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Research article

Comparison of acute pressor effects of plain water, oral rehydration solution, and fruit juice ingestion in healthy young adults

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ABSTRACT

Background and Objectives: Ingestion of plain water is associated with an acute rise in blood pressure, probably due to elicitation of a sympathetic reflex in patients with autonomic dysfunction. Whether the pressor response is similar in healthy individuals is disputed. Other types of fluid could have different effects. Comparison of the pressor effects of plain water ingestion with other types of fluids has been reported scantily.

Material and methods: In a cross-over experimental study, young medical students ingested 500 mL of plain water (PW), 500 mL of oral rehydration salt solution (ORS), or 400 mL of commercial fruit juice (FJ) on separate days, with at least two days' gap. Their heart rate (HR) and blood pressure (BP: systolic, SBP and diastolic, DBP) were recorded before, immediately after (0 min), and at 2, 5, 20, and 40 min after fluid ingestion and compared with baseline values.

Results: Sixty nine apparently healthy medical students (40 males and 29 females, age range 18-24 years) participated in the study. Compared to baseline, SBP and DBP were significantly higher at 0, 2, and 5 min measurements with ORS and FJ; then lowered at 20 and 40 min. With the PW, BP changes were not significant at any time of measurement. In all experimental set ups, HR increased significantly at 0, 2, and 5 min and lowered to near baseline levels then after.

Conclusion: Ingestion of ORS and FJ, but not PW, is associated with acute pressor effects in healthy young adults. This finding could have implications on the choice of fluid for prophylaxis in hypotensive conditions such as blood donation, postural hypotension, and autonomic dysfunction.

Key words: fluid ingestion, fruit juice, oral rehydration solution, plain water, pressor effect.

INTRODUCTION

The act of water ingestion has been shown to have hemodynamic effects. Drinking about half a liter of water was shown to elevate seated blood pressure in patients with severe autonomic failure and pure autonomic failure as well as in healthy controls, especially systolic blood pressure by up to 30-35 mmHg.[1] Cariga and Mathias (2001) have reported rise in systolic and diastolic blood pressures with ingestion of 500 mL of distilled water at room temperature in patients with autonomic failure; the blood pressure rise beginning a few minutes after water ingestion, plateauing between 10 and 35 min, and returning to baseline at 50 min.[2] The effect of increasing blood pressure has been termed the 'pressor response'. Such effects were also observed in healthy individuals, normotensive, and mild hypertensives; in rest and in exercising conditions.[3,4] There are some conditions that are characterized by sudden falls in blood pressure and subsequent risks for occurrence of syncope; examples are postural hypotension, heavy physical exercise, and autonomic failure such as multiple system atrophy. Consequently, acute water drinking has been suggested to be beneficial in such conditions.[5-7]

Following ingestion, water drinking was associated with increased plasma norepinephrine level, suggesting a sympathetic reflex as the mechanism of action in patients.[1,8] This has been proposed to be the mechanism for pressor response of water ingestion. Meanwhile, one study reported that water drinking caused a fall in heart rate and no significant changes in arterial blood pressure in healthy subjects and instead, suggested an increased cardiac vagal activity by water ingestion.[9] In an experimental cross-over study, subjects undergoing voluntary dehydration had better tolerance to orthostatic challenge with 500 mL of isotonic banana juice as compared to plain water.[10] Thus, pressor response to water ingestion is not undisputed.

For prophylaxis against syncope associated with conditions such as orthostatic hypotension, other types of fluid including fruit juices and salt water have also been suggested.[11] The institution of oral rehydration salt solution for hypovolemia due to diarrheal diseases is standard treatment. Similarly, athletes frequently take different energy drinks and fruit juices to replenish fluid loss due to sweating as well as prophylaxis to post-exercise hypotension. This study aims to compare the pressor effects of plain water, oral rehydration solution, and fruit juice in healthy young population; comparison of different fluids in a single study is lacking so far.

