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Menstrual Changes in Body Composition of Female Athletes

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ABSTRACT

The aim of the study was to determine whether the tendencies and scope of changes in body mass, body composition and body girths across the menstrual cycle were similar or different in women of different body build. Anthropometric examinations were carried out in a group of 40 naturally regularly menstruated females practicing team sports (aged 19–21, B-v 169.3+/–6.4 cm, body mass 59.6+/–7.0 kg), in the follicular, ovulatory and luteal phases of the menstrual cycle. The phases were determined on the basis of data from two consecutive menstrual cycles taking into account the cycle's length. To establish the type of body build, Body Mass Index, hydration status and skinfold thickness were measured. For a statistical analysis, a multiple comparisons with multiple confidence intervals were applied. The increase in body mass between the follicular and the luteal phases was observed in all groups of women, the biggest gain was recorded in slim women, who in the luteal phase weighted 0.8 kg more. The amount of fat mass increased significantly across the menstrual cycle only in more hydrated (by about 0.66 kg) and slim women (by about 0.54 kg). Significant changes between consecutive phases of the menstrual cycle in waist and hip girths, and suprailiac skinfold thickness in some groups of women also indicate influence of fatness and hydration status and slenderness. In view of the presented results, the body build seems important for an analysis of the pattern of each component's changes across the menstrual cycle, especially for female athletes. Certain changes can be seen only in some groups of women, therefore somatic features can be considered as a predictor of the intensity of changes.

Key words: *body components, body mass, body fat, fatness, hydration, body fluids, body water, BMI, menstrual cycle, female athletes*

Introduction

The hormonal changes during the menstrual cycle prepare the woman's body for pregnancy. Since sex hormones affect not only the woman's sex organs but her entire body, the periodical changes concern various body functions and components. It is assumed that the luteal phase of the menstrual cycle involves increases in body mass and body hydration[1–3]. The anthropometric measurements of skinfolds were recommended after or before menstrual bleeding, due to the possible increase in the fluid content of fat-free mass[4]. Some authors, however, did not notice significant changes in the hydration and adiposity levels across the menstrual cycle[5–7]. Taking into account that the intensity of changes of some body components during the menstrual cycle varies not only between different populations but also among women from the same population, the author of the present study decided to investigate the impact of body build's type on the pattern of body composition changeability during the menstrual cycle. The valuable element of presented study constitutes the highly significant – in the biological and evolutional sense – ovulatory phase, which allowed for a more comprehensive image of body composition variability during the menstrual cycle, when comparing to previous studies[5,7–9]. The difficulty in comparing different scientific results was caused by lack of consistency in the methodology used to determine menstrual phase[10]. In this study, we follow the common approach to menstrual cycle phase[11,12]. Apart from the follicular and luteal phases, we determined the ovulatory phase as the period of two days before and two days after ovulation, when the level of luteinzing hormone is expected to increase[12].

The scope and directions of changes in certain body components during the menstrual cycle are important in view of development in women's health and sport sciences. It is argued that body composition changes accompanying

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changes in the hormonal profile may affect women's physical fitness and motor performance[3,13,14]. This, in turn, is important for training planning and, ultimately, for sports performance of female athletes. The changes in body hydration or adiposity during the menstrual cycle can be of great significance in medicine, for example, in recommendations of proper drug dosage or treatment prescription. In fact, the differences in the metabolic effectiveness of some drugs have been found with regard to particular phases of the patient's menstrual cycle[15].

The aim of the present study was to demonstrate whether the tendencies and scope of changes in body mass, body composition and body girths in female athletes across the menstrual cycle were similar or different between women of different body build. Female athletes constitute a category of women especially interested in their body composition and in searching for factors connected with the experienced changes. Therefore, the results should be of interest to young women, who in view of their occupation or practiced sport, struggle with changes in their body mass and hydration level during the menstrual cycle. They are not aware, or not always accept the fact, that these changes are the natural consequence of maintaining fertility, and that pharmacological interventions aimed to affect changes in body composition may lead to impaired fertility.

Materials and Methods

Participants and procedure

Body composition and anthropometric measurements across the menstrual cycle supported by personal interview were carried out in a sample of 40 young (19–21 years old) and naturally menstruated (without hormonal supplementation or therapy) female athletes practicing team sports (soccer, volleyball, basketball, handball). The recruited athletes at the time of the study were not at the competitive stage of their training cycle. They attended training sessions two or three times a week (4.0 +/– 0.5 hours per week). Their training experience ranged between 4–7 years.

The women who were qualified for the study declared good health and regular menstrual cycles. Irregular menses, sometimes very long or very short menstrual cycles, use of hormonal contraception and therapies, slimming diets and dietary supplements were considered as exclusion criteria, which was the main factor of restricted sample size. Earlier studies had revealed that levels of certain body components (body water and body fat, in particular) were affected by the use of hormonal contraceptives as well as hormone replacement therapy[16–18].

The average body height of examined women was 169.3+/–6.4 cm, and average body mass in the follicular phase was 59.6+/–7.0 kg. All subjects had a normal BMI (mean 21.6+/–1.8 kg/m^2) in accordance with WHO criteria[19]. The length of the menstrual cycle during the study was 25–35 days, which is accepted as the correct length of the cycle[20,21].

The measurements of the subjects' body mass, body girths, skinfold thickness and body composition were taken every week, at least three times during the menstrual cycle (in the follicular phase – F, ovulatory phase – O and luteal phase – L). The phases of menstrual cycles were determined on the basis of self-reported onset of menses. The ovulatory phase corresponds to the estimated day of ovulation including two preceding days and two subsequent days[12]. The days of the cycle on which the measurements were carried out were chosen individually for each woman, after having taken into account their menstruation cycle's length and dates of previous menstrual cycles. The length of each phase of the menstrual cycle was adopted following the published data on this issue[11,12]. Assuming that the length of the luteal phase is relatively constant (14 days), we established the time of ovulation retrospectively by subtracting 14 days from the date of the last menstruation[11]. During the experiment each woman experienced menstrual bleeding twice, and a retrospective check-up of the dates chosen for measurements was done.

