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Monitoring Body Water Balance in Pregnant and Nursing Women: The Validity of Urine Color

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Keywords

Fluid intake · Hydration status · Biomarker · Pregnancy · Lactation · Urine · Osmolality · Concentration

Abstract

Background: Urine osmolality (U_{OSM}) reflects the renal regulation of excess fluid or deficit fluid, and therefore, serves as a marker of hydration status. Little is known about monitoring hydration in pregnant and lactating women despite significant physiological challenges to body water balance during that time. Therefore, we designed a study to assess if urine color (U_{COL}), an inexpensive and practical method, was a valid means of assessing urine concentration. Twenty-four hour U_{COL} was significantly correlated with 24 h U_{OSM} in all women: pregnant, lactating, and control ($r = 0.61–0.84$, all $p < 0.001$). Utilizing a receiver operating characteristic statistical analysis, we found that 24 h and single sample U_{COL} had excellent diagnostic accuracy for identifying U_{OSM} ≥500 mOsm·kg^{-1} in all women (area under the curve = 0.68–0.95, $p < 0.001–0.46$), and the U_{COL} that reflected this cut off was ≥4 on the U_{COL} chart. ***Summary:*** Therefore, U_{COL} is a valid marker of urine concentration and ultimately hydration status in pregnant, lactating, and non-pregnant, non-lactating women. For pregnant, lactating, and control women, the U_{COL} chart is a valid tool that can be used to monitor urine concentration in a single sample or over the course of the day via a 24 h sample. ***Key Message:*** Women who present with a U_{COL} of 4 or more likely have a U_{OSM} ≥500 mOsm·kg^{-1}. Given the positive health benefits associated with U_{OSM} <500 mOsm·kg^{-1}, women should aim for a 1, 2, or 3 on the U_{COL} chart. If a U_{COL} of ≥4 is observed, women should consider increasing fluid consumption to improve hydration status.

The Importance of Monitoring Body Water Balance during Pregnancy and Nursing

Water is essential for life and it plays a key role in maintaining the metabolic activities of the body through its contribution to cell volume homeostasis. Changes in cell volume have important implications for trafficking of nutrients and waste, while also affecting cellular metabolism and gene expression [1]. The largest source of water intake each day is obtained from the fluids we drink [2], and consuming inadequate fluid volumes for the body's

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needs results in lower water turnover through the kidneys and higher urine concentrations [3]. These characteristics of low fluid intake, low urine volume, and high urine concentration have been associated with negative health consequences, including chronic kidney disease [4], increased rate of decline in kidney function [5], constipation [6], and poor glucose homeostasis [7, 8]. Further, increased water intake for maintaining low urine concentration has been recommended for the treatment or prevention of constipation [9, 10], urolithiasis [11], and nephrolithiasis [12].

While adequacy of water intake seems important for the health of the general person, it is especially important during pregnancy and lactation, considering the challenges to fluid homeostasis and the watery environment in which the fetus develops. As early as the sixth week of gestation, the total blood volume expands and cardiac output increases [13]. Concurrently, the renal system increases the glomerular filtration rate, while maintaining a balance of natriuretic and anti-natriuretic factors to retain sodium and water levels throughout pregnancy [14]. This water retention is necessary for the development and maintenance of amniotic fluid and other components of gestation [13]. Following gestation, the need for additional fluid continuing as fluid balance is challenged during nursing. Nursing mothers lose an additional ~700 mL water per day via breast milk at 8 weeks postpartum [15]. Breast milk volume is defended across a wide range of fluid intakes; however, at lower total fluid intakes, nursing women consuming the same amount of fluid as non-lactating women, with slightly higher urine concentrations, demonstrate the additional challenge to fluid balance and importance of adequate fluid intake for nursing mothers [16].

