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Fluid Consumption and the Potential Role of Canteen Shape in Minimizing Dehydration

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Hypohydration can unknowingly occur in military personnel during exertion, especially in the heat. Such dehydration can impair cognitive and physical performance. Some portion of exercise-induced dehydration may be offset by changing the perceptual biases of soldiers when filling and drinking from canteens. Using comparably sized water bottles, we investigated this perceptual bias with 50 Army and Marine ROTC students by showing that those given short, wide, clear water bottles poured and drank more water than those given taller bottles that held the same volume. Even although those given short, wide water bottles poured 38% more water, they did not perceive themselves as having poured or drunk more. The implications for decreasing dehydration in the field and in garrison are discussed.

Introduction

Even mild dehydration under situations of physical exertion can impair both cognitive and physical performance.[1-3] The paradox with dehydration is that by the time a soldier is aware of needing water, some level of dehydration may have already occurred. Dehydration that occurs even when water is readily available is known as "voluntary dehydration."[4] Although the causes of voluntary dehydration are not fully understood, some factors that have been implicated include an inadequacy of the thirst mechanism to detect and respond to the deficit,[4] stress,[5,6] or otherwise distracting elements[5,6] which displace one's attention away from thirst.

Efforts to increase fluid consumption in the heat or during exercise often focus on maximizing the availability of fluids,[7] improving their appeal by cooling them or adding flavorants,[8] or through simple fluid discipline.[8] However, consideration should be given to the possibility of reducing exercise-induced dehydration through modification of the shape of the canteens from which soldiers drink. It has been recently found that people who are given short, wide glasses tend to unknowingly pour more of a liquid than when given tall, narrow containers holding the same volume.[9] Furthermore, it has been found that people tend to consume most of what is put in front of them.[10,11] As a result, any natural means by which soldiers can be encouraged to pour more water into their canteens or canteen cups is likely to result in them drinking more and being less likely to suffer from symptoms of dehydration.

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Piaget[12] and others have shown that when people observe a cylindrical object, they tend to focus on its vertical dimension at the expense of its horizontal dimension. Even if the vertical dimension is identical to that of the horizontal dimension, people still tend to overestimate the height by 20%.[13]

In the context of drinking glasses, when people estimate how much liquid they have poured into a glass, there is a fundamental tendency to focus on the height of the liquid that has been poured and to downplay its width. This basic visual bias caused teenagers to pour and drink 88% more juice or soda with short, wide glasses than with tall, narrow glasses that held the same volume.[9] These teenagers believed, however, that they poured one-half as much as they actually did. Similar results were found with veteran Philadelphia bartenders. When asked to pour 1.5 ounces of gin, whiskey, rum, and vodka into short, wide (tumbler) glasses, the bartenders poured 26% more than when they poured into tall, narrow (highball) glasses.[9]

Given the importance of avoiding dehydration to maintain maximum performance in the heat and during high-energy activities, a number of solutions have been proposed to increase fluid consumption for athletes, hikers, soldiers, and others engaged in these activities. These solutions include the use of over-the-shoulder "camel backs" and variations in the shape, length, and contour of the canteens. With soldiers in field situations, we believe that the elongation of a canteen will negatively influence the actual volume a soldier pours into the canteen in situations in which it is not completely filled. The rationale for this is that the larger perceived capacity of a more elongated vessel should have a correspondingly negative influence on how much a soldier believes he or she needs to pour to reach a target volume. Therefore, in a single-serving situation we expect a soldier will pour relatively less into a tall, slender canteen and relatively more into a short, wide one. If a soldier drinks all that he or she pours, the elongation of a canteen will negatively influence the actual consumption volume in a single-serving context. We assume that the volume the soldier intends to pour for a single serving is not affected by the perceived capacity of the canteen and that the canteens are large enough to hold the total volume they intend to pour.

The two studies reported here build on the foundation provided by Piaget et al.[14] and others.[9,15] We expect to show that when given short, wide canteens, soldiers will pour and drink more water than those given tall, narrow canteens. We further expect that they will be unaware of the difference.

Method

One hour after physical training exercises involving approximately 60 minutes of running and calisthenics (approximately 62°F and 56% humidity at 7:00 a.m.), 50 Army and Marine ROTC students at the University of Illinois at Urbana-Cham-

paign were brought into a facility where they were involved in a study for extra credit for a class or for a chance to win tickets to a football game. Following their exercise they were allowed to drink ad libitum. One issue of dehydration is that after people first drink their fill, it can prevent them from fully rehydrating on subsequent occasions within the same day. To examine this, water consumption was assessed 1 hour after they had exercised. To reduce suspicion that they were being singled out because of their ROTC status, they were joined by 50 other students at the same time who had also been recruited for classroom credit and who would serve as a distraction.

Upon entering the room where the study was to take place, the ROTC students were told that they would be trying some different foods and that it was important that they not be thirsty before trying the foods. Two assistants then handed out empty (clear) plastic water bottles to the individuals assembled there. Both bottles held 32 ounces of water, but one-half were tall and narrow and the others were shorter and wider.

The participants were individually led to the room where they were to get their water. They were directed to a 10-gallon water container similar to what they might obtain water from in the field. The container was sitting on a table and had a spigot on it. After they poured how much they wanted to drink into their water bottles, the researcher asked them to estimate how many fluid ounces they thought they had poured. The amount of water they had in their canteen was then weighed using a scale that was accurate to the tenth of an ounce and then converted into fluid ounces. They were then thanked and moved on to the next room where they stayed for up to 15 minutes before being moved to the next stage of the study. It was at this point that they could drink water unprompted. After 15 minutes their bottles were collected and weighed to determine how much they had consumed.

