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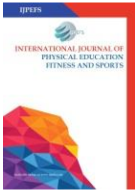

Effects of Smart Bottles on Water Consumption and Health Status of College Students

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Abstract: Hydration is important to a human body because it helps regulate body temperature, protect spinal cord, joints and other sensitive tissues, aid in the digestive system, remove body waste, and keep the brain function optimally. Despite the health benefits, most children and adults do not consume the recommended amount of water daily. Previous research suggested that interventions with a combination of educational/behavioral strategies and legislative/environmental prompts produced the best results to promote water intake. Existing in this technology-driven era, the invention of smart devices has changed the way we live. One type of devices, smart bottles, has been proved to be acceptable tools to monitor and promote water intake volume among kidney stone patients and senior citizens. This research aimed to examine the effects of smart bottles on college students' water consumption and health status. Daily water intake for 35 days and urine samples were collected from two groups of students enrolled in a walking class at a regional university in southeastern United States. Data were analyzed using descriptive statistics, independent-samples *t* test, and binary logistic regression. Results revealed that the bottle's smart features did not prompt or motivate the college students to drink more water and those who received the smart bottles did not show healthier results in urinalysis tests. A plausible explanation of the results can be caused by the lifestyle of typical college students who are more likely to consume beverages other than water because of personal preference and social influence.

Keywords: Hydration, Behavioral Strategies, Environmental Prompts, Smart Devices

1. Introduction

According to the Centers for Disease Control and Prevention (2022), benefits of staying hydrated include but are not limited to regulating body temperature, protecting spinal cord, joints and other sensitive tissues, aiding in the digestive system, helping remove body waste, and keeping the brain function optimally. Despite the numerous health benefits, most children and adults do not consume the recommended amount of water on a daily basis (Drewnowski, *et.al*, (2013a); Drewnowski, *et.al*, (2013b); Ferreira-Pego, *et.al*, (2015); Gibson & Shirreffs (2013); Roche, *et.al*, (2012); Sui, *et.al*, (2016); Vieux, *et.al,* (2017)). Lack of availability and knowledge, social influence, and preference are common barriers of drinking plain water (Block, *et.al*, (2013); Goodman, *et.al*, (2013); Hess, *et.al*, (2019); Vézina-Im, *et.al*, (2019); Wippold, *et.al*, (2020)). Apparently, when potable water is not an issue, most people would rather drink sugar-sweetened or alcoholic beverages for personal or social reasons. Consumption of these beverages could lead to health-related conditions and severe consequences caused by at-risk behaviors. Fellow scholars have highlighted the importance of hydration and implemented interventions to promote water consumption. Evidently, interventions based only on educational/behavioral theories or only on legislative/environmental components had no significant impact on the water consumption of adolescents (Collins, *et.al*, (2014); Contento, *et.al*, (2010); Elbel, *et.al*, (2015)). Using a combination of behavior change strategies (e.g., providing educational materials on (un)healthy diets, replacing obesogenic patterns with positive practices, or involving parents for holistic development) and environmental prompts (e.g., adding water coolers/fountains, distributing reusable bottles, or providing disposable cups), a significant increase in water consumption was found in many previous studies conducted on students at K-12 schools, overweight/obese adolescents and young athletes (Bogart, *et.al.*, (2014); Haire-Joshu, *et.al.*, (2015); Kavouras, *et.al.*, (2012); Kenney, *et, al.*, (2015); Loughridge, *et, al.*, (2005); Pate, *et, al.*, (2011); Wong *et, al.*, (2017)). As this line of research is still in its infancy, Vézina-Im and Beaulieu encouraged fellow scholars to conduct more research on different populations using objective measures and innovative interventions that include educational/behavioral and legislative/environmental components (Vézina-Im & Beaulieu (2019).

