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Pre-Exercise Hydration Status Changes in Females Throughout the Menstrual Cycle

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Abstract

In the field of athletics, research including females is limited. Oftentimes, research that only included male subjects is generalized and is later used to incorporate guidelines for both male and female athletes. This study focused on how the menstrual cycle, a female exclusive bodily process, could change hydration status. Participants within the study were between the ages of 18 and 35 and only data from females was analyzed. The study was designed as a crossover subject trial over the span of two months. Subjects participated in a total of four trials that were divided into phase-hydration groups. Two trials were in each phase of the menstrual cycle, follicular and luteal, and combined with a hydration status of euhydrated or dehydrated. The project focused on changes in blood pressure, weight, urine specific gravity (USG), rectal temperature, and estrogen and progesterone levels. Results indicated no significant change between any of the phase-hydration groups ($P > 0.082$). However, these results conclude that by the body not experiencing differences in the dependent variables analyzed, it is able to remain in a state of homeostasis, which could be overall more beneficial for ones' health.

Key words: menstrual cycle, hydration, female, progesterone, estrogen

Literature Review

Introduction

For generations, the main focus in the field of athletics has been on males. Researchers never considered how bodily differences between males and females could affect overall performance, especially due to the hormone fluctuations females undergo throughout their lifetime in the menstrual cycle. The menstrual cycle, defined as two overall phases, the follicular and luteal phase, (2) has the potential to cause drastic changes in a the female body. Changes include varying hormone levels, increased body temperature, fluid retention, and changes in systemic blood flow (8, 7, 4, & 6). With so many fluctuations occurring throughout an individual's body depending on her menstrual status, there is reason to believe that the hydration baseline of a female athlete would be altered as well. This review will focus on what the menstrual cycle entails, such as the hormones LH, follicle-stimulating hormone (FSH), estrogen, and progesterone and their effects on the body as well as other hormones.

The Menstrual Cycle

The menstrual cycle, as defined earlier, is comprised of a follicular and luteal phase. Each phase is categorized with the use of luteinizing hormone (LH). For women ages 18 to 30, the follicular phase is from the first day of menses to the peak of LH in the body with an average of 16.9 +/- 3.7 days, while the luteal phase is from the LH peak to the onset of menses, usually 12.9 +/- 3.6 days (1). Within each phase however there are different hormones that are abundant.

Follicular Phase Hormones and Cellular Effects

In the follicular phase, there is a small rise in FSH, which causes the follicles within the ovary to enlarge. While the follicles are growing, they eventually secrete estrogen, causing the follicle to become even more sensitive to FSH and grow at an increased rate (2). The first follicle to secrete estrogen oftentimes becomes the mature follicle that will continue to develop throughout the menstrual cycle. The maturing follicle will continue to secrete estrogen, causing LH to continue to increase until it hits its peak of about 74 mili-international units (mIU). Once LH is at its peak, FSH increases, estrogen decreases and progesterone begins to be secreted, marking the occurrence of ovulation and the transition from the follicular to luteal phase (2). On a cellular level, the innermost layer of cells in the uterus, the mucosal cells, will increase in size due to the elevated concentration of estrogen being secreted into the blood. As a result, the width of the mucosal layer will increase (2).

Luteal Phase Hormones and Cellular Effects

During the luteal phase, the predominant increasing hormone is progesterone, along with estrogen, while LH and FSH slowly decrease. Vascularity and size of the stromal layer, the area between glands in the uterus, begin to increase at the beginning of the luteal phase and continues to increase throughout the luteal phase (2). Menstruation begins at the end of the luteal phase when both progesterone and estrogen levels decrease (2). The uterine lining will shed as the epithelial cells in the mucosal layer are excreted and the stromal cell layer hemorrhages, causing the blood vessels in the layer to become necrotic (2).

