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Doubling of water intake increases daytime blood pressure and reduces vertigo in healthy subjects

Running head: High water intake can increase BP

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Abstract

We studied the effect of increased water intake on ambulatory BP in healthy individuals. BP was recorded after two weeks of either regular (RWI) or extra water intake (EWI, an additional 30 ml water/kg body weight per day) in 20 healthy subjects (10 males, 10 females). The extra water intake (RWI: 1.7 ± 0.59 l, EWI: 3.7 ± 0.84 l, respectively, $p < 0.0001$, **i.e. an increase of 2 litres**) induced an increase in mean arterial daytime BP from 89.0 ± 5.5 mmHg during RWI to 91.4 ± 6.4 mmHg during the EWI phase ($p = 0.005$) while night time BP was unchanged by the intervention. Visual-Analogue-Scale (VAS, maximum score of 10) score corresponding to the statement “I often experience vertigo” was 3.1 ± 2.6 during RWI and decreased to 2.1 ± 2.1 during EWI phase ($p = 0.008$). In conclusion two litres of extra water intake for two weeks significantly increased daytime blood pressure and reduced sense of vertigo in healthy individuals.

Key words: Water, Hypertension, Human, Blood Pressure, Prospective.

Introduction

The exact cause of essential hypertension is not known. In western societies high blood pressure is strongly linked to the metabolic syndrome. Hitherto all known monogenic forms of high blood pressure are the consequence of increased sodium and fluid retention (1), well known forms being quite rare disorders such as Liddle's syndrome and Familial Pseudo Hyper-Aldosteronism (2). The cornerstone of **insulin resistance** in the metabolic syndrome is a reduced sensitivity to the metabolic actions of insulin (3,4), initially leading to a compensatory increase in the levels of insulin to maintain glucose homeostasis. Indeed, recent findings suggest that raised levels of insulin in the metabolic syndrome stimulate the serum- and glucocorticoid-regulated kinase 1 (SGK-1) in effect prolonging the half-life of the epithelial sodium channel which leads to sodium and water retention and raised levels of blood pressure (5).

A high sodium intake is positively related to the incidence of hypertension (6) and since the beginning of blood pressure measurements it has been known that high blood pressure in general can be treated with sodium restriction (7), although sometimes extreme changes of lifestyle are **needed to limit sodium intake enough to substantially reduce blood pressure levels** (6,8). On the other hand, it is a well known fact that dehydration leads to low blood pressure and orthostatic hypotension (9,10), and therefore, considering the close relation between sodium and water balance and the level of blood pressure, we postulated that an increase in water intake *per se* would result in an increase in blood pressure levels in healthy individuals. Furthermore, since it is quite common to encounter recommendations to increase water intake for reasons such as to “facilitate kidney function to clean the blood”, or to “reduce wrinkling of the skin” in alternative medicine, we undertook a study of extra water-

intake corresponding to an additional 30 ml/kg body weight per day. The main outcome variables were day and night ambulatory blood pressure levels and the perception of different parameters of well-being measured by visual analogue scales (VAS) **that were specifically designed for this pilot study.**

Materials and methods

Subjects

We recruited 20 healthy students for the study, being 23 ± 2.0 years old. The 10 women were on average 169 ± 6 cm tall and weighed 61 ± 4 kg. The 10 men were 186 ± 6 cm tall and weighed on average 81 ± 10 kg. Blood pressure and anthropometric variables were measured as previously published (11). In brief subjects were equipped with a **Spacelab 90217** ambulatory blood pressure (ABP) measuring device, set at 3 recordings/hour, and a clinic blood pressure (CBP) was measured after 5 minutes of rest in the seated position. **Night time blood pressure was calculated based on the exact hours during which the subjects spent in bed** (so called diary method (11)). All participating subjects filled out the VAS-based questionnaire (20 questions with a maximal score, corresponding to the level of agreement with the statement/question, of 10 on each) and blood was drawn for analyses of aldosterone, renin and routine parameters such as haemoglobin and electrolytes as previously described (12). All subjects collected urine for 24 hours, for analysis of the volume and also of excretion of sodium, potassium and creatinine. All measurements were done at the end of two weeks of extra water intake (Extra Water Intake, EWI) or after two weeks of regular water intake (RWI). The subjects were randomised to begin either with the RWI or with EWI phase in this prospective **cross-over** study.