Monitoring Hydration Status

Reference total water intakes range from about 2–2.8 L per day for women who are not pregnant or nursing; these values increase by 300 mL per day during pregnancy [2, 17–19]. However, these reference values are often based on population average or median intakes. In contrast, formulating a personalized assessment of hydration status for each woman, based on her unique fluid challenges and water needs, is therefore sensible. Women gain water from food, metabolism, and by consuming fluids; they experience water losses mostly through urine excretion, but also lose water through skin, respiration, feces, and sweat [20]. However, in the case of nursing women, an additional 400–800 mL of water is lost each day through breast milk [15].

Urine osmolality (U_{OSM}) has been described as a marker that reflects the renal regulation of fluid excess or deficit [21], and therefore, is a marker of hydration status and water turnover. The 24 h U_{OSM} can also serve as an index for adequate water intake from a physiological and health perspective [22]. Twenty-four hour U_{OSM} lower than approximately 500 mOsm·kg^{-1} have been associated with positive health outcomes such as lower incidence of kidney stones and prevention of recurrent stones [22]. Physiologically, higher U_{OSM} and lower fluid intakes are associated with a higher plasma concentration of the fluid-regulating hormone vasopressin, as well as its more stable surrogate marker, copeptin. In pregnant women, high plasma copeptin concentration has been associated with pre-eclampsia [23]. Additionally, increased fluid consumption is indicated in the presence of oligohydramnios for the purpose of increasing amniotic fluid volume [24], as well as for the alleviation of constipation during pregnancy [9, 10]. Thus, maintaining an adequate fluid intake with a lower urine concentration appears to be the right thing to do during pregnancy and while nursing.

Using Urine Color to Monitor the Hydration Status of Pregnant and Nursing Women

Previous research has tracked urinary markers of body water balance during pregnancy and the postpartum period but without consideration of total fluid intake, experimental controls, or comparison to non-pregnant and non-nursing women [25]. Therefore, we designed a study to assess whether urine color (U_{COL}), an inexpensive and practical tool, was a valid means of assessing urine concentration, and thus a valid means of monitoring body water balance [26].

The University of Connecticut Institutional Review Board approved this study, and all participants provided voluntary informed consent to participate. Eighteen pregnant women (age: 31 ± 3 years, height: 165.5 ± 6.7 cm, body mass: 66.89 ± 19.24 kg) were pair-matched to 18 control women (age: 29 ± 4 years, height: 163.7 ± 8.29 cm, body mass: 64.83 ± 13.84 kg) and were enrolled in the study. These characteristics were similar between groups at the end of the first trimester and again at 3 ± 1 weeks

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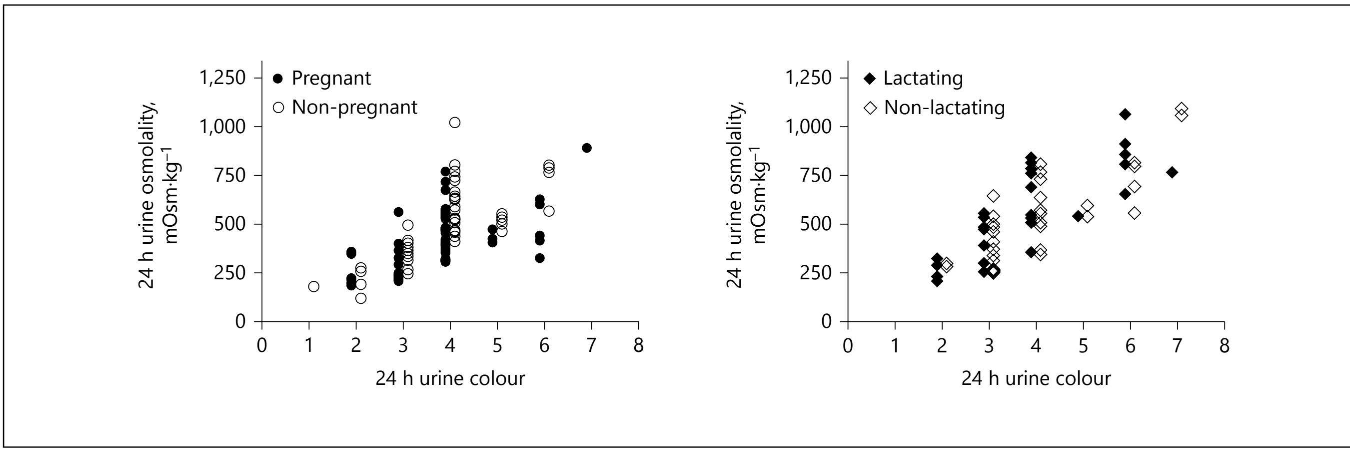

