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SHORT COMMUNICATION

Comparison between digital and paper urine color to assess hydration status

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Abstract

Purpose The purpose of this study was to investigate associations between digital urine color and paper urine color with other urine indices to assess hydration status.

Methods Twelve male subjects (mean ± standard deviation; age, 26 ± 8 years; body mass, 57.8 ± 5.3 kg; height, 177.5 ± 8.9 cm; VO_{2max}, 57.8 ± 5.8 ml·kg^{-1}·min^{-1}) performed four exercise trials in the heat. Before and following exercise trials, subjects provide urine samples. Urine samples were measured using a digital urine color chart on a portable device screen. Urine samples were also assessed with urine specific gravity (USG), urine osmolality (UOsmo), and a validated paper urine color chart.

Results There were extremely large associations found between digital urine color and paper urine color ($r = 0.926$, $p < 0.001$). Correlation coefficients showing associations with USG and UOsmo were similar between digital urine color (USG, $r = 0.695$, $p < 0.001$; UOsmo, $r = 0.555$, $p < 0.001$) and paper urine color (USG, $r = 0.713$, $p < 0.001$; UOsmo, $r = 0.570$, $p < 0.001$). Bland–Altman analysis indicated that no proportional bias was observed between digital and paper urine colors (bias, − 0.148; SD of bias, 0.492; 95% LOA, − 1.11, 0.817; $p = 0.094$).

Conclusions Strong associations were found between digital and paper urine colors with no proportional bias. Furthermore, the degree of associations with USG and UOsmo was similar between digital and paper urine color. These results indicate that digital urine color is a useful tool to assess hydration status and this method could be used as an alternative method to using paper urine color.

Keywords Hydration · Assessment · Urine · Dehydration

Introduction

Levels of dehydration greater than 1.5–2% impair aerobic exercise performance and 3–4% lower muscular strength and power [1, 2]. In addition to exercise performance, 2–4% of dehydration decreases sports-specific cognitive, motor, and skill execution performance [3]. Dehydration also increases the likelihood of developing heat illnesses, including heat exhaustion, exercise-associated muscle cramps, and exertional heat stroke [1]. Therefore, accurate hydration assessment is important to optimize exercise performance and safety. A time-efficient and cost-effective method such as colorimetric tests have been developed.

Urine color is widely used in both field and lab settings to assess hydration status. Urine color is a practical tool for assessing urine concentration and changes in body water [4, 5]. For example, maintaining urine color as "pale yellow" or "straw-colored" corresponds to euhydration [4–6]. A score greater than 5 out of 8 for urine color indicates a body mass loss of more than 2% [7]. Furthermore, strong correlation coefficients were shown between urine color and other urine indices, such as urine specific gravity (USG) and urine osmolality (UOsmo) [4]. Also, urine color has been reported as a valid method not only for adults but also for children to assess hydration status [8]. Therefore, urine color is a great tool to monitor hydration status as a practical,

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cost-efficient, portable, and easy method for different populations and settings.

Urine color measurement requires a validated paper urine color chart, which consists of the 1–8 Likert scale [4, 5]. Even though this is a relatively simple method, it might be hard to access this validated paper urine color chart, which can lead to invalid urine color charts being used in some situations, especially outside of the research settings. Our research team created a digital urine color chart using a digital tablet. This digital format is likely to increase accessibility and be more portable. Also, this digital format meets some important points, such as a simple display and easy navigation, when using the digital format [9]. However, it is critical to examine the accuracy of a digital urine color chart compared to a validated paper urine color chart. Therefore, the purpose of this study was to investigate associations between a digital urine color chart and a paper urine color chart with other urine indices, such as USG and UOsmo.

Methods

Twelve male subjects (mean ± standard deviation [SD]; age, 26 ± 8 years; body mass, 57.8 ± 5.3 kg; height, 177.5 ± 8.9 cm; VO_{2max}, 57.8 ± 5.8 ml·kg^{-1} min^{-1}) participated in this study. Following an explanation of study procedures, which was approved by the Institutional Review Board at the << removed for review >> where this study was conducted, participants provided written and informed consent to participate in this study. The ethical approval number of the study is H20-0160. Since this research question was assessed as a part of a cooling intervention study, the study procedure was designed to assess the primary research question regarding the effect of cooling interventions. In this study, subjects completed 90 min of four treadmill exercise trials in the heat. Before and after the exercise trials, subjects provided urine samples.