The logistics was as follows: subjects met the study organisers and were informed about study details, equipped with suitable water bottles (during the EWI period) and the CBP was measured with standard mercury sphygmomanometers, equipped with appropriate cuffs (8). Participants were asked to increase their regular fluid intake by drinking an additional 30 ml of tap water per kg body weight during each day of the 14 days of the EWI part of the study. The participants were individually responsible for calculating the amount of fluid intake each day and informed that they should consume 1/3 of the EWI before 1 o'clock pm, 1/3 between 1 o'clock pm and 6 o'clock pm and the remaining 1/3 of the extra water after 6 o'clock pm each day. **The subjects of the study were instructed to keep track of exact water intake by using supplied water bottles.** Blood for laboratory tests were drawn in the morning (between 8 and 9 o'clock am) when they returned the ABP monitor, in the non-fasting state. **The subjects collected urine for 24 hours during the same day as the ambulatory blood pressure recording was done (during the last day of each of the two week periods). The urine collection was performed after voiding of urine before starting collection for 24 hour, and terminated by voiding once more, using dedicated urine collection bottles provided by the University Hospital. The amount of sodium and potassium in urine and plasma was determined by ion selective electrode-based methods by the department of Clinical Chemistry at the University Hospital of Linköping.**

Statistics

Statistical calculations were done with StatView 4.5 (Abacus Concepts Inc., Berkeley, CA, USA) software. Comparisons within and between groups were done with Student's paired and unpaired 2-tailed t-test. Mean \pm SD is given unless otherwise stated. Statistical significance was considered at the 5% level ($p \leq 0.05$).

Ethics

The study was approved by the Ethics Committee of Linköping University and performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participating **subjects**.

Results

Since the mean weight of the 20 participants was 70.8 ± 13 kg the presumed increase in water was estimated to 2.1 l. Indeed, based on the measurement of urine volume for 24 hours, the volume of urine was on average 2.0 l larger when comparing the EWI with the RWI study-phases (RWI phase 1.7 ± 0.6 l, EWI phase 3.7 ± 0.8 l, paired t-test $p < 0.0001$, Figure 1).

There was no change in body weight during the two phases, nor were plasma sodium (RWI: 140 ± 3.8 mmol/l EWI: 139 ± 3.8 mmol/l, $p = 0.3$), **plasma** potassium (RWI: 3.9 ± 0.2 mmol/l, EWI: 3.8 ± 0.3 mmol/l, $p = 0.3$), **plasma** creatinine (RWI: 91 ± 13 μ mol/l, EWI: 93 ± 8.6 μ mol/l, $p = 0.3$) plasma renin (RWI: 15 ± 11 ng/l, EWI: 15 ± 10 ng/l, $p = 0.8$) or plasma aldosterone (RWI: 522 ± 443 pmol/l, EWI: 584 ± 597 pmol/l, $p = 0.3$) affected by the extra water intake. There was also no change in urinary sodium (RWI: 164 ± 90 mmol/24h, EWI: 146 ± 56 mmol/24h, $p = 0.4$), urinary potassium (RWI: 76 ± 30 mmol/24h, EWI: 72 ± 24 mmol/24h, $p = 0.97$) or urinary creatinine (RWI: 13 ± 4.4 mmol/24h, EWI: 12 ± 3.6 mmol/24h, $p = 0.8$) when comparing the two phases of the study.

The ABP recordings were technically successful in all the participants (successful recordings: RWI phase: 92 ± 7 %, EWI phase: 93 ± 5 %). Table 1 displays the increase in daytime BP during the EWI phase and also the results of the ABP recordings for the whole 24-hour period and during night time. Figure 2 shows the mean arterial pressure (MAP) during the RWI and

the EWI phases of the study. There was no change in the office BP or the night/day BP-ratio by the extra intake of water.

