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Diuretic potential of energy drinks

Short Communication

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Summary. Recent literature suggests that both caffeine and taurine can induce diuresis and natriuresis in rat and man. Although they act via different cellular mechanisms, their diuretic actions might be additive. This is of considerable interest, as several commercially available energy drinks contain both substances.

In this study we examined the possible diuretic effects of caffeine and taurine in a cross-over-design in which 12 healthy male volunteers received each of 4 different test drinks (750 ml of energy drink containing 240 mg caffeine and 3 g taurine, the three other test drinks either lacked caffeine, taurine or both) after restraining from fluids for 12 h.

Mixed model analyses demonstrated that urinary output and natriuresis were significantly increased by caffeine (mean differences 243 ml and 27 mmol; both $p < 0.001$) and that there were no such effects of taurine (mean differences 59 ml and −4 mmol). Additionally, urinary osmolarity at baseline was significantly related to the urinary output ($p < 0.001$). Urine osmolarity values at baseline and in the 6 h urine collection did not differ significantly between treatments.

Taken together, our study demonstrates that diuretic and natriuretic effects of the tested energy drink were largely mediated by caffeine. Taurine played no significant role in the fluid balance in moderately dehydrated healthy young consumers. Consequently, the diuretic potential of energy drinks will not differ significantly from other caffeine containing beverages.

Keywords: Caffeine – Taurine – Natriuresis – Diuresis – Energy drink

Introduction

In recent years, so-called energy drinks – usually based on caffeine, carbohydrates, vitamins and other ingredients such as taurine – have become popular. Several studies have shown effects of these drinks on physical and cognitive performance and mood (Barthel et al., 2001; Horner and Reyner, 2001; Reyner and Horne, 2002). Although energy drinks may also induce diuretic effects, to our knowledge no formal investigation of that topic has yet been performed.

Whereas diuretic effects have been known for a long time for the trimethylxanthine caffeine, similar effects were reported only recently for the amino acid taurine (Daly, 1993; Mozaffari and Schaffer, 2001). The mechanism for the diuretic actions of caffeine appears to be different from that of taurine, but nevertheless an amplifying effect on diuresis and natriuresis when caffeine and taurine are combined, cannot be ruled out. This is of considerable interest, as several commercially available energy drinks contain both substances.

The aim of this present study was to determine whether taurine would have an additive effect on the diuretic and natriuretic effects of caffeine in healthy participants.

Material and methods

In this study we examined the possible diuretic effects of caffeine and taurine in combination and separately in a cross-over-design in healthy male adults. Sixteen volunteers (median age 25, range 18–28 years) were invited to participate. All volunteers were non smokers and moderate drinkers of caffeinated beverages (defined as not less than 1 and not more than 4 caffeine containing drinks per day for the last 3 months). The participants underwent a physical examination, and had to pass a urinary concentration test with a urine osmolarity of higher than 800 mosm/l after a 12 h thirst period. Participants were informed that they would be consuming a variety of unspecified "energy drinks", and that they would be excluded from the study if they failed the urinary concentration test before the ingestion of the test drink. They had to sign written consent and the local ethic committee approved this study (EK 443/2004).

Four participants failed the urinary concentration test and therefore were excluded from the study. A total of twelve participants received each of the 4 different test drinks in weekly intervals in a blinded fashion. After restraining from food and drinks for 12 h and from alcohol for at least 48 h, 750 ml of test drink were ingested at 9 am within 30 min. One of the

drinks was Red Bull Energy Drink® (containing 80 mg caffeine and 1 g taurine per 250 ml). The other three test drinks either lacked caffeine, or taurine or, as placebo, both.

Urine was collected immediately before and for 6 h after the drink. Urine output was recorded hourly, and osmolarity (Fiske One-Ten Osmometer; Fiske Associates, Norwood, MA, USA) and Na^+ (Vitros® 250 Chemistry System, Ortho-Clinical Diagnostics, Rochester, NYC, USA) were analyzed in the total 6 h urine collection. In addition, body weight (Tanita BWB-620A, Tanita Corporation, Arlington Heights, IL, USA), blood pressure (Dinamap® Compact TS, Critikon Corp, Tampa, FL, USA) and body composition by bioimpedance (BIA 200-M analyzer, Data Input Comp., Frankfurt, Germany) were measured before and after each session.