Anthropometric measurements and body composition assessment

The measurements were carried out using the equipment of GPM Anthropological Instruments (Siber Hegner Machinery, Ltd, Switzerland). Body height was measured with a Martin-type anthropometer to the nearest 1.0 mm. Body mass was measured using an electronic weighing scale to the nearest 0.1 kg; body girths with an anthropometric tape to the nearest 1.0 mm. The thickness of skinfolds (triceps, suprailiac, abdominal) was measured with a Holtain skinfold caliper to the nearest 0.2 mm. One experienced investigator took a complete set of measurements three times and the mean value of the three measures was used for analyses. The assessment of measurement's reliability was conducted according to the recommendation of Ulijaszek and Kerr[22]. The intraobserver technical error of measurement (TEM) was between 0.4 mm and 1.0 mm for skinfold thickness and between 1.0 mm and 10.0 mm for circumference measurements.

The anthropometric measurements were then used to calculate the subjects' proportions: BMI, WHR and SFI – Subcutaneous Fatness Index (Equation 1).

$$SFI = (\text{sum of triceps, suprailiac and abdomen skinfolds [mm]} / \text{body height [cm]}) * 100.$$

On the basis of BMI median value, the body build type (BMI lower than 21.7 kg/m^2 *v.* BMI equal or higher than 21.7 kg/m^2) was determined for each participant; the SFI was used to determine the level of subcutaneous fatness in the examined women (less fatty, SFI<23.2 *v.* more fatty, SFI ≥23.2).

Body composition was estimated by means of a bioelectrical impedance analysis, with the use of BIA Akern® 101 Sport Edition analyzer in standard conditions. The content of fat mass, free fat mass and total body water was calculated with the use of Akern® Bodygram 1.3.1. soft-

ware package. On the basis of percentage of total body water (TBW) the subjects were divided into two body hydration types: less hydrated (TBW<54.7%) *v.* more hydrated (TBW ≥54.7%). The measurements were taken at the same time of the day (morning) to ensure the study's reliability. Body mass and body girths were measured in one's underwear.

Statistical analyses and ethics

During the statistical analysis the mean values of increases/decreases of each studied characteristic between two consecutive menstrual phases were calculated and compared using Student's t-test for repeated measures. The level of statistical significance was set at $p \leq 0.05$. Also multiple comparisons with multiple confidence intervals were applied with the confidence level at 95% (Student's t-test with the Bonferroni correction). These calculations allowed identification of two groups of similar (homogenous) means: Group A with higher increases and Group B with lower increases. The statistical analysis was made with the StatSoft® Statistica 9.0 and R software (GPL, The R Foundation for Statistical Computing; Version 1.9.0).

TABLE 1
CHANGES IN BODY MASS, BODY MASS INDEX AND BODY COMPONENTS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT SUBCUTANEOUS ADIPOSITY

Parameters	Body build type										
	Less fatty (SFI < 23.2)					More fatty (SFI ≥ 23.2)					
	F – L	F – P	P – L	Groups of menstrual phases		F – L	F – P	P – L	Groups of menstrual phases	
	BODY MASS					BODY MASS				
Average difference	0.64 *	0.21	0.42 *	L	A	0.58 *	0.06	0.53 *	L	A
Confidence interval	0.18 1.09	−0.19 0.62	−0.03 0.89	P	AB	0.25 0.92	−0.33 0.44	0.13 0.93	P	B
p-value	0.001	0.19	0.03	F	B	<0.001	0.71	0.002	F	B
	BMI					BMI				
Average difference	0.22 *	0.08	0.14 *	L	A	0.22 *	0.02	0.19 *	L	A
Confidence interval	0.07 0.38	−0.07 0.24	−0.03 0.31	P	AB	0.08 0.35	−0.13 0.18	0.03 0.35	P	B
p-value	<0.001	0.15	0.04	F	B	<0.001	0.66	0.004	F	B
	FAT MASS					FAT MASS				
Average difference	0.49	0.06	0.43	L	A	0.07	0.08	−0.02	L	A
Confidence interval	−0.37 1.35	−0.47 0.59	−0.50 1.36	P	A	−0.59 0.73	−0.36 0.53	−0.69 0.66	P	A
p-value	0.15	0.77	0.24	F	A	0.78	0.62	0.95	F	A
	FAT FREE MASS					FAT FREE MASS				
Average difference	0.16	0.16	−0.005	L	A	0.52	−0.03	0.54	L	A
Confidence interval	−0.64 0.96	−0.47 0.80	−0.89 0.88	P	A	−0.14 1.17	−0.46 0.40	−0.33 1.42	P	A
p-value	0.60	0.50	0.99	F	A	0.05	0.85	0.12	F	A
	TOTAL BODY WATER					TOTAL BODY WATER				
Average difference	0.13	0.13	0.00	L	A	0.38 *	−0.02	0.40	L	A
Confidence interval	−0.45 0.71	−0.34 0.60	−0.65 0.65	P	A	−0.11 0.86	−0.34 0.30	−0.23 1.02	P	A
p-value	0.56	0.47	1.00	F	A	0.05	0.87	0.11	F	A
	EXTRACELLULAR WATER					EXTRACELLULAR WATER				
Average difference	0.32 *	0.13	0.18	L	A	0.23 *	−0.06	0.29	L	A
Confidence interval	−0.07 0.70	−0.20 0.46	−0.20 0.48	P	A	−0.06 0.52	−0.33 0.21	−0.09 0.67	P	A
p-value	0.04	0.31	0.16	F	A	0.05	0.56	0.06	F	A
	INTRACELLULAR WATER					INTRACELLULAR WATER				
Average difference	−0.19	−0.005	−0.18	L	A	0.14	0.04	0.10	L	A
Confidence interval	−0.57 0.19	−0.29 0.28	−0.63 0.26	P	A	−0.18 0.46	−0.24 0.31	−0.33 0.54	P	A
p-value	0.19	0.96	0.28	F	A	0.25	0.74	0.53	F	A

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of SFI (Me_{SFI}=23.2), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

The figures were drawn using Microsoft® Office Excel 2003.

The study was approved by the appropriate University Committee for the Ethics and conducted according to the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects. Informed, written consent was obtained prior to the enrollment of each volunteer. The study was conducted within the framework of Young Scientists Research in Poland being funded by the Ministry of Science and Higher Education in Poland.