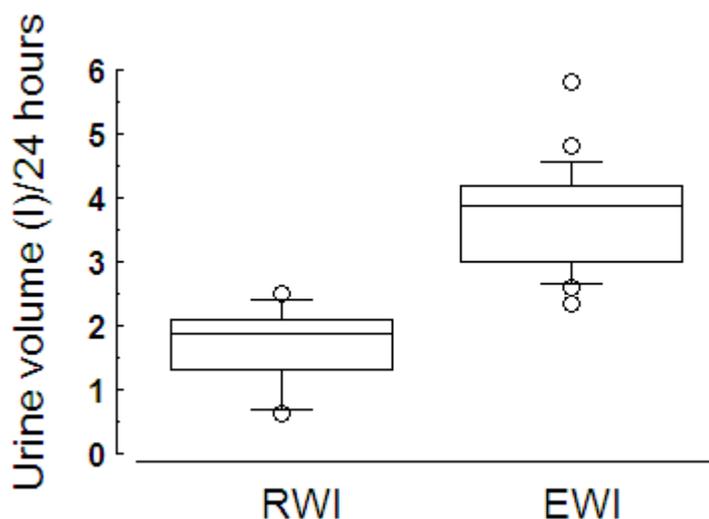


Figure 1
Urine volume during the Regular Water Intake (RWI) and Extra Water Intake (EWI) phases, respectively. The urine volume was on average 1.7 ± 0.6 l during RWI, and 3.7 ± 0.8 l during EWI, respectively (paired t-test $p < 0.0001$).

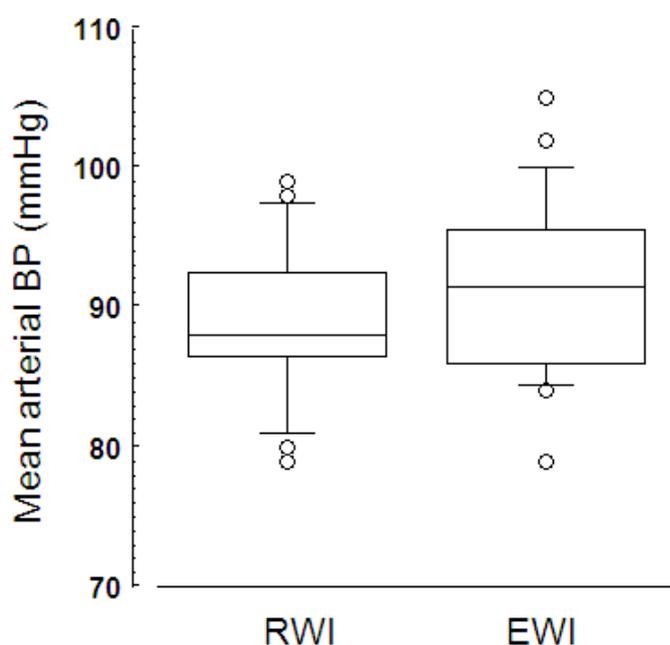


Figure 2
Mean arterial blood pressure (MAP) during the Regular Water Intake (RWI) and Extra Water Intake (EWI) phases of the study. Ambulatory blood pressure was carried out during the last day of each period and the daytime was defined according to the diary method (11). The MAP was 89 ± 5.5 mmHg during the RWI and 91.4 ± 6.4 mmHg during the EWI phases, respectively (paired t-test $p = 0.005$).

The extra intake of water induced an increased “sense of being swollen” in the skin ($p= 0.02$), and “sense of need to urinate” ($p< 0.0001$) and “sense of having a light coloured urine” ($p= 0.0003$). There was no change by EWI in the sense of having dry skin ($p= 0.9$) in the total material. However, when analysed separately according to gender, the decrease in the sense of having dry skin bordered on significance in women (mean VAS score of 6.0 ± 2.3 in the RWI phase to 5.0 ± 3.0 in EWI phase, $p= 0.052$). Surprisingly, two subjects experienced an increased “sense of thirst” when drinking extra water, scoring 2 and as much as 8 points higher, respectively, during the EWI compared with the RWI phases of the study. This was not a temporary misunderstanding of the VAS scale since the subject with the largest increase in sense of thirst induced by extra water intake also spontaneously described this experience to the study organizers.

The VAS score for “I often experience vertigo” was higher when comparing the RWI (3.1 ± 2.6) with the EWI phase (2.1 ± 2.1 , paired t-test $p= 0.008$). Interestingly, there was an inverse correlation between daytime systolic BP and the score for experiencing vertigo during the RWI phase (Figure 3a), a relationship that did not reach statistical significance in the EWI phase (Figure 3b). There were no differences in the VAS scores for “I feel alert”, “strong”, “well” or “fresh”, respectively, when comparing the two phases of the study.

