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Short communication

Effect of sex and menstrual cycle in women on starting speed, anaerobic endurance and muscle power

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The aim of our study was to compare the indicators of starting speed, anaerobic endurance and power in women as well as men, and to investigate whether the values of these indicators differ in women during the follicular and luteal phases of the menstrual cycle. The studied group included 16 men and 16 women. The subjects performed the 20-second maximal cycling sprint test. The men performed the test twice at 14-day intervals. The women undertook the test 4 times: twice during the middle of follicular phase and twice in the middle of luteal phase in separate menstrual cycles. Hormonal changes during the menstrual cycle do not influence anaerobic performance, starting speed or anaerobic endurance in women. Anaerobic performance in men is higher than in women with similar aerobic performance expressed as VO_2max/LBM (lean body mass). A lower power decrease with time was noted for women than men, with a similar time of maintaining power in both groups. This is evidence of women's better anaerobic endurance compared to men. At the same time, the men had significantly better starting speed rates than women.

Keywords: anaerobic power, anaerobic exercise, acid-base homeostasis, gender differences, menstrual cycle

Previous studies have clearly showed significant differences in anaerobic power between men and women, indicating the reason for the differences to be inter-sex differences in muscle histology and enzyme activity associated with anaerobic metabolism (2, 12). However, in previous studies, the impact of women's menstrual cycle on the level of analyzed indicators were not always taken into account, which are essential in the evaluation of anaerobic performance, i.e. peak and mean anaerobic power (8, 10, 15). Other important indicators of anaerobic performance in sports are the speed of obtaining the maximum power (i.e. the time necessary to obtain maximum power from the start) and anaerobic endurance

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presented as the ability to maintain peak power for as long as possible and the smallest possible loss of power during the exercise. The influence of the menstrual cycle and gender differences on the level of these indicators has not been evaluated in earlier studies.

Differences in the estradiol and progesterone concentration between follicular and luteal phases may cause different reactions to exercise in women, depending on the menstrual cycle (11, 13).

The aim of our study was to compare the indicators of starting speed and anaerobic endurance in women as well as men, and to investigate whether the values of these indicators differ in women during the follicular and luteal phases of the menstrual cycle.

Materials and Methods

The methodology of the study was approved by the Bioethics Committee of the Regional Chamber of Physicians (opinion No. 81/KBL/OIL/2013) and was performed in accordance with the Declaration of Helsinki.

Participants

The study participants included 32 healthy, non-smoking, physically active people: 16 men and 16 women who did not engage in competitive sports training (Table I). The women had a regular menstrual cycle and they did not take any hormonal drugs within the 12 months preceding the research.

Table I. The subject's characteristics

Variables	**men**	**women**
	mean ± SD	**mean ± SD**
Age [years]	20.8 ± 1.1	21.0 ± 1.1
BM [kg]	75.2 ± 8.2	59.8 ± 6.8*
BH [cm]	178.1 ± 3.6	167.7 ± 5.7*
LBM [kg]	64.5 ± 5.2	44.6 ± 4.0*
BMI [kg/m^2]	23.7 ± 2.3	21.3 ± 2.0
VO_2max/BM [mL/kg/min]	52.9 ± 7.5	42.2 ± 5.7*
VO_2max/LBM [mL/kg/min]	61.3 ± 7.4	56.5 ± 6.7
HRmax [b/min]	192 ± 8	190 ± 7

BM – body mass, BH – body height, LBM - lean body mass, BMI – body mass index, VO_2max/BM and VO_2max/LBM – relative value of maximal oxygen uptake, HRmax – maximal heart rate; *$p < 0.05$, statistically significant differences.

Study design

The performed exercise stress tests were the incremental cycle ergometer test (ICET) and the maximal cycling sprint test (MCST). All participants performed the ICET once. The men performed the MCST twice, at 2-week intervals. The women undertook the MCST four times (in two monthly research cycles): twice in the middle of the follicular phase (FP, days 6–9 of the cycle), and 2 times in the middle of the luteal phase (LP, 5–8 days after ovulation). The beginning of the follicular phase was indicated by the onset of menses, and the beginning of ovulation was indicated by an increase in basic body temperature by 0.5 °C. Additionally, estradiol (FP 0–160 pg/mL, LP 27–246 pg/mL) and progesterone (FP 0.32–2.00 ng/mL, LP 1.10–28.00 ng/mL) concentrations were used each time to verify the choice of the day to carry out the tests.