Urine samples were measured with a digital urine color chart (Fig. 1). It was used on an iPad screen (Apple, Cupertino, CA), which brightness was set as 100% to control the color of the screen. Urine samples were also assessed with USG using a handheld refractometer (Model TS400; Reichert Inc., Depew, NY), UOsmo using an osmometer (Osmo Pro; Advanced Instruments, Norwood, MA), and a validated paper urine color chart [4]. Both digital and paper urine color analyses were performed by trained researchers in random order of assessment.

Pearson product-moment correlations were used to calculate associations between variables. Correlation coefficient thresholds were set at 0.1, 0.3, 0.5, 0.7, and 0.9 depicting small, moderate, large, very large, and extremely large associations, respectively [10]. Alpha level was set at $\alpha < 0.05$. Bland–Altman analysis with regression analysis was used to assess the degree of proportional bias. The 95% limits of agreement (LOA) were also calculated. These statistical analyses were performed using SPSS (v.26. IBM Corporation, Armonk, NY) and GraphPad (v.9.3.1. GraphPad Software, San Diego, CA).

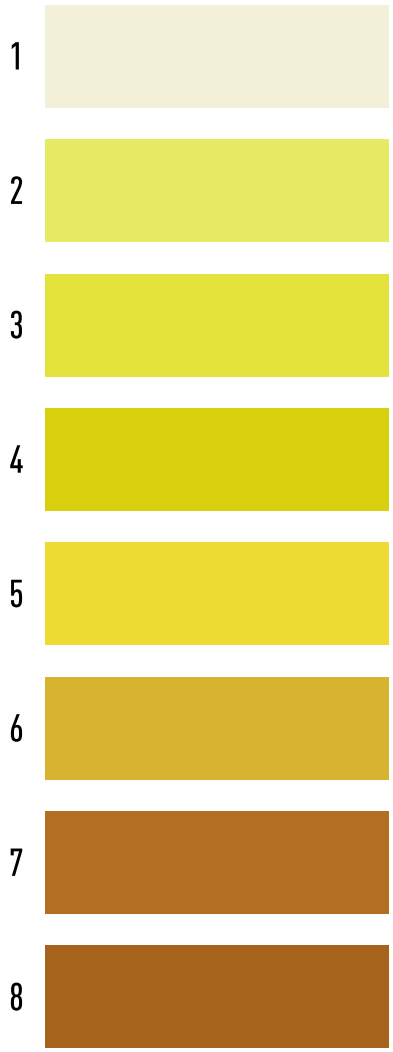

Fig. 1 A digital urine color chart. Copyright 2022 University of Connecticut and CamelBak Products, LLC. All rights reserved

Results

Mean, SD, and median for digital urine color (mean ± SD, 2.4 ± 1.2; median, 2.0), paper urine color (mean ± SD, 2.5 ± 1.3; median, 2.0), USG (mean ± SD, 1.009 ± 0.006; median, 1.008), and UOsmo (mean ± SD, 327 ± 219; median, 265) were calculated (Table 1). There were extremely large associations between digital urine color and paper urine color ($r = 0.926$, $p < 0.001$) (Fig. 2). Correlation coefficients to indicate associations with USG or UOsmo were similar between digital urine color (USG, $r = 0.695$, $p < 0.001$;

Table 1 Mean and standard deviation of digital and paper urine color, urine specific gravity, and urine osmolality

Digital urine color	Paper urine color	Urine specific gravity	Urine osmolality (mmol·kg^{-1})
2.4 ± 1.2	2.5 ± 1.3	1.009 ± 0.006	327 ± 219

UOsmo, $r = 0.555$, $p < 0.001$) (Fig. 3) and paper urine color (USG, $r = 0.713$, $p < 0.001$; UOsmo, $r = 0.570$, $p < 0.001$) (Fig. 4). Bland–Altman analysis indicated that no proportional bias was observed between digital and paper urine colors (bias, − 0.148; SD of bias, 0.492; 95% LOA, − 1.11, 0.817; $p = 0.094$) (Fig. 5).

