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Research report

Habitual total water intake and dimensions of mood in healthy young women ☆

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ABSTRACT

Acute negative and positive mood states have been linked with the development of undesirable and desirable health outcomes, respectively. Numerous factors acutely influence mood state, including exercise, caffeine ingestion, and macronutrient intake, but the influence of habitual total water intake remains unknown. The purpose of this study was to observe relationships between habitual water intake and mood. One hundred twenty healthy females (mean ± SD; age = 20 ± 2 y, BMI = 22.9 ± 3.5 kg·m^{-2}) recorded all food and fluids consumed for 5 consecutive days. Investigators utilized dietary analysis software to determine Total Water Intake (TWI; total water content in foods and fluids), caffeine, and macronutrient consumption (i.e. protein, carbohydrate, fat). On days 3 and 4, participants completed the Profile of Mood State (POMS) questionnaire, which examined tension, depression, anger, vigor, and confusion, plus an aggregate measure of Total Mood Disturbance (TMD). For comparison of mood, data were separated into three even groups (n = 40 each) based on TWI: low (LOW; 1.51 ± 0.27 L/d), moderate (MOD; 2.25 ± 0.19 L/d), and high (HIGH; 3.13 ± 0.54 L/d). Regression analysis was performed to determine continuous relationships between measured variables. Group differences ($p < 0.05$) were observed for tension (MOD = 7.2 ± 5.4, HIGH = 4.4 ± 2.9), depression (LOW = 4.5 ± 5.9, HIGH = 1.7 ± 2.3), confusion (MOD = 5.9 ± 3.4, HIGH = 4.0 ± 2.1), and TMD (LOW=19.0 ± 21.8, HIGH=8.2 ± 14.2). After accounting for other mood influencers, TWI predicted TMD ($r^2 = 0.104$; $p = 0.050$). The above relationships suggest the amount of water a woman consumes is associated with mood state.

Introduction

Chronic negative mood states (traits) can result in physiological dysfunction and reduced quality of life (Kubzansky, Cole, Kawachi, Vokonas, & Sparrow, 2006; Kubzansky & Kawachi, 2000). Mounting evidence suggests even transient negative mood states (e.g., anxiety and anger) impact physiological dysfunction, including the development of coronary heart disease (Kubzansky & Kawachi, 2000). Meanwhile, positive mood states appear to promote health, including but not limited to improved pregnancy outcomes and increased longevity (Pressman & Cohen, 2005).

Few investigations have examined acute water restriction and body water reduction (i.e., mild dehydration) on mood in healthy, young men and women, which resulted in elevated fatigue, confusion and tension with decreased vigor (Armstrong et al., 2012; Ganio et al., 2011; Pross et al., 2012). Two investigations to our knowledge have examined acute water boluses that did not result in changes in mood parameters (Edmonds, Crombie, Ballieux, Gardner, & Dawkins, 2013; Edmonds, Crombie, & Gardner, 2013). Even fewer studies have examined the relationship between habitual total water intake across days (TWI; total moisture in solid foods plus water and beverages) and mood; the simple act of changing drinking behavior might contribute to improved mood state. Further, little consideration has been given to other mood altering activities during examination of water intake on mood state, such as exercise habits (Hamer, Endrighi, & Poole, 2012; Larun, Nordheim, Ekeland, Hagen, & Heian, 2006), caffeine ingestion (Clementz & Dailey, 1988; Lieberman, Spring, & Garfield, 1986), and macronutrient intake (Kien et al., 2013; Leathwood & Pollet, 1982; Lieberman et al., 1986; Spring, Lieberman, Swope, & Garfield, 1986). Therefore, this investigation observed the relationship between habitual

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24 h TWI and mood, and accounted for multiple mood-altering factors, in healthy young women undertaking usual daily activities. We hypothesized that after accounting for exercise and dietary variables, low habitual 24 h TWI would adversely relate to mood dimensions, similar to previous acute water restriction studies (Armstrong et al., 2012; Ganio et al., 2011; Pross et al., 2012).

Materials and methods

Participants

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the University Institutional Review Board. Prior to testing, each participant read and signed an informed consent document. One hundred twenty healthy, college-aged females participated in this study (age = 20 ± 2 y, mass = 62.1 ± 11.0 kg, height = 164 ± 7 cm, BMI = 22.9 ± 3.5 kg/m^2 (97 "normal weight," 17 "overweight," and 6 "obese"; lean body mass likely contributed to elevated BMI given many of the participants regularly exercised)). All women used oral contraceptives for at least two months prior to enrolling; recruiting women who used combination drug (estradiol and progestin) oral contraceptives promoted hormonal homogeneity among participants to reduce fluctuations of total body water during observations and provided ecological validity. No participant reported any mood or fluid regulatory related disorder.