Results

Changes in body mass and Body Mass Index across the menstrual cycle

The analysis of changes in body mass across the menstrual cycle revealed a significant increase between the follicular phase and the luteal one (F-L) in all groups of women, regardless of their body build type (Table 1–3). This increment mainly resulted from the changes between the ovulatory and luteal phases (O-L; Table 1–3). No significant changes in body mass were noted between the

TABLE 2
CHANGES IN BODY MASS, BODY MASS INDEX AND BODY COMPONENTS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT BODY HYDRATION STATUS

Parameters	Body build type										
	Less hydrated (TBW < 54.7%)					More hydrated (TBW ≥ 54.7%)					
	F – L	F – O	P – L	Groups of menstrual phases		F – L	F – P	P – L	Groups of menstrual phases	
	BODY MASS					BODY MASS				
Average difference	0.54 *	0.14	0.40 *	L	A	0.68 *	0.12	0.56 *	L	A
Confidence interval	0.18 0.91	−0.23 0.53	−0.02 0.83	P	AB	0.25 1.10	−0.29 0.54	0.11 1.0	P	B
p-value	<0.001	0.33	0.02	F	B	<0.001	0.46	0.003	F	B
	BMI					BMI				
Average difference	0.18 *	0.06	0.12	L	A	0.26 *	0.04	0.22 *	L	A
Confidence interval	0.05 0.31	−0.09 0.22	−0.04 0.27	P	AB	0.10 0.42	−0.11 0.20	0.05 0.38	P	B
p-value	0.001	0.26	0.06	F	B	<0.001	0.45	0.002	F	B
	FAT MASS					FAT MASS				
Average difference	−0.10	−0.03	−0.07	L	A	0.66 *	0,18	0.48	L	A
Confidence interval	−0.95 0.75	−0.47 0.41	−0.96 0.72	P	A	0.04 1.28	−0.35 0.70	−0.23 1.20	P	AB
p-value	0.76	0.86	0.84	F	A	0.01	0.39	0.09	F	B
	FAT FREE MASS					FAT FREE MASS				
Average difference	0.65 *	0.18	0.47	L	A	0.02	−0.04	0.07	L	A
Confidence interval	−0.15 1.45	−0.26 0.62	−0.53 1.47	P	A	−0.60 0.65	−0.67 0.58	−0.70 0.84	P	A
p-value	0.04	0.29	0.23	F	A	0.92	0.85	0.81	F	A
	TOTAL BODY WATER					TOTAL BODY WATER				
Average difference	0.48 *	0.13	0.34	L	A	0.03	−0.02	0.05	L	A
Confidence interval	−0.11 1.06	−0.19 0.45	−0.37 1.06	P	A	−0.43 0.49	−0.48 0.44	−0.51 0.61	P	A
p-value	0.04	0.30	0.22	F	A	0.86	0.91	0.82	F	A
	EXTRACELLULAR WATER					EXTRACELLULAR WATER				
Average difference	0.40 *	0.07	0.34 *	L	A	0.14	0.00	0.14	L	A
Confidence interval	0.05 0.76	−0.19 0.33	−0.04 0.71	P	AB	−0.17 0.45	−0.35 0.35	−0.20 0.48	P	A
p-value	0.007	0.48	0.03	F	B	0.24	1.00	0.29	F	A
	INTRACELLULAR WATER					INTRACELLULAR WATER				
Average difference	0.06	0.06	0.01	L	A	−0.12	−0.02	−0.09	L	A
Confidence interval	−0.31 0.44	−0.21 0.32	−0.47 0.49	P	A	−0.46 0.23	−0.31 0.26	−0.49 0.31	P	A
p-value	0.65	0.59	0.96	F	A	0.38	0.82	0.56	F	A

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of TBW (Me_{TBW}=54.7%), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

TABLE 3
CHANGES IN BODY MASS, BODY MASS INDEX AND BODY COMPONENTS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT BODY SLENDERNESS

Parameters	Body build type											
	BMI < 21.7 kg/m²					BMI ≥ 21.7 kg/m²						
	F – L	F – P	P – L	Groups of menstrual phases		F – L	F – P	P – L	Groups of menstrual phases	
	BODY MASS					BODY MASS				
Average difference	0.80 *	0.37 *	0.43 *	L	A	0.40 *	−0.13	0.53 *	L	A
Confidence interval	0.43 1.17	−0.05 0.81	−0.008 0.87	P	AB	0.02 0.78	−0.40 0.14	0.11 0.96	P	B
p-value	<0.001	0.04	0.02	F	B	0.01	0.21	0.004	F	B
	BMI					BMI				
Average difference	0.30 *	0.14 *	0.17 *	L	A	0.13 *	−0.04	0.16 *	L	A
Confidence interval	0.17 0.44	−0.03 0.31	0.001 0.333	P	B	−0.01 0.26	−0.14 0.07	0.01 0.32	P	B
p-value	< 0.001	0.04	0.02	F	B	0.02	0.35	0.01	F	AB
	FAT MASS					FAT MASS				
Average difference	0.53 *	0.10	0.43 *	L	A	0.01	0.04	−0.04	L	A
Confidence interval	0.03 1.03	−0.35 0.55	−0.08 0.93	P	AB	−0.99 1.00	−0.49 0.58	−1.11 1.04	P	A
p-value	0.01	0.56	0.04	F	B	0.99	0.84	0.93	F	A
	FAT FREE MASS					FAT FREE MASS				
Average difference	0.29	0.29	0.00	L	A	0.39	−0.17	0.57	L	A
Confidence interval	−0.15 0.72	−0.17 0.74	−0.60 0.60	P	A	−0.60 1.39	−0.78 0.43	−0.57 1,7	P	A
p-value	0.10	0.11	1.00	F	A	0.31	0.45	0.20	F	A
	TOTAL BODY WATER					TOTAL BODY WATER				
Average difference	0.22	0.21	0.01	L	A	0.29	−0.12	0.41	L	A
Confidence interval	−0.09 0.53	−0.13 0.55	−0.43 0.44	P	A	−0.44 1.02	−0.56 0.33	−0.42 1.23	P	A
p-value	0.08	0.12	0.95	F	A	0.30	0.49	0.21	F	A
	EXTRACELLULAR WATER					EXTRACELLULAR WATER				
Average difference	0.27 *	0.07	0.20	L	A	0.28	0.00	0.28	L	A
Confidence interval	0.01 0.52	−0.23 0.36	−0.08 0.48	P	AB	−0.15 0.71	−0.32 0.32	−0.16 0.72	P	A
p-value	0.01	0.55	0.07	F	B	0.10	1.00	0.11	F	A
	INTRACELLULAR WATER					INTRACELLULAR WATER				
Average difference	−0.05	0.14	−0.19	L	A	0.00	−0.13	0.13	L	A
Confidence interval	−0.30 0.21	−0.11 0.39	−0.51 0.13	P	A	−0.46 0.46	−0.41 0.16	−0.41 0.67	P	A
p-value	0.63	0.14	0.13	F	A	1.00	0.25	0.54	F	A

