# Evaluation of Menstrual Cycle Phase in Hydration Status Based on Urine Specific Gravity following Basketball Training

## 性周期からみたバスケットボールトレーニング後の尿比重値に基づく体内水和状態の評価


YASUDA, Nobuo
Department of Health Science,
International Pacific University, Okayama, Japan
安田　従生

HARA, Aya
Department of Physical Education,
International Pacific University, Okayama, Japan
原　　彩

KAWAI, Yohjiro
Department of Health Science,
International Pacific University, Okayama, Japan
河合洋二郎

IIDE, Kazuhide
Department of Health Science,
International Pacific University, Okayama, Japan
飯出　一秀

MATSUMURA, Tomohiro
Department of Health Science,
International Pacific University, Okayama, Japan
松村　智弘



**Abstract**：The purpose of this study was to elucidate the effects of the menstrual cycle phase on hydration status following exercise training. Nine eumenorrhoeic female basketball players (age: 20.1 ± 1.5 year, height: 165.7 ± 5.5 cm; body weight: 59.4 ± 5.5 kg; BMI: 21.6 ± 1.2 kg/$m^2$, body fat: 21.8 ± 2.1 %) served as the subjects. The basketball training consisted of routine ball handling, shooting and other specialized drills. Spot urine was collected within 10 minutes before (Pre) and after (Post) each training session during the follicular (F: 6～10 days after the onset of the menses) and luteal (L: 5～9 days before the menses) phase. For analysis of hydration status, urine specific gravity (USG) was determined with a handheld refractometer before (Pre) and after (Post) the training. Each training session lasted 3 hours. A two-way analysis of variance (ANOVA) showed a significant main effect for time (Pre=1.021 ± 0.006, Post=1.025 ± 0.004 for F; Pre=1.024 ± 0.009, Post=1.028 ± 0.004 for L, $p<0.05$) before and after the basketball training session, but no difference across phase in urine specific gravity (g/mL). These findings indicate that the menstrual cycle phase *per se* appears not to directly influence hydration status after exercise training.



**Keywords**：exercise intensity, estrogen, progesterone, steroid hormones, non-invasive method



**要約**：本研究は，卵胞期及び黄体期における運動トレーニング後の体内水和状態を検討することを目的とした。被検者は，環太平洋大学体育会に所属する女子バスケットボール部員９名であった（age：20.1 ± 1.5 year，height：165.7 ± 5.5 cm；body weight：59.4 ± 5.5 kg；BMI：21.6 ± 1.2 kg/$m^2$, body fat：21.8 ± 2.1 %）。バスケットボールトレーニングはボールハンドリング，シューティング及びその他の技術練習から構成された。それらの練習は，約３時間に及んだ。卵胞期及び黄体期における運動トレーニング前後で，脱水症状の指標となる尿比重値を測定した。二元配置分散分析により，バスケットボールの練習後で尿比重値は有意に増加し，軽度の脱水症状になることが判明したが（Pre=1.021 ± 0.006，Post=1.025

±0.004 for F；Pre=1.024±0.009，Post=1.028±0.004 for L，p<0.05），性周期による差はみられなかった。これらの結果から，卵胞期及び黄体期における運動トレーニング後の体内水和状態は類似していることが示唆された。

## INTRODUCTION

On the basis of the evidence that thermoregulation is influenced by menstrual conditions, fluid loss during exercise or heat stress appears to fluctuate at different stages of the menstrual cycle in healthy young women (Stephenson and Kolka, 1993). It is demonstrated that several steroid hormones have an effect on fluid and electrolyte balance, and many women experience fluid retention in the luteal phase of the menstrual cycle (Stephenson and Kolka, 1993). According to Fong and Kretsch (1993), disparity in 24 hour urine output over the cycle can be observed regardless of a constant food and fluid intake. These findings raise questions with regard to whether there is an acute effect of hormonal status on fluid balance in healthy premenopausal women.

