Examining the Links Between Hydration Knowledge, Attitudes and Behavior

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This is a post-peer-review, pre-copyedit version of an article published in *European Journal of Nutrition.* The final authenticated version is available online at: https://doi.org/10.1007/s00394-019-01958-x

Abstract

Purpose: This study aimed to examine the psychological factors (knowledge, barriers and facilitators) that can contribute to hydration-related behaviors (i.e., fluid intake) in the general population and how these relate to physical health.

Methods: A structured survey was developed to examine the links between hydration knowledge (29 items), attitudes about hydration (80 items), and fluid intake behavior (8 items) among U.S. adults. Survey data from Phase 1 (n = 301 U.S. adults) psychometrically evaluated the items via item analysis (knowledge and fluid behavior) and factor analysis (attitudes). Phase 2 survey data (n = 389, U.S. adults and college students) refined and validated the new 16-item hydration knowledge measure, 4-item fluid intake behavior index, and 18-item attitude measure (barriers and facilitators of hydration-related behaviors) alongside indices of physical health (BMI and exercise behaviors).

Results: Participants had a moderate level of hydration knowledge (Phase 1: 10.91 ± 3.10; Phase 2: 10.87 ± 2.47). A five-factor measure of attitudes which assessed both facilitators (social pressure and attention to monitoring) and barriers (lack of effort, physical barriers and lack of a fluid container) to hydration demonstrated strong internal consistency (αs from .75 to .90). Attitudes about hydration—most notably barriers to hydration—were associated with indicators of health and with fluid intake behaviors, whereas hydration knowledge was not.

Conclusions: Increasing hydration knowledge may be necessary for people who hold inaccurate information about hydration, but attitudes about hydration are likely to have a larger impact on fluid intake behaviors and health-related outcomes.

Keywords: Hydration, Fluid Intake, Attitudes, Knowledge

Water is an essential nutrient for the maintenance of life [1]. Adequate water intake leads to ideal total water balance (i.e., euhydration). Euhydration is important for acute and chronic health; dehydration is a serious health issue associated with a host of physiological problems [2, 3], as well as deficits in cognition and increased negative mood [4–6]. Dehydration is particularly problematic for children [7, 8] and the elderly [9], as the effects of hydration (or dehydration) are pronounced in these populations [10]. Even more broadly, a substantial percentage of the population (at least in the United States) does not meet the minimum guidelines for fluid intake [11–13]. Because the largest contributing factor to adequate hydration is sufficient fluid consumption, understanding people's behavioral practices around fluid intake is important for understanding both euhydration and dehydration [14]. Moreover, as drinking fluids is a behavior people must choose to engage in, understanding the factors that facilitate fluid intake as well as the factors that might serve as barriers to fluid intake may be useful in developing interventions to improve hydration.

One potential factor that may influence fluid intake is knowledge about hydration[1]. Several studies have examined hydration knowledge in specialized samples, such as in dietitians [15] and in the context of sport [16–20]. Understanding knowledge of hydration in athletes is certainly important, as hydration is a key factor in sport performance [3]; the amount of fluid a person needs shifts during exercise, especially in the heat. These factors may contribute to why studies examining hydration knowledge tend to focus on specific practices (e.g., consumption of sports drinks) or areas of information (e.g., hydration specific to exercise and/or performance)

[1] In this paper, the term "hydration" is used as a verb, referring to the action of consuming fluids. "Hydration" is not used as an adjective, referring to adequate total body water. The distinction is important because it is possible for an individual to consume a high volume of fluid (i.e., engages in significant hydration practices) to exist in a dehydrated state, such as it is possible for a person who consumes a low volume of fluid to exist in a euhydrated state. The intention here is to gain insight into hydration practices, not to define an individual's hydration state.

that are salient for athletes. However, considering the role of hydration in maintenance of homeostasis outside of sports, a broader assessment of hydration knowledge is important. Only two studies we are aware of have examined hydration knowledge in representative general populations, which generally found poor knowledge about hydration [21, 22].

Beyond knowledge, psychological factors also likely influence hydration practice. That is, the attitudes which people hold toward hydration could either help or hinder engagement in fluid consumption. One qualitative interview study [23] of patients with the propensity to develop kidney stones (who theoretically have been instructed to consume larger volumes of water on a daily basis) found that barriers to hydration were generally grouped by success and motivation. Some people described unmotivated attitudes *via* forgetting to drink fluids or conveying that hydration behaviors were not important to them. Others described barriers such as disliking the taste of water or not having water available, and others reported environmental barriers such as not having a restroom available or not being able to take time from school or work to drink fluids [23]. A quantitative measure of hydration attitudes for general population use (beyond those assessing specific attitudes in athletes or physicians; [15, 18, 19]) would be valuable for examining the links between knowledge, attitudes and behavior, and a first step toward understanding how knowledge and attitudes contribute to objective hydration status.

