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Comparative analysis of pH measurements: Urine dipstick and pH meter

pH ölçümlerinin karşılaştırmalı analizi: İdrar dipstik ve pH metre

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ABSTRACT

Aim: Urine pH is a critical parameter in assessing an individual's metabolic and physiological status. The aim of this study was to compare dipstick measurement of urinary pH with gold standard pH meter readings.

Material and Methods: Each sample was tested by Jenway 3310 pH meter with a combined glass electrode and again using Meditape UC-9A urine dipsticks with Sysmex UC-3500 dipstick analyzer.

Results: A total of 3043 urine specimens were collected immediately after voiding from in-patients and out-patients at the Zonguldak Bulent Ecevit University Hospital. A strong correlation was found between urine dipstick and pH meter, with a rho value of 0.909 (95% CI 0,902 to 0.915), p<0.001. The bias values were between techniques was -0.18 (95% CI -0.1893 to -0.1695) with the two standard deviations establisheing the lower limit at –0.72 (95% CI -0.74 to -0.70) and the upper limit at 0.36 (95% CI 0.34 to 0.38), respectively.

Conclusion: Urine dipsticks offer expediency and practicality, making them suitable for routine checks and initial screenings. Conversely, pH meters deliver precision and reliability that is pivotal for comprehensive clinical assessments and research applications. Therefore, a pH meter with a glass electrode is mandatory when accurate measurement is necessary.

Keywords: Urine pH, urine dipstick, pH meter

ÖZ

Amaç: İdrar pH'ı, bir bireyin metabolik ve fizyolojik durumunu değerlendirmede kritik bir parametredir. Bu çalışmanın amacı, idrar pH'ının dipstik ölçümünü altın standart yöntem olan pH metre ile karşılaştırmaktır.

Gereç ve Yöntemler: Her numune, kombine cam elektrotlu Jenway 3310 pH metre ile ve ardından Sysmex UC-3500 idrar analizörü ile Meditape UC-9A idrar dipstikleri kullanılarak hemen test edildi.

Bulgular: Zonguldak Bülent Ecevit Üniversitesi Hastanesi'nde yatan ve ayaktan hastalardan toplam 3043 idrar örneği toplandı. İdrar dipstikleri ile pH metre arasında güçlü bir korelasyon bulundu, rho değeri 0,909 (95% CI 0,902 ila 0,915), p<0,001. Yöntemler arasındaki sapma değerleri -0,18 (95% CI -0,1893 ila -0,1695) idi, iki standart sapma alt sınırı -0,72 (95% CI -0,74 ila -0,70) ve üst sınırı 0,36 (95% CI 0,34 ila 0,38) olarak belirledi.

Sonuç: İdrar dipstikleri, rutin kontroller ve ilk taramalar için kolaylık ve pratiklik sunar. Buna karşılık, pH ölçerler kapsamlı klinik değerlendirmeler ve araştırma uygulamaları için çok önemli olan hassasiyet ve güvenilirlik sunar. Bu nedenle, doğru ölçüm gerektiğinde cam elektrotlu bir pH ölçer zorunludur.

Anahtar Kelimeler: İdrar pH, idrar dipstik, pH metre

Highlights

- This study compared urinary pH in 3,043 samples using a dipstick analyzer versus a glass-electrode pH meter.
- Although a strong correlation was observed (ρ = 0.909), this did not translate into acceptable clinical agreement.
- Bland–Altman analysis showed a negative bias and wide limits of agreement, indicating frequent measurement discrepancies.
- Clinically relevant errors occurred in approximately 7.5% of dipstick readings, often differing by ±1 pH unit.
- Accurate urine pH assessment—especially in pH-dependent therapies—requires a calibrated pH meter rather than dipstick testing.