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of BMI (Me_{BMI}=21.7 kg/m²), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

follicular and ovulatory phases (F-O), with the exception of slim women who gain in weight regularly during the whole cycle (Table 3). The maximum body mass increases during the whole cycle amounted to about 2 kg in individual cases but in several women the changes were smaller than 0.25 kg (Figure 1). Few cases of decreased body mass in individual women took place mainly in the first part of the menstrual cycle (between phases F and O), but were also rarely observed in the second part of the cycle (between O and L) (Figure 1). The comparison of changes between women with different subcutaneous adiposity levels showed that both less fatty and fattier women displayed the same tendencies of body mass changes during the menstrual cycle (Table 1). It should be noted, however, that the less fatty women had lower total gains in body mass in the cycle (F-L). The level of body hydration did not differentiate the direction of changes in body mass between subsequent phases, but women with more hydrated bodies showed higher increases in body mass in the whole menstrual cycle (F-O; Table 2). Significant changes in body mass gains were found between women with higher and those with lower BMI values. Slim women had twice

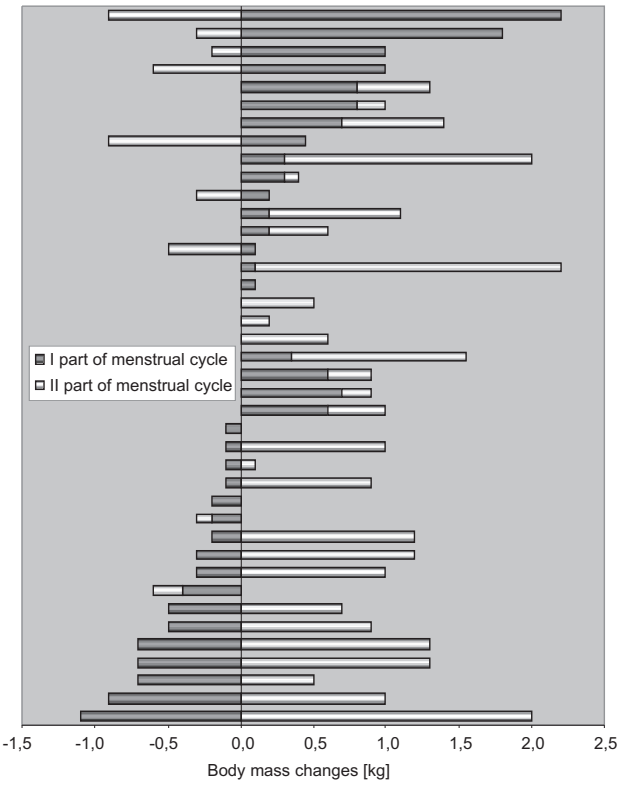

Fig. 1. Body mass changes in individual women under study; negative values »–« signify a decrease in body mass; »I part of menstrual cycle" means the differences between the measurements in follicular and ovulatory phases; »II part of menstrual cycle« means the differences between the measurements in ovulatory and luteal phases.

as high increases in body mass between the follicular phase and the luteal one than the women with higher BMI (Table 3). Moreover, increases in body mass between phases F and O in slim women were statistically significant and were only slightly lower than increases between phases O and L in this group of women (Table 3).

In all groups of women, significantly higher BMI values were noted in the luteal phase. The greatest BMI changes were found in slim women (Table 3) and more hydrated women (Table 2); the smallest ones in women with higher BMI (Table 3) and less hydrated women (Table 2).

Changes in body composition across the menstrual cycle

Fat mass increased significantly between phases F and L only in more hydrated women (Table 2) and in slim women (Table 3). The amount of subcutaneous fat did not affect significantly the changes in total fat mass between subsequent phases (Table 1). No changes in the amount of fat free mass across the menstrual cycle were found (Table 2).

There were no significant differences in terms of total body water content, with the exception of less hydrated women who had higher volumes of total body water in luteal phase (Table 2). The amount of extracellular water changed significantly between the follicular phase and the luteal one in almost all studied groups of women, and was greater in the second half of the cycle (Tables 1–3). The increases between phases F and L were significant both in less fatty and more fatty women (Table 1). In women with more hydrated bodies the content of extracellular water was almost unchanged in the consecutive phases of the cycle, whereas in less hydrated women a significantly higher level of extracellular fluid was found in the luteal phase (Table 2). A higher level of extracellular fluid in the luteal phase was also noted in slim women (Table 3); however, the increases were smaller than in the group of women with less hydrated bodies. In individual cases the amount of extracellular water rose by about 1.5 kg (Figure 2). In some women a decrease of about 1.0 kg was noted in the level of extracellular hydration in the follicular and luteal phases of the menstrual cycle (Figure 2). No significant differences in the amount of intracellular water were found between three consecutive phases of the menstrual cycle (Tables 1–3).

