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Comparison of Two Reminder Interventions to Achieve Adequate Water Intake and Hydration in Women: A Pilot Study

Original Research

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Abstract

Introduction: This pilot study examined the effectiveness of two different 5-week reminder interventions to achieve adequate water intake and hydration in women as well as the effects of body composition and self-efficacy on hydration.

Methods: Twenty-two apparently healthy adult women were randomly assigned to the 64 oz. motivational water bottle group (n = 11), or the water reminder – daily tracker app group (n = 11). Body composition, predicted VO_{2max}, and self-efficacy were assessed at baseline, post 5-week intervention, and after a 30-day follow-up period. Urine markers (color, specific gravity, and pH) were reported at baseline, weekly throughout the 5-week intervention, and the last 3 days of the 30-day follow-up period. During the interventions, participants self-reported daily step count, resting heart rate, water intake, and symptoms of dehydration.

Results: Both 5-week reminder interventions successfully increased water intake by an average of 29% with a mean daily consumption of 72.05 $\pm$ 18.75 ounces, meeting recommendations. Based on regression analysis, self-efficacy predicted daily water intake at the end of the 5-week intervention (p = 0.03). Urine markers of hydration classified several participants as dehydrated at the end of 5 weeks. In addition, there was a significant inverse relationship between BMI and U_{col} at baseline (p = 0.05), week 5 (p = 0.05), and follow-up (p = 0.04), indicating that women with a higher BMI were more dehydrated. In hydrated participants, memory and ability to concentrate significantly improved (p = 0.019). Results indicated there were no significant differences in water intake and hydration between the two groups at baseline, week 5, and follow-up.

Conclusions: Both 5-week interventions successfully increased water intake. However, based on urine markers of hydration women may be more prone to involuntary, chronic dehydration due to a higher body fat percentage.

Key Words: hydration, water intake, urine markers.

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Introduction

Euhydration refers to the state of "normal" body water content. Based on urine specific gravity, normal hydration is maintained within a narrow range of 1.013-1.029, while a value of 1.030 may indicate hypohydration.[1,2] Dehydration occurs when body water loss exceeds water replacement, creating a total body water deficit. For the purpose of this pilot study, hydration will refer to a state of euhydration, while dehydration will refer to a state of hypohydration. Since total body water accounts for approximately 60% (range of 45-75%) of a person's total body weight, hydration is essential to maintain normal body functions as well as overall cognitive and physical performance.[3,4] Even mild dehydration, with a body water deficit of $\geq$ 1.0%, has been shown to impair cognition, such as short-term memory, concentration, and critical thinking.[5] Physical symptoms of dehydration include headache, dizziness, weakness, and constipation.[4,5]

The current dietary reference intake (DRI) for adult women is 2.7 liters of fluids per day, and 3.7 liters for adult men, with approximately 20% coming from food sources.[6] In addition, according to the Mayo Clinic a water intake of 64 ounces is considered the minimum to achieve adequate hydration.[6] However, most adults fall short of meeting the DRI for fluid intake with one survey conducted by the Nutrition Information Center, New York Hospital-Cornell Medical Center reporting that 75% of American adults are chronically dehydrated.[7-9] In addition, researchers have reported that plain water intake is lower among overweight/obese women as well as middle-aged and older adults, increasing their risk of dehydration.[10-13]

The majority of research on hydration has examined athletes, older adults, or those with certain chronic diseases, such as renal disease.[14-17] These studies varied in duration and methodology. Studies on athletes evaluated acute bouts of dehydration; other studies used a 7-day collection period; and longer studies of 3 months to several years collected and evaluated samples periodically from patients in clinical or long-term care settings.[18] The duration of previous interventions to increase fluid intake lasted from 4 weeks to 12 months, depending on the type of data collected, and often used recall logs or surveys.[18] In addition, these studies typically evaluated a single approach, and did not consistently address: 1) self-efficacy related to behavior change, 2) individual fluid needs, 3) contributing factors for water loss and dehydration, 4) self-monitoring of symptoms of dehydration, and 5) follow-up assessments. The researchers did not find any previous studies on the assessment of water intake and hydration in adult women in a free-living environment. Therefore, the aim of this pilot study was to compare the effectiveness of 2 different 5-week reminder interventions to achieve adequate water intake and hydration in apparently healthy women 19 to 50 years of age in a free-living environment. Secondly, the researchers evaluated if body composition and self-efficacy affected water intake and hydration.

Scientific Methods

Participants

Researchers recruited female faculty, staff, and students at a medium-sized university in the Midwestern United States through email announcements. Prospective participants were invited to take part in a 5-week hydration study with a 30-day follow-up period to compare the effectiveness of 2 different reminder interventions. Both interventions aimed to encourage adequate water intake and hydration. Thirty participants volunteered to participate, and 22 completed the study.