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INTRODUCTION

Urine pH is a critical parameter in assessing an individual's metabolic and physiological status. It serves as a reflection of the body's acid-base balance and can provide valuable insights into various health conditions (1). The normal range for urine pH typically falls between 4.6 and 8.0, influenced by factors such as diet, hydration, and underlying health issues (2). For example, a diet rich in protein may lead to lower urine pH, reflecting increased acidity and conversely, a vegetarian diet often results in a more alkaline urine pH (2). Furthermore, hydration status significantly impacts urine concentration and consequently its pH (2).

Clinically, urine pH testing can be instrumental in diagnosing various disorders. For instance, a consistently high urine pH may suggest urinary tract infections (UTIs) caused by urease-producing bacteria, while a low pH can indicate conditions such as diabetic ketoacidosis or chronic respiratory acidosis (3-5). Moreover, urine pH can influence the solubility of certain substances, playing a critical role in the formation of kidney stones. Calcium oxalate stones, for example, tend to form in acidic urine, while struvite stones form more readily in alkaline urine (6).

Monitoring urine pH can also aid in managing certain medical treatments. Patients undergoing treatments for metabolic disorders or those on specific diets may need regular assessments of urine pH to evaluate the effectiveness of their management strategies (7,8).

Urine pH is a vital indicator of overall health, providing essential information regarding metabolic processes, dietary influences, and potential health complications. Its evaluation is an indispensable component of clinical diagnostics and management, thereby underscoring the necessity of further research into the diverse implications of urine pH variations in health and disease. The aim of this study was to compare dipstick measurement of urinary pH with gold standard pH meter readings.

MATERIAL and METHODS

A total of 3043 urine specimens were collected immediately after voiding from in-patients and out-patients at the Zonguldak Bulent Ecevit University Hospital. Samples were taken from both male and female patients. The protocol was approved by the Ethics Committee of Zonguldak Bulent Ecevit University (Date: January 13, 2025, Decision No: 2025/01).

Each sample was immediately tested by a fully trained operator via the two urinary pH testing methods. Once with the reference laboratory Jenway 3310 pH meter with a combined glass electrode (Jenway, Staffordshire, UK) and again using Meditape UC-9A urine dipsticks (Sysmex Corporation, Kobe, Japan). The pH meter was calibrated prior to use with pH solutions of pH 4, 7, and 10. The pH probe was placed in the urine sample and a pH reading was recorded for all samples tested with the previous methods. The Sysmex UC-3500 (Sysmex Corporation, Kobe, Japan) dipstick analyzer and an two levels of external daily quality control were performed.

Statistical analyses were conducted using SPSS Statistics Version 19.0 (IBM Corporation, Armonk, NY, USA) and MedCalc Statistical Software version 23.1.3 (MedCalc Software Ltd, Ostend, Belgium). Normality assumptions were controlled by the Shapiro–Wilk test. Descriptive analyzes were presented using mean±SD, median (min-max) or n (%), where appropriate. For pairwise comparisons between related samples, the paired samples t-test was used for normally distributed data. A two-tailed *p*-value of less than 0.05 was considered to be significant. To explore the linear relationships among the parameters, Spearman correlation coefficients and linear regression equations were calculated. The Bland-Altman test was applied to assess the agreement between pH results, with 95% confidence interval limits of agreement. We calculated the exact match concordance rate (%) and concordance rate (%) with ±1 grading difference rates (%) between Sysmex UC-3500 and Jenway 3310 pH meter. The sample size was calculated using G Power 3.1.9.4 software. The sample size calculation was based on a effect size 0.1, with a p-value of 0.05, a power of 95%, and a total sample size of at least 1073 subjects.

RESULTS

1450 of the specimens were from males, while 1593 were from females. The ages of the patients ranged from 1 to 95, with a mean age 52.0±18.9 median age of 55. A strong correlation between pH dipstick and pH meter was found, with a rho value of 0.909 (95% CI 0,902 to 0,915), p<0.001 (Figure 1). The linear function of pH dipstick for estimating pH meter was Y=-0.380 (95% CI -0,4650 to -0,2700) + 1.10 X (95% CI 1,0800 to 1,1150).