Effects of Progesterone and Estrogen on AVP

Estrogen and progesterone are mainly involved in the regulation of the menstrual cycle, but have other bodily effects, such as water regulation. Both hormones have receptors located in nonreproductive tissues for fluid regulation. Receptor locations include the hypothalamus, kidney tubules and the cardiovascular system (5). Arginine vasopressin (AVP), is a hormone in the body sensitive to both estrogen and progesterone and causes an increase in water retention as well as mood changes in females (8).

During the luteal phase, as discussed earlier, both progesterone and estrogen are present in the body. The homeostatic set point, or threshold is a specific urine osmolality the body has determined as the concentration at which AVP can be released into the blood to cause an increase in water retention. Therefore, water and sodium regulation in the body is minimally affected and progesterone and estrogen simply alter the set point instead of inducing excess sodium or fluid retention or loss (5). The presence of estrogen and progesterone in the blood causes the set point to decrease and the body retains more water. Therefore, more AVP will now be released into the body at a decreased osmolality. Studies have also shown the greatest increase in plasma volume occur when both estrogen and progesterone were present in the female body (5). However, it has been found that the release of AVP has limited effects on the overall water retention in the body as the amount of fluid lost in both stages of the menstrual cycle is not significant (5 & 3).

Blood Flow & Thermoregulatory Effects In Different Stages

While estrogen and progesterone cause changes in water regulation, they also induce alterations in blood flow and thermoregulation of a female. High blood estrogen levels (160 mIU) seen in the follicular stage have been found to decrease the thermoregulatory set-point of the body, allowing the body to function at a lower overall body temperature (7). In contrast, when there is a high level of both progesterone and estrogen in the body, such as during the luteal stage, the thermoregulatory set-point increases (7). Therefore, progesterone is able to mitigate the effects of estrogen on the body. In a previous study by Kolka and Stephenson, forearm blood flow (FBF) and esophageal temperature readings were used as tools to measure an individual's core body temperature; the study showed an increase in systemic blood flow during the luteal stage of menstruation. Thus, the increase in blood flow and therefore temperature, showed the skin vasodilates during the luteal stage(6).

Conclusion

While there is research to begin to understand the effects of the menstrual cycle on women, there are still many unanswered questions and gaps in our knowledge. It has been shown that during the luteal stage, body temperature, the thermoregulatory set-point, and water retention increase (6, 7, 5). One question, however, is whether or not the hydration status in females changes throughout the menstrual cycle in reaction to the hormonal and thermoregulatory changes that occur. Research could prove if there are certain times a female athlete is the most hydrated and would have the potential to perform to their highest capacity. However, there is not yet enough research on this subject and more is needed.

Introduction

The hormone pattern that occurs throughout the menstrual cycle may affect hydration levels in females. Due to high levels of progesterone and estrogen found in the luteal phase, the homeostatic set point for AVP release is decreased; AVP is released at a lower blood plasma osmolality and more water is retained in the body (19 & 26). Plasma volume and body temperature also increase and evidence has been found that the body vasodilates (6). Therefore, the body vasodilates during the luteal phase, causing the body to increase in temperature and keeps a constant blood pressure by increasing plasma volume.

All of these physiological changes are important because they could show researchers that there is indeed a point in time where a female athlete is the most hydrated, leading to the capability to perform to their highest potential. Also, if one were to know what stage of the menstrual cycle an individual were in, certain steps could be taken to increase hydration if it was known a female is less hydrated in certain stages. We hypothesize females who are in the luteal phase of the menstrual cycle and euhydrated will show signs of increased hydration; euhydrated luteal phase measurements will show the greatest increase in baseline body temperature, progesterone and estrogen levels, and weight, greatest decrease in USG and no change in blood pressure.

Methods

The study conducted was a crossover subject trail over the span of two months.

Participants in the study were deemed eligible by being between the ages of 18 and 35, not taking any form of contraceptive, recreationally active and cleared to do so, and finally having a VO_2 max greater than 35 mL/kg/min. A VO_2 max test was administered to participants upon the completion of a consent meeting. In total, 19 participants were screened for the study, 13 enrolled and 10 were included in data analysis.