Established inclusion criteria for study participants were: 1) being female between 19-50 years of age, 2) having no known metabolic or renal disease, 3) not currently taking a blood pressure medication or other medication with a diuretic, 4) owning a personal fitness tracker and smartphone to utilize apps, and 5) owning a personal water bottle. All participants completed an Institutional Review Board approved written liability waiver and informed consent, indicating their voluntary participation in the study.

Protocol

Based on availability, interested participants attended 1 of 3 information sessions scheduled mid-week in the late afternoon where researchers described the study and procedures, as well as provided an opportunity to ask questions. After completing the written liability waiver and informed consent, participants completed a self-efficacy and water consumption questionnaire. Using a 6-point Likert scale, participants were asked questions on 1) their level of confidence in meeting the water intake guideline of approximately 2.7 liters of water per day, 2) their level of confidence in meeting the water intake guideline of 2 liters of water per day, 3) the frequency in which they drank water when feeling thirsty, and 4) the frequency that they consumed beverages that contained some form of caffeine (e.g., soda, tea, coffee, energy drinks, etc.). Next, participants were randomly assigned to an intervention group. One group received a popular 64 oz. motivational water bottle with time markings and positive phrases. These participants also self-recorded voice reminders with 2 different positive affirmations to drink more water, and set alarms on their smartphones to play the reminders at least twice daily. The other group used the water reminder – daily tracker app, setting reminders based on personal preference. Researchers then instructed participants on how to set up an individual

Google drive folder to submit data. Based on their intervention group, participants downloaded and set up the appropriate apps on their smartphones. To assess hydration in a free-living environment, the researchers utilized 3 accepted, self-monitored markers, including urine color (U_{col}), urine specific gravity (U_{sg}), and urine pH (U_{pH}).[18] The researchers educated the participants on how to collect a "clean-catch" urine sample, and perform a dipstick urinalysis. Participants were shown how to electronically submit their results to include taking a picture of the urine collection container, urine color chart, and dipstick using the camera app on their smartphones. To account for physical activity throughout the intervention, daily step counts and resting heart rate were recorded.

Participants then reported to the exercise physiology laboratory. Researchers collected anthropometric data, including height (m) and weight (kg) using a SECA 700 column scale and SECA 220 telescopic measuring rod (Chino, CA). The researchers followed the manufacturer's instructions for the OMRON fat loss monitor for bioelectrical impedance analysis (BIA), HBF-306C, (Bannockburn, IL) to assess body mass index (BMI) and estimate percent body fat.[19] Based on estimated percent body fat and the participant's self-reported physical activity level, researchers utilized the University of Houston Non-Exercise Test for Predicting VO_{2max} to evaluate physical fitness level.[20] Questionnaire and anthropometric data were assessed again at the end of the 5-week intervention as well as the 30-day follow-up period, using a similar lab schedule and participant instructions.

Participants were provided 3 lay press equations commonly found on the Internet for how much water one should drink each day. All 3 equations were based on body weight, and included body weight in pounds divided by 2; body weight in pounds multiplied by 2/3; and body weight in kilograms multiplied by 30 mL. Participants were instructed on how to determine an individualized weekly water intake goal based on dipstick urinalysis results, U_{col}, and symptoms of dehydration. Researchers instructed participants on how to record their daily water intake as well as fitness tracker data, including resting heart rate and step count. To evaluate daily cognitive and physical symptoms associated with dehydration, a semantic differential scale with 2 bipolar adjectives was used for the following functions: energy level, concentration/memory, mood, sleep quality, and bowel movements. For example, energy level was evaluated using a dichotomous choice between energetic and tired/worn out. Data were recorded using a 7-day log from Monday to Sunday. During the 30-day follow-up period, only daily water intake was recorded. Researchers discussed the importance of limiting consumption of caffeine, energy drinks, and alcohol throughout the study. In addition, participants received weekly reminders that included infographics on the benefits of hydration on cognitive and physical performance.

At the end of the session, researchers provided the necessary supplies for urine collection and dipstick urinalysis throughout the study. The researchers utilized 3 days of monitoring, similar to other behavior studies, to establish a baseline for average water intake and hydration.[21] Participants collected their 1st void on 2 consecutive weekdays and 1 weekend day to perform dipstick urinalysis. For consistency throughout the 5-week intervention, participants were asked to collect their 1st void each Sunday morning for analysis. At the conclusion of the 30-day follow-up, a similar 3-day monitoring period was completed. Participants were instructed to submit all self-monitored data to their individual Google drive on Sunday evenings.