Testing protocol

A familiarization/baseline visit served to collect measures of height and weight, and verify the use of an acceptable oral contraceptive and introduce subsequent testing procedures including questionnaires. Additionally, participants were instructed on how to accurately record all food and fluid consumed during a 24 h period, and to maintain their regular diet during their participation with the exception of alcoholic beverage consumption, which they refrained from for the duration of their participation to avoid fluid balance and mood fluctuations. Testing occurred over 5 consecutive days. Participants returned to the laboratory each morning on each of the 5 days between 0530 h and 0800 h to review the previous day's diet record with a nutrition counselor. Diet records averaged over 5 consecutive days (compared to fewer days) permitted a more accurate representation of participants' typical dietary intake. Habitual total water intake (TWI; total water content in solid foods + fluid, calculated by moisture content analysis), caffeine ingestion, and macronutrient consumption (i.e. protein, carbohydrate, fat) were determined via commercial software (Nutritionist Pro™, Axxya Systems, Stafford TX).

Questionnaires

Prior to data collection days, participants were introduced to all questionnaires and how to properly complete them. On testing days 3 and 4 (of 5), participants were asked to complete the Profile of Mood State questionnaire (POMS; McNair, Lorr, & Droppleman, 1981) and rate their perception of thirst on a scale of one to nine (one representing not thirsty at all, and nine representing very very thirsty) (Engell et al., 1987). Having participants complete the same questionnaires on two consecutive days (which were averaged for analyses) reduced inaccurate perceptions of mood associated with unique and influential events on a given day and/or a new environment (which might have existed on earlier testing days) and any potential feelings of inconvenience (which might have existed on testing day 5). Participants circled one numerical value on the POMS questionnaire that best represented the extent to which they experienced the mood descriptor at that particular moment using the validated paper questionnaire. Participants were provided with a list of definitions for each of the mood descriptors, and they were asked to complete the questionnaire in numerical order (mood descriptors 1 through 65). The POMS questionnaire was administered in the same quiet, well lit room on the university campus with stable environmental conditions for every administration.

The POMS inventory is widely accepted in psychological research and is sensitive to numerous environmental stressors, including water restriction. The POMS is a 5-point self-administered scale that assesses 6 mood states: tension-anxiety (Tension), depression-dejection (Depression), anger-hostility (Anger), vigor-activity (Vigor), and confusion-bewilderment (Confusion). Greater values for POMS variables represent greater perceived mood state. The aggregate variable in the POMS inventory, total mood disturbance (TMD), represents the sum of negative and positive mood subscale scores. Thus, a large TMD value represents a negative mood state.

Personal characteristics

Acknowledging that numerous variables in addition to macronutrient intake likely influence mood state, participants were asked to provide information regarding their current illnesses, use of prescription drugs, supplements and vitamins, typical consumption of alcoholic beverages, family medical history (conditions that are considered hereditary risk factors for disease), and intentional exercise (mode, frequency, duration, and how long they had been practicing these habits). This information was collected on a medical history questionnaire created by university physicians; information recorded on this questionnaire was reviewed with a physician. The items collected allowed investigators to consider the influence of behaviors and predispositions on mood state.

Statistical analyses

All participants (n = 120) were evenly separated into 3 groups, on the basis of habitual TWI derived from averaged 5 d dietary records: low (LOW; n = 40), moderate (MOD; n = 40), and high (HIGH; n = 40) TWI. Macronutrient data were converted from grams per day to percentage of kilocalories (kcal) for analyses. Data analyses were performed with statistical software (SPSS version 19.0, IBM Corporation, Champaign, IL). Descriptive data (mean ± SD) were calculated for all outcome variables. Comparisons were made among groups via one-way analysis of variance (ANOVA) for all dependent variables (i.e., personal characteristics, dietary macronutrients, thirst, and POMS scores). In the event of a significant F statistic, *post hoc* multiple comparisons were performed using a Bonferroni correction for three comparisons. Investigators conducted multiple regression analyses to examine the influence of TWI on POMS category scores, above and beyond the impact of variables known to influence mood state (i.e., exercise, caffeine and macronutrient intake). In other words, the variance in POMS scores attributable to water intake was isolated by first accounting for the variance from other mood influencers; taking these influencers into account allowed for a conservative examination of water intake on mood. An average of thirst and POMS values from days 3 and 4 was used for all statistical analyses.