Existing in this technology-driven era, the Internet of Things (IoT) has changed the way we live drastically. From industrial establishments to consumer products, the paradigm of interacting people to people, people to machine, and machine to machine via wireless and wired connections creates an environment that enriches our lives in quality and quantity (Patel & Patel, S.M. (2016)). One evidence is the invention of smart devices. According to Silverio-Fernández, Renukappa and Suresh, "a smart device is a context-aware electronic device capable of performing autonomous computing and connecting to other devices wire or wirelessly for data exchange" (p. 8) (Silverio-Fernández, *et, al.,* (2018). In its simplest form, for a device to be "smart", it has a sensor (context-awareness) that detects and processes information (autonomous computing) and sends it through a network (device connectivity) to perform tasks. Today, smart devices such as phones, watchers, locks, and home appliances have increased convenience, productivity, and security in our day-to-day life. Over the past decade, several smart bottles have become available for health-conscious individuals to track fluid intake and develop a habit of regularizing adequate amount of water throughout the day. There are different designs of smart bottles, but they all have similar IoT-focused firmware, development board, ultrasonic distance sensor, piezo buzzer, and power supply to provide the users with water usage information on their smart phones (Jalagam, (2021). These smart bottles have been used in clinical research and filed studies and approved to be acceptable tools to monitor and promote intake volume among kidney stone patients and senior citizens (Bernard, *et.al.*, (2020); Conroy, *et.al.,*(2020); Fallmann, *et.al.*, (2017); Lee, *et.al.*, (2015); Plecher, *et.al.*, (2019). Out of the four common commercially available smart bottles, HidrateSpark 3 had an accuracy of measuring total intake within 3% error and upheld the most accurate sip recording compared to HidrateSpark Steel, H^{2}OPal, and Thermos bottle with a smart lid (HidrateSpar, (2019); HidrateSpark Steel (2020); H^{2}Opal, (2021); Thoermos Smart Lid, (2018); Borofsky, *et.al.*, (2018); Cohen, *et.al*.);. Since HidrateSpark 3 was not available during the course of this study and HidrateSpark PRO Lite was closely comparable to HidrateSpark 3 in terms of design and price, HidrateSpark PRO Lite was chosen to be used in the present study. HidrateSpark PRO Lite has a rechargeable weight sensor at the bottom, which calculates how much water a user takes (HidrateSpark PRO Lite (2021). Once connected to the app on a smart phone, the user can see the amount of water consume throughout the day. On the app, a user can set drink goals and have the bottle send reminders to drink more water throughout the day by glowing at the bottom. With the app, a user can also connect with others who share similar interests in the product and water drinking habits.

Up to date, most previous research integrating the use of smart bottles focused on clinical patients and senior citizens, this research aimed to examine college students' water consumption and health status using smart bottles as an innovative intervention and urinalysis as an objective measure. A quasi-experimental design was used for this research. Two groups of college students enrolled in a bi-term walking class were recruited to participate. Students reported their daily water intake for five weeks and deposited a urine sample at the end. Both groups underwent the same class activities and research protocols with one exception: one group was given smart bottles and the other was not. With the smart features, especially the one that reminds users to take a drink, we hypothesized that the group with smart bottles will consume significantly more amount of water than the group without smart bottles (#1). Because of the more amount of water they consume, we hypothesized that the group with smart bottles will be healthier than the group without smart bottles (#2). Lastly, to emphasize the importance of hydration to a person's overall health, we hypothesized that the amount of water intake will be a significant predictor of the college students' health status (#3).

2. Methods

2.1 Setting and Participants

Students enrolled in a walking class at a regional university in the southeastern United States were invited to participate in this research. There were two bi-term sections for this walking class in the spring of 2023. Both sections were taught by the same instructor with identical course activities and assignments, including the importance of hydration and how it related to physical activity and athletic performance. On the first day of the first bi-term section, both authors attended the class and presented the research project to the students. To be part of the experiment, students were to log their daily water intake for 35 days consecutively on Blackboard and deposit a urine sample at the end of the bi-term. As an incentive, students who completed the two tasks were exempted from the final project, which was a research paper on walking. All thirty students signed the consent forms to fulfill the institutional review board's requirement for conducting research on human subjects. After two students withdrawing from the class and three dropping out of the study, data from 25 students were obtained.

Both authors repeated the same procedure for the second bi-term section with one exception. Students who were interested in participating in the experiment were given a smart bottle that would track their water intake via a smart phone. Since they did not have to take the extra effort to log their daily water intake on Blackboard like their peers in the first bi-term section did, everyone in class was to complete the final project for the walking class. The smart bottle, which was worth $50 in retail, served as the incentive upon completion of the research project.

Table 1. Sex and age composition by academic term

	First bi-term	Second bi-term
Sex		
Male	8 (32%)	6 (35.3%)
Female	17 (68%)	11 (64.7%)
Age		
17 years	0	1 (5.9%)
18 years	1 (4%)	0
19 years	5 (20%)	3 (17.6%)
20 years	5 (20%)	4 (23.5%)
21 years	8 (32%)	5 (29.4%)
22 years	6 (24%)	2 (11.8%)
23 years	0	2 (11.8%)

Out of the 35 enrolled students, 30 signed the consent formed at first. Thirteen of them either decided not to continue the study and returned the bottles or failed to deposit their urine samples at the end. A total of 17 students were accounted for the second bi-term section. The participants' sex and age compositions in each bi-term section are illustrated in Table 1.