Statistical Analysis

Data were analyzed using SPSS version 27 (IBM Corp, 2020). Descriptive statistics were run on participant characteristics and fitness metrics at baseline, and at the end of the 30-day follow-up period. Mean water intake and urine markers (U_{col}, U_{sg} and U_{pH}) were evaluated at baseline, at the end of the 5-week intervention, and after the 30-day follow-up. In addition, Pearson's correlation analyses were calculated to assess the relationship between the urine markers at each time point. Paired samples t-tests were used to determine differences in mean water intake within each intervention group from baseline to week 5, and from week 5 to follow-up. To assess hydration, cut-offs were established for each of the urine markers. For U_{col}, a 7-point color chart was used, with each color being assigned a number.[22,23] "Very good" hydration was scored as 7 so that with increased water intake the number was greater, and "severe" dehydration was scored as 1. Therefore, the cut-off for hydration was set at > 4 (see Figure 1).[23,24] A common pH value for a 1st voided urine sample is 6.5 to 7.5, indicating an overall neutral pH.[25,26] In addition, uric acid (kidney) stones generally do not form with a sustained U_{pH} of ≥ 6.5.[27] Therefore, the researchers used ≥ 6.5 as the cut-off for hydration. For U_{sg}, a dichotomized variable was created to classify participants as either hydrated (< 1.020) or dehydrated (≥ 1.020).[4,28] Repeated-measures analysis of variance (ANOVA) was used to evaluate differences in the various urine markers between the two interventions over time. In order to determine the relationship between body composition and water intake, researchers created a dichotomized variable to classify participants as either obese (BMI ≥ 30 kg/m^2) or normal-to-overweight (BMI 18.5 to 29.9 kg/m^2), and conducted correlations between U_{col} and

BMI at baseline, 5 weeks, and follow-up. To assess whether self-efficacy was associated with daily water intake, researchers ran a linear regression with self-efficacy as the predictor variable. In addition, independent samples t-tests were calculated to test for significant differences in reporting of cognitive and physical symptoms associated with hydration.

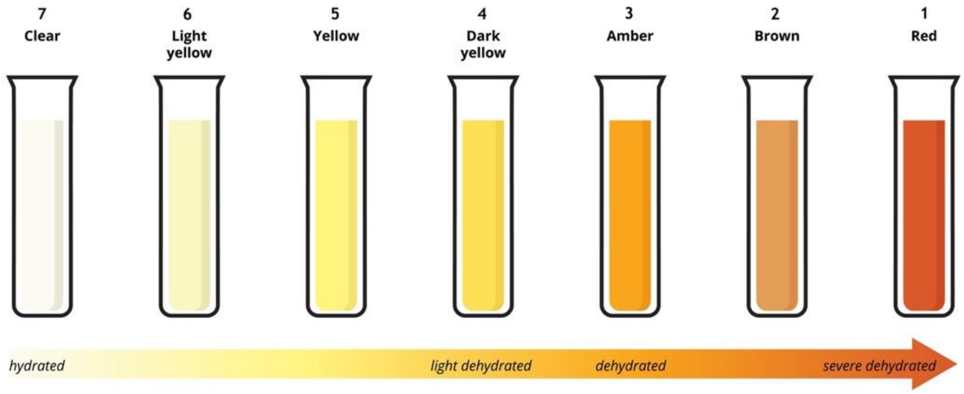

Figure 1. 7-point Urine Color Chart. For the purpose of this study, values were assigned in descending order, with "7" (Clear) representing optimal hydration, and "1" (Red) representing severe dehydration. The median value of 4 (dark yellow) was used as the cut-off for dehydration. Participants placed the filled urine collection container on the white space to the right of the chart and visually read the color. The picture of the 7-color urine chart was originally developed by Olha Creative, and available in Adobe Stock images.

Results

Participant characteristics

Twenty-two females completed the study with a mean age of 25.77 ± 8.90 years. Participant characteristics are reported in Table 1, and fitness metrics are displayed in Table 2. Body weight, BMI, estimated percent body fat, average daily step counts, and predicted VO_{2max} did not differ between groups from baseline to post-testing at the end of the 30-day follow-up period. Age and body composition did not influence physical activity during the study, regardless of intervention group.

Table 1. Participant characteristics.

	Water Bottle Group (*n* = 11)		**Reminder App Group (*n* = 11)**	
	Baseline	**Follow-up**	**Baseline**	**Follow-up**
Body weight (lb.)	147.3 ± 22.6	148.5 ± 21.0	153.9 ± 38.5	154.1 ± 39.2
BMI (kg/m^2)	23.8 ± 3.7	24.0 ± 3.4	25.6 ± 6.9	25.7 ± 7.1
% Body fat	24.6 ± 6.1	25.7 ± 6.1	26.5 ± 9.1	26.8 ± 9.7

Data are mean ± SD. BMI = body mass index.