For statistical analysis, the differences in diuresis (urinary output over 6 h in ml), urinary concentration (urine osmolarity in mosm/l) and natriuresis (sodium excretion in mmol/6 h) were compared by mixed model analyses (SAS Proc Mixed) with fixed factors caffeine (yes/no), taurine (yes/no), urine osmolarity at baseline, sequence (1–4) and random factor proband. The osmolarity values at baseline were compared with the mixed model analysis with the fixed categorical factor test drink (1–4) and random factor proband. The primary analysis was for diuresis. The mean between group differences with 95% confidence intervals were computed with the mixed model. The two-sided significance level was set to 0.05.

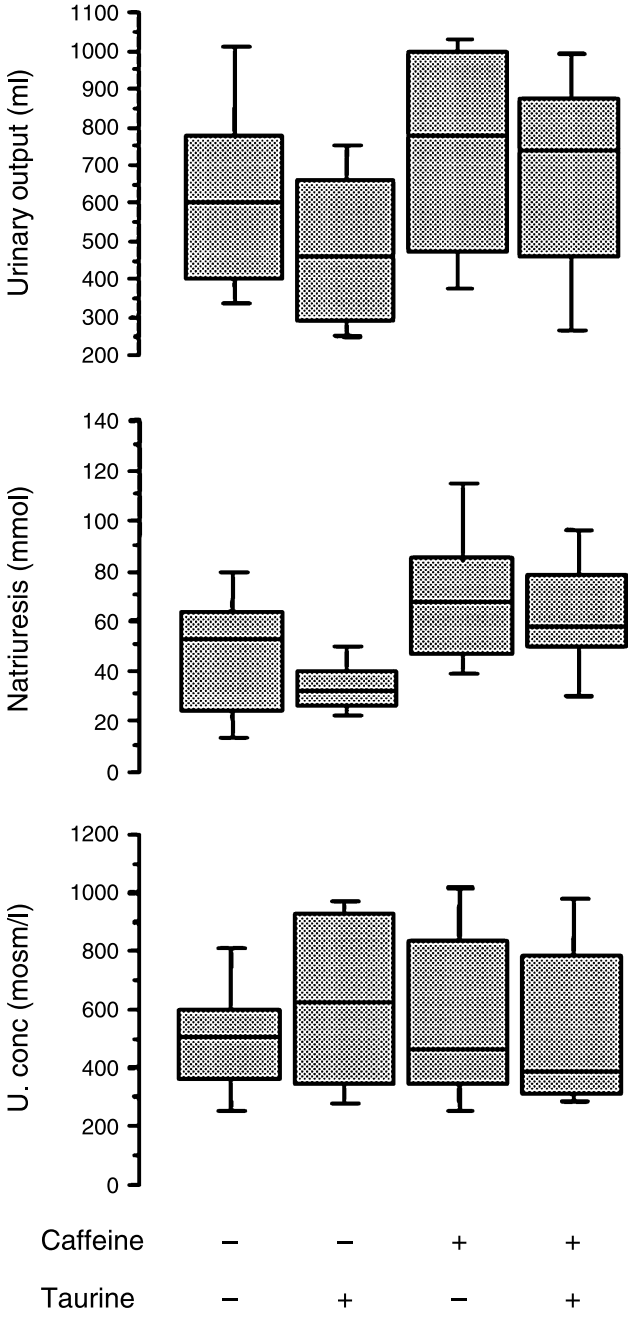

Fig. 1. Box and whiskers plot of urinary output (upper panel), natriuresis (middle panel) and urinary concentration (lower panel) of twelve healthy volunteers who consumed four test drinks with and without caffeine and/or taurine. Caffeine significantly increased urinary output ($p < 0.001$) and natriuresis ($p < 0.001$), taurine had no effects. The box represents the 25th and 75th, the whiskers the 10th and 90th percentile, respectively

Results

As shown in Fig. 1, urinary output and natriuresis increased with both caffeine containing test drinks.