Results

The mean (±SD) absolute and relative to body mass TWI for all 120 women was 2.30 ± 0.76 L/d and 37 ± 13 ml/kg/d, respectively, and these women exhibited a continuous habitual TWI range (Fig. 1). MOD (2.25 ± 0.19 L/d) approximated daily water intake recommended for adult women put forth by the Institute of Medicine

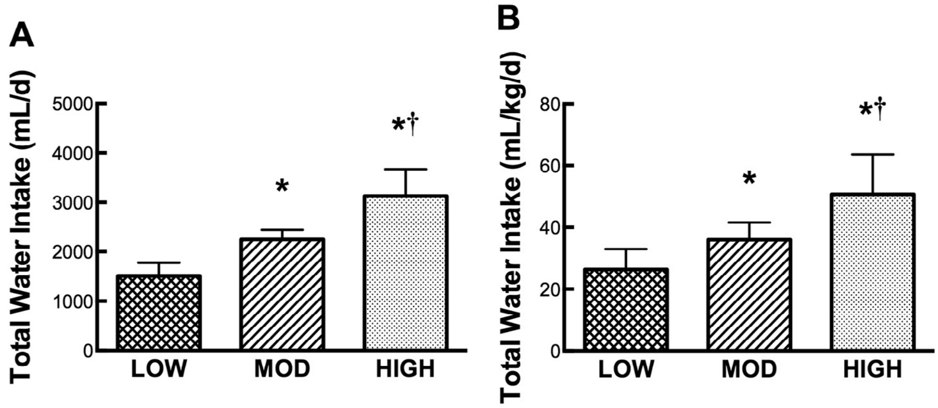

Fig. 1. Total water intake volumes (absolute (A) and relative to body mass (B)) among 120 healthy, college age females. * represents statistical differences ($p < 0.05$) from LOW and † from MOD.

(2.7 L/d) (Food and Nutrition Board, I. o. M, 2004) and the European Food and Safety Authority (2.0 L/d) (Authority, 2010); therefore, LOW and HIGH exhibited habitual TWI less and greater than recommended intakes, respectively. Absolute and relative TWI differed among groups (Fig. 1; $p < 0.001$), without a detected group difference for body mass ($p = 0.082$). Daily group means did not vary by more than 490 mL, and did not cross over the mean of another TWI group.

Habitual TWI group differences in mood, dietary factors, and exercise

Compared to POMS data that have been reported for college-aged adults (McNair et al., 1981), all recorded values fell between 0.5 and 1.5 standard deviations below college student population norms. Of the 6 POMS subscales, group differences were observed for Tension (HIGH < MOD; $p = 0.012$), Depression (HIGH < LOW; $p = 0.023$), and Confusion (HIGH < MOD; $p = 0.017$; Fig. 2). In the POMS aggregate measure (TMD), HIGH experienced less mood disturbance than LOW ($p = 0.019$), while HIGH trended toward a lower mood disturbance than MOD ($p = 0.051$; Fig. 2). No differences in thirst were detected among groups (all group average = 5 ± 2; $p = 0.121$).

Among dietary variables, consumption of caffeine was greater in HIGH than LOW and MOD ($p < 0.001$); carbohydrate intake was greater in HIGH than LOW and MOD ($p = 0.013$ and $p = 0.029$, respectively); fat consumption was lower in HIGH than LOW and MOD ($p = 0.0002$ and $p = 0.021$, respectively; Fig. 3). No differences were observed in dietary protein intake.

No differences were detected among groups for reported current illnesses, use of prescription drugs, supplements and vitamins, consumption of alcoholic beverages, or items reported in the family medical history. However, HIGH reported greater average exercise hours per week than LOW ($p = 0.001$; Fig. 3).

Isolation of the relationship between habitual water intake and mood after accounting for other mood influencers

Prediction of POMS categories revealed that after accounting for variables identified in previous literature that influence mood (protein, carbohydrate, fat, and caffeine intake, and weekly exercise duration) TWI predicted TMD (Table 1). Of all collected variables (i.e., dietary influencers and exercise), only TWI was significantly correlated with TMD ($r = -0.237$).

