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The Effect of the Menstrual Cycle on Body Composition Determined by Contact-Electrode Bioelectrical Impedance Analyzers

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ABSTRACT

International Journal of Exercise Science 11(4): 625-632, 2018. Bioelectrical impedance analysis (BIA) is a noninvasive and relatively inexpensive method of assessing body composition. Manufacturers of BIA technology recommend to avoid testing women when they perceive to be retaining water during the menstrual cycle. The purpose of the present investigation was to examine the effect of the menstrual cycle on body composition determined by contact-electrode BIA analyzers. Forty-three college-aged women volunteered to participate in this study (age=21.2 ± 1.1 years; body mass index = 24.0 ± 3.7 kg/m^2). Subjects had their body composition assessed using four different contact-electrode BIA analyzers during the following menstrual cycle phases: menstrual, follicular, early and late luteal. Regardless of the BIA analyzer used for the assessment, no significant differences in body composition measures were found between cycle phases. The results of this study indicate that the contact-electrode BIA devices used in this study can be used at any time during a woman's menstrual cycle without altering the body composition values.

KEY WORDS: Bioimpedance, menstruation, percent body fat

INTRODUCTION

Bioelectrical impedance analysis (BIA) is a noninvasive and relatively inexpensive method of assessing a person's body composition that does not require a high degree of technical skill. Due to these characteristics, BIA has become a common method of assessment in a variety of clinical and health/fitness settings (8, 11, 13, 14). The BIA method estimates body composition by sending an electrical current through the body while measuring the impedance or resistance to current flow. Fat-free mass has a high water and electrolyte content making this tissue highly conductive with a low resistance to current flow (7). Adipose tissue contains little water and electrolytes making it a poor conductor with a high resistance to current flow (7). The contact-electrode BIA analyzers of today differ considerably from the traditional BIA systems that required the placement of gel electrodes at specific anatomical locations. When using contact-electrode BIA analyzers, body composition measurements such as percent body fat and fat-free mass are automatically calculated using pre-programmed prediction equations (4, 8). These proprietary equations combine measured impedance with additional information such as height, body mass, gender, age and body type in order to estimate the body composition values (7).

BIA analyzers can be classified as single or multi-frequency based upon the electrical current(s) used to measure the impedance of body tissues. Single frequency analyzers commonly introduce a 50 kHz electrical current into the body to determine whole-body or segmental tissue composition (8). Conversely, multi-frequency analyzers send several frequencies, ranging from 1-1000 kHz, through the body to attain body composition measurements (8). At 50 kHz, single frequency analyzers provide estimates of total body water but are incapable of distinguishing between intracellular and extracellular water measurements (10). Whereas, multi-frequency analyzers can differentiate between intracellular and extracellular body water (5).

Previous research has shown that impedance is affected by factors that produce changes in body fluids or electrolytes (2, 3, 4, 11, 12). In order to control for fluid shifts and improve the accuracy of measurement, specific pre-testing guidelines have been recommended prior to using BIA technology (8). For instance, it is recommended that clients avoid eating, drinking, exercise, and taking diuretic medication prior to assessment (8). In addition, it is suggested that women should not be tested when they perceive to be retaining water during the menstrual cycle (8).

The menstrual cycle is a series of events that results in the maturation of a follicle and oocyte. Additionally, the uterus prepares for an embryo if fertilization occurs (9). In some women, the menstrual cycle may increase water retention resulting in temporary weight gain (6). However, past evidence examining the impact of the menstrual cycle on BIA measurements using traditional, gel-electrode technology have reported little or no impact (1, 6, 12). Given the recent advancements in BIA contact-electrode technology and the popularity of these devices, it is necessary to further examine the possible impact of the menstrual cycle on BIA measurements. As such, the purpose of this study was to examine the effect of the menstrual cycle on body composition determined by four commonly-marketed, contact-electrode BIA analyzers.

METHODS

Participants
Forty-three college-aged female volunteers participated in this study. Study protocol and methods were approved by the Bloomsburg University Institutional Review Board. Prior to participation, all subjects signed an informed consent document consistent with the Bloomsburg University policy for protection of human subjects.

Protocol
Each subject made four visits to the laboratory for testing separated by a period of exactly one week, with each visit lasting no more than 30 minutes. For all assessments of body composition,

subjects were asked to wear a t-shirt and shorts. Height (cm) and weight (kg) were measured using a wall-mounted stadiometer and digital scale. All subjects were asked to adhere to the following recommended pretesting guidelines (8): a) no physical exercise within 12 hours of the scheduled test; b) no eating or drinking within 2 hours of the test; c) empty bladder within 30 minutes of the test; d) no alcohol consumption within 48 hours of the test; and e) no diuretic medications within 7 days of the test.

