Effects of menstrual period on daily energy demands in a group of elite female rowers

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Abstract. *Introduction.* The impact that the menstrual cycle phase has on the energy demands of the female athlete is now a less known topic. Often, menstrual dysfunction can be reported, through hormonal changes, associated with stress, caused by training, mentioning either volume, or intensity of the effort as influence factors. *Aim.* Establishing energy requirements, along with determining the proportion of macronutrients in association with the menstruation period. *Material and method.* A cross-sectional study was conducted in February 2016, in Bucharest, Romania, on a group of 26 elite female rowers. The parameters analysed were related to the menstrual cycle of the athletes, in direct relationship with metabolic and respiratory parameters, determined through Cosmed Quark CPET equipment, applying the activity protocol regarding the resting metabolic rate (RMR). *Results.* In the study group (20.9±2.69 years), has been determined an energy requirement equivalent to 32.1±6.13 kcal/kg/day, divided into carbohydrates (317±89.2 gr/day) and lipids (104±55.4 gr/day), representing non protein food elements. Thus, it is noted that an increase in carbohydrate consumption proportion, during rest periods (%), was associated with menstrual cycle periods (0.231±0.43) during the test. Also, lack of menstruation (0.15±0.36) was associated with increased respiratory exchange ratio (0.86±0.04), and a decrease proportion of fat consumed during rest periods. *Conclusions.* Proper adaptation of the body, in different training seasons, within women athletes is directly related to energy intake, hormone levels, and recovery efficiency throughout distinct periods. Thus, various external factors will favour lack of menstrual cycle, hormonal imbalance, involving a decreased proportion of lipids used as energy source during recovery periods, increased CO_2 value, along with increased respiratory exchange ratio, indicating energy metabolism inefficiency.
Key words: *menstruation, amenorrhea, lipids, energy requirements*.

Introduction

Throughout specific effort, the distribution and usage of energy substrate is one of the most important aspects in ensuring metabolic efficiency (1). From a practical standpoint, the contribution that non-protein components, such as carbohydrates and lipids have during training is influenced by numerous factors. Among them, we will mention factors found in the literature, such as: physical effort (intensity, volume), sex, age, and food intake (2-3). The influence factors which were mentioned are often associated with sex hormones changes in female activity groups (4), especially female athletes, starting from adolescence to adulthood period, being reported the use of oral contraceptives in some cases (5).

From this point of view, energy substrate use, by female athletes, must be separately studied (6). Both physical and psychic stress factors, through the effort complexity carried out by the female athletes, can be related to hormonal unbalances, involving menstrual imbalance (7). Thus, according to various papers, 16-61% of the female athletes report menstrual imbalance (8-9). The sport disciplines practiced facilitates such manifestations. At the same time, these disorders have been identified in a proportion of 34.5% within aesthetic sports, 30.9% in endurance activity, 16.7% in technical sports, and 12.8% in specific strength activity, or team sports (10). From this point, various studies have focused on identifying the influence that predominant secretion of estrogen/progesterone, during the menstrual cycle, will have on the energy substrate used during rest/ effort periods in elite female athletes, stimulating metabolic efficiency (11). Thereby, it is noted that an increased concentration of estrogen, in the luteal phase, improves glucose muscle uptake compared with the decreasing phase of estrogen concentration (12). Furthermore, there are suggestions that indicate that elevated estrogen concentration, in the luteal phase, will decreases the use of

carbohydrates during exercise, stimulating the validity and usability of fatty acids, improving athlete's capacity during endurance effort (13).
Hypothesis of this study was the establishing energy requirements, along with determining the proportion of macronutrients, in the association with menstruation period is an important step toward individualizing the diet, both in training, and competition period. Concept intuited through changes in the energy metabolism within the menstrual cycle phases.