Incremental cycle ergometer test

After a 4-minute effort with the load set at 1.0 watt per lean body mass (W/LBM) for women and 1.1 watt per lean body mass for men, the load was increased by half of its initial value every 2 minutes in both of the tested groups until participants were unable to maintain a stable rhythm of pedaling, i.e. 60 rev/min (Monark 818E, Vansbro, Sweden). The test allows for the direct assessment of maximal oxygen uptake (VO_2max) (Medikro-919 ergospirometer, Kuopio, Finland), maximal power output (POmax) and maximum heart rate (HRmax) (Polar Vantage NV, Kempele, Finland).

Maximal cycling sprint test

In order to avoid the practice effect (1), one week before the MCST, all participants were familiarized with its technique by performing a 10-second version of the test. A 20-second maximal cycling sprint (Monark 824E, Vansbro, Sweden) was performed to evaluate anaerobic capacity; it was preceded by a 5-minute warm-up (40% POmax) performed at the speed of 60 rev/min, with 10-second maximal accelerations near the end of the second and fourth minute. After a 5-minute break, a MCST was performed. During the test, participants had to achieve maximum pedaling velocity as quickly as possible, and then maintain it throughout the test. The MCST had a stationary start, with the workload set prior to the test; its value equaled 7.5 and 8% of body mass for women and men, respectively. During the test, participants received energetic verbal encouragement and were required to remain seated.

The absolute values of peak anaerobic power (PP) and mean anaerobic power (MP), the time of attaining (TA) and maintaining (TM) peak power and power decrease (PD) were all registered during the study (MCE software, JBA Staniak, Warsaw, Poland).

Blood sampling and biochemical measurements

The arterialized blood was obtained from capillaries in the fingertip: 5 minutes before and 3 minutes after the MCST. The hydrogen ions (H^+) and the excess/deficiency of buffer base (BE) were measured using the Corning 238 pH/Blood Gas Analyser (Ferwald, Germany). The plasma lactate (La^-) was measured using the colorimetric method (UV/Vis Evolution 201 ThermoScientific spectrophotometer, Milwaukee, USA) with the enzymatic L-Lactate Randox (Crumlin, UK) test. The exercise changes of biochemical indicators (ΔH^+, ΔBE, ΔLa^-) were analyzed.

Statistical analysis

The results are expressed as means and standard deviation (SD). Statistical significance ($p < 0.05$) was tested using the *t*-test for independent samples, multivariate analysis of variance (ANOVA/MANOVA) with repeated measurements, and the F-test for planned comparisons (STATISTICA® 8.0 StatSoft, Inc., Tulsa, USA).

Results

There were no statistically significant differences between phases in the analyzed physiological (PP, PP/BM, MP, MP/BM, TA, TM, and PD) and biochemical (ΔH^+, ΔBE, ΔLa^-) indicators. For this reason, this factor was omitted in the evaluation of the differences between sexes in response to MCST. The results were also compared taking the order of the tests into account (MCST I, MCST II). The results of the women's first (MCST I) and second (MCST II) attempts were used in the analysis regardless of the menstrual cycle phase. The results are presented in Table II.

Table II. Average levels of anaerobic performance physiological indicators and biochemical indicators in men and women in first (I) and second (II) maximal cycling sprint test

Variables		**men**	**women**
		mean ± SD	**mean ± SD**
PP [W]	I	858.91 ± 102.79	550.18 ± 80.83*
	II	885.32 ± 107.53	565.28 ± 84.77*
PP/BM[1] [W/kg]	I	11.45 ± 0.96	9.21 ± 0.85*
	II	11.83 ± 0.92#	9.44 ± 0.74*
PP/LBM [W/kg]	I	13.34 ± 1.30	12.31 ± 0.98*
	II	13.75 ± 1.46#	12.64 ± 0.97*#
MP [W]	I	747.18 ± 76.81	481.99 ± 68.77*
	II	758.82 ± 79.10#	490.04 ± 71.48*
MP/BM [W/kg]	I	9.97 ± 0.71	8.06 ± 0.71*
	II	10.15 ± 0.70#	8.19 ± 0.65*
MP/LBM [W/kg]	I	11.61 ± 1.04	10.78 ± 0.75*
	II	11.80 ± 1.14#	10.96 ± 0.76*#
TA [s]	I	7.68 ± 1.35	9.02 ± 1.47*
	II	7.20 ± 0.83	7.95 ± 0.97*#
TM [s]	I	3.86 ± 1.12	3.65 ± 0.62
	II	3.52 ± 0.69	3.47 ± 0.80
PD [W/kg·s]	I	0.22 ± 0.06	0.18 ± 0.05*
	II	0.25 ± 0.06#	0.20 ± 0.04*
Δ La [mmol/L]	I	13.27 ± 2.16	10.90 ± 2.07*
	II	13.22 ± 2.28	11.34 ± 2.20*
ΔH^+ [nmol/L]	I	20.35 ± 6.61	16.12 ± 4.28*
	II	19.94 ± 6.61	17.68 ± 4.32
Δ BE [mmol/L]	I	–12.81 ± 2.15	–11.39 ± 2.10
	II	–13.02 ± 2.89	–12.20 ± 1.55

