycle ergometer test Physical Working Capacity (PWC_{170}) which was invented at Karolinska Institute in Stockholm in the 1950s (I. B. Ushakov, 2007). The primary load was 1.25 watts per 1 kg of the subject's body weight. The stepped load test was performed on a bicycle ergometer, the duration of cycling was 9 min. During that time the load was increased twice (after 3 and 6 min). The heart rate was measured during the last 15 seconds of each 3-minute step, the load was adjusted so that the female athlete's heart rate rose to 170bpm at the end of the test.

For the purpose of studying the functional capacity and reactions of the female athletes' organism systems that are characteristic of the training and competitive activity, we suggested a test with repetitive loads in the 4x400m distances with 5-minute rest periods, in addition, each successive segment was covered with higher intensity. At the same time the heart rate (HR) was measured with a heart rate monitor Polar S610i and the average heart rate was calculated.

Lactate concentration in blood is an important indicator of evaluation of anaerobic processes intensity in athletes' organisms, one of the main methods of operational control over the training process effectiveness.

In order to determine lactate concentration in blood of female athletes who specialize in the 800m and 1500m running four blood samples were taken after the female athletes had run the control segments 4x400m. Lactate was determined with the help of the test strips BM-Lactate # 25 and the Accutrend Plus device (Switzerland).

The processing of the female athletes research quantitative data was performed on a personal computer by using variational and dispersion analyses. The mean values ($\overline{X}$) and standard error (m) were calculated. The compliance of data with the normal distribution law was checked with the Shapiro-Wilk test.

The Student's *t*-test was used to determine the statistically significant differences between the samples, the distribution of which corresponded to the normal law.

Results

It is known that women, unlike men, have a distinct cyclic flow of hormonal processes. Although there are many publications on cyclic changes of some physiological parameters in women, still there are controversial issues on changes in work capacity, functional capacity, metabolic and psychophysiological indices during the menstrual cycle (MC) (L. I. Lubysheva (2004), I. B. Ushakov (2007), O. Roda (2014)).

We have found that all female athletes gained the maximum body weight in the premenstrual phase (54.19 ± 2.63 (Candidates for Master of Sports (CMS) and category I athletes), 61.60 ± 5.18 kg category II athletes)) (Table. 1) and lost body weight insignificantly starting in the menstrual and continuing during the postmenstrual, ovulatory and postovulatory phases of the MC. The highest indices of the physical performance of female athletes, who specialize in middle distance running (CMS and category I athletes) (Table 1) were recorded in the postmenstrual and postovulatory phases compared with the menstrual, ovulatory and premenstrual ones. Veritably higher indices of the physical work capacity were observed in category II female athletes during the postovulatory phase ($p<0.05$, compared with other phases of the MC) and a veritably lower index was observed during the premenstrual phase of the MC ($p<0.05$, compared with the postovulatory and postmenstrual phases).

During the premenstrual and menstrual phases the level of sex hormones decreases (Table 1), the female Candidates for Master of Sports and category I female athletes have the lowest PWC_{170} indices. The female athletes of category II have veritably lower mean values of PWC_{170} during the premenstrual phase (compared with the postovulatory and postmenstrual ones) and veritably lower indices in the menstrual phase ($p<0.05$).

So, a decline in the work capacity during the premenstrual phase of the MC may be connected with the deterioration of the cardiorespiratory system functional state as a result of the reduced concentration of sex hormones during the menstruation.

Table 1. Physical work capacity indices of women during different phases of the MC

MC Phase		Index		
		Body weight *(kg)*	PWC_{170} ($kgm \cdot min^{-1}$)	PWC_{170} ($kgm \cdot min^{-1} \cdot kg^{-1}$)
I	CMS, Category I	53.91±2.62	1018.70±101.66	18.97±2.39
II		53.84±2.50	1033.12±184.06	19.15±3.15
III		53.71±2.59	1000.13±129.86	18.62±2.37
IV		53.78±2.51	1080.29±137.80	20.06±2.06
V		54.19±2.63	926.81±189.08	17.14±3.52
I	Category II	61.34±5.22	947.56±275.75♦	15.34±3.93♦
II		61.32±5.18	1065.81±308.48*♦	17.18±4.12*♦
III		60.98±5.01	957.43±267.80♦	15.53±3.41♦
IV		60.98±4.94	1221.85±245.83*	19.88±2.72*
V		61.60±5.18	921.12±197.48♦	14.84±2.43♦

Notes: * – ($p<0.05$) – veritable changes in the results compared with the premenstrual phase of the MC; ♦ – ($p<0.05$) – veritable changes in the results compared with the postovulatory phase of the MC.

