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SHORT COMMUNICATION

Criterion values for urine-specific gravity and urine color representing adequate water intake in healthy adults

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Growing evidence suggests a distinction between water intake necessary for maintaining a euhydrated state, and water intake considered to be adequate from a perspective of long-term health. Previously, we have proposed that maintaining a 24-h urine osmolality (U_{Osm}) of $\leqslant$500 mOsm/kg is a desirable target for urine concentration to ensure sufficient urinary output to reduce renal health risk and circulating vasopressin. In clinical practice and field monitoring, the measurement of U_{Osm} is not practical. In this analysis, we calculate criterion values for urine-specific gravity (U_{SG}) and urine color (U_{Col}), two measures which have broad applicability in clinical and field settings. A receiver operating characteristic curve analysis performed on 817 urine samples demonstrates that a U_{SG} $\geqslant$1.013 detects U_{Osm} >500 mOsm/kg with very high accuracy (AUC 0.984), whereas a subject-assessed U_{Col} $\geqslant$4 offers high sensitivity and moderate specificity (AUC 0.831) for detecting U_{Osm} >500 m Osm/kg.

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INTRODUCTION

Water is essential to life, represents the largest single nutrient in terms of intake, and must be replenished daily through food and fluid consumption. Adequate intakes have been established based upon population median data. However, adequate intakes are not linked to specific health outcomes, and daily water needs are highly individual and depend upon environment, activity, diet and other factors. Thus, a dietary reference value for the general population is unlikely to have much relevance for the individual. Various biomarkers of urine concentration allow for individual-level daily hydration monitoring. Specifically, urine osmolality (U_{Osm}) is the most precise, non-invasive biomarker available to evaluate the 24-h hydration process, as it represents the net sum of water gains, losses and neuroendocrine responses that act to maintain body water homeostasis, and responds rapidly to changes in daily water intake.[1,2] Recently, we proposed a 24-h U_{Osm} of $\leqslant$500 mOsm/kg as a reasonable target for urine concentration, reflecting sufficient total water intake to compensate daily losses, reduce circulating vasopressin and ensure sufficient urinary output to reduce the risk of some renal health outcomes.[3] However, one limitation to a target based upon U_{Osm} is that it is not easily measured day to day; moreover, clinicians, coaches and dietitians lack the possibility to measure U_{Osm} within their practices or in the field, limiting its utility as a hydration monitoring tool for the larger population. Two alternate methods for measuring urine concentration with greater clinical and field applicability are urine-specific gravity (U_{SG}), which can easily be measured by clinicians, and urine color (U_{Col}), which may be self-assessed. To date, no criterion values for U_{SG} nor U_{Col}, corresponding to a U_{Osm} of 500 mOsm/kg, have been published. Thus, the objective of this analysis was to calculate the criterion values for U_{SG} and subject-assessed U_{Col}, which would have the best diagnostic accuracy for identifying U_{Osm} >500 mOsm/kg.

METHODS

Eighty-two healthy French adults (23.6 ± 2.9 years; 22.2 ± 1.5 kg/m^2; 41 women) provided informed consent (CPP Est-III, Nancy, France) and collected all individual voids produced over 1–4 consecutive days as part of a larger study (NCT02044679). On collection days, subjects woke up before 0700 hours, voided and discarded this first morning sample. Subsequent voids were collected in individual, clear plastic containers, including the first morning void of the following morning at 0700 hours. For each void, participants self-evaluated U_{Col} using Armstrong *et al.*'s color scale, under consistent lighting conditions.[4] Once samples were returned to the laboratory, U_{SG} (Pen Urine S.G.; Atago, Japan) and U_{Osm} (Advanced Model 2020 Multi-Sample Osmometer; Advanced Instruments, Inc., Norwood, MA, USA) were measured.