Participants came to the lab an average of 17 times to perform required baseline testing, trails, as well as a follow up after each trail. Trials consisted of three workout blocks that were a combination of running and walking based on each individual's VO_2 max. In total, subjects participated in four trails; two of the trials were in the follicular phase (days 10-13) and the other two were in the luteal phase (days 18-22). Within each phase, one of the two trials was a fluid restriction for 24 hours leading to dehydration and euhydration with no restrictions on fluid intake; the order of the two were randomized and counterbalanced. However, only data collected before exercise periods will be examined in this paper.

Upon arrival to the lab, it was confirmed with participants that they had not had any alcohol for 24 hours or caffeine for 12 hours before measurements were taken. If participants had consumed alcohol or caffeine, the trail was rescheduled. Participants were also asked to provide a urine sample upon arrival to ensure they had a USG of at most 1.025 for dehydration trails. If USG was higher than 1.025, the trail would be rescheduled but if between 1.020-1.025, 500mL of water was provided for the participant to drink before the trial. For euhydration trails, USG needed to be more than 1.020. Blood pressure was taken while the participant was sitting down in a chair using a sphygmomanometer and stethoscope. Participants then received an intravenous cannula for blood draws to be performed at the beginning of the trail and after each exercise block. The blood was centrifuged and the plasma was removed and used in the enzyme linked immunosorbent assay (ELISA) to determine the amount of progesterone and estrogen in the blood. Participants next went into the bathroom and inserted a rectal probe about 15cm into their rectum and stood on the scale provided in the bathroom for researchers to record a nude body weight. Once participants were clothed and out of the bathroom, four temperature probes were attached to obtain a baseline temperature.

Results

The variables used in this study were baseline blood pressure, USG, rectal temperature, weight, estrogen and progesterone level. The dataset included values for each of the four phase-hydration groups, as shown in Table 1. Blood pressure was converted to mean arterial pressure (MAP) for analysis. Variance and correlation between readings were analyzed through a General Linear Model Repeated Measure ANOVA. Pair-wise comparisons using Bonferroni were then examined to determine if there was any significance between the four phase-hydration groups (Table 1). Statistically significant data was identified as a p value of <0.05. P values <0.05 were not identified for any of the six dependent variables in any of the four phase-hydration groups.

Table 1. Characteristics of dependent variables collected in each phase-hydration group.

	Phase-Hydration Group			
Variable	Luteal - Euhydrated	Luteal- Dehydrated	Follicular - Euhydrated	Follicular - Dehydrated

MAP	85.50 ± 7.29	86.80 ± 9.42	85.57 ± 4.02	87.23 ± 5.26
USG	1.02 ± 0.01	1.02 ± 0.01	1.02 ± 0.01	1.01 ± 0.01
Temperature	36.92 ± 0.26	37.04 ± 0.38	36.83 ± 0.25	36.86 ± 0.31
Weight	57.31 ± 7.49	57.33 ± 7.58	58.25 ± 7.65	57.63 ± 7.65
Estrogen	124.00 ± 77.47	130.82 ± 67.16	115.29 ± 54.89	112.33 ± 46.47
Progesterone	3.70 ± 4.21	5.19 ± 4.92	0.85 ± 0.61	1.16 ± 0.98

Pattern of dependent variables (means ± SD) during each phase-hydration group. *P<0.05.

Discussion

This study presents evidence that the luteal-euhydrated group does not show signs of increased hydration when compared to the other three phase-hydration groups made in the study. There was no significant difference between USG, baseline rectal temperature, weight, MAP, progesterone or estrogen levels. Therefore, there was no evidence for an increase in hydration during the luteal-euhydrated group. However, the hypothesis that blood pressure would remain constant throughout each phase of the menstrual cycle was supported. Since there was no significant difference between MAP in any of the four phase-hydration groups, blood pressure was relatively constant due to an increase in plasma volume in the luteal phase, confirming work previously conducted (6).