PP – absolute value of anaerobic peak power, PP/BM – value of anaerobic peak power in relation to body mass, MP - mean anaerobic power, MP/BM – value of mean anaerobic power in relation to body mass, TA – time of attaining anaerobic peak power, TM – time of maintaining anaerobic peak power, PD – power decrease, La^- – lactate concentration, H^+ – hydrogen ions concentration, BE – excess/deficiency of the buffer bases, Δ – post-exercise changes; *$p < 0.05$, statistically significant gender differences; $^{\#}p < 0.05$, statistically significant differences between repeated maximal cycling sprint test

Discussion

The novelty of our study was comparison of the time for obtaining, maintaining peak anaerobic power time as well as declining pace in men and women. In addition, we assessed whether the menstrual cycle phase affects the level of analyzed indicators. In our study, the men attained peak power in a significantly shorter time than the women; the power decrease was also significantly quicker with time in the men's group. The time of maintaining power was similar in both groups. In this study, the post-exercise concentration increase in blood lactate was significantly higher in men in comparison to women. The production of lactate caused an increase in the concentration of hydrogen ions in the blood and a decrease in the concentration of buffer base. These changes were slightly greater in men. In our study, in women, there were no significant differences between menstrual cycle phases in anaerobic power, in post-exercise changes of blood lactate concentration and in post-exercise changes of acid-base balance indicators. The results of previous research have shown that the follicular phase favors speed-based exercise, which mostly involves anaerobic energy metabolism (7). These results are inconsistent with the results of our study. In contrast to our study, the choice of day for conducting the experiment in the aforementioned studies was not confirmed by the analysis of hormones (7). In order to obtain fully credible results in our study, the tests were conducted during two menstrual cycles.

The MCST used in this study was a modified version of the Wingate test (6). In our study, we applied a stationary start with a load determined beforehand in comparison to the flying start in the original Wingate test. Thus, we were able to measure other indicators during the test as well. Time to attain peak power indicates the starting speed of a participant, i.e. the time necessary to attain peak power output starting from a static position. Other indicators assessed in our study were: time of maintaining peak power and power decrease, which are indicators of anaerobic endurance.

Other authors also found similar differences between sexes in peak and mean anaerobic power (2, 10). The significant decrease of the differences between genders in the amount of generated anaerobic power, as caused by the relativization of the obtained results to muscle mass, confirms the significant influence of this factor on the reactions observed during supramaximal efforts (10, 14, 15). Nevertheless, it does not fully explain the differences between genders in anaerobic capacity. These results may reflect the differences in muscle histological structure of women and men (12). This may be the reason why aerobic processes play a greater part in providing energy during supramaximal efforts in women (5, 9).

The considerable differences between genders in the post-exercise concentration of lactate and its concentration increase indicate that the intensity of glycolysis is different in men and in women. The greater amount of glucose used as an energy substrate during anaerobic effort observed in men may be caused by the higher concentration of adrenaline in men than in women (3), which may result in greater glycogen phosphorylase activity (4).

Conclusions

Hormonal changes during the menstrual cycle do not influence anaerobic performance, starting speed or anaerobic endurance in women. Anaerobic performance in men is higher than in women with similar aerobic performance expressed as VO_2max/LBM.

A lower power decrease with time was noted for women than men, with a similar time of maintaining power in both groups. This is evidence of women's better anaerobic endurance compared to men. At the same time, the men had significantly better starting speed rates than women.

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