Markers for water intake and hydration

At baseline, participants consumed an average of 55.85 ± 18 ounces of water per day. The urine markers of U_{col}, U_{sg}, and U_{pH} were examined to assess hydration. Mean U_{col} was 4.55 ± 0.74. Based on the established cut-off and frequencies for U_{col}, 50% (*n* = 12) of participants were classified as dehydrated.[23,24] Both mean U_{sg} (1.010 ± 0.005) and U_{pH} (6.77 ± 0.55) fell within normal values. At the conclusion of the 5-week intervention, the average water intake for participants increased to 72.05 ± 18.75 ounces. At the end of the 30-day follow-up period, water intake decreased slightly to 69.65 ± 20.65 ounces (Table 3). Based on frequencies for U_{col} at 5 weeks, 41% (*n* = 9) of participants were classified as dehydrated. Mean U_{sg} at 5 weeks was 1.017 ± 0.004. Based on the established cut-off and frequencies for U_{sg}, 45% (*n* = 10) of participants were classified as dehydrated.[4,28] At baseline, there was no association between U_{sg} and U_{col} in classifying hydration (r = -0.23, p = 0.31). However, there was a significant negative correlation between U_{sg} and U_{col} at week 5 (r = -0.46, $p < .05$), as well as at follow-up (r = -0.58, $p < .01$). Mean U_{pH} at 5 weeks fell slightly (6.50 ± 0.345) with 18% (n = 4) of participants falling below the cut-off of 6.5, suggesting more acidic urine and mild dehydration.[27] There was a moderate, albeit nonsignificant, negative correlation between U_{sg} and U_{pH} in classifying hydration (r = -0.70, p = 0.73).

Table 2. Physical activity and fitness metrics.

	Water Bottle Group (n = 11)		**Reminder App Group (n = 11)**	
	Baseline	**Follow-up**	**Baseline**	**Follow-up**
Daily steps	6608.6 ± 3049.7	6306.9 ± 2841.2	6090.4 ± 2312.7	6884.5 ± 2365.9
Predicted VO_{2max} (ml/kg/min)	35.0 ± 5.5	34.3 ± 6.4	35.6 ± 7.5	35.7 ± 7.8
RHR (beats/min)	68.2 ± 7.2	68.2 ± 6.5	64.3 ± 7.1	62.7 ± 7.9

Data are mean ± SD. RHR = resting heart rate.

The average water intake was slightly higher in the water reminder – daily tracker app intervention group throughout the study with a mean difference of approximately 11 ounces (Figure 2). However, there were no significant differences in water intake between the 2 groups at baseline (t(11) = -0.14, p = 0.89), week 5 (t(16) = -0.384, p = 0.46), and follow-up (t(19) = -1.27, p = 0.96). Overall, there were no changes in hydration within the two groups based on U_{col} and U_{pH} from baseline to week 5, (t(21) = -0.720, p = 0.48), and (t(21) = 1.916, p = 0.07), respectively. However, there was a small statistically significant increase in mean U_{sg} from baseline (1.010 ± 0.005) to week 5 (1.017 ± 0.004), (t(21) = -5.020, $p < 0.001$). There were no significant differences within the groups from week 5 to the end of the 30-day follow-up based on U_{col}, (t(21) = -0.495, p = 0.626), U_{sg}, (t(21) = 1.667, p = 0.110), and U_{pH}, (t(21) = -1.350, p = 0.191).

In addition, repeated-measures ANOVAs were conducted to test differences between the two intervention groups for U_{col}, U_{sg}, and U_{pH} from baseline to week 5. Results indicated there were no significant differences between the two interventions for U_{col}, $F(1, 20) = 1.471$, p = 0.239, and U_{sg}, $F(1, 20) = .690$, p = 0.416. There was a significant interaction between U_{pH} and intervention group at week 5, $F(1, 20) = 9.014$, p = 0.007, such that mean U_{pH} values were lower in the reminder app group (6.364 ± 0.234) as compared to the water bottle group (6.636 ± 0.393), suggesting a more acidic U_{pH} and mild dehydration. However, all values fell within normal limits.

Table 3. Mean water intake by intervention.

	Water Bottle Group (n = 11)	**Reminder App Group (n = 11)**
Baseline	52.1 ± 17.0	59.6 ± 19.0
5-week intervention	66.6 ± 21.9	77.5 ± 15.6
30-day follow-up	62.3 ± 19.7	77.0 ± 21.6

Data are mean ± SD.

To evaluate the relationship between body composition and hydration, a dichotomized variable was created, identifying those participants with a BMI ≥ 30 kg/m² (n = 8, obese) v. < 30 kg/m² (n = 14, normal-to-overweight). Based on BMI classification, there were no significant differences in water consumption at baseline (t(11) = 0.298, p = 0.77), week 5 (t(16) = 0.732, p = 0.48), and follow-up (t(19) = -0.058, p = 0.95) between the 2 intervention groups. However, there was a significant inverse relationship between BMI and U_{col} at baseline (r(20) = -0.47, p = 0.05), week 5 (r(20) = -0.46, p = 0.05), and follow-up (r(20) = -0.45, p = 0.04), indicating that women with a higher BMI were more dehydrated based on U_{col}. In addition, there was a nonsignificant inverse correlation between BMI and U_{sg} at baseline (r(20) = -0.03, p = 0.90), week 5 (r(20) = -0.14, p = 0.52), and follow-up (r(20) = -0.06, p = 0.79).