Leg-to leg bioelectrical impedance analysis (LBIA) measurements were determined using the Tanita® model TBF-300A analyzer (Arlington Heights, IL, USA). The LBIA consists of four contact electrodes (two anterior and two posterior) that are mounted on the surface of a platform scale (4). Each subject stood erect with bare feet placed on the contact electrodes of the LBIA device, per manufacture specifications. During the measurement, a single frequency (50 kHz) is passed through the anterior electrode on the scale platform, and the voltage drop is measured on the posterior electrode. Lower-body impedance and body mass were measured simultaneously while the subject stood on the LBIA platform (4). The LBIA analyzer, using pre-programmed equations, automatically calculated body composition measurements such as percent body fat, fat mass and fat-free mass.

Segmental bioelectrical impedance analysis (SBIA) measurements were determined using the Tanita® model TBC-418 analyzer (Arlington Heights, IL, USA). Each subject stood erect holding the hand electrodes with bare feet placed properly on the contact electrodes of the SBIA instrument. Arms were placed in a straight down position without touching the side of the body. As previously described, the SBIA system consists of four contact electrodes (two anterior; two posterior) that are mounted on the surface of a platform scale and each extremity hand-grip has an anterior and posterior electrode (4). All measurements are carried out using a constant single frequency current (50 kHz). Whole-body impedance was measured using an ipsilateral foot-hand electrical pathway.

Multi-frequency bioelectrical impedance analysis (MFBIA) was measured using the InBody 520 and InBody 720 devices (Beverly Hills, CA, USA). The InBody 520 measures segmental impedance across both legs, arms and the trunk at frequencies of 5, 50, and 500 kHz. The InBody 720 measures segmental impedance across both legs, arms and the trunk at frequencies of 1, 5, 50, 250, 500, and 1000 kHz. Similar to the SBIA system, there are eight electrodes in contact with the body, two in each hand and foot. Body mass and five segmental impedance measurements (right arm, left arm, trunk, right leg and left leg) are automatically measured while the subject stands erect holding the hand electrodes with bare feet placed properly on the contact electrodes of the MFBIA scale-like platform.

Each subject completed a two-month calendar to record the start and end of their past two menstrual cycles. From these calendars, the average cycle length was calculated in order to determine the targeted dates for all testing visits. Testing occurred during the menstrual (cycle days 1-7), follicular (cycle days 8-14), early luteal (cycle days 15-21) and late luteal (cycle days 22-28) phases. Each subject completed a prescreening questionnaire to determine birth control medication use prior to testing. Of the 43 subjects, 28 subjects reported taking a combination pill made of progesterone and estrogen, one subject reported using a progesterone only implant and 14 subjects reported no use of birth control medications.

On all visits, a urine sample was collected from each subject to assess hydration status and to identify the presence or absence of luteinizing hormone (LH). Hydration status was assessed by examining urine specific gravity, using a digital optical refractometer. The presence of LH was determined using an over the counter ovulation test kit. An indication of the presence of LH determines when the subject is in the follicular phase of their cycle.

Statistical Analysis
Data were analyzed using Sigma Plot Version 13.0 (San Jose, CA, USA). All values are expressed as mean ± standard deviation. Body composition variables were evaluated during the four phases of the menstrual cycle for each subject. A repeated measures ANOVA was used to determine significance in the variables over the four phases of the menstrual cycle. The significance level was set a priori at $p \leq 0.05$ for all analyses.

RESULTS

Characteristics of the 43 subjects involved in this study are presented in Table 1. Subjects were healthy with an average BMI (24.0 ± 3.7 kg/m^2, Table 1). The average documented menstrual cycle length for our subjects was reported as 29.0 ± 3.5 days (Table 1). Urine specific gravity values were not significantly different between cycle phases (Table 2).

Table 1. Characteristics for the study participants.

N = 43	Age (years)	Height (cm)	Weight (kg)	Body Mass Index (kg/m^2)	Length of Cycle (days)
	21.3 ± 1.1	163.5 ± 6.6	63.8 ± 10.9	24.0 ± 3.7	29.0 ± 3.5

All values are mean ± SD.

Table 2. LBIA body composition measurements & urinalysis throughout the phases of the menstrual cycle.