Discussion

The purpose of this study was to investigate associations between a digital urine color chart and a paper urine color chart with other urine indices. Extremely large associations were found between digital and paper urine color. Furthermore, the degree of associations with USG and UOsmo were similar between digital and paper urine color charts. A proportional bias was not found between digital and paper urine colors. These results indicate a digital urine color chart can be used as an alternative method to a paper urine color chart.

A paper urine color chart has been used in different settings (i.e., research, sports, lab, field) for different populations (i.e., adults, children) [4, 8]. A systematic review of urine color validation studies concluded that urine color measurement is a valid method to assess hydration status [11]. In addition to its practicality, urine color has been shown as effective as USG, UOsmo, urine volume, plasma osmolality, plasma protein, and total plasma protein to monitor hydration status [4, 5]. Furthermore, urine color is a valid assessment method for not only adults but also children [8]. Based on agreements shown by Bland–Altman analysis as well as correlation coefficient agreements between digital urine and paper urine color charts, as shown in the current study, a digital urine color chart is an effective tool to assess hydration status.

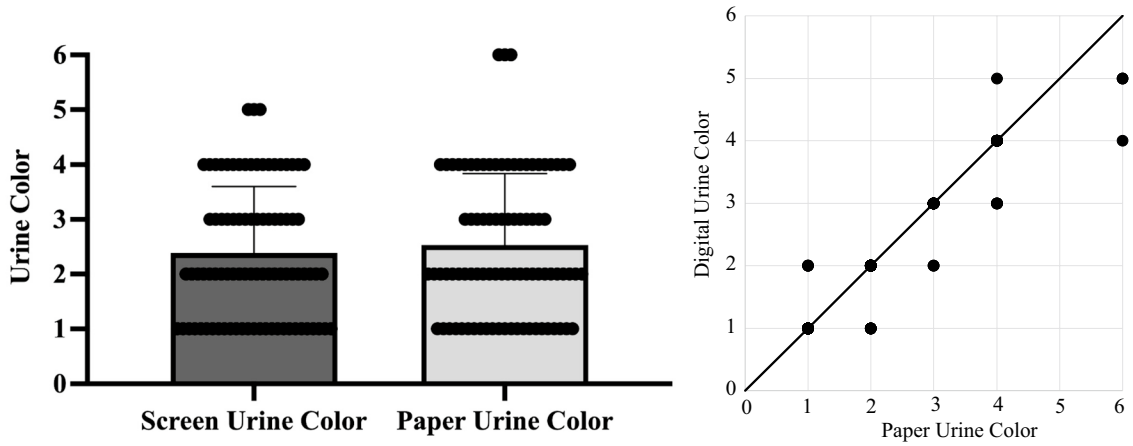

Fig. 2 Digital urine color and paper urine color ($r = 0.926$, $p < 0.001$)

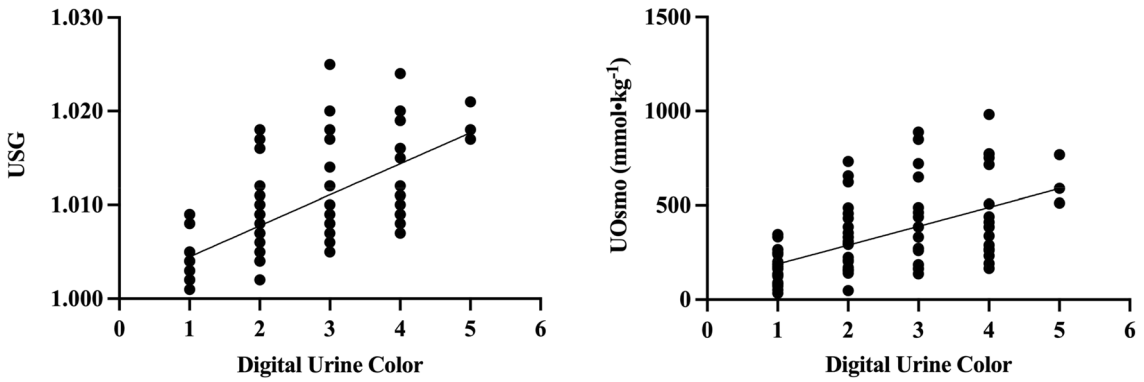

Fig. 3 Associations between digital urine color and urine specific gravity (USG) and urine osmolality (UOsmo)