The mixed model analysis demonstrated that these effects were caused by caffeine (both alone and when combined with taurine) for urine output (estimated difference versus placebo: 243 (95th confidence interval 115, 372) ml/6 h) and natriuresis (diff: 27; CI: 13, 41 mmol/6 h) (both: $p < 0.001$). There was no effect of caffeine on osmolarity (diff: −84; CI: −214, 46; $p = 0.2$), neither alone nor combined with taurine. There were no effects of taurine (neither alone nor combined with caffeine) on urine output (diff: 59; CI: −225, 343 ml/6 h; $p = 0.67$), natriuresis (diff: −4; CI: −35, 27 mmol/6 h; $p = 0.8$) and urinary osmolarity (diff: −230; CI: −517, 57; $p = 0.11$).

The urinary osmolarity at baseline was significantly inversely correlated to the urinary output ($r = 0.37$; $p < 0.001$). The higher urinary osmolarity was at baseline, the lower the following urinary output. Neither the urine osmolarity values at baseline nor in the 6 h collection differed between the 4 treatments.

There were also no differences in bodyweight, blood pressure or changes of body composition by bioimpedance between the 4 treatments.

Discussion

In our experimental system, moderate dehydration was induced in the young healthy participants by a 12 h thirst period. As expected, this pretreatment not only resulted in a standardized "dry" volume status of the participants (urine osmolarity higher than 800 mosm/l), but also induced a significant stimulus for fluid retention. As a consequence, differential diuretic effects should have become

particularly evident under these conditions. Indeed, natriuretic effects of caffeine were readily detectable. However, neither diuresis, natriuresis nor urinary osmolarity were affected by taurine.

Diuretic effects of caffeine are well established. The antagonism of adenosine receptors explains most actions of moderate doses of caffeine (Daly, 1993). The renal effect of caffeine mainly results from increased natriuresis due to inhibition of fractional tubular sodium reabsorption (Shirley et al., 2002). Our results are comparable to findings of a previous report, in which an oral 250 mg caffeine dose, which is close to the 240 mg as given in our study, also induced a significant increase in diuresis and natriuresis (Nussberger et al., 1990).

In addition to caffeine, this study also tested the possible diuretic effects of taurine (2-aminoethane sulfonic acid), since recent literature suggests that taurine may also induce diuresis and natriuresis, in rat and man (Gentile et al., 1994; Mozaffari and Schaffer, 2001).

Taurine is thought to act via inhibition of central release of the anti-diuretic hormone, ADH (Hussy et al., 2001). In rats, a high dose of taurine in the drinking water, equivalent to about 1500 mg/kg bw, was required to elicit diuresis (Mozaffari and Schaffer, 2001). However, 1 g of taurine, given intravenously over 15 min (about 15 mg/kg bw) was sufficient in humans with liver cirrhosis and ascites (Gentile et al., 1994). Although caffeine and taurine apparently act via different cellular mechanisms, their diuretic actions might still be additive.

In our study, taurine at a dose of 3 g neither induced diuresis or natriuresis nor did it reduce overall urinary osmolarity in young healthy adults. The differences to the effects observed in the cirrhotic patients might be explained by the difference in the route of taurine administration (intravenously vs oral), since intravenous administration is known to lead to earlier and higher C_{max} (Gentile et al., 1994). Alternatively, the observed diuretic effects might have also been caused by a relative taurine deficiency in these severely debilitated patients. In the rat model, increased natriuresis and urinary output became primarily evident in the taurine depleted animals following taurine repletion (Mozaffari and Schaffer, 2001).

Taken together, our study demonstrates that the diuretic potential of the tested energy drink is largely mediated by caffeine. In contrast to experimental data, taurine had no diuretic effects in moderately dehydrated healthy young consumers at an intake of 3 g within 30 min. The diuretic potential of energy drinks does not differ significantly from other caffeine containing beverages.

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