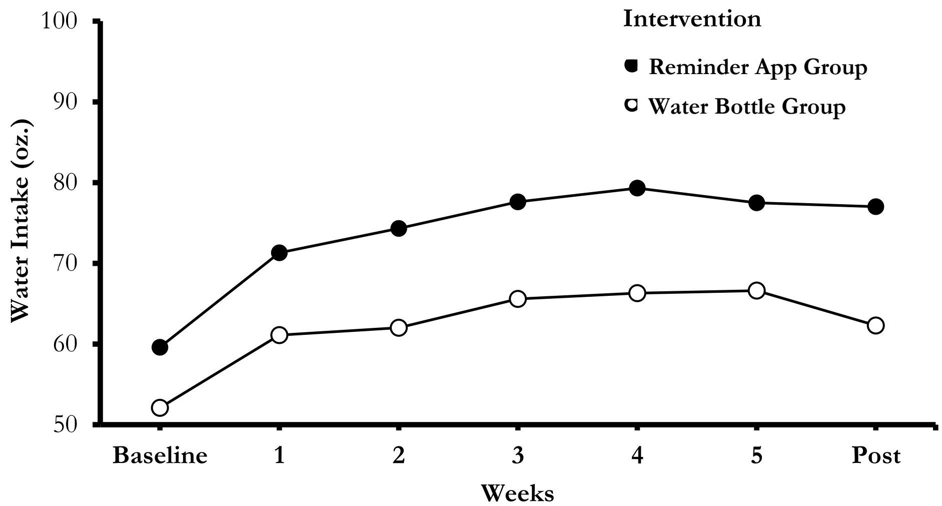

Figure 2. Average water intake for Reminder App Group (*n* = 11) and Water Bottle Group (*n* = 11) at baseline, weeks 1-5, and post 30-day follow-up period.

Self-efficacy and water intake

Based on a composite score for the 2 questions on self-efficacy, the difference from baseline (6.82 $\pm$ 2.26) to week 5 (7.96 $\pm$ 2.06) approached significance (p = 0.054), indicating an improvement in self-efficacy. In addition, the linear regression was statistically significant (R^2 = 0.262, $F(1, 16)$ = 5.69, p = 0.03), indicating that self-efficacy predicted daily water intake at the end of the 5-week interventions (β = 4.18, p = 0.03). Increased levels of self-efficacy were associated with increased water intake. However, at the 30-day follow-up, self-efficacy was not statistically significant (7.69 $\pm$ 2.27), and water intake decreased slightly.

S*elf-monitoring and hydration*

Based on hydration, self-reported symptoms of dehydration were examined during the week 5 interventions and at the end of the 30-day follow-up. Participants with increased water intake from baseline self-reported improvements in energy level, sleep quality, memory/ability to concentrate, and regular bowel movements. However, only memory and ability to concentrate significantly improved in hydrated participants ($t(19)$ = -1.54, p = 0.019). After the 30-day follow-up, there were no significant differences between the intervention groups.

At the conclusion of the intervention, participants self-reported that they did not frequently utilize their assigned hydration reminder tool during the 30-day follow-up period. However, participants reported improved confidence related to self-monitoring of hydration. Using a 5-point Likert scale (1 = strongly disagree or not confident at all, and 5 = strongly agree or very confident), participants reported confidence in their ability to self-monitor hydration based on urine color (4.55 $\pm$ 0.51*),* and to recognize the symptoms of dehydration (3.5 $\pm$ 0.51*).* Participants also acknowledged that hydration can impact personal health (4.73 $\pm$ 0.46) as well as cognitive and physical performance (4.5 $\pm$ 0.51).