MATERIAL AND METHODS

To compare the pressor effects of ingestion of different fluids, a cross-over comparative experimental study was designed and conducted from April to June, 2017 at the Department of Physiology of the Nepal Medical College, Kathmandu, Nepal. Apparently healthy and volunteering medical students who were non-smokers, not having any diseases or medications and exams at the time of participation, and not engaged in endurance exercises were included in the study. Informed written consent was taken at the time of registering for the study. Students usually reported in the morning – after about two hours of having a light breakfast. Their general information including measurements of height (cms) and weight (Kg) were taken. After adequate rest, their blood pressure (BP in mmHg; systolic – SBP and diastolic – DBP) and heart rate (HR as beats per minute - bpm, from the radial artery pulse) were measured (baseline measurements). BP was measured manually by the auscultatory method, using the aneroid sphygmomanometer for clinical use and HR by counting pulse rate for one minute. One type of fluid was randomly selected for each experimental set up and ingested in about two minutes – 500 mL of plain water (PW), 500 mL of oral rehydration solution (ORS), or 400 mL of fruit juice (FJ). PW was from a mineral water bottle, ORS was prepared freshly by mixing ORS powder in 1 liter of water, and fruit juice consisted of two pouches of commercial beverage (Rio® juice) available in 200 mL volume in each pouch. BP and HR were measured just before fluid ingestion (before) and immediately after (0 min), 2 min, 5 min, 20 min, and 40 min after the fluid ingestion. The participants were restricted to only light movements for the duration of observation and the measurements were done only at rest. The same procedure was repeated for each student for the other two types of fluid on two other occasions, after a minimum of two days' gap, thus completing the set of three fluids.

Differences of SBP, DBP, and HR at various times of recording from the values at baseline and before fluid ingestion were calculated. The mean differences were compared by paired t test for each record as well as within group differences by repeated measures ANOVA (SPSS version 16.0). Level of significance was set at a p value of 0.05.

RESULTS

Altogether, the study was completed in 69 students - 40 males (58%) and 29 females (42%). Overall, females had less age (19.83±1.23 vs 20.58±1.3 years in males), less height (158.41±6.66 vs 170.55±4.79 cms in males), and less weight (55.1±8.07 vs 63.85±9.44 Kgs in males).The baseline measurements of HR, SBP, and DBP for each experimental set up (PW, ORS, and FJ) were comparable (Table 1). Also, there were no significant differences in all the measurements for values at baseline and before fluid ingestion (Table 2).

Subsequently, the fluid ingestion was done and measurements were taken at different intervals. The HR and BP values were compared with the baseline values to evaluate the changes within each experimental set up (Table 2).

Within group comparisons showed that there were significant changes in the measured parameters in all experimental set ups except for the SBP and DBP changes in relation to ingestion of PW.

Ingestion of each kind of fluid was associated with an immediate rise in HR which generally lowered in 20 and 40 minutes. In case of ORS, the 20 min HR was still significantly higher than baseline. Fluid ingestion also resulted in increases in SBP and DBP, but variably with different fluids. SBP increased immediately with ORS and FJ. With FJ, a higher SBP was observed for 5 min then lowered by 20 min. With ORS, there was gradual increase in SBP up to 5 min, then lowered. However, SBP was significantly higher with ORS for the whole duration of observation. In case of PW, the SBP remained mostly unchanged and the only significant change was a late increase at 40 min.

Table 1: Comparison of baseline heart rate and blood pressures for different experimental set ups

Baseline Measurements	Experimental groups			ANOVA (between groups)	
	PW	ORS	FJ	F value	P value
HR, bpm	74.25±7.55	74.08±7.15	74.28±7.31	0.014	0.986
SBP, mmHg	116.87±6.24	116.83±5.83	117.34±6.01	0.145	0.865
DBP, mmHg	75.77±5.97	76.03±5.32	75.53±5.37	0.130	0.878

Table 2: Comparison of mean differences in HR, SBP, and DBP within groups in different experimental set ups