Fig. 1. Relationships of 24 h U_{COL} to 24 h U_{OSM} during pregnancy and lactation. Individual data points represent 24 h U_{COL} and 24 h U_{OSM} for pregnant (visits 1–3 pooled, $r = 0.6085$, $p < 0.0001$), non-pregnant (visits 1–3 pooled, $r = 0.7826$, $p < 0.0001$), lactating (visits 4–5 pooled, $r = 0.8390$, $p < 0.0001$), and non-lactating women (visits 4–5 pooled, $r = 0.7736$, $p < 0.0001$). Reprinted from McKenzie et al. [26].

postpartum during lactation, compared to women who were not lactating (all $p > 0.05$).

Data were collected from pregnant women at the end of the first, second, and third trimesters and at 3 ± 1 and 9 ± 1 weeks postpartum. Control women were taking a combination drug oral contraceptive; data was collected only during the early follicular phase of the menstrual cycle and observed at similar time intervals to the pregnant/lactating participants. On the day of each observation, women collected a 24 h urine sample, plus all individual single samples from any overnight voids following a 200 mL water bolus before going to sleep. Osmolality (via freezing point depression osmometry), specific gravity (U_{SG}; via refractometer), and color (via a previously published U_{COL} scale [27] ranging from 1 to 8, lightest to darkest) were assessed in each of these samples.

Using these biomarkers, we assessed the validity of U_{COL} in 2 ways. The first aim was to evaluate the relationship between 24 h U_{COL} and other markers of hydration, 24 h U_{OSM} and 24 h U_{SG}. Twenty-four hour U_{COL} was significantly correlated with 24 h U_{OSM}, the gold standard for evaluating urine concentration, in all women: pregnant, lactating, and control (Fig. 1; $r = 0.61–0.84$, all $p < 0.001$). Twenty-four hour U_{COL} was also significantly correlated with 24 h U_{SG} in all women ($r = 0.62–0.89$, all $p < 0.001$).

The second aim was to determine whether U_{COL} in 24 h and single samples could accurately determine whether U_{OSM} was greater than or equal to the 500 mOsm·kg^{-1} threshold associated with less desirable health outcomes. Utilizing a receiver operating characteristic statistical analysis, we found that 24 h U_{COL} had excellent diagnostic accuracy for identifying U_{OSM} ≥500 mOsm·kg^{-1} in all women (area under the curve = 0.68–0.95, $p < 0.001–0.46$) and the U_{COL} that reflected this cut off was ≥4 on the U_{COL} chart. When choosing the best criterion value for the test, a tradeoff between sensitivity and specificity between the 4 and 5, respectively, was present (Table 1). A criterion value of 4 provided a more sensitive cut off, identifying as many of the samples with U_{OSM} ≥500 mOsm·kg^{-1} as possible. A criterion value of 5 was more specific, resulting in very few false positives (i.e., a U_{COL} of 5 or higher that is actually <500 mOsm·kg^{-1}).