Discussion

At baseline, participants consumed an average of 55.85 $\pm$ 18 ounces of water per day, suggesting underhydration, and 50% of participants were classified as dehydrated based on urine biomarkers. [6] Both 5-week reminder interventions successfully increased water intake by approximately 29% with an average daily water intake of 72.05 $\pm$ 18.75 ounces at week 5, meeting the minimum adequate water intake recommendations based on the DRI for adult women and the Mayo Clinic. Self-efficacy significantly increased at week 5, and was associated with increased water intake. At the end of the 30-day follow-up, the average decrease in daily water intake for participants was 7%. Although there was not a statistically significant difference in water intake between the 2 interventions throughout the study, the mean water intake for water reminder – daily tracker app group was approximately 11 ounces higher. This anecdotal finding supports that mobile phone apps are established tools for monitoring fluid intake as well as the findings of Han and Lee (2018) that mobile health (mHealth) apps have a positive impact on health-related behaviors and outcomes.[29,30] While water intake increased approximately 16 ounces at the end of the 5-week interventions, there were no significant changes in overall hydration within or between the 2 groups. However, there was a small, significant interaction between U_{pH} and intervention group with lower U_{pH} values in the reminder app, suggesting a more acidic urine and mild dehydration. This difference may be attributed to increased physical activity based on daily steps. Data were collected over the spring semester, and there may have been a greater impact on the reminder app group due to seasonal changes in physical activity and temperature.[31,32] Based on urine biomarkers of U_{col}, U_{sg} and U_{pH}, several of the participants were still classified as dehydrated at the end of 5 weeks, 41%, 45% and 18%, respectively. The researchers also evaluated the relationship between body composition and hydration. There was a significant inverse relationship between body composition and U_{col} at baseline, week 5, and at the end of the 30-day follow-up, indicating that women with a higher BMI were more dehydrated, which corroborates previous findings that women who are overweight or obese are at a higher risk of dehydration.[10-13] These data may suggest that women are more prone to involuntary, chronic dehydration due to a higher percent of body fat, and a lower percent of total body water. Based on the established cut-off of $U_{sg} < 1.020$ for a classification of hydrated, participants who met this criterion consumed an average daily intake of at least 65.79 ounces of water, which corroborates the recommended minimum intake of 64 ounces for adequate hydration by the Mayo Clinic.[6,28] Participants with increased water intake from baseline self-reported improvements in energy level, sleep quality, memory/ability to concentrate, and regular bowel movements. However, only the cognitive functions of memory and ability to concentrate significantly improved in the hydrated participants. These data support previous research that the specificity and sensitivity for U_{sg} of 1.020 is an appropriate cut-off for hydration, and that values below this cut-off are associated with mild dehydration and impaired cognitive function.[4,28] Interestingly, participants that achieved an intake of at least 65.79 ounces of water consumed approximately 55% of their body weight (in pounds) instead of the common recommendation of 50%. An intake of 55% of body weight appears consistent with the common reference that for the average female 55% of her total body weight is water.[33]

Currently, there is no universal gold standard to assess dehydration across different populations and settings. Our pilot study intentionally utilized practical, self-monitoring methods to assess hydration, including U_{col}, U_{sg} and U_{pH}. Therefore, the participants had to visually interpret their urine color as compared to a 7-point color chart as well as the results from the urinalysis dipsticks rather than using refractometry, which is considered the gold standard. Visual readings introduce subjectivity, resulting in errors of $\pm$ 1 color block on the dipstick and potential misclassification.[34,35] Another short-coming of urinary markers is that they can be affected by changes in diet, physical activity, and environmental conditions, which means that water intake requirements may fluctuate daily.[36-41] While the present pilot study attempted to control for chronic changes in body composition and physical activity that affect total body water, in a day-to-day real-world setting it is not feasible to control for all possible confounding factors that could affect hydration. In addition, the simple lay press equations available to the public to estimate how much water to drink did not calculate the amount of water needed to meet the classification of hydrated. Therefore, it is important to provide education and self-monitoring tools to assess hydration and daily water requirements. Previous research findings support that U_{col} demonstrates reasonable accuracy, based on specificity and sensitivity, for detecting dehydration across different categories of hydration as compared to U_{sg}. In addition, U_{col} is a quick, convenient, cost-effective method to assess hydration as compared to dipstick urinalysis due to supplies, cost, and collection requirements.[42,43] At the conclusion of the current study, participants reported confidence in their ability to self-monitor hydration status based on U_{col}. Finally, this pilot study had a small sample size, and focused only on adult women of child-bearing age between 19-50 years of age. Based on the findings of the current pilot study, future studies may want to evaluate the effectiveness of different water tracker apps, utilizing urine color to assess daily hydration and water requirements, with a larger sample and longer duration. In addition, researchers may want to compare hydration with performance on cognitive tasks in women.

Conclusions

The main finding of the current pilot study was that both 5-week reminder interventions successfully increased water intake. The inclusion of a mobile health app to self-monitor fluid intake may increase adherence. While water intake increased, there was not a significant change in hydration, and women classified as overweight or obese were at a higher risk of dehydration. Women who met the classification of hydrated (U_{sg} of $\leq$ 1.020) consumed at least 65.79 ounces of water per day, meeting the current recommendation of the Mayo Clinic for minimum adequate water intake of 64 ounces. They also self-reported significant improvements in memory and ability to concentrate as well as fewer cognitive and physical symptoms of dehydration. Participants also reported confidence in their ability to self-monitor hydration based on U_{col} as compared to other markers. Based on the findings of this study, U_{col} was a valid, convenient, and cost-effective method for women to assess hydration in a free-living environment.