Many studies have shown the effects of providing beverages of different compositions on fluid homeostasis and exercise performance during exercise (Coyle and Coggan, 1984; Lamb and Brodowicz, 1986; Maughan, 1991). However, the effects of menstrual cycle on hydration status after exercise still remain to be clarified. In this respect, estrogens or progesterone may have an influence on physiological responses concerning regulation of body fluids and sodium content, receptors for estrogens and progesterone are found in nonreproductive tissue associated with fluid regulation, such as the hypothalamus (Heritage et al., 1980; Sar and Stumpf, 1980), the cardiovascular system (Dubey and Jackson, 2001; Orshal and Khalil, 2004) and the kidney tubules (Dubey and Jackson, 2001). Furthermore, the influence of sex hormones on body fluid and sodium regulation has important implications for a number of syndromes in women, including orthostatic hypotension, insulin resistance, polycystic ovary syndrome, and neurological consequences from postoperative (Fraser and Arieff, 1997) and exercise-associated hyponatremia (Almond et al., 2005).

There are several methods for evaluating hydration status, which are: (i) urine specific gravity, (ii) urine conductivity, (iii) plasma or urine osmolarity, (iv) urine color, and (v) assessment of pre-exercise and post-exercise body mass (Armstrong et al., 1994). Although determination of plasma osmolality is referred to as the gold standard (Casa et al., 2000), more simple methods such as urine specific gravity can be practical in a field setting.

Taken together, whether or not an acute effect of sex steroid hormones on fluid balance over the menstrual cycle would be found after exercise-induced sweat loss is the key to understanding menstrual cycle-related physiological responses. Therefore, the purpose of this study was to clarify the effects of the menstrual cycle phase on hydration status following exercise training.

## METHODS

### *Subjects*

Nine healthy female collegiate basketball players completed this study. The physiological characteristics of the subjects are demonstrated in Table 1. All subjects had no major medical problems, a normal menstrual history and no intake of any steroid contraceptives at the time of the study. The

Table 1. Physical characteristics of the subjects (N=9)

| Variable | Mean±SD |
|---|---|
| Age (years) | 20.1±1.5 |
| Height (cm) | 165.7±5.5 |
| Body mass (kg) | 59.4±5.5 |
| BMI (kg/m$^2$) | 21.6±1.2 |
| Body fat (%) | 21.8±2.1 |
| Body surface area (m$^2$) | 1.656±0.100 |

All data are mean±SD.

experimental procedures were approved by the ethics committee of International Pacific University. Each subject provided their written consent before participating in this study.

### *Overall protocols*

No strenuous exercise was undertaken by the subjects before each experiment. Each subject undertook a total of two training sessions representing different stages of the menstrual cycle. All training sessions began in the midafternoon and the subjects were allowed to drink water *ad libitum* during each training session over the follicular and luteal phases. Each training session lasted 3 hours. Basketball training consisted of 5 min warm-up, 20 min ball handling, 30 min shooting, 30 min formation, 30 min defense and offense, 30 min game, 30 min shooting and 5 min cool-down, including a rest interspersed over the training (Figure 1A). Spot urine was collected within 10 minutes before (Pre) and after (Post) basketball training sessions during the follicular (F: 6~10 days after the onset of the menses) and luteal (L: 5~9 days before the menses) phase. Body weight and ratings of perceived exertions were also measured before and after all training sessions. During all experimental days, the wet-bulb globe temperature (WBGT) was measured with a WBGT-203A system (Kyoto Electronics Manufacturing Co., LTD., Kyoto, Japan) as the WBGT provides an index for comparing environmental heat stress across training sessions (Daanen et al., 2011).

### *Determination of Exercise Intensity*

In order to compare physiological effects of the menstrual cycle, heart rate was monitored over the training sessions. As a consequence, %HRmax was calculated which should be identical as exercise intensity during the two menstrual cycles.

All subjects performed an incremental cycling exercise until volitional exhaustion to obtain maximal heart rate (HRmax) on an electromagnetically braked cycle ergometer. Each subject performed a cycling exercise at an initial power output of 0 W for 3 minutes, which was increased by 25 W every 1 min until exhaustion. Pedaling frequency was 60 rpm. Heart rate was continuously measured using an electrocardiograph (Model BSM-2401, Nihon Kohden Corporation, Tokyo, Japan).

### *Quantification of Hydration Status*

In order to test hydration status over the menstrual cycle, urine specific gravity was assessed using a handheld refractometer (MASTER-URC/J$\alpha$). Distilled water was used to calibrate the refractometer before each use (Sherwood, 1999). While the instrument was in a horizontal position, a small drop of urine was placed on the prism, and the cover plate was placed over it. The scale seen in the eyepiece was focused, and the specific gravity was determined.