In the training process multiple runnings of segments at a race speed or close to it ones with rest periods between intervals are used to develop special endurance of athletes who specialize in middle distance running. The highest results of 4x400m segments running were shown by the female CMSs and the female athletes of category I during the postmenstrual and especially during the postovulatory phases of the MC affirming high special efficiency (Table. 2) compared with the ovulatory and premenstrual phases and significantly lower results during the menstrual phase.

Table 2. The dynamics of special efficiency of women who specialize in middle distance running during different phases of the MC

Segment (4x400m)	Result, sec					
	MC phase		I	II	III	IV	V
1	CMS, Category I		74.87±5.91	72.64±5.79	73.01±5.61	72.42±5.72	73.77±5.06
2			74.32±5.61♦	72.23±6.11	73.50±5.79	71.51±5.03	72.87±8.01
3			74.21±5.43	73.21±7.05	73.71±5.55	71.85±5.67	74.29±5.53
4			75.31±7.81♦	71.25±6.38	72.28±5.69	70.53±5.06	73.48±5.97
1	Category II		88.58±9.00	86.78±7.60	88.34±9.17	86.48±7.81	87.00±10.16
2			90.48±9.51♦	86.48±7.82*	89.08±10.23*♦	86.10±8.48*	92.16±11.04♦
3			90.98±9.98♦	85.76±7.95*	89.16±10.54*	85.68±7.62*	92.38±11.06♦
4			91.42±11.61♦	82.12±10.07*	85.74±12.62♦	83.12±10.19*	87.12±12.99♦

Notes: * – ($p<0.05$) – veritable changes in the results compared with the premenstrual phase of the MC; ♦ – ($p<0.05$) – veritable changes in the results compared with the postovulatory phase of the MC.

The female athletes of category II have the same tendency to achieve the best results during the postmenstrual and postovulatory phases of the MC. Thus, they have veritably lower results during the premenstrual, menstrual and ovulatory phases of the MC.

One of the most effective criteria characterizing the adaptation of the cardiovascular system (CVS) to physical loads is a heart rate analysis. This simple and informative method allows control over the intensity of physical loads, analysis of the training process and individualization of the loads depending on the current functional level of an athlete.

We have found that the mean value of the HR (Table. 3) for the female CMSs and the female athletes of category I after running the 4x400m distance was lower during the postmenstrual phase and veritably lower during the postovulatory phase ($p < 0.05$) in comparison with the premenstrual and menstrual phases.

Table 3. The dynamics of the mean values of HR in women who specialize in middle distance running during different phases of the MC

Segment (4x400m)	MC phase	Mean Values of Heart Rate				
		I	II	III	IV	V
1	CMS, Category I	171.25±1.61♦♦	164.88±1.84	170.50±2.38♦	164.00±2.21*	170.13±2.33
2		171.38±1.93♦	165.00±1.55	165.38±3.23	166.75±1.93	169.73±3.49
3		170.00±2.31	164.50±2.76*	167.63±3.27	166.38±2.68	169.13±2.94
4		170.13±4.19	168.63±2.40*	170.25±3.51	168.38±1.70*	174.88±2.24
1	Category II	174.40±1.29♦	166.20±1.07*	163.80±5.97*	164.20±2.23*	173.40±1,25
2		171.60±1.63	169.40±0.24*	169.80±1.16*♦	168.00±0.84*	173.00±1.05
3		173.60±1.86	169.60±0.81	168.20±2.60	169.80±1.07	172.40±2.77
4		176.00±2.41	172.20±1.24	174.20±2.01	171.80±1.77	174.80±3.85

Notes: * – ($p<0.05$) – veritable changes in the results compared with the premenstrual phase of the MC; ♦ – ($p<0.05$), ♦♦ – ($p<0.01$) – veritable changes in the results compared with the postovulatory phase of the MC (CMS, Category I).

The mean values of HR for female athletes of category II (Table. 3) during the segments running veritably differed ($p<0.05$) in the postmenstrual, ovulatory and postovulatory phases in comparison with the premenstrual and menstrual ones.The highest index of average heart rate was in the menstrual phase, which is veritably higher ($p < 0.05$), if compared with the postovulatory phase.