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References

1. Riebl SK, Davy BM. The hydration equation. *ACSM'S Health Fit J*. 2013;17(6):21-28. Doi:10.1249/fit.0b013e3182a9570f
2. Armstrong LE. Hydration assessment techniques. *Nutr Rev*. 2005;63. Doi:10.1111/j.1753-4887.2005.tb00153.x
3. Tannenbaum SL. An investigation into equations for estimating water requirements and the development of new equations for predicting total water intake. *FIU Electronic Theses and Dissertations*. 2011. Doi:10.25148/etd.fi11040602
4. Exercise and fluid replacement. *Med Sci Sport Exerc*. 2007;39(2):377-390. Doi:10.1249/mss.0b013e31802ca597
5. McDermott BP, Anderson SA, Armstrong LE, et al. National athletic trainers' association position statement: Fluid replacement for the physically active. *J Athl Train*. 2017;52(9):877-895. Doi:10.4085/1062-6050-52.9.02
6. Mayo Clinic. How much water do you need to stay healthy? Mayo Clinic. October 14, 2020. Accessed September 9, 2022. https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/water/art-20044256.
7. Levine B. Hydration 101: The case for drinking enough water. Team Unify. Accessed February 13, 2023. https://www.teamunify.com/canbyst/UserFiles/File/Hydration%20101.pdf.
8. Taylor K, Jones E. Adult Dehydration. *StatPearls*. StatPearls Publishing; 2022.
9. Reinagel M. Fact check: Three quarters of Americans are chronically dehydrated. Nutrition Over Easy. April 6, 2022. Accessed February 13, 2023. https://nutritionovereasy.com/2017/06/fact-check-three-quarters-of-americans-are-chronically-dehydrated/.
10. Wang ZM, Deurenberg P, Wang W, Pietrobelli A, Baumgartner RN, Heymsfield SB. Hydration of fat-free body mass: Review and critique of a classic body-composition constant. *Am J Clin Nutr*. 1999;69(5):833-841. Doi:10.1093/ajcn/69.5.833
11. Chang T, Ravi N, Plegue MA, Sonneville KR, Davis MM. Inadequate hydration, BMI, and Obesity Among Us Adults: NHANES 2009-2012. *Annal Fam Med*. 2016;14(4):320-324. Doi:10.1370/afm.1951
12. Maffeis C, Tommasi M, Tomasselli F, et al. Fluid intake and hydration status in obese vs normal weight children. *Euro J Clin Nutr*. 2015;70(5):560-565. Doi:10.1038/ejcn.2015.170
13. Ritz P, Vol S, Berrut G, Tack I, Arnaud MJ, Tichet J. Influence of gender and body composition on hydration and body water spaces. *Clin Nutr*. 2008;27(5):740-746. Doi:10.1016/j.clnu.2008.07.010
14. Judelson DA, Maresh CM, Anderson JM, et al. Hydration and muscular performance. *Sport Med*. 2012;37(10):907-921. Doi:10.2165/00007256-200737100-00006
15. Bunn D, Jimoh F, Wilsher SH, Hooper L. Increasing fluid intake and reducing dehydration risk in older people living in long-term care: A systematic review. *J Am Med Dir Assoc*. 2015;16(2):101-113. Doi:10.1016/j.jamda.2014.10.016
16. Begum MN, Johnson CS. A review of the literature on dehydration in the institutionalized elderly. *e-SPEN, the Euro J Clin Nutr Metab*. 2010;5(1). Doi:10.1016/j.eclnm.2009.10.007
17. Manz F, Wentz A. The importance of good hydration for the prevention of chronic diseases. *Nutr Rev*. 2005;63. Doi:10.1111/j.1753-4887.2005.tb00150.x
18. Chua TXW, Prasad NS, Rangan GK, Allman-Farinelli M, Rangan AM. A systematic review to determine the most effective interventions to increase water intake. *Nephrol*. 2016;21(10):860-869. Doi:10.1111/nep.12675
19. Fat loss monitor - omron healthcare. OMRON healthcare. Accessed February 13, 2023. https://omronhealthcare.com/wp-content/uploads/hbf-306c-instruction-manual.pdf.
20. De Santiago V. The accuracy of non-exercise VO2max prediction equations in college students. *Int J Exer Sci*. 2012;2(4).
21. Falligant JM, McNulty MK, Kranak MP, Hausman NL, Rooker GW. Evaluating sources of baseline data using dual-criteria and conservative dual-criteria methods: A quantitative analysis. *J Appl Behav Anal*. 2020;53(4):2330-2338. Doi:10.1002/jaba.710
22. Wardenaar FC, Thompsett D, Vento KA, Pesek K, Bacalzo D. Athletes' self-assessment of urine color using two color charts to determine urine concentration. *Int J Environ Res Public Health*. 2021;18(8):4126. Doi:10.3390/ijerph18084126