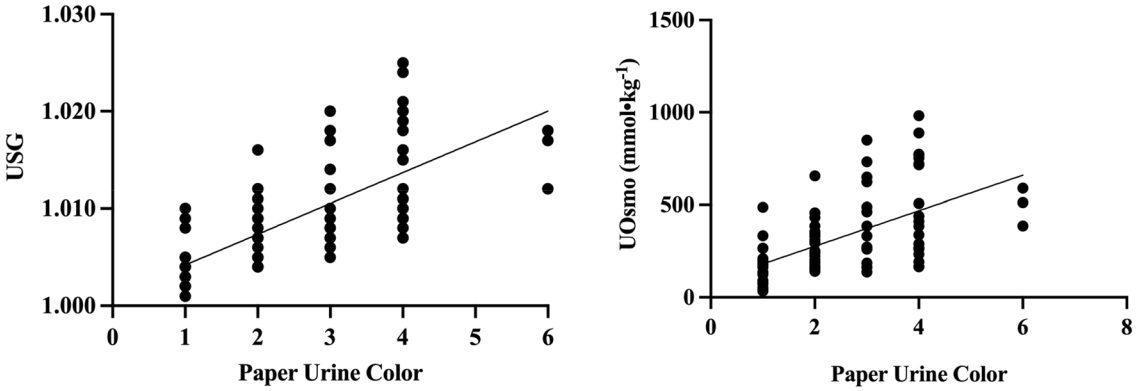

Fig. 4 Associations between paper urine color and urine specific gravity (USG) and urine osmolality (UOsmo)

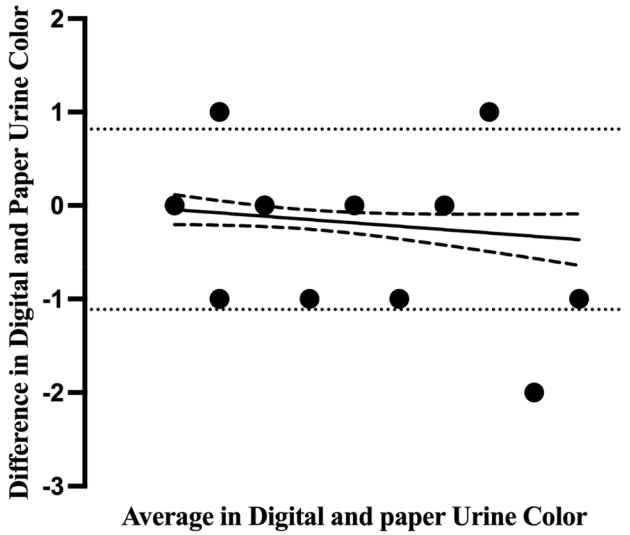

Fig. 5 Bland–Altman analysis with the solid diagonal line representing the relationship between digital and paper urine colors. The dot lines around the solid diagonal line represent 95% confidence intervals for linear regression lines. The horizontal dashed lines indicate the upper and lower limits of agreement (LOA). (bias, − 0.148; SD of bias, 0.492; 95% LOA, − 1.11, 0.817; $p = 0.094$)

A digital urine color chart is a practical, cost-efficient, portable, and easy tool to assess hydration status. [9] This digital urine color chart is easy to share with individuals, such as coaches, sports scientists, research teams, and medical staff. The digital nature of the chart allows it to be brought anywhere with the use of portable tablets or phones.

Conclusion

A digital urine color chart created in this study demonstrated strong associations with a validated paper urine color chart without a proportional bias. Also, the degree of associations with USG and UOsmo were similar between digital and paper urine color charts. This indicates that a digital urine color chart is a useful tool to assess hydration status. This allows many individuals to use validated urine color charts in a practical and portable way.

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Declarations

Conflict of interest The authors have no conflicts of interest to disclose for the submitted work.

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