When athletes, who specialize in middle distance running, perform training exercises, their anaerobic system provides a rapid supply of energy but at the same time lactate is accumulated in the muscles. The highest indices of lactate concentration in arterial blood observed in the female CMSs and the female athletes of category I were measured during the premenstrual and menstrual phases of the MC (Fig. 1). Lactate after running the segments was veritably lower during the postmenstrual ($p<0.01$), ovulatory and postovulatory ($p<0.05$) phases in comparison with the premenstrual phase of the MC.

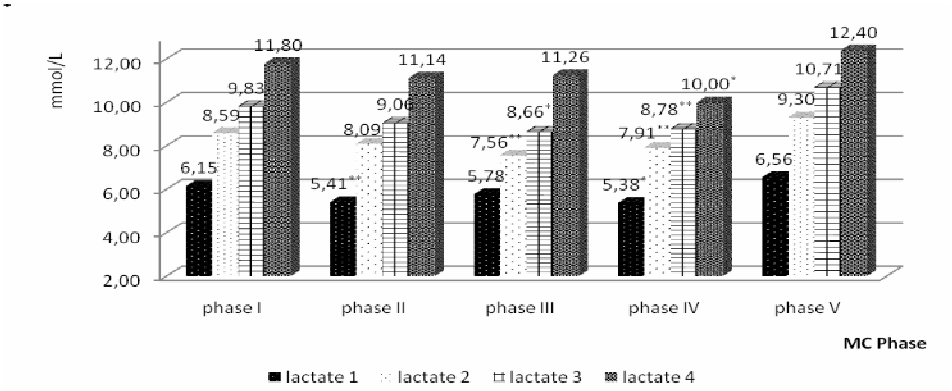

Fig. 1. The dynamics of lactate indices in women's blood during different MC phases (CMS, Category I)

Notes: * – ($p<0.05$), ** – ($p<0.01$) – veritable changes in the results compared with the premenstrual phase of the MC.

The dynamics of lactate concentration in blood of the female category II athletes (Fig. 2) was similar to the one of the female CMSs and female athletes of category I. Thus, veritably lower ($p<0.05$) lactate indices were observed during the postmenstrual and postovulatory phases compared with the premenstrual one; veritably ($p<0.05$) higher lactate indices were determined in the menstrual and ovulatory phases, compared with the postovulatory MC phase.

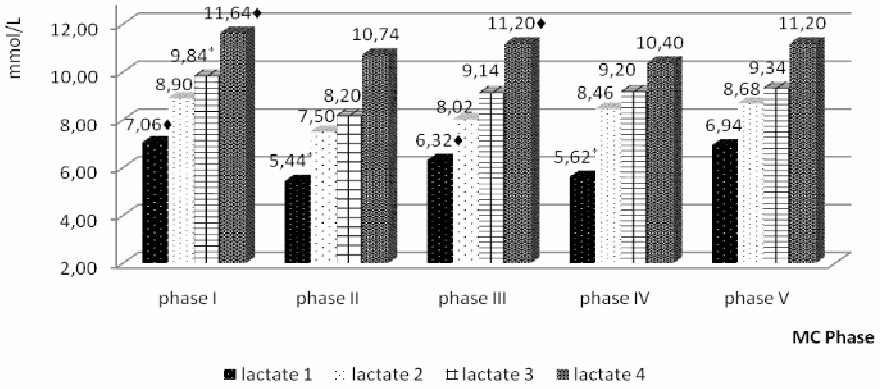

Fig. 2. The dynamics of lactate indices in women's blood during different MC phases (Category II)

Notes: * – ($p<0.05$) – veritable changes in the results compared with the premenstrual phase of the MC; ♦ – ($p<0.05$) – veritable changes in the results compared with the postovulatory phase of the MC.

Disscussion

The analysis and synthesis of the scientific literature and our own research results reveal that one of the most urgent issues in the practice of athletic training is efficient planning of the training process for athletes who specialize in middle distance running. Efficiency lies in the fact that the rational volume and intensity of training load should be based on functional capacity and physical performance capacity of specific athletes during load planning in the different structures of the training process.