23. Perrier ET, Bottin JH, Vecchio M, Lemetais G. Criterion values for urine-specific gravity and urine color representing adequate water intake in healthy adults. *Euro J Clin Nutr*. 2017;71(4):561-563. Doi:10.1038/ejcn.2016.269
24. Kostelnik SB, Davy KP, Hedrick VE, Thomas DT, Davy BM. The validity of urine color as a hydration biomarker within the general adult population and athletes: A systematic review. *J Am Col Nutr*. 2020;40(2):172-179. Doi:10.1080/07315724.2020.1750073
25. Jaffe R. First morning urine pH: A window on acid:alkaline balance. Holistic Primary Care. December 13, 2009. Accessed February 13, 2023. https://holisticprimarycare.net/topics/prevention-practice-pearls/first-morning-urine-ph-a-window-on-acidalkaline-balance/.
26. Qadir I. Correlation of ph in urine with capacity of drinking water per day. *Int J Res Stud Microbiol Biotech*. 2019;5(2). Doi:10.20431/2454-9428.0502002
27. Mannish KC, Leslie S. Uric Acid Nephrolithiasis. *StatPearls*. StatPearls Publishing; 2022.
28. Sommerfield LM, McAnulty SR, McBride JM, et al. Validity of urine specific gravity when compared with plasma osmolality as a measure of hydration status in male and female NCAA collegiate athletes. *J Stren Condition Res*. 2016;30(8):2219-2225. Doi:10.1519/jsc.0000000000001313
29. Han M, Lee E. Effectiveness of mobile health application use to improve health behavior changes: A systematic review of randomized controlled trials. *Healthcare Informatics Res*. 2018;24(3):207. Doi:10.4258/hir.2018.24.3.207
30. Philip-McKenzie Y, Jamnadass E, Hameed BMZ, et al. A content analysis of 'water apps' and prevention of urological diseases: Do apps really help? *Central Euro J Urol*. June 2020. Doi:10.5173/ceju.2020.0136
31. Garriga A, Sempere-Rubio N, Molina-Prados MJ, Faubel R. Impact of seasonality on physical activity: A systematic review. *Int J Environ Res Public Health*. 2021;19(1):2. Doi:10.3390/ijerph19010002
32. Cepeda M, Koolhaas CM, van Rooij FJA, et al. Seasonality of physical activity, sedentary behavior, and sleep in a middle-aged and elderly population: The Rotterdam study. *Maturitas*. 2018;110:41-50. Doi:10.1016/j.maturitas.2018.01.016
33. Radhakrishnan R. What percentage of your body should be water? Fluid intake chart. MedicineNet. September 20, 2021. Accessed February 13, 2023.
34. Rumley A. Urine dipstick testing: Comparison of results obtained by visual reading and with the bayer CLINITEK 50. *Annal Clin Biochem: Int J Lab Med*. 2000;37(2):220-221. Doi:10.1258/0004563001899041
35. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. *Nutr Rev*. 2010;68(8):439-458. Doi:10.1111/j.1753-4887.2010.00304.x
36. Fassett RG, Owen JE, Fairley J, Birch DF, Fairley KF. Urinary red-cell morphology during exercise. *BMJ*. 1982;285(6353):1455-1457. Doi:10.1136/bmj.285.6353.1455
37. Perez-Reyes M, Guiseppi SD, Brine DR, Smith H, Cook CE. Urine ph and phencyclidine excretion. *Clin Pharmacol Therapeut*. 1982;32(5):635-641. Doi:10.1038/clpt.1982.214
38. Adeva MM, Souto G. Diet-induced metabolic acidosis. *Clin Nutr*. 2011;30(4):416-421. Doi:10.1016/j.clnu.2011.03.008
39. Zubac D, Reale R, Karnincic H, Sivric A, Jelaska I. Urine specific gravity as an indicator of dehydration in olympic combat sport athletes; considerations for Research and Practice. *Euro J Sport Sci*. 2018;18(7):920-929. Doi:10.1080/17461391.2018.1468483
40. Silva R, Mündel T, Altoé J, Saldanha M, Ferreira F, Marins J. Preexercise urine specific gravity and fluid intake during one-hour running in a thermoneutral environment – a randomized cross-over study. *J Sport Sci Med*. 2010;9(3):464-471.
41. Rosinger A. Heat and hydration status: Predictors of repeated measures of urine specific gravity among Tsimane' adults in the Bolivian amazon. *Am J Physical Anthropol*. 2015;158(4):696-707. Doi:10.1002/ajpa.22813
42. Shirreffs SM. Markers of hydration status. *Euro J Clin Nutr*. 2003;57(S2). Doi:10.1038/sj.ejcn.1601895
43. McKenzie AL, Muñoz CX, Armstrong LE. Accuracy of urine color to detect equal to or greater than 2% body mass loss in men. *J Athl Train*. 2015;50(12):1306-1309. Doi:10.4085/1062-6050-51.1.03