2.2 Data Collection

Daily water intake for both bi-term sections were collected for five consecutive weeks, starting on a Wednesday and ending on a Tuesday. For the first bi-term section, the second author was added on the course Blackboard by the instructor as a way to monitor and collect the water intake of the participants. Assignments worth of zero point were created, through which the participants had until the next day by 10 A.M. to submit their water intake. The second author sent out an individual reminder to the participants whose water intake for the day before was still missing at 9 A.M. and again in 30 minutes as needed. Participants who missed more than two logs per week were dropped out of the study. Missing logs were excluded from calculating weekly water intake average. For the second bi-term section, the participants' water intake was collected through the HidrateSpark Water Tracker, an app that synced with a HidrateSpark bottle via Bluetooth. Its smart features tracked users' water consumption, reminded them to drink more water by glowing on the bottom of the bottle, allowed them to set water intake goals, and so forth. As the app administrator, the second author had access to every participant's daily water intake as long as they were using the bottle and the app on their smart phones. The syncing process, however, was frustrating to many participants, which led to a greater amount of drop-outs than the first bi-term section.

At the end of each bi-term section, the participants had five weekdays to deposit a urine sample at a local health center. Using the dipstick urinalysis, the participants' health status was evaluated by urine color and transparency, specific gravity of urine, pH level, and the amount of leucocytes, nitrites, protein, glucose, ketones, blood, bilirubin and urobilinogen in urine. According to Simerville, Maxted and Pahira, urine is typically clear in some shade of yellow. Cloudiness or a non-yellowish color can be a problem (Simerville, *et.al.,* (2005). For this age group, specific gravity of urine is normal between 1.005 and 1.030; a test result that falls outside of this range indicates a kidney problem. Another test for kidney function is the pH level as the kidneys play an important role in acid-base regulation. A normal urinary pH ranges between 5.0 and 6.0 for this age group. Leucocytes and nitrites determine the presence of white blood cells and certain bacteria in urine; a positive test result can be a sign of an infection. An exceeding amount of protein or glucose in urine is another sign of kidney dysfunction because protein should not leak through kidneys into urine and glucose is normally filtered by kidneys. Proteinuria (i.e., protein in urine) or an abnormal amount of glucose in urine is a sign that the kidneys are damaged. Ketones refer to the chemicals when fats are broken down for energy. It is normal to have some ketones in urine; however, an unbalanced level of ketones in urine can build up in blood and poison a human body. Blood in urine can be a sign of an infection of the bladder, kidney, prostate, or urethra. Lastly, the presence of bilirubin and urobilinogen in urine can be an early indicator of liver diseases.

3. Data Analysis and Results

Means and standard deviations of the participants' weekly and overall water intake were calculated and illustrated in Table 2. Data normality for the continuous variables as a sample group and as two separate groups by section was checked using the probability-probability plots and they appeared to be normally distributed visually. To confirm the normal distribution, the values of skewness and kurtosis, converting to *z*-scores, were calculated. All values, except for week 2 and week 5 water intake of the sample group and of the participants in the first bi-term section, were below the upper threshold of 1.96 for a small sample size at $p < .05$, indicating a normal distribution (Field, *et.al.*, (2009). Besides, using Levene's test, the assumption of homogeneity of variance was met for all continuous variables. An independent-samples *t* test was calculated comparing the average weekly and overall water intake of the participants between the first and second bi-term sections. No significant difference was found in any of the five weeks or the overall water intake. This result contradicted the first hypothesis, indicating that the bottle's smart features did not prompt or motivate the participants in the second bi-term section to drink more water.

All dipstick urinalysis items except for the urine color and transparency were treated as dichotomous variables for the negative/normal and the positive/abnormal test results. Frequencies and percentages of the 12 items were calculated for each bi-term section. Over two-thirds of the participants (*n* = 19, 76%) in the first bi-term section had normal urine color while the other six (24%) had an abnormal urine color of straw. The majority of the same group of participants had clear transparent urine (*n* = 20, 80%), four (16%) had cloudy or slight cloudy urine, and one (4%) had slight hazy urine. As for the participants in the second bi-term section, 14 of them (82.4%) had healthy urine color, two (11.8%) appeared to be straw and one (5.8%) was dark yellow. Also 14 of them had clear urine while the other three (17.6%) had hazy or slight hazy urine. According to Table 3, the participants reported to have similar health status regardless of the type of bottles used. They both had low percentages of positive/abnormal test results in specific gravity, nitrites, glucose and bilirubin, and similar percentages of split test results in pH level, blood and urobilinogen. The participants in the first bi-term section, however, had higher percentages of negative/normal test results in leucocytes, protein and ketones. What was observed rejected the second hypothesis, suggesting that the participants in general had similar health status. If anything, the participants with smart bottles were slightly less healthy than their peers without the same bottles for the percentages of negative/normal test results being lower in most dipstick urinalysis items.