Changes in the concentration of sex hormones during the MC significantly influence women's metabolism, causing fluctuations in body weight. In the premenstrual phase the change in the balance of steroid hormones, especially progesterone deficiency and estrogen excess involved in the water-salt metabolism regulation, increases sodium reabsorption (reuptake) in the kidneys. In addition, the osmotic pressure of blood and interstitial fluid rises. As a result, water is retained in the body to maintain homeostasis and, consequently, the body weight increases, the tidal volume decreases, and therefore, the respiratory rate and heart rate increase, which significantly influences the decrease of work capacity (S. V. Kalitka, L. Shakhlina (2002), J. Mouzon, J. Testar, B. Lefewre, J. Pouly et al. (1984)).

In the postmenstrual phase the level of estrogen in blood increases, which positively affects the body functions, particularly the cardiovascular, respiratory and nervous systems, and improves the efficiency of the body. In the postovulatory phase of the MC the cardiovascular system of female athletes is characterized by the significant increase in the potential and adaptive capacity. Functional readiness of the cardiorespiratory system for physical loads is the highest, the efficiency of the body and metabolic rate increase due to an increased concentration of progesterone in blood (Aulik, I.V. (1990), Burrows M. (2005)).

The obtained results show that the highest efficiency and therefore the highest level of the functional capacity of the cardiorespiratory system are observed in female athletes during the postovulatory and postmenstrual phases of the MC and slightly lower one in the menstrual, ovulatory and premenstrual phases.

In the process of the research we have found that the performance capacity manifestation PWC_{170} of the female athletes, who specialize in middle distance running, has a cyclic character. During the ovulatory phase the level of estrogen in a woman's body decreases and a dominant state of the central nervous system, aimed at the optimal flow of the ovulation process, prevails, which, in our opinion, reduces the level of efficiency: the PWC_{170} data in female CMSs and Category I athletes are lower as compared to the postmenstrual and postovulatory phases, Category II female athletes have a veritably lower index ($p<0.05$), compared with the postovulatory phase. This study has confirmed the results reported by Professor Radzievskiy A.R. and Shakhlina L. Y.-G. about the changing of the female athletes' work capacity during the MC and the necessity of taking into account the influence of physiological mechanisms and changes in hormones concentration in blood when planning a training process (A.R. Radzievskiy, L. G. Shakhlina, S. G. Yatsenko, T. P. Stepanova 1990).

It should be mentioned that consistently high results of the 4x400m segments running were achieved in the postmenstrual and postovulatory phases with a gradual improvement of a result in the final segment, which indicates high functional capacity of the CVS and, consequently, high special performance capacity of female athletes. The average performance was recorded in the ovulatory phase. The tendency for improvement of the fourth segment result in this phase is the same as the one in the postmenstrual and postovulatory phases, which indicates a slight decrease in functional and special performance capacity due to a woman's dominant state of the central nervous system aimed at the occurrence of ovulation. The worse results obtained when repeating the given training load in the menstrual and premenstrual phases indicate deterioration in the functional state of the cardiorespiratory system and special performance capacity.The initial manifestation of fatigue was noted,

possibly due to the reduction in the concentration of sex hormones (V. B. Faynberg, U. Y. Podar, S. F. Sibul, A. A. Syarg (1970), J. Mouzon, J. Testar, B. Lefewre, J. Pouly et al. (1984)). This is confirmed by the increase of race time and concentration of lactate. Thus, changes in hormonal status that occur during the MC have a significant impact on special performance and functional capacity of women who specialize in middle distance running.

All female athletes showed the highest results in the postmenstrual and postovulatory phases of the MC, which indicates high special efficiency. They exceeded the results obtained in the menstrual ($p<0.05$), ovulatory and premenstrual phases. The data on changes in special performance capacity of female athletes, who specialize in middle distance running, have been presented for the first time. So, during these phases female athletes doing anaerobic work showed the best results, which indicates high speed capabilities, confirming the anabolic effect of estrogens, whose concentration in blood of women in these phases is the highest (J. Mouzon, J. Testar, B. Lefewre, J. Pouly et al. (1984)).