Changes in body girths during the menstrual cycle

The analysis of multiple comparisons did not result in an identification of phases with significantly different mean lengths of waist girths in any of the studied groups

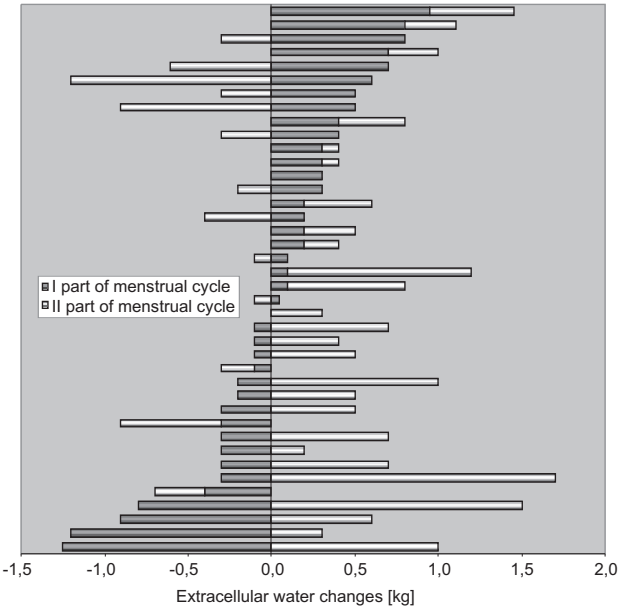

Fig. 2. Extracellular water changes in individual women under study; negative values »–« signify a decrease in extracellular body volume; »I part of menstrual cycle« means the differences between the measurements in follicular and ovulatory phases; »II part of menstrual cycle« means the differences between the measurements in ovulatory and luteal phases.

of women (Tables 4–6). However, a tendency towards longer waist girth in the first phase of the menstrual cycle was observed. An increase in the hip girth – above 1cm – was noted in the first half of the menstrual cycle (F-O) in less fatty women and slim ones (Tables 4, 6). A statistically significant change was also found in women with more hydrated bodies (Table 5) and in less fatty women (Table 4). In the second half of the menstrual cycle (O-L), the hip girth remained the same or decreased insignificantly (Tables 4–6).

The WHR index was lower between the follicular phase and the luteal phase in all groups of women with different body build types (Tables 4–6); however, the changes were statistically non-significant. Furthermore, the WHR changes in individual women varied, and in some women

TABLE 4
CHANGES IN SELECTED BODY GIRTHS, WAIST-TO-HIP RATIO AND SELECTED SKINFORLDS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT SUBCUTANEOUS ADIPOSITY

Parameters	Body build type										
	Less fatty (SFI <23.2)					More fatty (SFI ≥23.2)					
	F – L	F – P	P – L	Groups of menstrual phases		F – L	F – P	P – L	Groups of menstrual phases		
	WAIST GIRTH					WAIST GIRTH					
Average difference	3.9	6.3 *	–3.3	L	A	0.3	0.0	0.0	L	A	
Confidence interval	–5.0 12.8	–0.6 13.2	–13.8 7.1	P	A	–6.3 6.8	–10.6 10.6	–9.3 9.3	P	A	
p-value	0.26	0.03	0.41	F	A	0.91	1.00	1.00	F	A	
	HIP GIRTH					HIP GIRTH					
Average difference	10. 8 *	14.7 *	–3.3	L	AB	5.0	2.5	1.4	L	A	
Confidence interval	–1.4 23.0	3.0 26.4	–14.7 8.1	P	A	–7.5 17.5	11.2 16.2	–8.4 11.1	P	A	
p-value	0.03	0.004	0.45	F	B	0.30	0.64	0.71	F	A	
	WHR					WHR					
Average difference	–0.004	–0.005	–0,001	L	A	–0.003	–0.002	–0.001	L	A	
Confidence interval	–0.016 0.007	–0.015 0.005	–0.008 0.006	P	A	–0.013 0.007	–0.012 0.009	–0.011 0.009	P	A	
p-value	0.34	0.23	0.74	F	A	0.43	0.69	0.78	F	A	
	ARM GIRTH					ARM GIRTH					
Average difference	1.9	0.5	1.1	L	A	2.5	1.3	1.7	L	A	
Confidence interval	–2.4 6.3	–4.9 5.9	–3.4 5.7	P	A	–3. 5 8.5	–3.5 6.1	–4.5 7.9	P	A	
p-value	0.25	0.80	0.52	F	A	0.28	0.47	0.48	F	A	
	THIGH GIRTH					THIGH GIRTH					
Average difference	–2.2	5.5	–7.5 *	L	B	1.0	–2.2	3.1	L	A	
Confidence interval	–10.1 5.7	–2.2 13.3	–14.7 –0.3	P	A	–5.4 7.4	–10.2 5.8	–5.2 11.4	P	A	
p-value	0.46	0.07	0.01	F	AB	0.68	0.47	0.34	F	A	
	TRICEPS SKINFOLD					TRICEPS SKINFOLD					
Average difference	0.16	0.23	–0.06	L	A	0.28	0.38	–0.17	L	A	
Confidence interval	–0.75 1.08	–0.41 0.86	–0.90 0.77	P	A	–0.62 1.19	–0.27 1.03	–1.36 1.03	P	A	
p-value	0.64	0.35	0.84	F	A	0.41	0.13	0.71	F	A	
	ILIAC SKINFOLD					ILIAC SKINFOLD					
Average difference	0.14	0.68	–0.54	L	A	0.74	0.05	0.73	L	A	
Confidence interval	–0.78 1.06	–0.31 1.67	–1.48 0.41	P	A	–1.22 2.70	–1.77 1.87	–0.73 2.20	P	A	
p-value	0.69	0.09	0.15	F	A	0.33	0.94	0.20	F	A	
	ABDOMINAL SKINFOLD					ABDOMINAL SKINFOLD					
Average difference	0.97	1.03	–0.05	L	A	0.47	0.56	–0.11	L	A	
Confidence interval	–0.46 2.41	–0.51 2.56	–1.20 1.10	P	A	–1,20 2.13	–0.98 2.10	–2.17 1.95	P	A	
p-value	0.09	0.09	0.90	F	A	0.47	0.35	0.89	F	A	

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of SFI (Me_{SFI}=23.2), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

the WHR decreased in the follicular phase and also in the luteal one of the menstrual cycle.