Logistic regression curves were generated with U_{SG} and U_{Col} as predictor variables, and U_{Osm} as a binary outcome variable, with U_{Osm} >500 mOsm/kg defined as 'condition present', and U_{Osm} $\leqslant$500 mOsm/kg as 'condition absent'. The optimal cutoffs for U_{SG} and U_{Col} for identifying U_{Osm} >500 mOsm/kg were determined by receiver operating characteristic (ROC) curve analysis. We were equally interested in evaluating sensitivity (if U_{Osm} is >500 mOsm/kg, how often will U_{SG}, U_{Col} be at or above the cutoff values?) and specificity (if U_{Osm} is $\leqslant$500 mOsm/kg, how often will U_{SG}, U_{Col} be below the cutoff values?); thus, our analysis favored neither sensitivity nor specificity.

RESULTS

A total of 817 urine samples were analyzed for U_{Osm} and U_{SG}. One sample had a missing value for U_{Col} (816 samples). The mean (5th; 95th percentile) for U_{Osm}, U_{SG} and U_{Col}, respectively, were 436 (192; 938) mOsm/kg, 1.012 (1.003; 1.025) and 4 (1; 7). The ROC analysis revealed the optimal U_{SG} cutoff for identifying U_{Osm} >500 mOsm/kg was 1.013 (AUC 0.984), whereas the cutoff for U_{Col} was 4 (AUC 0.831) (Figure 1). A U_{SG} of $\geqslant$1.013 offered very

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high sensitivity and high specificity; whereas a U_{Col} of $\geqslant 4$ had good sensitivity and moderate specificity (Table 1).

DISCUSSION

Insufficient water intake or low urinary output has been associated with health outcomes, including recurrent kidney stones, increased risk of renal insufficiency and impaired glucose regulation.[5–7] A U_{Osm} of less than 500 mOsm/kg has been proposed as a reasonable target for 'optimal hydration',[3] but U_{Osm} is not a practical field measure and to date, no corresponding values for U_{SG} nor U_{Col} have been published. In this analysis, we demonstrate that both U_{Col} and U_{SG} may be used as surrogates for U_{Osm} to identify individuals above or below the 500 mOsm/kg target. U_{SG} is both sensitive and specific, suggesting its utility for health care professionals and clinicians within their daily practice. Subject-assessed U_{Col} demonstrated good sensitivity and moderate specificity. To our knowledge, this is the first subject-self-assessment of U_{Col} by healthy adults, confirming U_{Col} as a practical field measure with utility in day-to-day individual hydration monitoring.

These findings confirm and build upon recent work by McKenzie *et al.*,[8] who validated a U_{Col} of 4 or greater as a practical field measure for detecting $U_{Osm} > 500$ mOsm/kg in pregnant and breastfeeding women. Moreover, our U_{SG} and U_{Col} criterion values for detecting $U_{Osm} > 500$ mOsm/kg (1.013 or higher, and 4 or higher, respectively) are similar to those first published by Armstrong *et al.*, who reported that in a sample of young, mostly male college students, for a sample with U_{Col} of 3 or lower, the respective mean U_{Osm} and U_{SG} were less than 520 mOsm/kg and 1.014.[4]

Finally, the U_{SG} and U_{Col} criterion values for $U_{Osm} < 500$ mOsm/kg continue to build upon a new but growing distinction between the hydration state (acute dehydration), the upper limit of euhydration and being well-hydrated from the perspective of disease risk. Cheuvront *et al.*'s decision levels for detecting dehydration (body mass loss of 3.7 ± 1.0%) based upon U_{Osm} and U_{SG} were 1018 ± 245 mOsm/kg and 1.028 ± 0.006, respectively,[9] whereas an acceptable euhydration cutoff has been reported as < 700[10] to < 830[1] mOsm/kg for U_{Osm} and < 1.020 for U_{SG}.[10] This paper complements the existing literature by providing calculated cutoff values for U_{SG} ($\geqslant$1.013) and self-assessed U_{Col} ($\geqslant$4) that accurately detect $U_{Osm} > 500$ mOsm/kg. Given the recent associations between low water intake, low urine output and some renal and metabolic health outcomes,[5–7] we propose remaining below these cutoff values as a target for being well or optimally hydrated.