However in female athletes of category II significantly worse results were observed in the premenstrual, ovulatory, and especially in menstrual phases ($p<0.05$, compared with the postovulatory one), which confirms that it was harder for them to manage a training load in these phases as compared to the CMSs and female athletes of category II. In all female athletes the average heart rate after running the segments was veritably lower in the postmenstrual and postovulatory ($p<0.05$) phases compared with premenstrual, menstrual and ovulatory ones. The highest heart rate in the premenstrual and menstrual phases indicates less efficient functioning of the heart, which can cause myocardial strain and lead to decreased performance (J. H. Wilmore, D. L. Costill 1994, L. Shakhlina (2000)). More intensive lactate production in the menstrual and premenstrual phases indicates that the training load was fulfilled mainly due to the inclusion of anaerobic metabolism because of reduced oxygen delivery to working muscles, which for its part leads to the decreased special performance compared to postmenstrual, ovulatory and postovulatory phases of the MC (A. J. Anderson (2008), S.V. Kalitka (2002)).

In the ovulatory phase a slight increase in the average heart rate during 4x400m segments running indicates a slight decrease in the functional state of the CVS which causes the decreased performance of female athletes, as compared to the postmenstrual and postovulatory phases of the MC. Slightly elevated lactate level in blood has been determined as compared to the postmenstrual and postovulatory phases of the MC. In the premenstrual and menstrual phases of the MC a significant decrease in the functional state of the CVS, which causes decreased performance, has been observed. A significant increase in the average heart rate indicates a high functional value of the performed work. High levels of lactate in blood indicate harder metabolism in the body.

The functional value of the work performed in the postmenstrual and postovulatory phases, estimated by the average heart rate indices, decreased, which indicates the efficiency of the CVS. The level of lactate in blood is the lowest, which indicates its high utilization during the work performance. So, the hormonal status changes occurring during the MC play a significant role in the female athletes' energy supply processes that significantly influence the special performance capacity, which was the highest in the postmenstrual and postovulatory phases, compared to the menstrual, ovulatory and premenstrual ones, confirming the data obtained by a number of scientists (S.V. Kalitka, L.G. Shakhlina (2002), M.O. Chistyakova (2014)).

We have found that postovulatory and postmenstrual phases are optimal for the manifestation and development of the quality of endurance, which is confirmed by differences in functional capacity of female athletes in each phase of the MC. The redistribution of training loads according to volume and intensity considering functional capacity of female athletes in different phases of the MC will enable the coach to have their planned training load 100% fulfilled, besides it will preserve female athletes' health and therefore create conditions for the achievement of high sports results and maintain sports longevity of athletes.

Our study confirms the important role of the development and planning of the atheletes' training process (V.M. Platonov (2004)) according to the organism's level of fitness for physical loads.

The results of this study significantly add to the data obtained by L. Y.-G. Shakhlina (1995) and S.V. Kalitka (2002) on the planning of the female atheletes' training process taking into account functional capacity of female athletes during the MC.

Conclusions

We have found that physical performance and functional capacity of women specializing in 800m and 1500m running depend on the hormonal status during the MC, as indicated below:

1) the highest indices of the physical performance capacity (PWC_{170}) of female athletes were recorded in the postmenstrual ($p<0.05$ compared with the premenstrual one) and postovulatory phases ($p<0.05$); they significantly decrease in the ovulatory ($p<0.05$), premenstrual and menstrual phases ($p<0.05$);

2) the highest indices of the special physical performance in women, affirmed by the results of the female athletes' 4x400m segments running, were recorded in the female athletes (CMSs and the female athletes of category I) in the postmenstrual and postovulatory phases of the MC, which exceeded the results obtained in the menstrual and ovulatory phases, and the results veritably decreased in the premenstrual phase ($p <0.05$); in

the female athletes of category II we observed veritably higher results in the postmenstrual and postovulatory phases of the MC and lower results in the premenstrual, menstrual and ovulatory phases of the MC;

3) the average heart rate during the 4x400m segments running in the postmenstrual ($p<0.05$) and postovulatory ($p<0.05$) phases was veritably lower compared with the premenstrual phase, which indicates the decrease of the functional value of the performed work; in the ovulatory phase the average heart rate veritably increased ($p <0.05$) compared with the postovulatory phase and the veritable increase in the average heart rate in the premenstrual ($p<0.05$) and menstrual ($p<0.05$) phases indicates a high functional value of the performed work;

4) veritably higher indices of lactate concentration in arterial blood were recorded in the menstrual ($p<0.05$), premenstrual ($p<0.05$) and ovulatory ($p<0.05$) phases of the MC compared with the postmenstrual and postovulatory ones.

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