Discussion

This investigation examined the relationship between habitual TWI and mood state in 120 healthy young women undertaking their usual daily activities. Confirming our hypothesis, the primary findings of this study illustrated that greater habitual water intake accompanied more favorable mood states. Specifically, TWI distinguished categories of habitual drinking behavior (low, moderate, and high) in the Tension, Depression, Confusion, and TMD mood dimensions. Further, TWI predicted TMD in a conservative regression model which accounted statistically for other factors that influence mood state (exercise and dietary variables). These findings indicate a measureable relationship of water intake on mood state in healthy young women.

The POMS inventory is widely accepted in psychological research and is sensitive to numerous environmental stressors including water restriction. All POMS measures in the current study were lower than previously reported norms for a similar population (McNair et al., 1981); we propose that perhaps individuals with less mood disturbance are more willing to participate in interventional research (as these observations were part of a larger study that later manipulated water intake). Our findings indicate that HIGH experienced a smaller TMD than LOW (Fig. 2). Interestingly, differences in TWI between HIGH and LOW were two-fold (i.e., LOW consumed almost half of what HIGH consumed), and the differences observed in TMD mirror this two-fold relationship, in that TMD in LOW was double that of HIGH. While approximately two to three units on the POMS subscales differentiate TWI groups, we believe these ~20% differences express meaningful variations potentially with a simple act of greater water consumption, in a healthy population that hypothetically expresses less mood sensitivity than unhealthy populations. These findings, however, are not able to distinguish improved mood state as a function of (1) upbeat/positive women tending to consume more water, or (2) if drinking water enhanced mood state in these women. Although difficult to discern, future investigations are required to clarify these relationships. Further, future research should address the generalizability of these findings to other populations (i.e., those with chronic disease, elevated BMI, sedentary individuals, children, older men and women, etc.).

As reported in previous publications, acute reductions in body water and fluid intake volumes corresponded with more pronounced Fatigue (Armstrong et al., 2012; Ganio et al., 2011; Pross et al., 2012), Tension (Ganio et al., 2011) and Confusion (Pross et al.,