Material and method

A cross-sectional study was conducted in a group of elite female rowers after receiving the acceptance from the Ethics Committee, and subjects informed conscience to participate in the research. The study included a total of 26 elite female athletes with an average age of 20.9±2.69 years, 182±4.01 cm height, and 72.3±5.49 kg weight.
The data was collected in two stages. During stage 1 we collected the data regarding the menstrual cycle, during two months of activity, representing the month prior (A1) resting metabolic rate test (T) and the month post resting metabolic rate test (A2). The information collected focused the exact classification of the female athletes within the menstrual cycle phases: follicular phase, ovulation, luteal and menstrual period, reported in days (number of days). Moreover, menstrual dysfunction, and menstrual phase day, on the test day, were recorded and interpreted separately.
During stage 2 we gathered data concerning the energy metabolism, through Cosmed Quark CPET equipment (Rome, Italy) applying the activity protocol regarding the resting metabolic rate (RMR) on the following considerations for pre-testing activities, and ingestions: lack of effort (24 hours), food intake (5 hours), absence of caffeine (12 hours), sports supplements and nicotine (12 hours) (14). Parameters determined through this method assessed the resting energy expenditure (EE- kcal/day; kcal/kg/day; kcal/h) divided into non-protein elements represented by carbohydrates (CHO- gr/% /kcal) and lipids (Fat- gr/% /kcal). The respiratory parameters associated to the determined energy parameters, through the protocol mentioned above, were: carbon dioxide output (VE/VCO_2), respiratory frequency (Rf- b/min), end-Tidal oxygen tension ($PetO_2$- mmHg), end-Tidal carbon dioxide tension ($PetCO_2$- mmHg), the respiratory exchange ratio (RER), metabolic equivalent (METS), Tidal Volume (VT- l), expired oxygen volume (CO_2exp- ml), the amount of oxygen expired (O_2exp- ml), minute ventilation (VE- l/min), ventilatory equivalent ratio for oxygen (VE/VO_2), the rate of carbon dioxide elimination (VCO_2- ml/min), end Tidal CO_2 fraction ($FetCO_2$- %), end Tidal O2 fraction ($FetO_2$- %).
Statistical evaluation was performed using GraphPad Prism 7.0 software. Statistical indicators used were represented through the average value (Mean), their median (Median), standard deviation (SD), standard error (SE), and coefficient of variation (CV). For data normalization we used Pearson correlation index (r) and Student's t-test (non-paired). Level of significance, $p<0.05$, was considered statistically significant, while the obtained values illustration was made through the mean value and standard deviation (mean±SD).

Results

The study included a total of 26 elite female rowers, worldwide representative in the specific rowing activity. Thereby, anthropometric data revealed a mean age of 20.9±2.69 years, 182±4.01 cm height, and 72.3±5.49 kg weight. A1 determination period was estimated, through the collected data, at 27.3±10.5 days, with a reported menstrual phase of 4.54±2.1 days, and an ovulation day at 13.5±5.18. A2 determination period was estimated to be at 27.4±8.37 days with a menstrual phase of 4.69±1.76 days, and a reported ovulation at 13.6±4.15 day of the menstruation cycle. At the same time, the respiratory/ metabolic testing day (T) was associated with the $20.7±18.8^{th}$ day of the menstrual cycle. As we can see, the data was relieved from subjects which were in the follicular, ovulatory, luteal, or menstrual phase, calculated by days. Therefore, the distribution of the menstrual cycle phase was performed according to the following table (Table I.)

Table I. Athletes distribution within the menstrual cycle

Menstrual Cycle (30±2 days)						
Menstrual Phase	**Follicular**	**Ovulatory**	**Luteal**	**Menstrual**	**Amenorrhea**	**Total number**
Number of athletes	4	2	10	6	4	**26**

The energy ratio obtained through applying the activity protocol, for the female athletes, was 32.1±6.13 kcal/kg/day, divided into 104±55.4 gr of fat, and 317±89.2 gr carbohydrates, throughout the day, related to a respiratory exchange ratio value of 0.86±0.04. Thereby, in energy terms, relevant data was statistically significant, indicating that menstrual dysfunction will influence the energy costs at rest.