Consistent with the cover story, respondents were then given various samples of food that they had been promised and asked sensory questions about them. Following this, they were asked to estimate how much water they had drunk before the experiment. They were then debriefed, thanked, and dismissed.

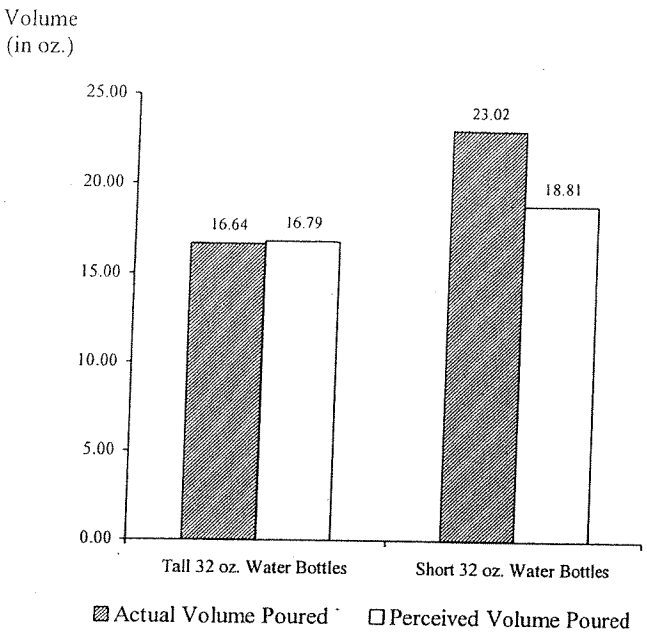

Fig.1. How elongation influences the perceived and actual volume of water poured.

TABLE I

THE SHAPE OF WATER BOTTLES BIASES HOW MUCH WATER IS POURED AND CONSUMED

	Tall, Slender Water Bottles (n = 25)	Short, Wide Water Bottles (n = 25)	F test df(1,49)
Actual ounces poured	16.64 (5.12)[b]	23.02 (3.91)	21.2[a]
Estimated ounces poured	16.79 (4.91)	18.81 (3.89)	2.3
Actual ounces consumed	16.33 (4.3)	21.81 (4.85)	16.1[a]

[a] $p < 0.01$; $p < 0.05$.
[b] Standard deviations are in parentheses.

Results

Recall that it was expected that the Army and Marine ROTC students would pour and drink more water when they poured into short 32-ounce water bottles than when they poured into tall 32-ounce water bottles, even though they might believe themselves to have poured less. Indeed, ROTC students who had been given short, wide water bottles poured 38% more water than those given tall, slender water bottles (23.02 vs. 16.64 ounces; $F_{(1,49)} = 21.2$; $p < 0.01$), but they perceived themselves as having poured a similar amount (18.81 vs. 16.79 ounces; $F_{(1,49)} = 2.3$; $p > 0.10$). This gap between actual and perceived volume poured is illustrated in Figure 1.

It is also important to note that if ROTC students poured the water, they generally drank the water (Table I). Approximately 96% of the volume of water that was poured was drunk (19.1 ounces were consumed from the 19.8 ounces poured). The Pearson correlation coefficient between what was poured and what was drunk was $r = 0.92$ ($p < 0.001$). What is critical to realize is that individuals drank most of what they poured regardless of whether they had estimated its volume correctly or not. Those pouring into short, wide water bottles poured less than they thought, yet they still consumed what they had poured.

To summarize, two important elements are of interest here to those concerned with keeping soldiers hydrated for reasons of health and performance. First, people unknowingly pour more water into short, wide water bottles (compared with tall, narrow water bottles) than they intend. Second, they drink most of what they pour.

Discussion

People in strenuous field situations, be they soldiers, laborers, or athletes critically rely on water. The concern, however, is that it is often difficult to detect when a person is actually dehydrated until it is too late.

These results underscore two key findings. First, we find that the elongation of a water bottle negatively influences pouring volume. Because 86% of the students drank all of the water they poured, we can conclude that elongation negatively influences consumption volume in a single-serving context. Army and Marine ROTC students poured and consumed more water when

they poured into short, wide water bottles than into tall, slender water bottles. Second, they tended to believe they poured less when pouring into the short, wide water bottles than into the tall, slender water bottles. This indicates that elongation positively influences perceived volume.[16]

One limitation to this study is that we were restricted to the use of the single-serving context. To have measured how much a person drank on repeated occasions would have been unnaturally invasive. Another limitation has to do with the nature of the clear, nonmilitary-issue water bottles used in this study. Pilot studies suggest, however, that similar effects occur with opaque, olive-drab canteens.

A second study involving 37 military police cadets in basic training at Fort Leonard Wood, Missouri, indicated that there was a similar tendency to pour more water into a short, wide opaque canteen than into a tall, narrow prototype canteen bottle (11.6 vs. 10.2 ounces; $F_{(1,35)} = 4.02$; $p < 0.05$). Nevertheless, the potential demand effects associated with cadet training (such as the presence of drill instructors and the emphasis on speed) suggests that a field test with deployed soldiers may be the most appropriate context for further study.

The implications also go beyond field situations. In basic training situations or in mess halls, glasses can be modified to be short and wide instead of tall and narrow. In this way, people will be more likely to consume more liquid without perceiving they have done so.

The shape of drinking containers, such as water bottles, canteens, and canteen cups, can bias how much people think they pour and how much they actually pour and drink. One solution is to design these containers to be short and wide, so there will be a perceptual tendency to pour too much. Although they may initially pour more water than they think they will need to drink, they will generally drink the amount they pour.

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