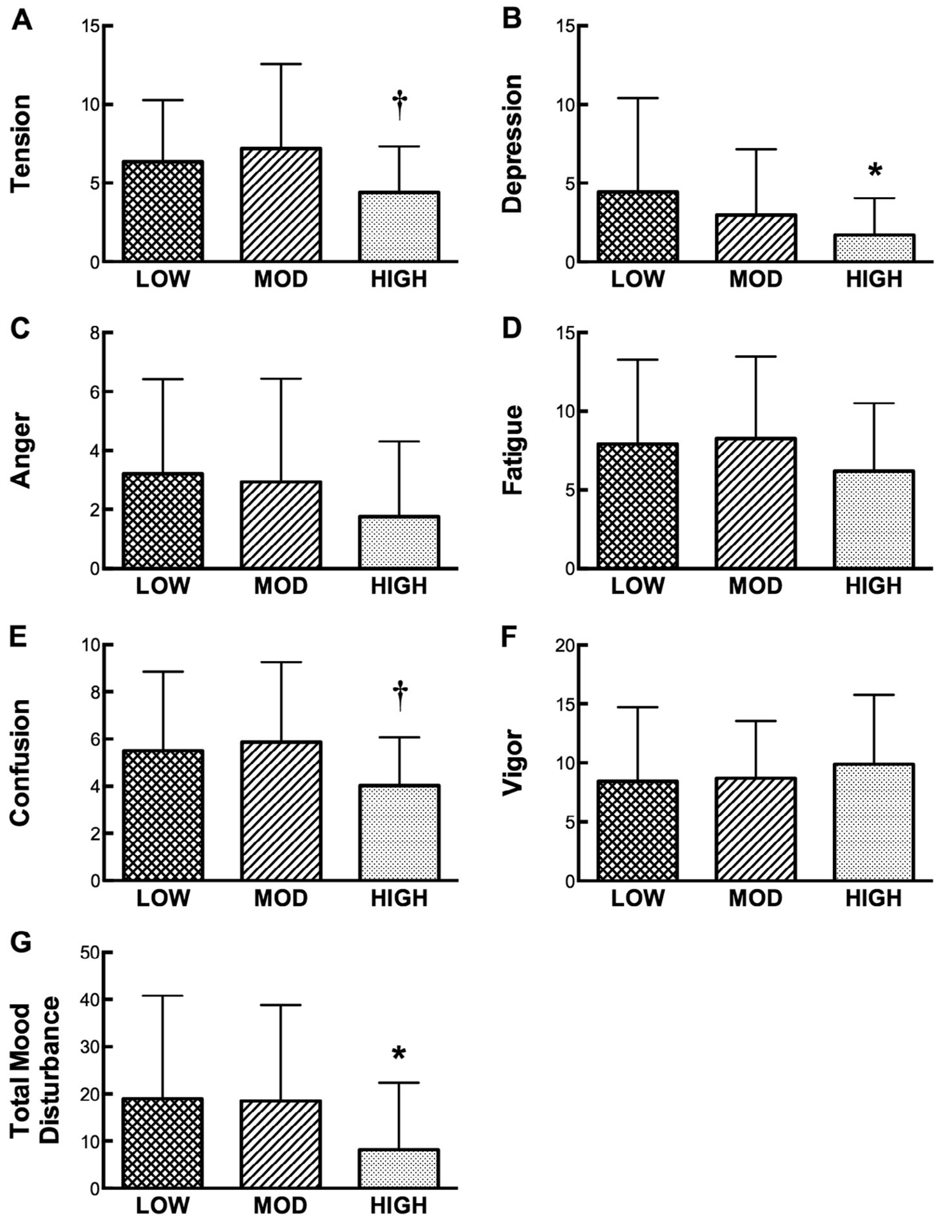

Fig. 2. Influence of habitual low (LOW), moderate (MOD), and high (HIGH) total water intake on mood state measured via the Profile of Mood States Questionnaire: Tension (A), Depression (B), Anger (C), Fatigue (D), Confusion (E), Vigor (F), and Total Mood Disturbance (G). * represents statistical differences ($p < 0.05$) from LOW and † from MOD.

2012), with less Vigor (Armstrong et al., 2012; Pross et al., 2012). In the current investigation, HIGH experienced lower Tension than MOD, but statistically no differences in Tension existed between LOW and MOD. This suggests a potential threshold of TWI to achieve a reduction in perceived Tension, but this highly theoretical relationship mandates further investigation. Previous literature did not observe the dose-dependent relationship observed between TWI and Depression that existed in the present investigation. This may be due to the fact that women in the present investigation were habituated to TWI (which is supported by similar thirst perception among groups), versus acute TWI manipulations in previous studies. While many factors influence thirst, similarities among groups were anticipated. Regardless of typical chronic water intake discrepancies, regulatory mechanisms tightly control plasma composition, and two prominent thirst mechanisms include a plasma sodium-osmolality-arginine vasopressin (Verney, 1947) and/or renin-angiotensin II-aldosterone system (Fitzsimons, 1976). Interestingly, two previous investigations found no influence of water intake on mood state (Edmonds, Crombie, Ballieux, et al., 2013; Edmonds Crombie, & Gardner, 2013); these findings might have resulted due to the small bolus (165 mL; Edmonds, Crombie, Ballieux, et al., 2013) and large range of consumed water volumes (125–2500 mL; Edmonds Crombie, & Gardner, 2013), or due to the sensitivity of the Visual Analog Scale used to evaluate mood. One publication to our knowledge investigated habitual TWI followed by controlled TWI manipulation on mood state (Pross et al., 2014). Contrary to our findings, these authors noted HIGH expressed greater Depression than LOW at baseline; however, these results might be influenced by (1) the six day inpatient experience where activities were restricted, and (2) differential impacts of water intake on mood between males and females, as HIGH included only females in the present study.

The present investigation uniquely accounted for several variables that have been shown in previous literature to influence mood; weekly exercise duration, caffeine, protein, carbohydrate, and fat consumption together accounted for 6.8% of the variance in TMD. As a result, TWI significantly predicted TMD ($p = 0.050$), after