Total carbohydrates consumption (58.5±16.6%) was significantly correlated with A2 menstrual cycle, identifying that the increase proportion of carbohydrates consumption at rest (%) is encountered, within the study group, during the menstruation phase, which was equal or less than 5 days (p=0.0086, r=-0.5, CI95%= -0746 to -0145). Possible action suggested through female athletes hypoxic conditions as a result of increased blood loss during menstruation phase (3 to 6 days). However, CHO value (%) was significantly correlated (p=0.0457, r =-0.395, CI95% =-0.679 to -0.00932) with the number of days, during the menstrual phase, in the respiratory/ metabolically test period (T).

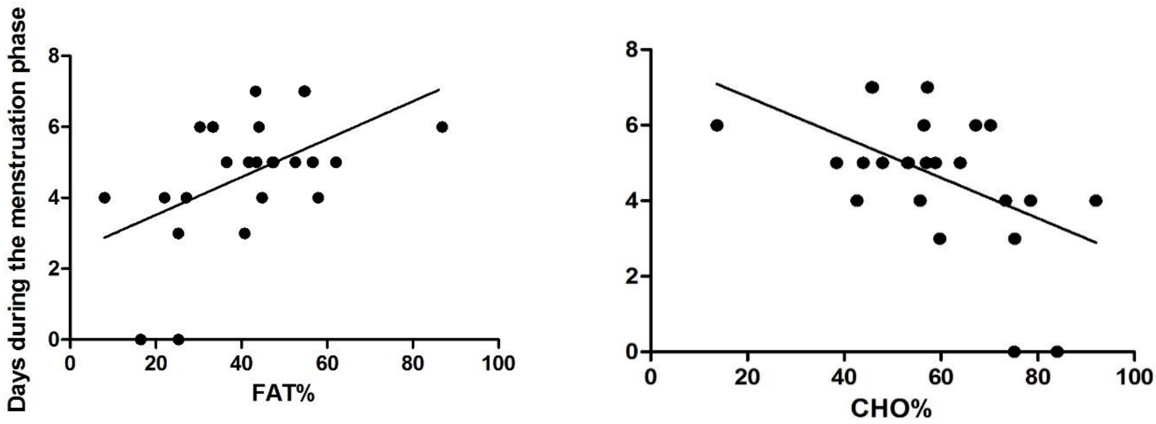

Figure 1. Energy source changes based on the number of days during the menstruation phase (FAT% - CHO%)

Through these data, we can highlight the assumption that increased proportion of fat consumed during rest periods (%) was significant in the female athletes which were in the menstrual phase (Figure 1), being reported a decrease in the percentage of total carbohydrate use, during rest periods to a limit of 40% of total energy demands, by increasing the number of days in the menstrual phase (p=0.0087, r=0.504, CI95%=0145 to 0746).

On the other side, increasing the amount of carbohydrate used during rest periods (317±89.2 gr/day) was associated with athletes menstrual dysfunction, characterized through amenorrhea (p=0.0106, r=0.492, CI95%=0.13 to 0.739). In its association we report an increase in both respiratory exchange rate value (0.86±0.04), and O_2exp value (108±19.9 ml). From a practical perspective, in the study group, the presence of amenorrhea was associated with decreased levels of O_2exp (p=0.039, r=0.411, CI95%=0.0284 to 0.689), increased RER value (p=0.0059, r=-0.525, CI95%=-0758 to -0173) along with increased carbohydrate, as an energy resource, during rest periods, stimulating the oxidative metabolism. Additionally, the energy needs of the female athletes (32.1±6.13 kcal/kg) was significantly correlated with the ovulatory phase, during A1, suggesting that a menstrual cycle longer than 27 days can induce a growth regarding the total body's energy requirements, in this case, at values between 32-36 kcal/kg/day (p=0.0474, r=-0.392, CI95% =-0.677 to -0.00603). However, minute ventilation (VE- 9.58±1.45 L/min) was correlated significantly with the menstrual period of the female athletes, observing that increased menstrual period is associated, in the study group, with decreased total VE value (p=0.0435, r=-0.399, CI95%=-0.681 to -0.0137). Association carried out as well with the ventilatory equivalent ratio for oxygen (VE/VO_2- 29.3±2.75 l/min), being identified an increase VE/VO_2 value in association to a decreased number of days within the menstrual phase (p=0.0327, r=-0.4199, CI95%=-0.6943 to -0.03872).