The purpose of the current project was to examine hydration knowledge, attitudes (e.g., facilitators and barriers) and behaviors around fluid intake in U.S. adults. A primary function was to (Phase 1) derive measures of knowledge, attitudes and practices with strong psychometric properties for use in future work. The secondary function was to report on relationships among these factors and how knowledge, attitude and practice relate to perceptions of overall health and activity (Phase 2). The hypothesis was that knowledge would exhibit low to mild relationships with fluid intake behaviors and overall health, considering that the link between knowledge and behavior is often weak in other health-related outcomes [24, 25].

Method

This study was completed in two phases. Before initial data collection, items were generated to measure three separate aspects of hydration: knowledge, self-reported behavior, and attitudes (i.e., facilitators and barriers). In Phase 1, these measures were psychometrically evaluated with an initial sample. In Phase 2, using a separate unique sample, the factor structure of the attitudes scale was verified, and the number of overall items in the attitude scale was reduced to produce a quick but comprehensive measure of both barriers to and facilitators of hydration. Finally, in Phase 2, initial validation of the three hydration measures was assessed by examining relationships with indicators of health. These procedures follow guidelines for scale development [26, 27].

Development of Preliminary Item Pools

Items were developed toward three separate measures: (1) hydration knowledge; (2) fluid intake behaviors, and (3) attitudes consisting of facilitators and barriers toward hydration.

Knowledge Items. This project was a collaboration between exercise physiology and psychology, where the exercise physiology team provided content expertise about hydration, and the psychology team provided expertise in measurement development and validation. In developing knowledge items, the exercise physiology team prioritized information about hydration that they felt were essential to the concept. They generated top priority concepts (e.g., “You can be dehydrated without being thirsty” and “Dark urine is indicative of dehydration”) and several lower-priority concepts (e.g., “Fluid is retained better when combined with eating.”) From this list, the psychology team generated a set of items that captured these concepts with both “true” and “false” versions of most concepts. For example, the item “People can be dehydrated without being thirsty” was phrased so that a correct response is “true” and the analogous item “If someone is dehydrated, they will be thirsty” would correspond with a “false” correct answer. In total, 29 items were generated and checked by the exercise physiology team for accuracy. These items were administered on a 5-point Likert scale from -2 (*Definitely Inaccurate*) to 2 (*Definitely Accurate*) where 0 meant “*not sure*.” This structure assessed for confidence in knowledge, but could also be scored explicitly for accuracy.

Behavior Items. To get a basic assessment of hydration related behaviors, participants were asked 8 *yes* or *no* questions related to fluid intake—do you carry a water bottle, do you usually have fluid nearby, do you drink even when not thirsty, do you drink during meals, do you drink at least once per hour when awake, do you monitor your urine color, do you drink from a water fountain and do you drink tap water. Participants also completed items about overall daily fluid intake on a 5-point scale (0 = *None*, 1 = *Less than 16 oz*, 2 = *Between 16 and 32 oz,* 3 = *Between 33 and 63 oz* and 4 = *64 oz or more*[2]). Finally, an item asked people how confident they were in being well hydrated, from 1 (*Not at all confident*) to 5 (*Extremely confident*).

Facilitator and Barrier Items. The items assessing facilitators and barriers to hydration were developed from a series of separate focus groups, which included groups of university students, student athletes, middle aged adults and older adults in a retirement community. Participants in the focus groups were asked questions about what helped and hindered their ability to stay hydrated. The psychology team conducted the focus groups, and the conversations were transcribed. The psychology team then met to identify categories generated by the focus group participants (i.e., access to fluids, activity levels, awareness, environmental factors, habit,

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[2] Because this study was conducted in the U.S., measurements were presented in fluid ounces. In the Appendix, measures are given in both fluid ounces and Liters.

knowledge, motivation, safety, social, mood or physical state, and taste). From these categories, the psychology team then generated 80 items, retaining wording from focus group members where possible but rephrasing when needed for clarity. Item anchors ranged from 0 (*not at all like me*) to 5 (*very much like me*) Likert-type scale. Each category included barriers (e.g., "I don't drink fluid when it's not easily accessible") and facilitators (e.g., "I'm more likely to drink fluids if I have a bottle with me").

Phase 1

Participants and Procedure

Participants (n = 301), were recruited via Amazon's Mechanical Turk, a web-based service where "workers" complete online tasks (including research surveys) for money. For Phase 1, inclusion criteria were that participants needed to be over 18 years of age and live in the United States. Data collection took place via TurkPrime [28]. The sample of participants was slightly less than half women, predominantly White, and geographically diverse, with 46 of the U.S. states represented in the sample (see Table 1). Participants were paid $1.50 to complete the items (average duration 12.52 min, SD = 6.30). Participants saw the behavior items first, followed by the knowledge items, and finally the facilitator and barrier items. All procedures were approved by the Institutional Review Board at the University of Arkansas, and were performed in accordance with U.S. law and international ethics standards.

Phase 2

Participants and Procedure

Participants (n = 403) were recruited from two sources, a psychology subject pool at a Midsouthern University in the United States who completed the study for course credit (n = 204) and from mTurk (n = 199) who were paid $1.50 for completing the items. There were no exclusion criteria for students, and the mTurk sample was required to be over 18 and a resident of the U.S. See Table 1 for demographics. Just as with Phase 1, participants saw the behavior items first, followed by the knowledge items, and then the facilitator and barrier items. Finally, participants completed the individual difference measures assessing exercise, with demographic questions at the end of the study including height and weight for calculating BMI.