	Menstrual	Follicular	Early Luteal	Late Luteal
Body Mass (kg)	63.5 ± 10.9	63.4 ± 10.8	63.6 ± 10.9	63.6 ± 10.9
Body Fat (%)	28.2 ± 7.2	27.9 ± 7.1	28.2 ± 7.1	28.1 ± 6.8
Fat Free Mass (kg)	44.9 ± 3.6	45.0 ± 3.6	45.0 ± 3.7	45.1 ± 3.8
Fat Mass (kg)	18.6 ± 7.9	18.4 ± 7.7	18.6 ± 7.8	18.5 ± 7.5
Total Body Water (kg)	32.9 ± 2.6	32.9 ± 2.7	32.9 ± 2.7	32.9 ± 2.7
Impedance (Ohms)	570.0 ± 67.4	566.6 ± 63.5	569.1 ± 74.9	563.0 ± 66.5
Urine Specific Gravity	1.020 ± 0.007	1.019 ± 0.006	1.019 ± 0.006	1.019 ± 0.007

All values are mean ± SD.

Table 3. SBIA body composition measurements throughout the phases of the menstrual cycle.

	Menstrual	Follicular	Early Luteal	Late Luteal
Body Mass (kg)	63.8 ± 10.9	63.6 ± 10.8	63.8 ± 10.9	63.8 ± 10.9
Body Fat (%)	29.4 ± 6.8	29.2 ± 6.4	29.5 ± 6.6	29.4 ± 6.3
Fat Free Mass (kg)	44.4 ± 4.1	44.4 ± 4.1	44.4 ± 4.2	44.5 ± 4.4
Fat Mass (kg)	19.4 ± 7.7	19.2 ± 7.5	19.4 ± 7.6	19.4 ± 7.3
Total Body Water (kg)	32.5 ± 3.0	32.5 ± 3.0	32.5 ± 3.1	32.6 ± 3.2
Impedance (Ohms)	691.9 ± 70.3	692.8 ± 67.2	692.7 ± 78.5	689.8 ± 76.1

All values are mean ± SD.

Body composition measurements during each phase of the menstrual cycle when using single frequency analyzers are presented in Table 2 (LBIA) and Table 3 (SBIA). No significant differences were observed for any body composition measurement during any menstrual cycle phase when assessed by LBIA (Table 2) or SBIA (Table 3). Multi-frequency BIA body composition measurements during each phase of the menstrual cycle are presented in Table 4 (InBody 520) and Table 5 (InBody 720), respectively. No differences in body composition measures were determined over the menstrual cycle when using multi-frequency technology for the assessment (Table 4 and Table 5).

Table 4. InBody 520 body composition measurements throughout the various phases of the menstrual cycle.

	Menstrual	Follicular	Early Luteal	Late Luteal
Body Mass (kg)	63.9 ± 11.0	63.8 ± 10.8	64.0 ± 10.9	64.0 ± 11.0
Body Fat (%)	27.6 ± 8.1	27.4 ± 8.1	27.4 ± 7.7	27.5 ± 7.6
Lean Body Mass (kg)	45.7 ± 6.0	45.7 ± 5.9	45.9 ± 5.9	45.9 ± 6.1
Fat Mass (kg)	18.2 ± 8.1	18.1 ± 8.0	18.1 ± 7.9	18.2 ± 7.8
Intracellular Water (kg)	21.0 ± 2.8	21.0 ± 2.8	21.1 ± 2.8	21.1 ± 2.8
Extracellular Water (kg)	12.4 ± 1.6	12.4 ± 1.6	12.5 ± 1.6	12.5 ± 1.7
Total Body Water (kg)	33.4 ± 4.4	33.4 ± 4.3	33.5 ± 4.3	33.5 ± 4.5
5 (Ohms)	1495.0 ± 158.1	1490.8 ± 141.4	1494.0 ± 166.6	1484.3 ± 160.7
50 (Ohms)	1323.7 ± 142.8	1319.4 ± 130.2	1323.2 ± 146.2	1317.3 ± 143.3
500 (Ohms)	1134.9 ± 126.9	1129.5 ± 118.0	1133.3 ± 128.4	1129.7 ± 127.9

All values are mean ± SD.

Table 5. InBody 720 body composition measurements throughout the various phases of the menstrual cycle.