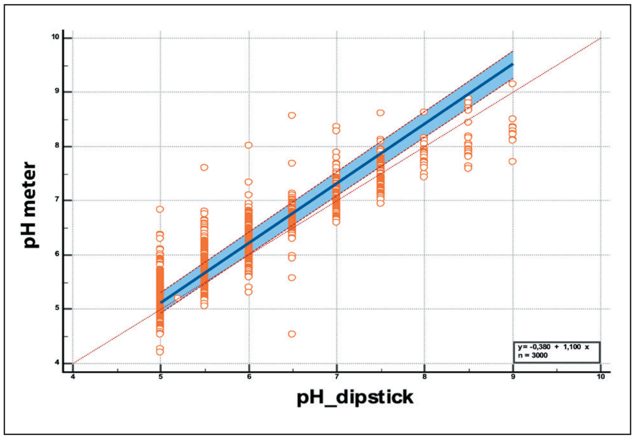

Figure 1: A comparative analysis of pH levels

Table 1. pH values of the patients with dipstick and pH meter

Dipstick pH Value	pHmeter				p-value
	Mean±SD	Difference±SD	Median	Min-Max	
5.0 (n=1036)	5.21±0.25	0.21±0.25	5.22	4.20-6.84	<0.001
5.5 (n=991)	5.69±0.24	0.19±0.24	5.61	5.05-7.61	<0.001
6.0 (n=424)	6.24±0.27	0.24±0.27	6.23	5.30-8.01	<0.001
6.5 (n=215)	6.63±0.28	0.13±0.28	6.62	5.54-8.57	<0.001
7.0 (n=172)	7.05±0.27	0.05±0.27	6.99	6.60-8.36	0.160
7.5 (n=107)	7.48±0.29	0.02±0.29	7.41	6.94-8.62	0.092
8.0 (n=47)	7.82±0.24	0.18±0.24	7.80	7.44-8.63	<0.001
8.5 (n=28)	8.14±0.39	0.36±0.39	8.02	7.59-8.88	<0.001
9.0 (n=22)	8.29±0.34	0.71±0.34	8.24	7.72-9.15	<0.001

Table 2. The distribution of the pH values

	pH	± 1 rank match concordance rate (%)	pHmeter (n)									
			<5.0	5-5.5	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	>9.0
Dipstick (n)	5.0 (n=1036)	90.3	**201**	**735**	93	6	1	0	0	0	0	0
	5.5 (n=991)	91.7	0	**207**	**702**	70	11	0	1	0	0	0
	6.0 (n=424)	83.9	0	3	**55**	**301**	63	1	0	1	0	0
	6.5 (n=215)	93.0	0	0	4	**47**	**153**	9	2	0	0	0
	7.0 (n=172)	94.7	0	0	0	0	**91**	**72**	7	2	0	0
	7.5 (n=107)	95.3	0	0	0	0	1	**63**	**39**	3	1	0
	8.0 (n=47)	87.3	0	0	0	0	0	2	**21**	**20**	4	0
	8.5 (n=28)	71.4	0	0	0	0	0	0	8	**9**	**11**	0
	9.0 (n=22)	40.1	0	0	0	0	0	0	1	8	**9**	4

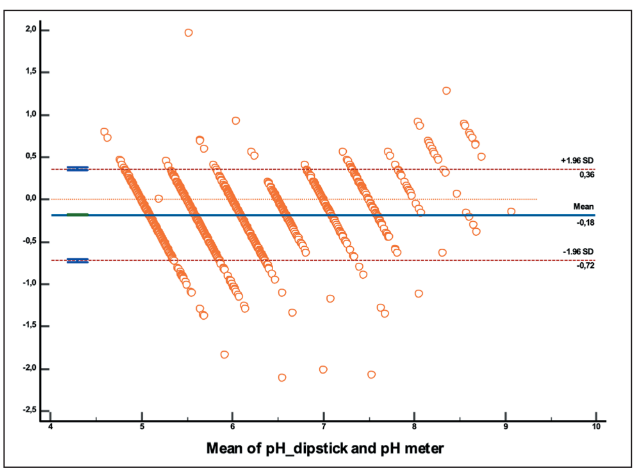

Figure 2: The means, mean differences, and agreement limits (bias ± 2 SD) of pH results according to Bland-Altman analyses

The Bland-Altman plots depict the differences between the means of pH dipstick versus pH meter (Figure 2). The bias values between techniques was -0.18 (95% CI -0.1893 to -0.1695) with the two standard deviations established the lower limit at –0.72 (95% CI -0.74 to -0.70) and the upper limit at 0.36 (95% CI 0.34 to 0.38), respectively.