Discussion

Our study showed a statistically significant increase in MAP by an extra intake of on average 2.0 l of water in healthy normotensive subjects, on average being 2.4 mmHg. The absolute differences in daytime systolic and diastolic BP were of a similar magnitude as the MAP, while night time BP was completely unaffected by the extra water intake. The unchanged amount of urinary creatinine in the two **phases of the study suggests that the two**

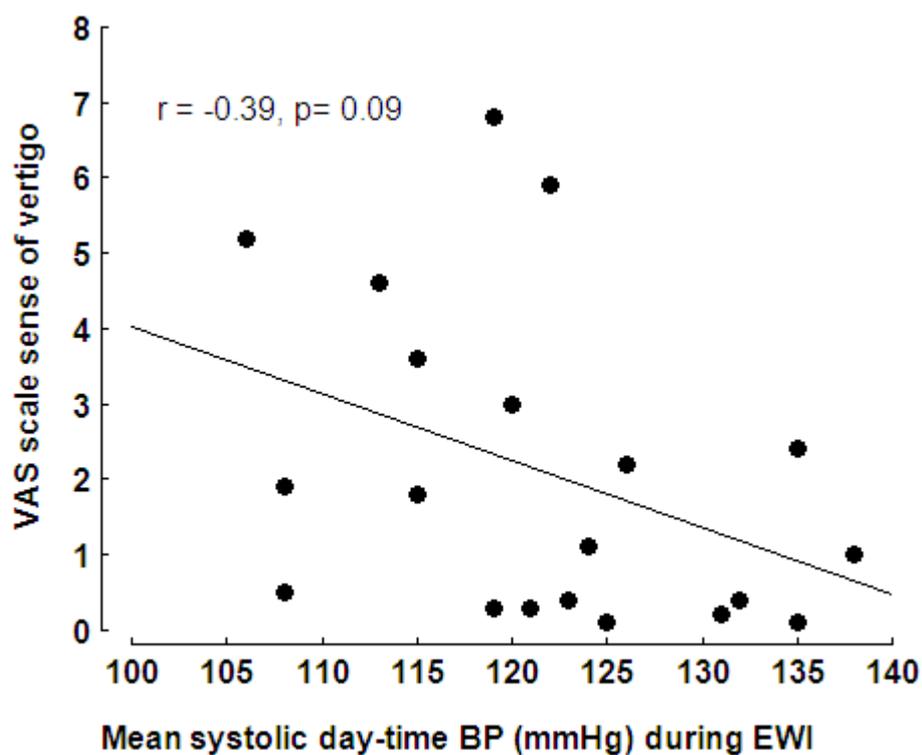
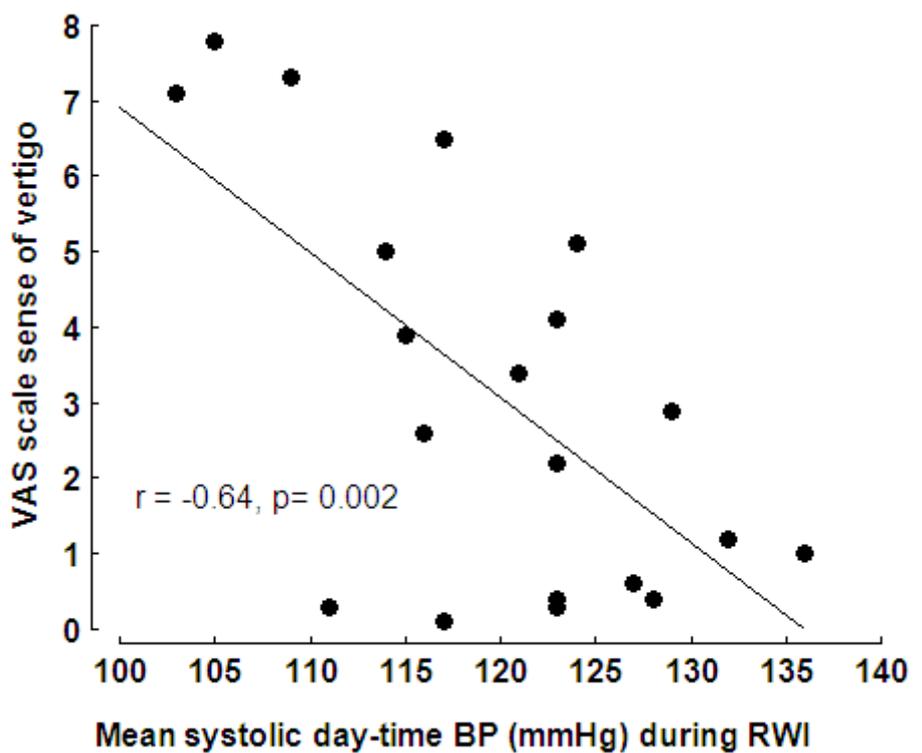


Figure 3

Relationship between the VAS score corresponding to “I often experience vertigo” with maximal score of 10, and daytime systolic BP during the Regular Water Intake (RWI) (a) and Extra Water Intake (EWI) (b) phases of the study. The correlations between BP and VAS score were $r = -0.64$ ($p = 0.002$) during the RWI, and $r = -0.39$ ($p = 0.09$) during the EWI phases, respectively.

collections of urine of the 20 participants were complete and thus representative.