### *Statistical Analysis*

Overall data were analyzed by two-way (time × phase) analysis of variances (ANOVA) with repeated measures using STATISTICA version 5.0 for Windows. Significant differences for any dependent variable were accepted when a P value of less than 0.05 was obtained. Pearson's product-moment correlation coefficient was also determined if there was a linear relationship between RPE and USG. All data were expressed as mean ± SD.

## RESULTS

During each exercise training session over the menstrual cycle, the WBGT ranged from 28.3℃ to 29.5℃, and the thermal stress was classified as "very high risk" represented by a WBGT of >28℃ (Daanen et al., 2011). No significant differences were observed in water intake between the two menstrual cycles. A total volume of water intake *ad libitum* ranged from 550 to 1400 mL/3h after each training during the two menstrual cycles. Regarding exercise intensity, average %HRmax was identical between follicular and luteal phases (Figure 1B).

In terms of body weight (kg) and urine specific gravity (g/mL), a two-way analysis of variances (ANOVA) showed significant main effects for time (Figure 2A and 2B) before and after the basketball training session, whereas no significant main effects for phase or interactions were observed (Figure 2A and 2B). The results of RPE also demonstrated a similar pattern (Figure 3A). Moreover, linear regression analysis of the present data revealed no significant correlations between USG and RPE (Figure 3B).

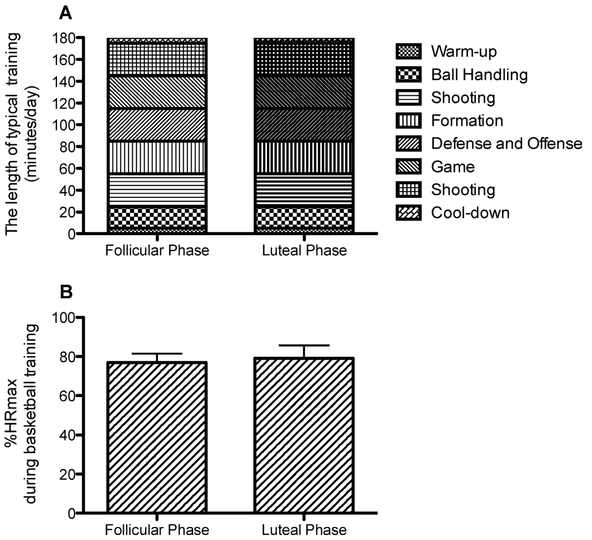


Figure 1. The length of daily practice (A) and average %HRmax (B) during basketball training over the menstrual cycle.

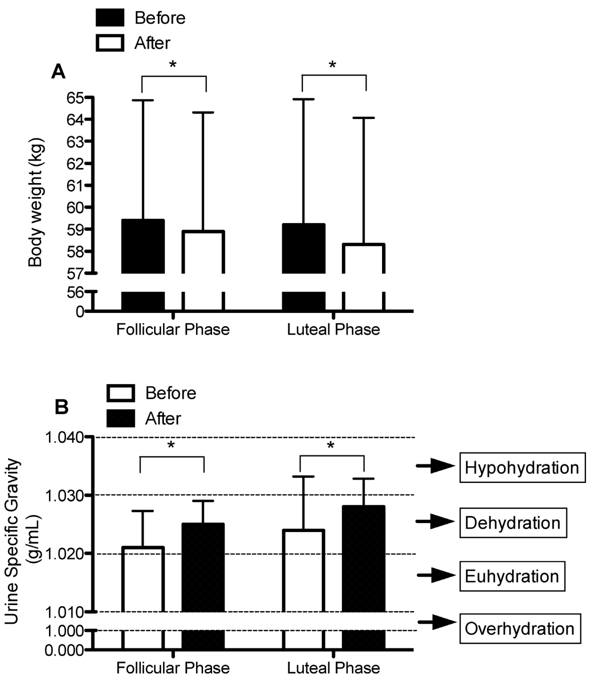


Figure 2. Changes in body weight (A) and urine specific gravity (B) during the training Session at the follicular and luteal phase.