Table 2. Means and standard deviations of weekly and overall water intake in each section

	First Bi-Term Section		Second Bi-Term Section	
	Mean	Standard Deviation	Mean	Standard Deviation
Week 1	51.67 oz	24.54	53.64 oz	25.62
Week 2	54.35 oz	26.39	48.22 oz	28.33
Week 3	48.10 oz	24.54	48.35 oz	22.68
Week 4	46.14 oz	22.88	49.97 oz	20.99
Week 5	48.73 oz	25.03	48.39 oz	24.39
Overall	49.80 oz	23.45	49.71 oz	21.38

Table 3. Summary of dipstick urinalysis test results by section

	First Bi-Term Section		Second Bi-Term Section	
	Negative/Normal	Positive/Abnormal	Negative/Normal	Positive/Abnormal
Specific Gravity	25 (100%)	0	17 (100%)	0
pH Level	13 (52%)	12 (48%)	9 (52.9%)	8 (47.1)
Leucocytes	21 (84%)	4 (16%)	11 (64.7%)	6 (35.3%)
Nitrites	25 (100%)	0	16 (94.1%)	1 (5.9%)
Protein	18 (72%)	7 (28%)	10 (58.8%)	7 (41.2%)
Glucose	25 (100%)	0	16 (94.1%)	1 (5.9%)
Ketones	23 (92%)	2 (8%)	12 (70.6%)	5 (29.4%)
Blood	21 (84%)	4 (16%)	15 (88.2%)	2 (11.8%)
Bilirubin	25 (100%)	0	16 (94.1%)	1 (5.9%)
Urobilinogen	17 (68%)	8 (32%)	11 (64.7%)	6 (35.3%)

Binary logistic regression was conducted to predict the participants' health status based on their overall water intake in two bi-term sections. The regression equation was not significant in any of the dipstick urinalysis items calculated (i.e., pH level, leucocytes, protein, ketones, blood and urobilinogen).

Water intake was not a significant predictor of the participants' health status. This finding rejected the third hypothesis, indicating that the amount of water they had consumed for the 35 consecutive days did not make them healthier or less healthy. This was the case whether they were self-reporting their daily water intake or had the smart devices (i.e., bottle and phone) taken care of it for them.

4. Conclusion

Per Vézina-Im and Beaulieu's suggestions, this research investigates college students' water consumption and its association with their health status. Both educational/behavioral (i.e., water hydration-related materials) and legislative/environmental (i.e., distributing smart bottles) components were used as the intervention strategies. Objective measures (i.e., urinalysis and a water tracker app) were used to increase data credibility, although self-report numbers were used in the first bi-term section. Findings were inconsistent with previous research conducted on clinical patients and senior citizens. In the present study, the smart bottles were not an impactful tool for college students to drink more water and consequently display healthier markers in the urinalysis test results. Data from both groups also did not show a positive association between water consumption and health status. A plausible explanation of the contradicting results to the existing literature can be caused by the lifestyle of typical college students. Compared to kidney stone patients and older adults who need to be conscientious about their water intake due to medical conditions, college students are more likely to consume beverages other than water because of personal preference and social influence.

There are a few limitations in this study. First, it presented a small sample size. The amount of drop-outs from non-completion and frustration caused by technical difficulties do not help with the already small class sizes. Follow-up studies with much larger sample sizes are needed before a sounding conclusion can be drawn regarding whether smart bottles can or cannot be a significant motivator to college students' water consumption behaviors. Second, the decision to distribute smart bottles to the second bi-term group is made so the gadget will not be a reason for the group without the same bottles to intentionally drink more water to outperform the previous bi-term group had the group assignment reversed. We believe that the influence of a group's competitive nature is smaller if the smart bottles are distributed in the second bi-term section. Future research can attempt the reverse order of group assignment, which may result in interesting findings. Lastly, the participants have five days to deposit a urine sample at the end of the bi-term sections. Because data collection ends on a Tuesday, this five-day period crosses over a weekend, during which they could be drink more or less significant amount of water. Although most of the participants choose to drop off their urine sample on the first two days, a few do not go to the medical center until the last two days. The beverages, food, and possibly other substances they consume over the weekend may reflect on the urinalysis results. Fellow researchers who are interested in replicating this line of research should take the precaution of this drawback and perhaps move the start and end day of the week for data collection.

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Author contribution Statement

YuChun Chen - Conceptualization, Supervision, Methodology, Data collation, Analysis, Validation, Writing - review & editing; **Farrah Castleman** - Data collection. Both authors read and approved the final version of the manuscript.

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author upon approval of the request.

Conflict of interest

The authors declare no conflict of interest.

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Yes

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