Hydration Measures. The 16 item Hydration Knowledge Scale (HyKS), the 4-item Fluid Behavior Index, and the 35 items assessing facilitators and barriers retained from Phase 1 were given again in Phase 2.

Overall Health. A single item from the Short Form Health Survey [29] assessed general perception of overall health. Participants were asked "In general, would you say your health is" and asked to respond from 1 (*Poor*) to 5 (*Excellent*). This single item has been used as a proxy of health in other studies [30].

Physical Activity & Exercise. The short form of the International Physical Activity Questionnaire (IPAQ; [31]) assessed exercise involvement. This measure assesses physical activity in the last week, and inquires about the amount of time spent doing vigorous activities (i.e., heavy lifting, digging, aerobics, fast bicycling), moderate activities (doubles tennis, bicycling at a regular place, carrying light loads), walking (at work or home), and sitting. This measure was given in self-administered format and is applicable for adults aged 15 to 69 years old. Scoring focused on vigorous exercise as a metric of health, via calculation of Metabolic Equivalent (MET) scores for vigorous exercise. This score multiplies the daily minutes of vigorous activity x days per week x 8.0 (see scoring at www.ipaq.ki.se and [31]). A second calculation classified participants as (a) meeting recommendations for health-enhancing physical activity (HEPA), (b) minimally active or (c) insufficiently active based on published scoring protocols (see www.ipaq.ki.se; [31, 32]).

Results

Phase 1

Knowledge. As the goal was to create a brief index of hydration knowledge applicable to the general population, items were first scored as correct or incorrect (i.e., for items that described accurate or true hydration information, a score of 1 was given for an answer of “probably accurate” or “definitely” accurate, and 0 for other responses; for items that described inaccurate or false hydration information a score of 1 was given if a person said “probably inaccurate” or “definitely inaccurate” with a score of 0 for other responses) and then a total number of items correct was calculated for each person. Item statistics (% of the sample who got the item correct, correlation with the total score, mean and standard deviation of the overall item) for each item were examined to select well-performing items for the final scale, where we retained a mixture of true and false items as well as items with varying difficulty (see Supplemental material for item statistics; see Appendix for final version of the scale). The final 16-item knowledge scale was named the Hydration Knowledge Scale (HyKS).

Overall, the average number of items correct (out of 16) was 10.91 ± 3.10, with a range of 1 to 16. A “knowledge score” was calculated by adding the total score from the full five-point scale (with false items reverse scored), where a perfect score of 32 would indicate all items were correct and the person was “definitive” about each item. The average knowledge score was 13.64 ± 7.63. The number correct and the knowledge score were correlated at $r = .90$, $p < .001$.

Behavior. Initially, descriptive statistics were reviewed for the item directly assessing fluid intake, where participants were asked how many ounces of fluid people think they drink on a typical day. Results indicated that only 1% (n = 3) people reported drinking no fluids, and only 2% (n = 6) reported drinking less than 16 oz. (less than 473 ml) per day. About one-fifth (20.9%, n = 63) reported drinking between 16 and 32 oz per day (473 - 946 ml), and about a third (35.5%, n = 107) indicated they drink between 33 and 63 oz (946 ml - 1.86L). The largest group of 40.5% (n = 122) reported drinking 64 or more ounces (>2L) of fluid per day. Descriptive statistics for the confidence of personal hydration item revealed the average confidence on a 1 to 5 scale was 3.31 ± 1.23.

The eight behavior questions were evaluated by examining the percentage of people who endorsed each item. The majority indicated they typically have a beverage within arms' reach (82.4%), that they drink fluids even when they are not thirsty (71.1%), that they drink fluids with meals (94.7%), and that they do not regularly drink water from a water fountain (80.4%). The other items had greater variability; slightly over half reported regularly carrying a water bottle (57.8%), drinking fluid at least once per hour when awake (58.5%), and drinking tap (unfiltered) water (51.5%) whereas less than half indicated attention to urine color to monitor hydration status (45.5%).

The ultimate intention of examining the behavior items was to create a brief self-report index of hydration behavior. For this, the score from the ordinal variable addressing ounces reported daily (from 0 to 4) was added to "yes" responses (each yes received 1 point) for beverage proximity, drinking when not thirsty and monitoring urine items that were associated with greater reported fluid intake to create a fluid behavior index (see Appendix for final measure). These specific items were retained because people who said "yes" to those items reported greater fluid intake overall. The possible responses to the fluid behavior index ranged from 0 to 7, though actual scores ranged from 1 to 7, with an average score of 5.24 ± 1.47. The negative skew to this variable suggests that the majority of people report engaging in fluid intake behaviors. Greater fluid intake as measured by the fluid behavior index was associated with greater hydration knowledge, $r = .16$, $p = .01$, and with greater confidence in being well-hydrated, $r = .50$, $p < .001$.