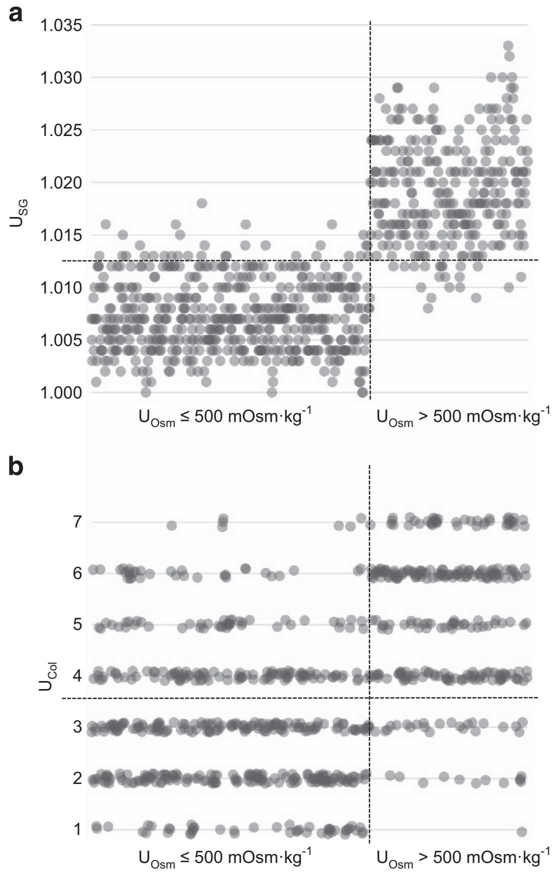

Figure 1. Distribution of (**a**) U_{SG} and (**b**) U_{Col} measures as a function of U_{Osm}. $U_{SG} \geqslant 1.013$ offered both very high sensitivity and high specificity to detect $U_{Osm} > 500$ mOsm/kg. $U_{Col} \geqslant 4$ provided good sensitivity and moderate specificity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Table 1. Urine samples classified according to U_{Osm}, U_{SG} and U_{Col} values; followed by metrics from ROC analysis

Criterion value for test measure (U_{SG}, U_{Col})	*Reference measure (U_{Osm})*		*Metrics from ROC analysis*[a]				
	$U_{Osm} > 500$ (n = 295)	*$U_{Osm} \leqslant 500$ (n = 521, U_{Col}) (n = 522, U_{SG})*	*Sensitivity*	*Specificity*	*Accuracy*	*PPV*	*NPV*
$U_{SG} \geqslant 1.013$ ($n = 307$)	275	32	0.984	0.932	0.939	0.896	0.961
$U_{SG} < 1.013$ ($n = 510$)	20	490					
$U_{Col} \geqslant 4$ ($n = 445$)	259	186	0.878	0.643	0.728	0.582	0.903
$U_{Col} < 4$ ($n = 371$)	36	335					

[a]Sensitivity: Percentage of true positives (that is, $U_{Osm} > 500$ mOsm/kg) detected by $U_{SG} \geqslant 1.013$ or $U_{Col} \geqslant 4$. Specificity: Percentage of true negatives (that is, $U_{Osm} \leqslant 500$ mOsm/kg) detected by $U_{SG} < 1.013$ or $U_{Col} < 4$.Accuracy: Percentage of all samples (positive or negative) accurately classified by U_{SG} or U_{Col}. Positive predictive value (PPV): Probability that a urine sample with $U_{SG} \geqslant 1.013$ or $U_{Col} \geqslant 4$ has a $U_{Osm} > 500$ mOsm/kg.Negative predictive value (NPV): Probability that a urine sample with $U_{SG} < 1.013$ or $U_{Col} < 4$ has a $U_{Osm} \leqslant 500$ mOsm/kg.

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