The void in using urine concentration to assess population fluid intake adequacy or hydration status1,2

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ABSTRACT

Urine concentration can be used to assess fluid intake adequacy or to diagnose dehydration. However, too often urine concentration is used inappropriately to draw dubious conclusions that could have harmful health and economic consequences. Inappropriate uses of urine concentration relate primarily to convenience sampling (timing) and problems related to convenience sampling (misapplication of thresholds), but a conceptual problem also exists with using urine concentration in isolation. The purpose of this Perspective article is to briefly explain the problematic nature of current practices and to offer a possible solution to improve practice with minimal added complication.

When urine is used exclusively to assess fluid intake adequacy and hydration status in adults, we propose that only when urine concentration is high (>850 mmol/kg) and urine excretion rate is low (<850 mL/24 h) should suspicion of inadequate drinking or impending dehydration be considered. Prospective tests of the 850×850 thresholds will provide supporting evidence and/or help refine the best thresholds for men and women, young and old. Am J Clin Nutr 2016;104:553–6.

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BACKGROUND

Urine concentration is under the dynamic influence of fluid regulatory hormones, diet (food and fluid), and metabolism. The osmolality, specific gravity, and color of urine are commonly used to quantify its concentration, although osmolality is most tell-tale of osmotic balance and renal function (1, 2). The renal capacity to dilute and concentrate urine creates a wide possible range in osmolality (>1000 mmol/kg) (Figure 1) (3, 4) that is considered normal in healthy, free-living people (2). Spot- or spontaneously voided urine samples are most variable (5–7) because of the acute influences that fluid intake, activity, and other factors have on glomerular filtration and/or tubular re-absorption of water (8). It is even possible for a spontaneous void to appear quite dilute in response to fluid intake (9, 10), despite the presence of experimental dehydration (11). For this reason, the uniformity of first morning urine voids is preferred for clinical urinalysis interpretations, and first morning voids are commonly used for establishing dehydration thresholds (12, 13). The 24-h urine concentration generally increases or decreases with high and low fluid intakes and increases in response to a body-water deficit (i.e., dehydration) (14, 15). Importantly, 24-h urine also provides for an assessment of urine volume. The convenient, noninvasive, and easily quantified (e.g., specific gravity) nature of urine collection and analysis makes urine concentration a field-expedient measurement to assess fluid intake or hydration status (i.e., dehydration) in large populations (16); however, methodology matters.

Fluid intake adequacy can be dually defined as a volume of fluid adequate to balance the renal solute load (diet and metabolism) and replace total body–water losses (perspiration, respiration, urine, feces) (3). As mentioned above, the renal capacity to dilute and concentrate urine makes wide-ranging fluid intakes compatible with adequacy according to the first part of our definition; therefore, inadequacy of fluid intake is better assessed definitively by a failure to match intake to output (3). Urine concentration thresholds reported for dehydration range from 586 to 1052 mmol/kg (osmolality), 1.02 to 1.03 (specific gravity), and 5.5 to 7.0 (color) (17–20). These relatively wide ranges are a function of both biological variation and experimental research design, as well as the desired a priori level of diagnostic confidence for decision making. Many of these thresholds overlap those of normal spontaneous urine voids or 24-h urine volume concentrations (4–7, 10) because it is ultimately the ratio of water to total solids in urine that determines concentration, regardless of whether the specimen is obtained under conditions of renal water retention or renal solute excretion (21). For this reason,
concentrated urine may or may not alone reflect inadequate fluid intake (or dehydration).

PROBLEMS

The NHANES urinalysis procedures for epidemiologic studies may include spontaneous, first morning, or 24-h void samples, depending on the purpose for urine sampling and whether data are obtained by mobile research laboratory or home collection methods (22). When the desire is to use urine concentration to assess the hydration status of a population, the convenience of spontaneous urine void collection is an attractive option (16). Unfortunately, a spontaneous void or spot measure is the most variable of urine concentration methods (5–7) and should not be used for this purpose (12). Assessing hydration status via spot-measured collections and comparing with uniform, first morning urine concentration thresholds is an inappropriate and erroneous practice that should be curtailed (12). First morning voids are preferred for hydration testing given the protracted overnight period of abstention from activity, eating, and drinking, which influence renal function (13). However, a circadian rise in nocturnal arginine vasopressin (AVP), which is normal, produces a rise in urine concentration that is reciprocal to the urine production rate; thus, first morning urine samples are more concentrated than daytime measures (10, 23). The first morning concentration may therefore be near or slightly above commonly reported dehydration thresholds. As a consequence, the first morning void may potentially give the wrong impression about hydration state also. Twenty-four-hour urine collection provides the best composite picture of water and solute balance, but it is often viewed as the most impractical and error prone (16). Figure 1 illustrates the ranges of possible 24-h urine concentrations and urine volumes and underscores the important roles that diet and metabolism play in conjunction with fluid intake to produce any given urine concentration. Clearly, small volumes of dilute urine and large volumes of concentrated urine are possible and defy interpretation toward hydration assessment when viewed in isolation. For this reason, >1 measure of hydration status (e.g., body mass change, blood, urine) has long been recommended to provide greater confidence for diagnosing dehydration (or fluid intake inadequacy) in both clinical and sports medicine (24–26).