Facilitators and Barriers. After removing items with poor variability ($n = 2$) and items with high (>.60) correlations with other items ($n = 9$), an exploratory factor analysis (EFA) was conducted on the remaining 70 items, using maximum likelihood with oblique rotation. The data were suitable for factor analysis according to the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO = .89; Cerny, & Kaiser, 1977), and a significant ($p < .001$) Bartlett's test of sphericity.

The factor structure was evaluated using (1) the scree plot (2) the Kaiser criteria (i.e., eigenvalues over 1) and the expected eigenvalues from a Monte Carlo parallel analysis [33]. The number of suggested factors varied by method. There were 15 factors with eigenvalues above 1, which seemed untenable. The scree test suggested about 8 factors, and the parallel analysis suggested 6 factors. Thus, 6, 7 and 8 factor models were examined. The 7-factor and 8-factor models both had factors with only two items, and thus did not suggest good model fit. The 6-factor model was clean, with all items loading primarily onto one factor (albeit with some cross-loadings). After excluding items that did not load onto any factor and trimming items with low factor loadings or significant cross-loadings, there were 35 items on 6 interpretable factors (see Supplemental material for factor loadings). The first factor, which had 8 items, was titled "Lack of Effort Barrier" factor as this captures barriers to hydration involving laziness, lack of habit, business, and generally factors that suggest an unwillingness to put effort into hydration. The second factor, with 5 items, was called the "Social Facilitators" factor, where items center upon accountability and social proximity as contributors to increased hydration. The third factor, with 8 items, was named the "Contextual Facilitators" because the items are associated with specific situations (e.g., environmental heat exposure, exercise, spicy foods, illness) that tend to increase hydration. The fourth factor, with 7 items, was named the "Monitoring Facilitator" factor had items that capture the importance of hydration, planning, and checking physical status to facilitate hydration. The fifth factor, with 4 items, was dubbed the "Physical Barriers" which are about bathroom access and dislike of urination as barriers to hydration. Finally, the sixth factor, with 3 items, was named the "Lack of Container Barrier" factor, which assesses willingness to carry a water bottle to make fluids readily available. After creating these factors, items that loaded oppositely to the rest of the items on the factor were reverse scored (Items 5, 27, 61, 78) and reliability ratings were calculated. The Cronbach alphas for each scale were acceptable (between .75 and .80).

Relations among knowledge, behavior and attitudes. Finally, the initial correlational relationships between knowledge, behavior and the attitudes assessed by the facilitators and barriers to hydration were examined (see Table 2). All of the facilitators and barriers were associated with fluid intake behaviors, and most (all except contextual factors) were associated with confidence in being well hydrated. All of the barriers and the social facilitator item were associated with lower fluid behaviors and lower confidence, whereas the contextual and monitoring facilitators were associated with greater fluid intake and greater confidence (though only the monitoring facilitator correlation was statistically significant). However, knowledge was negatively associated with lack of effort and positively associated with contextual facilitation.

Phase 2

Samples. Three participants who took over an hour to complete the study (all 3 were in the subject pool) were excluded, along with 11 participants who completed the study in less than 5 minutes, which was judged as too short to reasonably complete all the items based on pilot testing. These exclusions left a final sample size of 389 (see Table 1). In comparing the subsamples, the mTurk sample had a smaller percentage of women, college students, and White people than the university subject pool sample, and the mTurk sample was also older (see Table 3 for demographics by sample).

On average, participants answered 10.87 ± 2.47 items correctly out of 16, where the mTurk sample answered more items correctly than the university subject pool sample (see Table 2). This was accounted for by the significant correlation between knowledge and age, $r = .21$, $p < .001$. When age was controlled for, there were no longer any sample differences on knowledge scores, $F(1, 386) = .75$, $p = .39$.

Just as in Phase 1, the Fluid Behavior Index scores ranged from 1 to 7 (see Table 3). Confidence in hydration near the mid-point of the scale, as were perceptions of overall health. There were no sample differences in fluid intake behaviors, confidence or overall health.

Facilitator and barrier items. Cronbach's alphas on the 6 subscales determined in Phase 1 were calculated to confirm internal consistency. The contextual subscale had poor internal consistency ($\alpha = .60$), not attributable to any particular items, suggesting that these items did not coalesce. Items on this scale were thus removed from the overall measure.

Although the other subscales had adequate internal consistency (between .70 and .87), the decision was made to trim the other subscales, with the goal of reducing the total number of items on the measure. To do this, two random halves of the dataset were created. The first half had 194 people (100 subject pool, 94 mTurk) and the second half 195 (98 subject pool, 97 mTurk). The inter-item correlations and corrected item-total correlations for each subscale were then examined to trim each subscale to 3-4 items per scale. The internal consistency of the revised subscales was then evaluated in the second half of the dataset. All of the subscales demonstrated adequate internal consistency, with 3 items on the Physical Barriers subscale (α = .75) and 3 items on the Lack of Containers Barrier subscale (α = .90), and 4 items each on the Lack of Effort Barrier subscale (α = .82), the Social Facilitator subscale (α = .80) and the Monitoring Facilitators subscale (α = .81). The trimmed subscales correlated highly with the longer scale (all correlations above .90) suggesting the removed items did not significantly alter the constructs measured. The final 18-item measure is called the Hydration Facilitators and Barriers (Hy-FAB) scale (see Appendix).