Secondary, through indirect correlation, and undetermined statistically connection, we mention the relationship of VE, and/or VE/VO_2 within the energy balance, and energy efficiency. Therefore, the growth of minute ventilation (VE) was associated with an increase in respiratory frequency (15.5±3.39 b/min),

VCO_2 (287±38.9 ml/min), METS (1.31±0.25), energy expenditure (32.1±6.13 Kcal/kg), while $FetCO_2$ (5.05±0.19%), $PetCO_2$ (35.2±1.47 mmHg) growth, was associated with a decrease in VE. At the same time, increased VE/VCO_2 (29.3±2.75) was associated with the rise of the following parameters: Rf (15.5±3.39 b/min), VE (9.58±1.45 l/min), VE/VO_2 (29.3±2.75), $FetO_2$ (15.3±0.41%), while lowering VE/VCO_2 was associated with the growth of VT (0.63±0.12 l), O_2exp (108±19.9 ml), CO_2exp (24.2±5.68 ml), $FetCO_2$ (5.05±0.19%), and $PetCO_2$ (35.2±1.47 mmHg) parameters. Thus, through indirect correlation, the parameters mentioned will be associated, mentioning that extending the period of menstruation (≥4 days) may be associated, during resting periods, with low respiratory parameters, such as: VE, Rf, VCO_2, METS, VE/VCO_2, and $FetO_2$ values. At the same time being reported elevated values of other influence parameters, such as $FetCO_2$, $PetCO_2$, VT, O2exp, facilitating the increased consumption of fat at rest, and decreasing the consumption of carbohydrates in hormonal balance (Table II.).

Table II. Statistical significance of the secondary parameters influencing the menstruation phase

Determined respiratory parameters		Reported Data					
Parameter 1 (Mean+SD)	Parameter 2	Mean+SD	*p*	Median	95% Confidence Interval of the Difference		*r*
					Lower	Upper	
VE (l/min) 9.58±1.48	Menstruation (days)	4.54±2.1	0.0435	9.67 / 5	-0.681	-0.0137	-0.399
	Rf (b/min)	15.5±3.39	0.0037	9.67 / 15.7	0.205	0.772	0.549
	VCO_2 (ml/min)	287±38.9	0.0001	9.67 / 283	0.766	0.95	0.89
	VE/VCO_2 (ml/min)	33.4±2.27	0.0098	9.67 / 33.4	0.136	0.742	0.497
	METS	1.31±0.25	0.0001	9.67 / 1.24	0.546	0.892	0.77
	$FetCO_2$ (%)	5.05±0.19	0.0215	9.67 / 5.03	-0.712	-0.0741	-0.449
	$PetCO_2$ (mmHg)	35.2±1.47	0.0019	9.67 / 35.1	-0.79	-0.25	-0.581
	EE (kcal/kg/day)	32.1±6.13	0.0001	9.67 / 30.3	0.579	0.901	0.79
VE/VCO_2 (ml/min) 33.4±2.27	Rf (b/min)	15.5±3.39	0.0001	33.4 / 15.7	0.49	0.875	0.737
	VE (l/min)	9.58±1.48	0.0098	33.4 / 9.67	0.136	0.742	0.497
	VE/VO_2	33.4±2.27	0.0001	33.4 / 29.1	0.616	0.911	0.81
	VT (l)	0.63±0.12	0.0132	33.4 / 0.625	-0.731	-0.113	-0.479
	O_2 (ml)	108±19.9	0.0348	33.4 / 107	-0.692	-0.0336	-0.416
	$FetO_2$ (%)	15.3±0.41	0.0044	33.4 / 15.3	0.194	0.767	0.54
	$FetCO_2$ (%)	5.05±0.19	0.0001	33.4 / 5.03	-0.914	-0.625	-0.815
	$PetCO_2$ (mmHg)	35.2±1.47	0.0001	33.4 / 35.1	-0.925	-0.666	-0.837