SOLUTIONS

First morning and 24-h urine osmolality thresholds related to dehydration or inadequate fluid intake are often referenced between 800 and 900 mmol/kg (15, 19, 20, 27), but as stated earlier, this range may also be perfectly normal (2). Dehydration urine volumes are not generally reported, but may be defined as excretion rates < 30 mL/h (13, 28). Urine excretion rates can increase to >700 mL/h in response to large oral fluid overload (29), but in moderately fluid-overloaded volunteers infused with AVP, urine excretion rates decreased no lower than 35–55 mL/h and urine osmolality did not exceed ~850 mmol/kg (30, 31). Andersen et al. (30) concluded that these values could be interpreted as the approximate limits of the renal concentrating capacity during fluid overload. Although the phenomenon of AVP escape due to vascular fluid expansion will contribute to these observations (32), it remains plausible that the concentration and excretion limits identified by these studies also approximate the normal boundaries of renal actions independent of dehydration. With significant knowledge of approximate urine concentration thresholds for dehydration already in hand, our goal was to identify a threshold excretion rate that could be combined with concentration to better diagnose a true state of dehydration or inadequate fluid intake in a population.

Figure 2 illustrates the relation between dehydration as a percentage of body mass (y axis) and 24-h urine volumes (x axis) expressed as an excretion rate (mL/h). Data (n = 58) are from 5 studies (33–37) that use fluid restriction while measuring 24-h urine volumes and body mass losses. A power curve was fit to the data (y = a × x^b) by using 1/y^2 weighting to account for the relative sums of squares influence on goodness-of-fit parameters (38). The equation describing the line on the graph indicates that urine excretion rates of 20–30 mL/h (480–720 mL/24 h) are consistent with dehydration from –1.2% to –3.2% of body mass. This excretion rate is likewise consistent with a long-recognized

FIGURE 1 Interrelation of 24-h urine volume (L), urine osmolality (mmol/kg), and RSL (mmol). When extra-renal water losses are small, the minimum 24-h water intake may be approximated by 24-h urine volume (1:1). Therefore, 24-h urine osmolality may be seen to covary with fluid intake and RSL (metabolism, diet). RSL, renal solute load. Reproduced from reference 3 with permission.

FIGURE 2 Relation between dehydration (% body mass) and 24-h urine volume expressed as an excretion rate (mL/h). Data are from 5 studies (33–37) of fluid restriction. Ten of 58 data points represent group average data (closed circles) (34, 37), whereas the remainder are individual observations (open circles). Data are analyzed by power curve analysis (y = a × x^b) by using 1/y^2 weighting.
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critical 24-h urine volume below which urine concentration cannot increase further (500–700 mL/24 h) (28). In every case in which excretion rates were <30 mL/h (<720 mL/24 h), urine osmolality (35, 37) or urine specific gravity (33, 35, 36) was above thresholds commonly reported for dehydration. A urine excretion rate of 35 mL/h (840 mL/24 h) was associated with only ~0.81% dehydration, which is within the realm of normal daily body water flux (~1% body mass) (39).

As an analytic check of the power curve interpretation, a receiver operating characteristic analysis was performed by using both 1% (26 control and 32 treatment) and 2% (34 control and 24 treatment) dehydration body-weight losses as criterion values. In both cases, the urine excretion rate cutoff providing the highest combined sensitivity and specificity for the diagnosis of dehydration was 33 mL/h (82% accuracy for 2% dehydration, 89% accuracy for 1% dehydration), which fell directly between values of 30 mL/h (dehydrated) and 35 mL/h (euthydrated) by using the power curve approach. The entire spectrum of sensitivity and specificity yielded a high area under the receiver operating characteristic curve ranging from 0.84 (2% dehydration) to 0.92 (1% dehydration) (40). All curve analyses were performed with the use of GraphPad Prism 5.0 (GraphPad Software, Inc.)

Where convenience is concerned, urine specific gravity is preferred to urine osmolality for population testing (16). A urine osmolality of ~850 mmol/kg is approximately equal to a urine specific gravity of ~1.021 (41), which is also a commonly used threshold for dehydration (26). However, it must be remembered that the renal concentrating process depends on an osmotic gradient (osmolality) and not particle mass (specific gravity); thus, urine osmolality can range widely at one particular urine specific gravity. For example, Jacobson et al. (1) reported that urine osmolality ranged from 720 to 914 mmol/kg when urine specific gravity was 1.020. A urine specific gravity of 1.025 was associated with a urine osmolality range from 925 to 1167 mmol/kg. Therefore, if urine specific gravity is used for population hydration assessment, a dehydration cutoff of ~1.025 may provide greater test specificity (1, 18, 19, 42).

APPLICATIONS AND RECOMMENDATIONS

When urine is used exclusively to assess fluid intake adequacy and hydration status in adults, we propose the necessity for dual conservative thresholds of concentration (~850 mmol/kg) and excretion rate (~<35 mL/h or ~<850 mL/24 h) as a more definitive approach. The value of using the combined and easy-to-recall 850 × 850 urine concentration and urine excretion rate thresholds may be in providing a solution for stronger 24-h and first morning hydration assessment. It may even provide a means of legitimate spot urine sampling for hydration assessment; however, stable conditions (i.e., dietary and exercise practices) remain critically important.

In situations in which 24-h urine volume and concentration are measured, simply apply the above thresholds. A first morning void will be higher in concentration and lower in excretion rate (10), but it should not exceed the combined 850 × 850 thresholds suggested unless perhaps sleep is very protracted (1). For a first morning void measurement only, simply capture the entire void volume and ask how many hours intervened between the first morning void and the void immediately preceding it. Measure the concentration and volume, and calculate the hourly excretion rate. A similar procedure could also be performed for spontaneous voids. Ask volunteers to empty their bladders completely and avoid food, drink, and exercise for a period of several hours (e.g., 4 h) (12). Then, collect the entire volume of their next void and approach the same way as for first morning samples. Only when urine concentration is high and urine excretion rate is low, relative to the thresholds reported herein, should suspicion of inadequate drinking or impending dehydration be considered. Prospective tests of the 850 × 850 thresholds will provide supporting evidence and/or help refine the best thresholds for men and women, young and old.

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