	Menstrual	Follicular	Early Luteal	Late Luteal
Body Mass (kg)	64.0 ± 10.9	63.9 ± 10.8	64.1 ± 10.9	64.1 ± 10.9
Body Fat (%)	28.8 ± 7.6	29.1 ± 7.6	28.5 ± 7.7	28.6 ± 7.5
Lean Body Mass (kg)	45.5 ± 6.2	44.7 ± 5.2	45.2 ± 5.3	45.2 ± 5.2
Fat Mass (kg)	19.0 ± 7.9	19.2 ± 8.0	18.6 ± 8.4	19.0 ± 8.0
Intracellular Water (kg)	20.9 ± 3.0	20.5 ± 2.4	20.9 ± 2.5	20.7 ± 2.4
Extracellular Water (kg)	12.4 ± 1.6	12.2 ± 1.4	12.6 ± 2.4	12.3 ± 1.5
Total Body Water (kg)	33.3 ± 4.6	32.7 ± 3.8	33.6 ± 4.6	33.0 ± 3.8
1 (Ohms)	1511.2 ± 148.9	1516.1 ± 139.7	1515.5 ± 167.9	1513.7 ± 170.5
5 (Ohms)	1484.4 ± 147.2	1488.8 ± 140.3	1485.6 ± 168.2	1476.1 ± 158.7
50 (Ohms)	1314.2 ± 134.4	1321.4 ± 127.2	1316.5 ± 149.7	1311.7 ± 141.3
250 (Ohms)	1174.0 ± 129.8	1186.0 ± 116.9	1181.2 ± 135.0	1174.0 ± 128.9
500 (Ohms)	1131.2 ± 131.1	1145.0 ± 113.4	1140.7 ± 131.0	1138.3 ± 124.8
1000 (Ohms)	1095.9 ± 132.8	1106.9 ± 106.7	1106.7 ± 126.9	1104.7 ± 119.5

All values are mean ± SD.

DISCUSSION

When using BIA technology to assess body composition, it is recommended that clients adhere to a series of pre-testing guidelines designed to control for fluctuations in hydration status. One such guideline is that a woman should not be tested during the phase of the menstrual cycle in which she perceives to be retaining water (8). If necessary, this guideline may impact the utilization of this technology in the clinical setting where appointments are often scheduled without consideration of a woman's specific menstrual cycle phase. The purpose of this study was to examine the effect of the menstrual cycle on body composition determined by four contact-electrode BIA analyzers. Overall, we found that the phase of the menstrual cycle had no effect on the body composition measures determined by the BIA analyzers used in this study.

Previous research has examined the impact of menstrual phase on body composition determined by single frequency BIA (1, 6). Chumlea et al. (1) reported that the day of the menstrual cycle had no effect on BIA measures. Gleichauf and Roe (6) reported small changes in body weight (≈ 0.2 kg), fat-free mass (≈ 0.2 kg) and resistance (≈ 7 Ohms) between the menstrual phases (6). The authors of that study noted that although the alterations were most likely related to hydration status during menses, the small magnitude of change should not prevent clinicians from using BIA technology to assess body composition (6). In the present investigation, no statistically significant differences in body mass, fat-free mass or impedance were found between menstrual cycle phases when using the LBIA and SBIA single frequency contact-electrode analyzers. As such, we agree that single frequency BIA can be used to assess body composition without consideration of a female clients menstrual cycle phase.

In 1993, Mitchell and colleagues (12) examined the ability of a gel-electrode, multi-frequency BIA system (Xitron 4000B, Xitron Technologies Corporation) to estimate fluid volume changes at different phases of the menstrual cycle in 21 females. Although body mass was unchanged, they reported significant differences ($p \leq 0.05$) in the measurements of intracellular fluid, total body water, and lean body mass over the menstrual cycle phases (12). The authors concluded that the multi-frequency BIA system under investigation could be used to determine the distribution of total body water between intracellular and extracellular fluid compartments and possibly provide an instrument to objectively assess symptoms of premenstrual syndrome (12). In the present investigation, we examined two commercially-available, multi-frequency BIA analyzers (InBody 520 and InBody 720) that use contact-electrode technology for the assessment. In contrast to the findings of Mitchell and colleagues (12), we found no significant changes in total body water, intracellular water, extracellular water, or body composition measures. Possible explanations for the contrasting findings between these two investigations may include differences in: sample size, technology (gel-electrode vs contact-electrode), prediction equations, electrical frequencies, or some other unknown variable. Nevertheless, our findings related to the contact-electrode BIA technology are of importance since the currently examined systems have, in most instances, replaced the original gel-electrode BIA technology.

Limitations of the present study include that the assessment only lasted for one cycle. A more longitudinal approach with the assessment over more than one cycle may prove to be beneficial. In addition, we did not to monitor dietary habits of participants. It is possible that dietary intake could influence body composition variables.

In conclusion, when using BIA to estimate body composition it is recommend that no testing of female clients occur when they perceive to be retaining water during their menstrual cycle (8). However, our data indicate that the phase of the menstrual cycle has no effect on the body composition measures determined by BIA. As such, it appears that the single and multi-frequency contact-electrode BIA devices examined in this investigation can be used at any time without concerns of menstrual-induced alterations to body composition values. These findings may prove of interest to those currently using contact-electrode BIA technology in the clinical/health-fitness setting or those considering the purchase of BIA to assess the body composition of their clients.

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