Hydration knowledge, behavior, attitudes and health outcomes. Due to sample differences on many of the variables (Table 3), partial correlations between hydration knowledge, the fluid behavior index, the facilitators and barriers to hydration and health outcomes controlled for sample (subject pool or mTurk). Results presented in Table 4 indicate that hydration knowledge is not correlated with hydration behaviors, attitudes or health outcomes. In contrast, greater self-reported fluid intake behaviors were associated with fewer barriers to hydration and greater monitoring. Moreover, all of these factors (greater hydration behavior, fewer barriers and greater monitoring) were associated with greater perception of overall health.

The only hydration attitude not associated with increase self-reported fluid intake was social facilitation. In fact, the pattern of correlations suggests that the social facilitator operated differently than the other facilitator (monitoring). Specifically, greater social facilitator scores were significantly associated with greater lack of effort toward hydration and more physical barriers to hydration, and higher levels of monitoring. Moreover, social facilitation was the only hydration variable to demonstrate a significant association with BMI, such that higher BMI was associated with greater endorsement of social facilitation attitudes.

Greater fluid intake behaviors and fewer barriers were also associated with greater engagement in vigorous exercise, though surprisingly neither of the facilitator attitude measures were correlated with vigorous exercise. Because people can exercise via lower-impact methods than “vigorous” exercise, the secondary scoring of the IPAQ (categorical distinctions of insufficiently active, minimally active or HEPA-active categories) was used to evaluate categorical difference on each hydration variable (Table 5). There were no differences in hydration knowledge based on activity categories. The insufficiently active group endorsed higher Lack of Container barriers and lower Monitoring compared to the HEPA-active group. Finally, those in the HEPA active category reported greater fluid intake behaviors and fewer effort barriers compared to the insufficiently active or minimally active groups, which did not differ from one another.

Discussion

The overall function of this work was to develop and psychometrically evaluate new measures assessing hydration knowledge, attitudes and behavior in the general population. Using strategies espoused by measurement experts [34], development of these measures varied based on content, with the knowledge items determined by hydration experts and the attitude items developed from focus group qualitative responses. The 16-item knowledge measure can be scored based on the number of items correct or can incorporate the degree of certainty a person has in their response. The knowledge measure assesses hydration knowledge more broadly than existing measures which focused on hydration in the context of sport only and were not typically psychometrically evaluated [18, 19]. The attitudes measure, which was distilled down to a well-performing set of 18 items, includes both factors that serve as barriers to hydration (lack of effort, physical barriers such as wanting to avoid frequent bathroom visits, and lack of regular access to a cup or bottle to drink from regularly) as well as factors that help facilitate hydration (social pressures and effort to monitor hydration levels). The behavioral measure simply assesses self-reported fluid intake and other related fluid intake behaviors (proximity to fluid and regular drinking throughout the day). Each of these scales is brief, such that all three can be completed easily in less than 5 minutes, making these ideal tools for studying how knowledge, attitudes and behavioral factors are associated with hydration practices.

Across both phases of data collection, average hydration knowledge was relatively high, in terms of number of items correct (around 11 out of 16). Considering that the knowledge scores that incorporated confidence ratings were only slightly greater than the number of items correct, most people likely answered items by choosing the "probably" accurate or inaccurate level, rather than "definitely" accurate or inaccurate level. Thus, confidence in knowledge may not be particularly high, but the basic knowledge seemed to be present for the majority of the sample. However, and importantly, hydration knowledge was not strongly associated with either self-reported fluid intake or attitudes toward hydration. From a psychological perspective, the lack of association between knowledge and behavior is understandable; knowing the "right" thing to do often fails to translate into consistent actions [25, 35]. Attitudes, perceptions of self-efficacy, norms, motivations and other forces exert stronger influences on behavior than knowledge. For hydration, knowledge is likely important to some degree, as fluid intake needs change based on context (e.g., in the heat, after exercise) and there are plenty of common misconceptions about hydration (e.g., that thirst is an early indicator). However, for those who want to improve hydration practices, this study provides evidence that knowledge is not enough to change behavior, and may not even exert a significant influence on attitudes.

In contrast to hydration knowledge, attitudes toward hydration were significantly associated with self-reported fluid intake, also consistent with psychological theories of behavior change [35, 36]. In this work, the three barrier scales were all associated with lower self-reported fluid intake behaviors, and the monitoring facilitator was associated with greater fluid intake behaviors. The social facilitator was uncorrelated with fluid intake in Phase 2, and had a negative relationship with fluid intake in Phase 1. This lack of association may have occurred because social facilitation is context dependent and may not relate to *overall* fluid intake, but may be associated with greater fluid intake in social situations. Further assessment of how social factors can facilitate fluid intake behaviors contextually is certainly warranted, particularly because our data found that relying on others to facilitate hydration (i.e., higher social facilitate scores) may be more important factor for higher-BMI individuals. Importantly, fluid intake had the strongest correlation with the lack of effort barrier, suggesting that motivational factors and habit formation are likely particularly important for behaviors associated with increased fluid consumption [23].