Furthermore, the fact that there was no change in the amount of urinary sodium or potassium suggests that the changes in BP and VAS scores were consequences of the amount of water *per se* and not due to potential confounders such as changes in salt intake concomitant to the extra water intake.

It is reasonable to assume that, in a similar manner as BP control is harder to achieve in hypertensive subjects with reduced kidney function that ingest large amounts of salt (13), that an increase in water intake would also induce a stronger effect on BP in subjects that have a reduced glomerular filtration rate and hence that a high water intake could have a larger impact on blood pressure in hypertensive patients than in the healthy cohort studied herein. In a corresponding manner, it could be implicated that a reduced water intake also would lower BP in subjects with hypertension, and perhaps act in concert with a reduced sodium intake (7,14,15) to result in better control of blood pressure in hypertensive subjects.

Somewhat surprisingly we found that a sense of feeling of vertigo was quite common in our cohort of healthy 20-year-old subjects, and that this was related to low daytime BP levels. The extra intake of water reduced the **VAS scale-reported** “I often feel Vertigo” while at the same **time it was linked to higher daytime, but not night time, BP**. Indeed these **effects that were associated with the increased water consumption** are corroborated by several studies in which an acute intake of water reduces orthostatic hypotension in patients with autonomic failure as well as in healthy subjects (16-20). **However, our study was limited to a duration of only 14 days, and it is possible that long term effects of an increased water intake would yield different results. We can also not exclude the possibility that other reasons**

than the increased water intake influenced the reported vertigo. It should also be pointed out that the VAS scale used in this trial was newly designed and has not been used earlier. In these respects, our study should be viewed as a pilot study. Indeed, importance of volume regulation due to other causes than sodium retention/excretion can now be further explored by newly developed vasopressin antagonists. Recent studies of such drugs do suggest blood pressure reducing effects of water loss, at least in the acute phase (21,22). Interestingly, blood pressure reduction linked to osmotic diuresis by use of the new antidiabetic drug dapagliflozin, an inhibitor of renal sodium-glucose cotransporter 2, has recently been reported in a clinical trial (23) and this supports indirectly that water content *per se* affects blood pressure.

We found no changes in the VAS-score on any of the three questions that related to a more general sense of health such as feeling “strong”, “fresh” or “healthy”. It is possible that the **decrease in VAS-scale determined vertigo linked to extra water intake** was balanced by an increase in the more unpleasant sense of feeling swollen or need to urinate often. Anyhow, the results of this study could support a recommendation to increase water intake in healthy subjects with low daytime blood pressure and symptoms of vertigo. However, the long term effects of a change of water drinking habits warrants further studies, since potential side effects could be that cardiovascular disease increases in the same way as related to other causes of an increased BP, or that urinary incontinence could be developed in some subjects. Furthermore, if an extra intake of water would be a common recommendation against vertigo, the number of cases with water intoxication could potentially also increase, as suggested by the fact that one of our study subjects paradoxically experienced a strong increase in the sense of thirst during the EWI phase of the study.

Acknowledgments

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Conflicts of interest

The authors declare that there are no conflicts of interest with regard to this study.

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Table 1. Results of the ambulatory blood pressure recordings during daytime, night time according to the diary method (11) and for the whole 24-hour period, n= 20 (10 women and 10 men).

	Regular water intake phase	Extra water intake phase	p (paired t-test)
Mean 24-hour systolic	114.0 ± 7.6	115.8 ± 9.3	0.07
Mean 24-hour diastolic	69.0 ± 5.4	71.4 ± 6.2	0.002
Daytime systolic	119.8 ± 8.8	121.8 ± 9.3	0.06
Daytime diastolic	74.4 ± 6.3	76.4 ± 6.3	0.01
Daytime MAP	89.0 ± 5.5	91.4 ± 6.4	0.005
Night time systolic	100.3 ± 8.7	100.6 ± 9.6	0.8
Night time diastolic	56.1 ± 5.6	57.8 ± 6.0	0.1
Night time MAP	72.2 ± 5.8	73.6 ± 6.3	0.2