**VE/VCO_2 (carbon dioxide output), Rf (respiratory frequency), $PetCO_2$ (end-Tidal carbon dioxide tension), METS (metabolic equivalent), VT (Tidal Volume), O_2exp (the amount of oxygen expired), VE (minute ventilation), VE/VO_2 (ventilatory equivalent ratio for oxygen), VCO_2 (the rate of carbon dioxide elimination), $FetCO_2$ (end Tidal CO_2 fraction), $FetO_2$ (end Tidal O_2 fraction), EE (Energy expenditure – Kcal/kg/day)*

Discussions

Energy system efficiency, through hormone secretion, will be imposed by physiological adaptation of the female athletes in the effort performed (15). The training and competition activity carried out by female

athletes, in all phases of the menstrual cycle, has determined the need for comparison, and evaluation, of the physiological response during different periods of the menstrual cycle phases (12).
Thereby the menstrual cycle is divided into two periods called the follicular phase and the luteal phase, ovulation separated, and the physiological response of the body being considered slightly influenced by the particularities mentioned above (16). In the literature, it is highlighted that the menstrual phase may partially influence maximal aerobic exercise performance, along with maximal anaerobic performance, during specific effort (17-19). At the same time, changes in the respiratory system are associated to the secretion of ovarian hormones, while simple metabolism changes can influence the performance of high intensity effort (20-21).
Menstrual phase, in the specificity of the competition period, has an important role. One of the most important elements of influence is represented by the amount of blood lost during menstruation phase, reported in amount, days, and stages of the competition season (22). From a practical perspective, the report of significant losses will be associated with increasing possibilities to identify decrease serum iron levels (23), having a decisive effect on the production of hemoglobin (24). The implication is significant from this point of view regarding the biological function, oxygen transport, cell and mitochondrial respiration, cell growth, as well as differentiation, and their differentiation (24-25). In this way, being explained the increased consumption of fat, and also the decrease carbohydrate consumption. However, in the effort specificity, increasing the menstrual phase, through number of days, associated to significant increases in blood loss, will impose significant increase in oxidative metabolism (26). Among them, it is directly related to the hemoglobin total mass, the oxygen carrying capacity, all representing elements associated with sports performance (27), and as well with the distribution, and function that the energy metabolism holds.
In terms of the respiratory system, in different papers, was reported an increase in the VE, during the luteal phase compared with the follicular phase, while the influence of VO_2 value was reported as insignificant (28-29). Moreover, the correlations established between sex hormones and respiratory muscle function changes suggest positive female sex hormones, adapting respiratory function through thoracic muscle control in the luteal phase (29). Thereby respiratory volume changes can be dictated by the saturation level of oxygen in the blood, amplifying oxidative metabolic activity during specific activity. Moreover, the modification of VE, VE/VCO_2 parameters, in association to $PetO_2$, $FetCO_2$, O_2exp, CO_2exp and RER, will represent the adapting process of the female athlete. This will be achieved by losses reported through the menstrual cycle, food intake, and exercise parameters, representing the association of elevated, or decreased lipid energy metabolism, during rest periods, indicating metabolic efficiency (30-31).

Conclusion

In the study group, we highlighted the association between macronutrients distribution and consumption, during rest periods, in association with the menstruation phase in an elite group of female rowers. As a result, increasing the number of days reported in the menstrual phase, is associated with modifying the energy resource used in rest periods, establishing the importance of nutrition, during all menstrual cycle phases, towards meeting the energy needs of female athletes, as well as metabolic balances.

Conflicts of interest. There are no conflicts of interest in terms of the results and methodology applied in the study.

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Received: February 15, 2016
Accepted: May 20, 2016