No significant changes in arm girth and thigh girth were found across the menstrual cycle in the studied women (Tables 4–6). The exception was the group of less fatty women, who featured a longer thigh girth in the first half of the cycle and a shorter thigh girth in the second half, thus resulting in the highest mean value of the thigh girth in the ovulatory phase (Table 4).

Changes in subcutaneous adiposity during the menstrual cycle

No significant changes in the triceps skinfold thickness were noted between the consecutive phases of the men-

TABLE 5
CHANGES IN SELECTED BODY GIRTHS, WAIST-TO-HIP RATIO AND SELECTED SKINFORLDS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT HYDRATION LEVELS

Parameters	Body build type										
	Less hydrated (TBW < 54.7%)					More hydrated (TBW ≥ 54.7%)					
	F – L	F – P	P – L	Groups of menstrual phases		F – L	F – P	P – L	Groups of menstrual phases	
	WAIST GIRTH					WAIST GIRTH				
Average difference	1.4	2.6	–1.9	L	A	2.8	3.7	–1.4	L	A
Confidence interval	–6.4 9.2	–0.8 13.3	–10.5 6.6	P	A	–5.2 10.8	–3.6 11.0	–12.6 9.8	P	A
p-value	0.64	0.52	0.55	F	A	0.37	0.20	0.74	F	A
	HIP GIRTH					HIP GIRTH				
Average difference	6.1	9.2	–2.2	L	A	9.7 *	8.0	0.3	L	A
Confidence interval	–7.7 19.9	–3.7 22.1	–11.8 7.4	P	A	–1.2 20.6	–5.7 21.7	–11.4 12.0	P	A
p-value	0.25	0.07	0.54	F	A	0.03	0.14	0.95	F	A
	WHR					WHR				
Average difference	–0.004	–0.003	–0.001	L	A	–0.004	–0.002	–0.002	L	A
Confidence interval	–0.011 0.004	–0.010 0.004	–0.007 0.005	P	A	–0.014 0.006	–0.010 0.007	–0.009 0.006	P	A
p-value	0.20	0.26	0.37	F	A	0.29	0.55	0.57	F	A
	ARM GIRTH					ARM GIRTH				
Average difference	0.6	0.5	–0.3	L	A	3.9	1.3	3.1	L	A
Confidence interval	–4.2 5.3	–4.5 5.5	–6.4 5.9	P	A	–1.6 9.4	–3.9 6.5	–1.3 7.4	P	A
p-value	0.76	0.78	0.91	F	A	0.07	0.51	0.08	F	A
	THIGH GIRTH					THIGH GIRTH				
Average difference	0.8	3.4	–2.2	L	A	–2.1	–0.1	–2.2	L	A
Confidence interval	–5.8 7.4	–5.1 11.9	–10.7 6.2	P	A	–9.8 5.7	–7.9 7.7	–10.7 6.3	P	A
p-value	0.74	0.30	0.49	F	A	0.49	0.97	0.50	F	A
	TRICEPS SKINFOLD					TRICEPS SKINFOLD				
Average difference	0.18	0.05	0.14	L	A	0.26	0.56 *	–0.38	L	A
Confidence interval	–0.68 1.04	–0.58 0.67	–0.85 1.12	P	A	–0.70 1.22	–0.06 1.19	–1.40 0.64	P	A
p-value	0.58	0.84	0.72	F	A	0.48	0.03	0.34	F	A
	ILIAC SKINFOLD					ILIAC SKINFOLD				
Average difference	0.91	0.68	0.23	L	A	–0.07	0.05	–0.08	L	A
Confidence interval	–0.78 2.60	–0.95 2.30	–1.01 1.47	P	A	–1.28 1.14	–1.23 1.34	–1.39 1.24	P	A
p-value	0.17	0.28	0.63	F	A	0.88	0.91	0.88	F	A
	ABDOMINAL SKINFOLD					ABDOMINAL SKINFOLD				
Average difference	0.83	1.28 *	–0.45	L	A	0.62	0.31	0.31	L	A
Confidence interval	–1.09 2.74	–0.18 2.74	–1,96 1,06	P	A	–0.39 1.63	–1.25 1.86	–1.43 2.05	P	A
p-value	0.27	0.03	0.44	F	A	0.12	0.61	0.64	F	A

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of TBW (Me_{TBW}=54.7%), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

strual cycle in any of the studied groups of women (Tables 4–6). An increase in the thickness of the suprailiac skinfold was found between the follicular phase and the luteal one in the group of women with lower BMI (F-L; Table 6). The abdominal skinfold was found to be thicker between the follicular phase and the ovulatory one in slim women (Table 6) and in less hydrated ones (Table 5). The tendency towards a thicker abdominal skinfold in the ovulatory phase was observed in all studied groups; however, the results of multiple comparison tests did not allow for an identification of menstrual cycle phases of significantly different values of abdominal skinfold thickness and the observed changes were smaller than the measuring error (Tables 4–6).

TABLE 6
CHANGES IN SELECTED BODY GIRTHS, WAIST-TO-HIP RATIO AND SELECTED SKINFORLDS BETWEEN THREE PHASES OF THE MENSTRUAL CYCLE IN WOMEN WITH DIFFERENT BODY SLENDERNESS