The results of the comparison between the three methods when compared with the reference method are summarized in Tables 1 and 2.

DISCUSSION

The measurement of urine pH is a vital component of clinical diagnostics, offering critical insights into both metabolic and renal function. Fluctuations in urine pH can signal a variety of health issues, ranging from urinary tract infections to systemic metabolic disorders. Traditionally, urine pH has been evaluated using dipstick tests, which are popular due to their convenience and speed. However, the advent of pH meters presents a more accurate and dependable alternative. This essay will explore the advantages and limitations of both methods, highlighting their respective roles in clinical practice and research settings.

Dipstick tests for urine pH utilize a straightforward colorimetric method, wherein a reactive dipstick changes color in response to the acidity or alkalinity of a urine sample. In a study conducted by Desai and Assimos, the pH levels of 100 fresh urine specimens from patients with urologic diseases were measured. The findings indicated that urinary dipsticks serve as reliable indicators of urinary pH, making them valuable tools for both physicians and patients to monitor pH manipulation therapy within the targeted range of 6 to 7 (9). Similarly, Johnson et al. analyzed 201 free-catch urine samples from 114 hospitalized dogs and concluded that urine reagent dipstick can provide estimates of pH for routine urinalysis (10). However, they cautioned against relying on these dipsticks when precise and consistent pH measurements are essential for the diagnosis, prevention, and management of diseases. This testing technique offers numerous advantages, particularly its ease of use and rapid results, making it an ideal choice for point-of-care testing in outpatient settings and laboratories with limited resources. Dipsticks are widely accessible, cost-effective, and require minimal training to operate, thereby facilitating routine screening. Nevertheless, while dipstick tests provide a quick overview of urine pH, they are inherently limited by their qualitative nature and the potential for subjective interpretation. Factors such as the freshness of the urine sample, laboratory conditions, and user variability can introduce inconsistencies in results, ultimately affecting diagnostic accuracy. Therefore, while dipstick tests are a valuable tool in clinical practice, they should be complemented with more precise methods when accuracy is paramount.

Mina et al. conducted a study involving 210 urine samples, utilizing the Mettler Toledo Seven Compact pH meter method, which demonstrated an 85.7% agreement with the dipstick method (11). In a separate evaluation, Coninck et al. assessed 77 urine aliquots from 20 healthy volunteers using reagent dipsticks, a portable pH meter, and a laboratory pH meter as the gold standard. Their findings indicated that the portable electronic pH meter provided more accurate readings compared to the reagent dipsticks according to the laboratory pH meter as the gold standard (12). Ilyas et al. collected urine samples from 200 patients attending stone clinics and emphasized the importance of using a pH meter for urinary pH readings in patients at risk for pH-dependent stone formation (13). In contrast to dipstick methods, pH meters offer a quantitative assessment of urine pH, delivering a higher level of precision and reproducibility. These meters operate on the principles of potentiometry, employing a glass electrode to accurately measure the hydrogen ion concentration in urine samples. This methodological rigor makes pH meters particularly well-suited for research environments and clinical investigations that demand high-quality data granularity. Moreover, pH meters provide definitive numerical values and facilitate the evaluation of urine samples under controlled conditions, thereby minimizing environmental influences and inter-user variability. However, the use of pH meters requires a certain level of technical proficiency and proper calibration, which can present challenges in settings where resources and trained personnel are limited. This study highlights that while the correlation between the two different modalities of urine pH measurement is statistically good, clinically significant discrepancies occur with an unacceptable frequency. Approximately 7.5% of dipstick measurements resulted in clinically relevant errors, with the majority deviating by one pH unit from the true urine pH value. Although a strong correlation coefficient ($r=0.909$) was observed between the two measurement methods, this does not necessarily imply clinical reliability. A correlation value only reflects the strength of a linear relationship, not the degree of agreement or interchangeability between methods. In clinical contexts such as urinary alkalinization therapy or stone prophylaxis, even a ±1 pH unit deviation can lead to inappropriate treatment decisions or missed therapeutic targets. Therefore, despite the statistically robust correlation, the observed discrepancies highlight that the dipstick method cannot substitute for pH meter measurements when accurate urine pH assessment is essential.