These studies provide initial support for the idea that hydration behaviors and attitudes are associated with health outcomes. People who are more active (according to HEPA category designations) consume more fluid than people who are insufficiently active. Moreover, those who are more active are less likely to endorse container barriers and lack of effort barriers, and are more likely to monitor fluid intake as a hydration motivator. The HEPA-active category likely includes athletes and people who prioritize exercise in their lives, such that attention and effort toward hydration are more likely. In addition, greater hydration monitoring was associated with higher perceptions of health, and greater reliance on others to facilitate hydration (i.e., higher scores on the social facilitation measure) was associated with higher BMI. Unexpectedly, BMI was not associated with hydration attitudes or fluid intake, contrary to predictions and surprising considering the known relationship between obesity and inadequate fluid intake [11]. Therefore, future work examining hydration attitudes alongside other markers of health are certainly warranted.

The measures developed in this study have several strengths, including a cross-disciplinary collaboration that included exercise physiologists with expertise in hydration, and psychologists with expertise in measurement development and behavior change. Items were developed using expert review and focus groups, the latter of which allowed people of varying backgrounds and experiences to contribute their perspective on hydration. The resulting measures are easy to administer and score. The data in current study are particularly informative considering the inclusion of both undergraduate students, and a broader sample of adults across the United States. The differences between these samples on demographic characteristics and in hydration knowledge suggests that assessing hydration knowledge and practices in different groups is warranted in future work.

Limitations and Future Directions

Limitations of this study include the fallible nature of self-report measures, which is particularly important for hydration, as physiological hydration status cannot be assessed via self-report. In addition, even when water intake is assessed via self-report, methods vary widely across studies [37]. Future work will need to examine the validity of the presented fluid behavior index in terms of hydration status and recent retrospective fluid intake methods such as 24-hour recall [37] or 7-day recall [14], as well as to examine the relationship between hydration attitudes, knowledge, and physical indices of hydration. In addition, the current study did not explicitly include groups who may be important targets for hydration interventions, such as the elderly [9, 38], renal patients [23], and athletes [16, 20]. This was intentional, as the purpose of this study was to develop broad measurement tools to be used with the general public and then assess the levels of knowledge, attitudes and behavior in particular subsamples of interest to hydration researchers. Moreover, considering that one group of people who differ in hydration needs are children [1], future work may want to amend these measures for children, and/or evaluate these indicators in parents or caregivers of young children. Finally, larger representative samples are needed to fully assess population-level knowledge, attitudes and behaviors. National and international representative samples would also have the advantage of reducing potential selection bias or volunteer bias, as it is possible that the recruitment method may have inadvertently influenced the results in the current work. Additional demographic characteristics such as educational level, profession (i.e., medical professionals, dieticians) and disease state are all potential variables which could influence knowledge, attitude and behavior and would be worth exploring in future work.

Conclusion

As adequate hydration is essential to health [1], understanding the factors that contribute to fluid intake behaviors is important information for developing more effective hydration interventions. Increasing knowledge may be necessary for people who hold inaccurate information about hydration, but attitudes are likely to have a larger impact on fluid intake behaviors. The measures developed here can facilitate future hydration research by furthering understanding of the relationships between knowledge, attitude and behaviors contribute to hydration.

Conflicts of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Table 1. *Sample characteristics in for Phase 1 and Phase 2 data collection.*

	Phase 1	Phase 2
Age	33.59 ± 8.98	27.43 ± 10.93
Women, *n* (%)	143 (47.5)	230 (59.1)
White, *n* (%)	227 (75.4)	304 (78.1)
Marital Status, *n* (%)		
Single (never married)	176 (58.5)	290 (74.6)
Married	102 (33.9)	79 (20.3)
Separated, Divorced or Widowed	23 (7.6)	20 (5.2)
Employment, *n* (%)		
Unemployed	53 (17.6)	180 (46.3)
Employed part time (1-30 hrs/week)	60 (19.9)	89 (22.9)
Employed full time	188 (62.5)	120 (30.8)
Education Level, *n* (%)		
High school	39 (13.0)	109 (28.0)
Some college	126 (41.9)	256 (65.81)
Bachelors degree	112 (37.2)	3 (.8)
Advanced degree	24 (8.%)	21 (5.4%)
Weight Status, *n* (%)		
Lean (BMI < 25)	161 (53.49)	232 (60.1)
Overweight (BMI 25-30)	75 (25.0)	87 (22.5)
Obese (BMI > 30)	64 (21.3)	67 (17.4)

Table 2. *Correlations between facilitator and barrier factors, knowledge and behavior in Phase 1.*

	Hydration Knowledge Score	Fluid Behavior Index	Confidence in being well hydrated
1. Lack of Effort Barrier	-.19*	-.54**	-.57**
2. Physical Barriers	-.08	-.21**	-.21**
3. Lack of Container Barrier	-.08	-.31**	-.28**
4. Social Facilitator	-.04	-.12*	-.16**
5. Contextual Facilitator	.46**	.17*	.09
6. Monitoring Facilitator	-.07	.13*	.32**