Parameters	Body build type											
	BMI < 21.7 kg/m²						BMI ≥ 21.7 kg/m²					
	F – L	F – P	P – L	Groups of menstrual phases			F – L	F – P	P – L	Groups of menstrual phases		
	WAIST GIRTH						WAIST GIRTH					
Average difference	2.5	4.2	–1.8	L	A		1.6	1.9	–1.6	L	A	
Confidence interval	–3.3 8.3	–1.8 10.3	–10.2 6.7	P	A		–8.8 12.0	–10.0 13.3	–13.4 10.3	P	A	
p-value	0.27	0.08	0.59	F	A		0.69	0.67	0.73	F	A	
	HIP GIRTH						HIP GIRTH					
Average difference	8.2	10.5 *	–2.2	L	A		7.5	6.5	0.6	L	A	
Confidence interval	–4.1 20.6	–0.2 21.2	–12.2 7.7	P	A		–5.0 20.0	–9.4 22.4	–11.0 12.2	P	A	
p-value	0.09	0.02	0.56	F	A		0.12	0.29	0.89	F	A	
	WHR						WHR					
Average difference	–0.003	–0.003	–0.000	L	A		–0.004	–0.003	–0.002	L	A	
Confidence interval	–0.014 0.007	–0.012 0.006	–0.009 0.009	P	A		–0.015 0.007	–0.015 0.009	–0.009 0.005	P	A	
p-value	0.42	0.36	0.99	F	A		0.32	0.50	0.44	F	A	
	ARM GIRTH						ARM GIRTH					
Average difference	3.0	1.8	1.2	L	A		1.2	0.0	1.6	L	A	
Confidence interval	–1.8 7.8	–2.8 6.3	–3.4 5.9	P	A		–4.4 6.9	–5.6 5.6	–5.0 8.1	P	A	
p-value	0.12	0.32	0.48	F	A		0.55	1.00	0.53	F	A	
	THIGH GIRTH						THIGH GIRTH					
Average difference	0.6	2.1	–1.5	L	A		–2.1	1.2	–3.1	L	A	
Confidence interval	–7.3 8.5	–5.4 9.6	–10.6 7.6	P	A		–7.7 3.5	–7.8 10.1	–10.2 4.0	P	A	
p-value	0.84	0.47	0.67	F	A		0.32	0.73	0.25	F	A	
	TRICEPS SKINFOLD						TRICEPS SKINFOLD					
Average difference	0.26	0.34	–0.09	L	A		0.18	0.26	–0.14	L	A	
Confidence interval	–0.75 1.26	–0.26 0.95	–1.18 1.00	P	A		–0.55 0.92	–0.43 0.95	–1.03 0.75	P	A	
p-value	0.51	0.15	0.83	F	A		0.51	0.32	0.68	F	A	
	ILIAC SKINFOLD						ILIAC SKINFOLD					
Average difference	0.68 *	0.30	0.38	L	A		0.15	0.44	–0.27	L	A	
Confidence interval	–0.13 1.48	–0.74 1.33	–0.66 1.42	P	A		–1.99 2.29	–1.45 2.34	–1.79 1.25	P	A	
p-value	0.04	0.46	0.35	F	A		0.86	0.54	0.64	F	A	
	ABDOMINAL SKINFOLD						ABDOMINAL SKINFOLD					
Average difference	1.06	1.35 *	–0.29	L	A		0.34	0.17	0.16	L	A	
Confidence interval	–0.34 2.46	–0.004 2,704	–1.58 1.00	P	A		–1.38 2.05	–1.48 1.86	–1.85 2.18	P	A	
p-value	0.06	0.02	0.56	F	A		0.61	0.78	0.83	F	A	

F – follicular phase, P – periovulatory phase, L – luteal phase, average difference – mean value of differences between particular phases of the menstrual cycle, body build type defined on the basis of median value of BMI (Me_{BMI}=21.7 kg/m²), groups of menstrual phases (on the basis of Bonferroni correction): A – higher value of analyzed feature, B – lower value of analyzed feature, *p<0.05.

Discussion

Results of some previous studies indicated that women's body mass increased in the luteal phase of the menstrual cycle by about 0.1–0.2 kg, and in some cases even by 0.5 kg[1,3,6,8,9]. Comparing to that, the female athletes in our study, especially those characterized by slim body build (lower BMI), presented more substantial increases of body mass. Tasmektepligil et al. also observed that changes in body mass were greater in sportswomen than in controls[3]. The increase in body mass between the follicular phase and the luteal one in the present study was noted in all groups of women of different body build. It should be stressed, however, that the absolute gain in body mass was the biggest in slim women, who in the luteal phase weighted 0.8 kg more than in the follicular phase. In women with lower BMI the increase in body mass in the first part of the menstrual cycle was similar to the increase in the second part of the cycle. The tendencies were, however, different in women with different body build types: the increase in body mass between the follicular phase and the ovulatory phase was far lower than in the second part of the cycle. It must be stressed that in individual cases a body mass loss was observed in the studied women in the consecutive phases of the menstrual cycle (F-O-L), despite exclusion of a slimming diet factor and impact of treatment. The factors affecting these individual cases might not have been considered during the experiment (undiagnosed hormonal disorders). Some earlier studies failed to reveal any significant changes in body mass during the menstrual cycle, however, they did not take into account different body build types of their subjects[5,7].

Body mass changes during the menstrual cycle are hormonally driven; however, their intensity, which varies in different individuals, may depend on a variety of factors such as increased consumption or limited physical activity[23–25]. Several earlier studies reported increased appetite and food intake during the luteal phase of the menstrual cycle, and these changes were connected not only with estrogen and progesterone levels but also with leptin and insulin levels[26,27]. These results can be confirmed by the noted heightened sleeping metabolic rate in the luteal phase, which is commonly thought to reflect the cost of tissue regeneration and energy storage[28]. The consequence of body mass changes during the menstrual cycle is BMI variability. A significantly higher BMI was observed in the luteal phase in all groups of women under study. The most significant changes of the BMI were found in slim women and in more hydrated ones, and the least significant in women with higher BMI and in less hydrated ones.

The body composition analysis made it possible to find those body components whose changes increase body mass in the consecutive phases of the menstrual cycle. In the present study a significant increase in lean body mass between the follicular and ovulatory phases was only found in the group of less hydrated women, but not in the other groups. It should be stressed that the amount of fat free mass is calculated on the basis of intracellular water volume estimates. Gleihauf and Roe using BIA revealed changes in fat free mass (by 0.1 kg lower in the follicular phase)[8]. In the present study on female athletes the extracellular water level was higher in the second part of the cycle by about 0.4 kg in less hydrated women, and by about 0.3 kg in other groups of women with different body builds types. Also Tomazo-Ravnik and Jakopič showed that body hydration was the highest in the luteal phase[9]. Some earlier studies, with the use of magnetic resonance imaging, showed that the water content was the lowest between the 6th and the 15th day of the menstrual cycle[2]. These parameters then soared in the second part of the menstrual cycle reaching the peak after the 25th day[2]. In the majority of female athletes in the current study, no changes in body hydration were noted in the first phase of the menstrual cycle. The amount of fat mass in women under study increased significantly between the follicular and ovulatory phases only in more hydrated women (by about 0.7 kg) and in slim women (by about 0.5 kg). The amount of subcutaneous adiposity did not affect the changes in total fat mass between subsequent phases. According to Wickham et al., the adiposity level decreases in the luteal phase[7]. Ellard et al. in their hydrodensitometric analysis, as well as Gleihauf and Roe and some other authors did not note any significant changes in fat mass and total body water during the menstrual cycle[5,8,29,30]. McKee and Cameron did not find any differences in body composition, despite increased body mass[6]. They asserted that BIA did not reflect changes in body composition taking place during the menstrual cycle[6]. However, Dehghan and Merchant revealed that the given phase of the menstrual cycle influences the bioimpedance and body composition estimation[31].