While 24 h urine collection is the gold standard for assessing the 24 h fluid balance, collecting 24 h samples repeatedly in order to monitor body water balance can be impractical. Further, a woman may want to try out a change in fluid consumption throughout the day based on the color of each individual sample. Here, we evaluated the diagnostic accuracy of individual samples and found that single samples also accurately identified U_{OSM} ≥500 mOsm·kg^{-1} with excellent accuracy and sensitivity (Table 1). Figure 2 depicts the relationship between single-sample U_{OSM} and single-sample U_{COL}. Given the high sensitivity of the test, we can confidently rule out U_{OSM} ≥500 mOsm·kg^{-1} when U_{COL} of 1, 2, or 3 is observed. Given the importance of water balance during pregnancy, it appears prudent to choose the criterion value with higher sensitivity than specificity.

Table 1. Results of the receiver operating characteristic statistical analyses

Group	AUC	SE	*p* value	Criterion value	Sensitivity	Specificity
Diagnostic accuracy of U_{COL} to identify U_{OSM} ≥500 mOsm·kg^{-1} in 24 h samples						
Pregnant	0.685	0.077	0.046	4	0.92	0.41
				5	0.23	0.85
Lactating	0.951	0.036	<0.0001	4	0.91	0.93
				5	0.36	1.0
Control	0.911	0.031	<0.0001	4	0.96	0.80
				5	0.38	0.98
Diagnostic accuracy of U_{COL} to identify U_{OSM} ≥500 mOsm·kg^{-1} in single samples						
Pregnant	0.919	0.019	<0.0001	4	0.98	0.70
				5	0.65	0.93
Lactating	0.922	0.024	<0.0001	4	0.90	0.78
				5	0.52	1.0
Control	0.909	0.021	<0.0001	4	0.86	0.88
				5	0.50	0.96

Modified from McKenzie et al. [26].

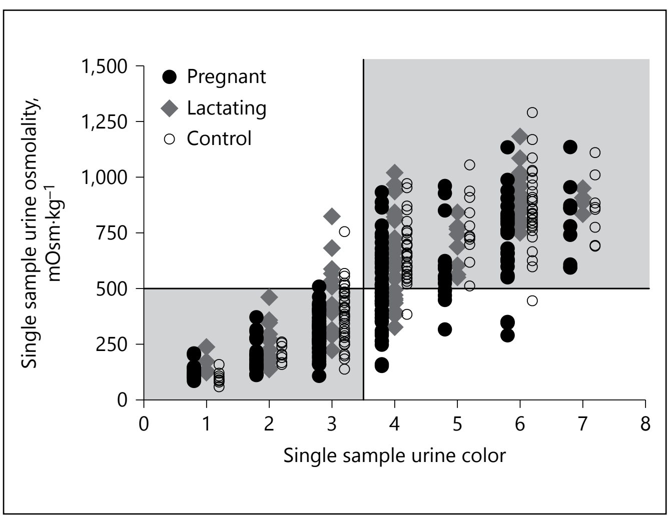

Fig. 2. Contingency plots for U_{COL} and U_{OSM} in single samples. Vertical line represents the U_{COL} ≥4 criterion value determined by the receiver operating characteristic curve analysis to identify U_{OSM} ≥500 mOsm·kg^{-1} (horizontal line). Modified from McKenzie et al. [26].

Considering all of the aforementioned analyses, we conclude that U_{COL} is a valid marker of urine concentration and ultimately of body water balance in pregnant, lactating, and non-pregnant, non-lactating women because it was significantly correlated with other markers of hydration status such as U_{OSM} and U_{SG}. For pregnant, lactating, and control women, the U_{COL} chart is a valid tool that can be used to monitor urine concentration in a single sample, or across the entire day through a 24 h sample.

Women who present with a U_{COL} of 4 or more likely have a U_{OSM} ≥500 mOsm·kg^{-1}. Given the positive health benefits associated with U_{OSM} under that threshold (see above), women should aim for a 1, 2, or 3 on the U_{COL} chart. If a U_{COL} of ≥4 is observed, women should consider increasing fluid consumption to improve hydration status.

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Disclosure Statement

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