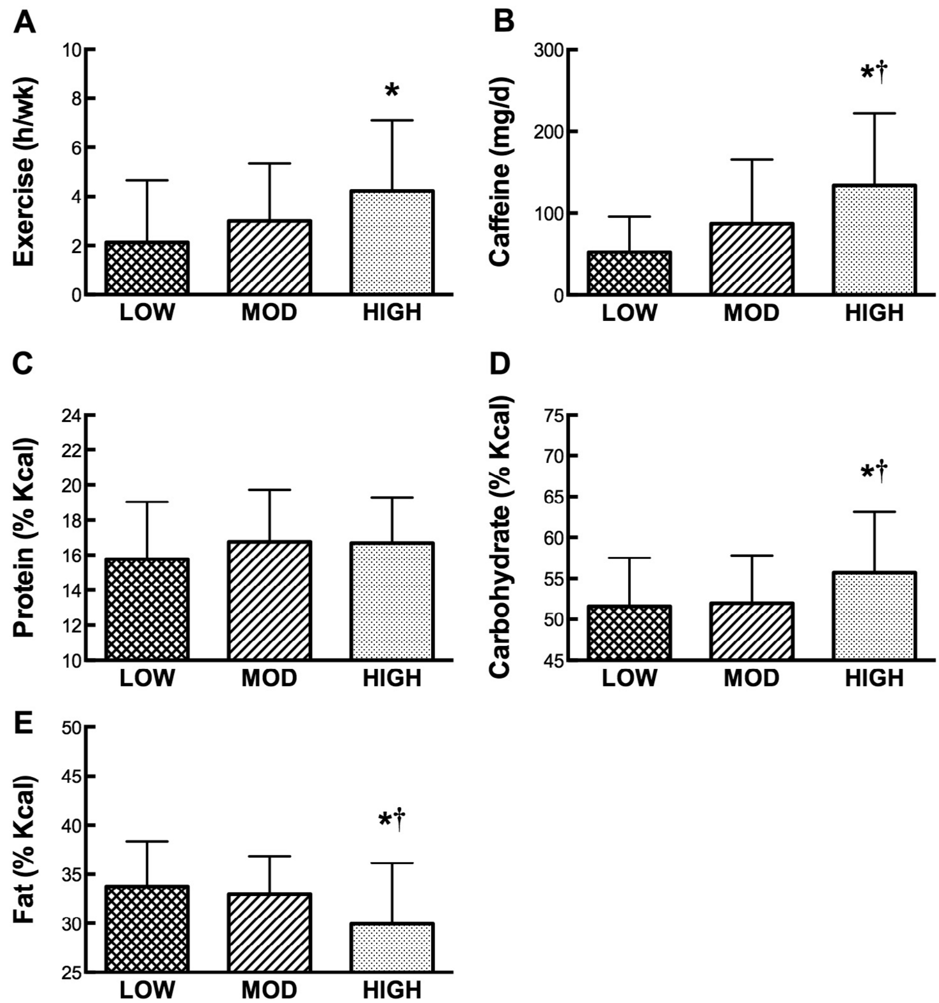

Fig. 3. Potential contributors to mood state other than total water intake as determined from previous literature in low (LOW), moderate (MOD), and high (HIGH) habitual total water intake groups: exercise hours per week (A), caffeine (B), protein (C), carbohydrate (D), and fat (E) intake. * represents statistical differences ($p < 0.05$) from LOW and † from MOD.

accounting for the acknowledged behaviors known to influence mood. While additionally explained variance in TMD attributable to TWI (after accounting for all other influential variables) was somewhat small (10.4%), this finding is likely due to the complexity of mood state. The authors do acknowledge limitations in self-reported exercise habits; considering some individuals over-report exercise practices, this likely exaggerated any influence of exercise on mood in our statistical modeling and therefore conservatively evaluated the influence of TWI on mood.

Presently, substantiated mechanisms to explain relationships between TWI and negative mood do not exist. However, two theoretical mechanisms have been advanced. The first involves an association between negative mood state and β-adrenergic receptors (Yu, Kang, Ziegler, Mills, & Dimsdale, 2008), the target receptors of catecholamines. Water deprivation (graded and chronic) elicits an amplification of the sympathetic nervous system (Antunes, Yao, Pickering, Murphy, & Paton, 2006; Colombari et al., 2011, respectively), which may in turn induce negative mood states via reduced sensitization of β-adrenergic receptors. Second, dehydration has been shown to reduce neuronal excitability and survival, as well as gene transcription in animals (Tang et al., 2011), suggesting that chronically reducing TWI might threaten brain neuronal function and integrity, in turn altering mood.

Conclusions

This investigation observed quantifiable adverse mood states in healthy, young women who habitually consumed low (versus high) daily total water. While explained variance in mood scales attributable to total water intake was small (~10%), this is reasonable as numerous variables contribute to mood complexity and the effect of any one variable might be small. These findings suggest that total water intake should be considered when (a) attempting to

Table 1
Regression models for the influence of TWI on POMS category scores, above and beyond the impact of variables known to influence mood state.

Predicted variable	Model	R^2	p	F change	R^2 change
TMD	Model 1 (protein, carbohydrate, fat, caffeine, exercise duration)	0.068	0.068	1.500	0.150
	Model 2 (protein, carbohydrate, fat, caffeine, exercise duration, TWI)	0.104	0.036	0.035	0.050

optimize day to day mood state and (b) designing future experiments that involve measures of mood.

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