The present study showed that the interpretation of observed changes in body girths and skinfold thickness during the menstrual cycle is problematic because of measurement error values. However, significant positive correlation between the observed interphases changes in girths (hip and waist) and suprailiac skinfold thickness indicate the influence of some biological factors. Among all measured body girths, only the hip girth changed in the consecutive phases of the cycle, with the lowest values in the ovulatory phase. The differences in the hip girth in examined women did not affect significantly the WHR. A tendency towards a lower WHR was noted between the follicular phase and the ovulatory one, however, a non-significant WHR drop was observed after ovulation in many women. Kirhengast and Gartner found a significantly decreased WHR in women in the ovulatory phase, which was explained by the sexual selection mechanism[1]. In the study of Tasmektepligil et al. the waist girth was the longest and hip girth was the shortest during menses[3]. The abdominal and subscapular skinfolds were the thickest after menstruation, whereas the triceps, calf and iliac skinfolds remained the same in the follicular and the luteal phases[3]. Those researchers did not, however, perform measurements in the ovulatory phase. The present study showed that the abdominal skinfold in studied women was a little thicker in the ovulatory phase than in the follicular phase, but only in less hydrated women and in slim women. The iliac skinfold in slim women was a little thicker in

the luteal phase than in the follicular phase. The triceps skinfolds did not differ in thickness between the subsequent phases of the cycle in any of the studied groups of women. The performed multiple comparison tests that accounted for interactions between the phases of the menstrual cycle did not permit discerning one phase with significantly different skinfold thickness and the value of observed differences was smaller than measurement error. However, autocorrelation between measurements and phases is another source of error which should be taken into consideration. According to Dehghan and Merchant, the thickness of subcutaneous adiposity varies throughout the menstrual cycle[31]. Some other authors did not observe any differences in skinfold thickness or fat distribution during the menstrual cycle[5,8,29,30].

Limitation of the study

Besides interesting findings resulted from the longitudinal study design on female athletes, the presented study had several limitations which should be discussed. The basic problem in research on the menstrual cycle is a proper determination of the cycle's phases. Self-reported onset of menses, although is the most popular method, when introduced alone (without any additional method) may provide some errors in determining phases of the menstrual cycle. It is recommend combining several methods to improve accuracy of phase identification, minimize costs and burden, and reduce selection bias and confounding[10]. In our sample we introduced a careful selection of females with respect to menses regularity and also a retrospective (after following menses) check-up of the dates chosen for measurements. Additionally, it is worth mentioning that previous studies reported some different confounders of the changeability of body mass across the menstrual cycle which was not tested in detail during this study[23–27]. The overall dietary inhabits, consumptions of supplements and level of physical activity were checked using a questionnaire and interview once before inclusion to the study.

Conclusion and implication of the findings

The increase in body mass and intracellular water content between the follicular phase and the luteal one of the menstrual cycle is very common among female athletes, but the intensity of observed changes depends on female body build. Considering the results of the present study and previously published data it seems that slim women with more hydrated body build characteristic for athletes are more exposed to cyclic changes in body mass and tissue composition.

The obtained results are most likely to be of interest for young women, especially athletes, who in view of their occupation or practiced sport, struggle with changes in their body mass and hydration during the menstrual cycle. They are not aware, or not always accept the fact, that these changes are the natural consequence of maintaining fertility, and that pharmacological interventions aimed to affect changes in body composition may lead to impaired fertility. The physicians and trainers should also consider these findings while preparing medical diagnosis or training plan and controlling their results in female athletes.

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MENSTRUALNE PROMJENE SASTAVA TIJELA KOD GRAĐE TIJELA ATLETIČARKI

S A Ž E T A K

Cilj istraživanja bio je utvrditi da li su tendencije i opseg promjena u tjelesnoj masi, sastavu tijela i opsegu tijela u menstrualnom ciklusu bili slični ili različiti kod žena različite tjelesne građe. Antropometrijska ispitivanja provedena su u grupi od 40 žena koje imaju menstruaciju i redovito se bave sportom (u dobi od 19 do 21, 169, 3 +/– 6,4 cm BV, tjelesna masa 59,6 +/– 7,0 kg) u folikularnoj, periovulatornoj i lutealnoj fazi menstrualnog ciklusa. Faze su određene na temelju podataka iz dva uzastopna menstrualnog ciklusa, uzimajući u obzir duljinu ciklusa. Kako bi se utvrdio tip tjelesne građe, mjereni su indeks tjelesne mase, status hidratacije i debljina kože. Za statističku analizu su primijenjene višestruke usporedbe s više intervala pouzdanosti. Porast tjelesne mase između folikularne i lutealne faze bio je uočen u svim skupinama žena, najveći dobitak je izmjeren kod mršavih žena, koje su u lutealne faze u prosjeku imale 0,8 kg više. Količina masnog tkiva značajno je porasla u prvom dijelu ciklusa samo kod više hidratiziratiziranih i vitkih žena. Značajne međufaze promjene kod obujma struka i kuka I debljine kože u jednoj skupini žena također ukazuje na utjecaj somatskih čimbenika. S obzirom na prikazane rezultate, građa tijela se čini važnim za analizu uzoraka promjena pojedinih komponenti na cijelom menstrualnom ciklusu, posebno kod sportašica. Neke promjene mogu se vidjeti samo u nekim skupinama žena, dakle, somatske značajke mogu se uzeti u obzir kao prediktor intenziteta promjena.