Wockenfus et al. conducted a study involving 116 urine samples from pediatric patients undergoing high-dose methotrexate therapy (14). They measured the pH of these samples using both the Clinitek Status dipstick and a pH meter. Their findings revealed a significant bias in pH readings among patients receiving high-dose methotrexate therapy, with an average discrepancy of 0.7 ± 0.4. Notably, this bias was most pronounced in urine samples with pH values exceeding 8. In our study, we observed a similar trend: at dipstick pH readings above 8.5, there was a tendency for the dipstick to undervalue the pH compared to the pH meter. A critical distinction between these two methods is their diagnostic utility. Urine pH levels can be influenced by various factors, including dietary habits, medications, and underlying health conditions. While dipstick tests may serve as a preliminary screening tool, they often lack the precision necessary for accurate clinical decision-making. In a cohort of 98 patients where pharmacological manipulation of urinary pH was indicated based on true pH measurements, it was found that 14 patients would not have received appropriate treatment, and 5 patients would have been unnecessarily medicated if only the dipstick pH values had been considered (15). In contrast, pH meters provide healthcare professionals with more reliable data, facilitating better patient management and therapeutic interventions. Our data indicate that while dipstick pH readings of 7 and 7.5 closely aligned with the mean pH meter readings, higher pH values were associated with a greater likelihood of overestimation by the dipstick method. Furthermore, when urine pH measurements are integrated with other diagnostic tests, the enhanced precision offered by pH meters significantly improves the interpretability of results, ultimately leading to more informed clinical judgments.

A limitation of our study is that dipstick pH results were treated as continuous variables for statistical analyses. Although this approach facilitates correlation and regression testing, it may not fully reflect the ordinal nature and potential rounding bias inherent in dipstick readings. Future studies employing categorical or interval-based analysis could provide additional insights into the agreement between the two methods.

Conclusion

Both dipstick tests and pH meters offer distinct advantages and limitations when it comes to measuring urine pH. Dipsticks are valued for their speed and convenience, making them ideal for routine checks and initial screenings. In contrast, pH meters provide the precision and reliability essential for thorough clinical assessments and research applications. The selection between these two methods should be tailored to the specific context, ideally combining the rapid results of dipsticks with the accuracy of pH meters to create a comprehensive diagnostic strategy. Enhancing our understanding and methodologies for measuring urine pH can significantly elevate its role in clinical practice, ultimately leading to improved patient outcomes and stimulating further research in metabolic health. Therefore, when precise measurements are critical, the use of a pH meter equipped with a glass electrode is indispensable.

Author Contributions

Study conception and design: **Murat Can, Berrak Güven;** data collection: **Murat Can, Berrak Güven, Osman Emre Ünlü;** analysis and interpretation of results: **Murat Can, Berrak Güven, Osman Emre Ünlü;** draft manuscript preparation: **Murat Can, Berrak Güven, Osman Emre Ünlü**. The author(s) reviewed the results and approved the final version of the article.

Conflicts of Interest

The authors declare that there is no conflict of interest to disclose.

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The authors did not receive financial support for the study.

Ethical Approval

The research was approved by the Research Ethics Committee at Ethics Committee of Zonguldak Bulent Ecevit University (Date: January 13, 2025, Decision No: 2025/01).

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