*$p < .05$
**$p < .001$

Table 3. *Subsample differences in demographic and study variables for Phase 2.*

	Total (n = 389)	mTurk (n = 191)	Subject Pool (n = 198)	Statistical Test (χ^2 or t)	p
Age	27.43 ± 10.93	32.71 ±10.17	19.43 ± 2.17	t = 22.00	< .001
Gender (% Women)	59.1%	46.07%	71.71%	χ^2 = 26.45	< .001
Ethnicity (% White)	78.1%	71.73%	84.34 %	χ^2 = 9.06	.003
% current college students	57.6 %	13.61%	100%	χ^2 = 297.04	< .001
BMI	25.38 ± 6.01	27.17 ± 6.94	23.38 ± 4.21	t = 6.53	< .001
% Overweight/Obese (BMI >=25)	39.9%	52.66%	27.78%	χ^2 = 38.14	< .001
HyKS items correct	11.10 ± 2.33	11.53 ± 2.42	10.69 ± 2.16	t = 3.23	< .001
HyKS Score	13.75 ± 6.07	14.93 ± 6.53	12.61 ± 5.37	t = 3.36	< .001
Fluid Behavior Index	5.04 ± 1.53	5.19 ± 1.56	4.91 ± 1.49	t = 1.84	.07
Overall health	3.36 ±.89	3.30 ± .98	3.41 ± .79	t = 1.28	.20

HyKS = Hydration Knowledge Scale

Table 4. *Partial correlations among constructs in Phase 2, controlling for sample (subject pool or mTurk).*

	Subscale Name	1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	Hydration Knowledge Score	--								
2.	Fluid Behavior Index	.08	--							
3.	Lack of Effort Barrier	-.08	-.66**	--						
4.	Physical Barriers	-.09	-.14**	.28**	--					
5.	Lack of Container Barrier	.07	-.36**	.39**	.08	--				
6.	Social Facilitator	.01	-.004	.12*	.29**	-.07	--			
7.	Monitoring Facilitator	-.003	.37**	-.36**	.05	-.39**	.24**	--		
8.	Overall Perception of Health	.04	.24**	-.31**	-.18**	-.16**	-.04	.16**	--	
9.	BMI	-.07	.06	-.02	.06	.02	.11*	.04	-.19**	--
10.	Vigorous Exercise METs	.01	.21**	-.17**	-.14**	-.18**	-.06	.08	.17**	-.08

*p < .05, **p < .001

Table 5. *Relationship between knowledge, behavior facilitator and barrier factors and indicators of health and fitness, controlling for sample*

	ANCOVAs with IPAQ categories			
	Insufficiently Active (*n* = 81) *M* ± *SE*	Minimally Active (*n* = 221) *M* ± *SE*	HEPA Active (*n* = 87) *M* ±*SE*	*F*(2, 385)
Hydration Knowledge Score	14.93 ± .69	13.63 ±.40	12.98 ±.65	2.12
Fluid Behavior Index	4.60[a] ±.17	4.93[a] ±.10	5.77[b] ±.16	13.90**
Lack of Effort Barrier	2.47[a] ±.10	2.33[a] ±.06	2.03[b] ±.10	5.49*
Physical Barriers	2.98 ±.12	3.02 ±.07	2.78 ±.11	1.60
Lack of Container Barrier	2.85[a] ±.13	2.54 ±.08	2.26[b] ±.13	4.89**
Social Facilitator	3.07 ± .10	3.25 ±.06	3.03 ±.10	2.54
Monitoring Facilitator	2.73[a] ± .11	2.99±.06	3.24[b] ±.10	5.92**

*p < .05 **p < .001

Note: IPAQ = International Physical Activity Questionnaire; HEPA = Health-Enhancing Physical Activity.
Within each row, superscripts with different letters are significantly different using Bonferroni post-hoc tests
Means are adjusted based on covariate (subject pool = 0; mTurk = 1).

HyKS (Hydration Knowledge Scale)

Instructions: Below you will see a series of statements about hydration and fluid intake. Decide whether you think the statement is accurate or not. If you *know* the statement is accurate, select 2. If you are pretty sure that the statement is accurate, but you're not entirely sure, select 1. If you don't know, select 0. If you're absolutely positive the statement is inaccurate, select -2, and if you are pretty sure the statement is inaccurate select -1.

Please answer all questions just based on your own knowledge. Do not use your phone or a computer to look up the answers to these items.