A previous study by Stachenfeld et al. has shown that an increase in estrogen causes an increase of AVP to be released into the body, leading to an increase in water retention (5). However, Stachenfeld et al. has found evidence that the increased release of AVP has limited effects on the body's' overall water retention, leading to no significant difference between fluid levels throughout the menstrual cycle in another study (3). Therefore, while our hypothesis that there would be an increase in weight in correlation with an increase in water retention levels was not supported, we were able to support the Stachenfeld et al. outcome for overall body fluid retention. In conjunction, we hypothesized USG would decrease due to AVP being released at a lower blood plasma osmolarity, causing an increase in water retention (5). However, USG did not show a significant difference between phase-hydration groups. Since the body has been shown to increase in water retention during the luteal phase, there isn't an increase of water being excreted in the urine to cause a lower USG, therefore USG would remain constant.

Temperature has been found to increase in the luteal phase in a previous study using forearm blood flow (FBF) to study core temperature (6). However, no significant data was found in our study using rectal temperatures. Kolka and Stephenson's previous study found an increase in temperature because the temperature measurement being used was FBF (6). The increase in temperature can be explained by blood vessels vasodilating and coming closer to the skins' surface to cool the rest of the body. Therefore, FBF will show an increase in temperature, while rectal temperature will show no change. Also, the increase in water retention can also aid the body in cooling.

Throughout the luteal phase, estrogen and progesterone increase to cause various systemic effects, such as an increase in AVP and plasma volume discussed earlier (2, 3, & 6). Since estrogen is secreted in both the follicular and luteal phase, it is possible the difference between estrogen concentrations in each phase is negligible. However, progesterone is only secreted in the luteal phase, so a significant difference should be found between progesterone concentrations when comparing phase-hydrations groups, but there was not. These results could be explained by the participant pool being relatively small, as only ten individuals were included in data analysis. Subject 18 could also be a potential outlier due to markedly higher progesterone and estrogen levels than other participants. No tests were run to confirm or deny this information. Specific time points when measurements were taken could have also been misaligned, as menstrual cycles vary and calculations for time points were determined by a strict 28 day menstrual cycle.

Clearly, further studies are necessary to determine if hydration levels for females change in concurrence with the menstrual cycle. There needs to be studies with a larger participant pool and time points for data collection should be tailored to each individual to the best of the researcher's ability. Future studies could also include multiple ways to determine hormone levels and ensure readings are accurate. If further studies are conducted, results could be used to influence many practices and groups of women, such as the army, professional sports, and even women who are recreationally active.

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References

1. Sherman BM, Korenman SG. Hormonal Characteristics of the Human Menstrual Cycle throuhout Reproductive Life. The Journal of Clinical Investigation. 1975;55:699-706.

2. Owen Jr JA. Physiology of the menstrual cycle. The American Journal of Clinical Nutrition. 1975;28:333-8.

3. Stachenfeld NS, DiPietro L, Kokoszka CA, Silva C, Keefe DL, Nadel ER. Physiological variability of fluid-regulation hormones in young women. J Appl Physiol (1985). 1999 Mar;86(3):1092-6.

4. Oian P, Tollan A, Fadnes HO, Noddeland H, Maltau JM. Transcapillary fluid dynamics during the menstrual cycle. American journal of obstetrics and gynecology. 1987 Apr;156(4):952-5.

5. Stachenfeld NS. Sex hormone effects on body fluid regulation. Exerc Sport Sci Rev. 2008 Jul;36(3):152-9.

6. Stephenson MAKaLA. Effect of luteal phase elevation in core temperature on forearm blood flow during exercise. 1997.

7. Kolka MA, Stephenson LA. Resetting the thermoregulatory set-point by endogenous estradiol or progesterone in women. Ann N Y Acad Sci. 1997 Mar 15;813:204-6.

8. Forsling ML, Stromberg P, Akerlund M. Effect of ovarian steroids on vasopressin secretion. J Endocr. 1982;95:147-51.