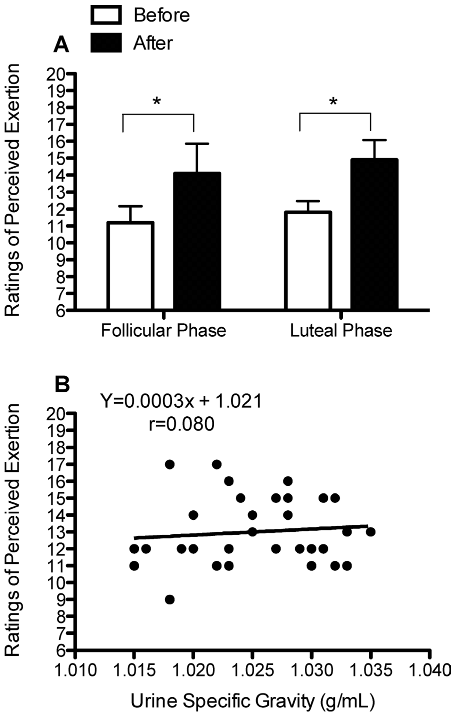


Figure 3. Ratings of perceived exertion (A) and relation between ratings of perceived exertion and urine specific gravity (B).

## DISCUSSION

The primary finding of the present study is that the menstrual cycle *per se* did not directly have an influence on hydration status following exercise training although there was a tendency for female athletes to be in a modest dehydration state after exercise training. These results may provide important messages for female athletes regarding optimal fluid intake pattern during exercise.

Although the number of subjects in the present study was relatively smaller, each subject had a regular menstrual cycle. In this respect, many athletes who engaged in rigorous exercise training experience disturbances of hormonal status leading to amenorrhoea or oligomenorrhoea (Maughan et al., 1996). In the present study, there was a modest level of dehydration even when each subject took water fluid *ad libitum* during exercise. One reason for this is that the athletes did not have sufficient electrolytes such as sodium (which retains water in the body) even when they took a plenty of water during exercise training. Another reason is that altered hydrostatic and osmotic forces result in movement of water from the vascular space to the interstitial spaces of the exercising muscles during exercise (Harrison, 1985). Conversely, the data of the present study showed that hydration status based on urine specific gravity in the follicular phase was similar to that of the luteal phase, which is in line with the previous results (Maughan et al., 1996; Volpe et al., 2009). However, there is further evidence that water retention and associated body mass increases in relation to the luteal phase of the menstrual cycle (Greene and Dalton, 1953; Sweeney, 1934). According to Briggs et al. (1990), the retention of water and accompanying electrolytes may partly be due to the effects of estrogens with increased contribution of vasopressin secretion (Forsling et al., 1982). In addition, an augmented storage of muscle glycogen in the mid-luteal phase in healthy women taking their normal diet has been reported (Hackney, 1990), which leads to the effect of retaining more water (McBride et al., 1941; Olsson and Saltin, 1970). In the present study, measurement of body weight on experimental days showed similarity at different menstrual cycle stages while the reduction of body weight was observed after exercise, indicating that no fluid retention during the luteal phase was found in the subjects.

Previous studies have demonstrated that core temperature is increased in the luteal phase of the menstrual cycle (Kleitman and Ramsaroop, 1947; Rothchild and Barnes, 1952) and the onset of sweating occurs at a higher core temperature during this phase of the menstrual cycle compared to the follicular phase in women regularly having a menstrual cycle (Bittel and Henane, 1975; Haslag and Herztman, 1965; Hessemer and Bruck, 1985a, 1985b). In contrast, Sargent and Weinman (1966) have shown no discrepancies over the menstrual cycle in eccrine sweat gland activity concerning the latent period of reflex sweating, sweat rate, the number of active sweat glands and the gland flow. Taking into account those evidences, all trials should begin at approximately the same time of day in order to allow menstrual cycle stage comparisons rather than diurnal fluctuations. For instance, circadian fluctuations in body temperature with mean core temperature is approximately 0.4℃ lower in the early morning than in the mid-afternoon (Kolka and Stephenson, 1989). In the present study, all experiments began in the midafternoon and as a consequent, the present study demonstrated no differences in hydration status with different phases of the menstrual cycle. However, urine specific gravity or plasma osmolarity needs to be compared within the same athletes at different times in their menstrual cycles in order to confirm hydration status induced by the menstrual cycle phase.

In conclusion, the findings of present study suggest that hydration status following exercise training appears not to directly be affected by the menstrual cycle in trained eumenorrheic young women.

## ACKNOWLEDGEMENT

We are grateful to Drs. Elisa I. Glover and Christian Burrows for their productive comments in this manuscript.

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