-2	-1	0	1	2
Definitely Inaccurate	Probably Inaccurate	Not Sure	Probably Accurate	Definitely Accurate

1. ___________ People can be dehydrated without being thirsty.
2. ___________ Dehydration does not increase the risk for chronic diseases like kidney and heart disease.
3. ___________ Older adults feel less thirsty than younger adults even when equally dehydrated.
4. ___________ Water in food doesn't "count" toward daily hydration needs.
5. ___________ When people are dehydrated, they think less clearly.
6. ___________ Light urine is an indicator of dehydration.
7. ___________ All people require the same amount of fluid per day to stay hydrated.
8. ___________ Eight glasses of water per day is not a rule that applies to everyone.
9. ___________ Hot and humid environments don't change the amount of fluid needed.
10. ___________ Dehydration can be associated with negative mood.
11. ___________ It's impossible to drink too much water.
12. ___________ Dehydration has the same effect on infants/children as on adults.
13. ___________ When people are dehydrated, they are at higher risk for heat-related illnesses.
14. ___________ Caffeinated drinks "count" towards daily fluid intake.
15. ___________ People need the same amount of fluid each day, regardless of activity level.
16. ___________ Fluid is retained better when combined with eating.

SCORING:

1. Number correct can be scored by
    a. giving 1 point for each of the following items marked as either Probably Accurate (a rating of 1) or Definitely Accurate (a rating of 2): Items 1, 3, 5, 8, 10, 13, 14, 16)
    b. Giving 1 point for each of these items marked as -2 (Definitely Inaccurate) or -1 (Probably Inaccurate): Items (2, 4, 6, 7, 9, 11, 12, 15)
2. An overall knowledge score (from -32 to 32) can be calculated by:
    a. Reverse scoring all of the “inaccurate” items (2, 4, 6, 7, 9, 11, 12, 15)
    b. Summing the reverse scored items with the rest of the items
    c. A “perfect” score would be 32, which would be if each item were answered correctly and definitively.

Fluid Behavior Index (FBI)

The questions in this section ask about your behaviors regarding hydration. We say “typically” or “usually” to mean “more often than not.” So, if you carry a water bottle in your backpack, purse or briefcase and you have that bag with you much of the time, you’d probably select “yes” for the first question, even if you are not actually carrying the water bottle in your hand all of the time.

1. Do you usually have a beverage within arm’s reach? No Yes

2. Do you drink fluid even when you’re not thirsty? No Yes

3. Do you drink fluid at least once per hour when awake? No Yes

4. How many ounces [Liters] of fluids do you think you drink on a typical day? (Fluids includes water, milk, juice, soda, tea, coffee, sports drinks and energy drinks). See below for a key.

   A None

   B Less than 16 oz/473mL (less than 1 turquoise bottle)

   C Between 16 and 32 oz (473mL to 949mL) (between 1-2 of the turquoise bottles; maybe 1 of the larger bottles)

   D Between 33 and 63 oz (950L to 1.86L) (more than 2 but less than 4 of the turquoise bottles)

   E 64 oz (1.86L) or more (i.e., at least 4 of the turquoise bottles)

5. How confident are you that you are well-hydrated?

   Not at all confident

   Mildly confident

   Moderately confident

   Mostly confident

   Extremely confident

SCORING:

- For items 1-3, give 0 points for “No” and 1 point for “yes”
- For item 9, A = 0, B = 1, C = 2, D = 3, E = 4
- These four items together provide a fluid behavior index, which ranges from 0 to 7.

- Item 5 is not included in the behavior scale but is retained in this measure for use as a single item index of confidence.

Hydration Facilitators and Barriers (H-FAB)

This section includes questions about your attitudes toward hydration and drinking fluid. **The word "fluids" includes water, milk, juice, soda, tea, coffee, sports drinks and energy drinks**.

1	2	3	4	5
Not at all like me	Not much like me	Somewhat like me	Mostly like me	Very Much Like me

Item #		Item
1.	____________	I have a habit of drinking fluid regularly.*
2.	____________	I'm more likely to drink fluid if other people near me are drinking too.
3.	____________	Monitoring my fluid consumption helps me stay hydrated.
4.	____________	I'd drink more fluids if I didn't have to pee so often.
5.	____________	I don't want to carry a water bottle.
6.	____________	I'm more likely to drink fluids if I'm accountable to someone else.
7.	____________	I'm often too busy to go get a drink of water.
8.	____________	I'm used to drinking fluids regularly; I don't even have to think about it.*
9.	____________	It's important to me to have clear fluid consumption goals.
10.	____________	I avoid drinking fluids if I'm going to be somewhere without a bathroom
11.	____________	If someone checks with me about my fluid intake, I'm more likely to stay hydrated.
12.	____________	I carry a bottle with me to make hydration easier.*
13.	____________	I'm often too lazy to drink more liquid.
14.	____________	I know how much I'm supposed to drink to stay hydrated.
15.	____________	I hate having to go to the bathroom all the time.
16.	____________	Carrying a water bottle is annoying.
17.	____________	Seeing other people drinking fluid helps me drink more.
18.	____________	I think about what kinds of fluids my body will need later in the day.

*Reverse scored

SCORING:

1. Reverse score items 1, 8, and 12
2. Calculate averages for each subscale:
    a. Lack of Effort Barrier: 1R, 7, 8R, 13
    b. Physical Barrier: 4, 10, 15
    c. Lack of Container Barrier: 5, 12R, 16
    d. Social Facilitator: 2, 6, 11, 17
    e. Monitoring Facilitator: 3, 9, 14, 18