Parameters	Record times	PW		ORS		FJ	
		Mean±SD	P value (paired t test)	Mean±SD	P value (paired t test)	Mean±SD	P value (paired t test)
HR, bpm	Baseline	74.25±7.55		74.08±7.15		74.28±7.31	
	Before	74.48±7.73	0.419	74.09±7.04	0.921	74.44±6.83	0.409
	0 min	75.36±7.69	0.002	75.62±7.79	0.000	75.91±7.09	0.000
	2 min	76.23±7.37	0.000	76.28±7.86	0.000	76.73±9.31	0.000
	5 min	75.52±7.41	0.001	76.52±7.62	0.000	76.5±7.69	0.000
	20 min	74.49±6.7	0.541	74.97±6.9	0.001	74.78±6.85	0.166
	40 min	73.25±10.17	0.281	74.22±6.62	0.657	74.39±6.33	0.754
	ANOVA	F=6.289; p=0.000		F=19.756; P=0.000		F=18.445; P=0.000	
SBP, mmHg	Baseline	116.87±6.24		116.83±5.83		117.34±6.01	
	Before	116.87±6.26	1.000	116.65±5.74	0.203	117.19±5.98	0.409
	0 min	116.87±6.61	1.000	117.63±5.96	0.002	118.5±6.11	0.000
	2 min	116.93±6.45	0.883	118.4±5.95	0.000	118.5±9.48	0.000
	5 min	117.36±6.12	0.052	119.25±5.67	0.000	118.78±6.43	0.000
	20 min	117.12±6.22	0.522	118.77±5.39	0.000	117.94±6.64	0.166
	40 min	117.65±6.3	0.034	118.22±5.16	0.000	118.03±6.7	0.754
	ANOVA	F=1.704; P=0.133		F=17.315; P=0.000		F=6.768; P=0.000	
DBP, mmHg	Baseline	75.77±5.97		76.03±5.32		75.53±5.37	
	Before	75.45±±5.95	0.062	76.15±5.46	0.418	75.78±5.81	0.159
	0 min	75.42±±5.79	0.247	77.05±5.23	0.000	76.78±5.05	0.000
	2 min	75.62±5.61	0.557	77.45±4.97	0.000	76.84±5.55	0.000
	5 min	75.88±5.69	0.706	77.51±5.09	0.000	76.59±5.95	0.014
	20 min	75.59±6.04	0.446	76.86±4.51	0.001	75.53±5.85	1.000
	40 min	75.53±5.65	0.321	76.65±5.09	0.032	75.34±5.94	0.560
	ANOVA	F=0.621; P=0.684		F= 6.788; P=0.000		F= 8.475; P=0.000	

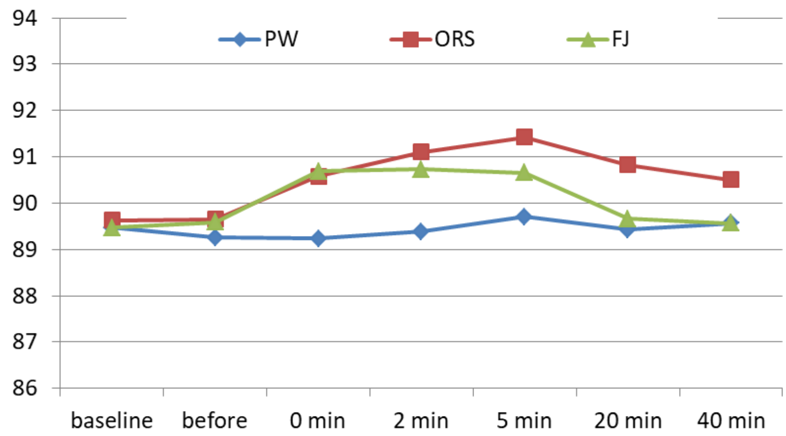

Figure 1: Mean arterial pressure changes over time in different experimental set ups

DBP change was generally similar to SBP change. The DBP increase was significant and sustained over all measurements for ORS, the most increase being in early minutes after ingestion. With FJ, rise in DBP was observed from immediately after up to 5 min, and then lowered to almost baseline values. In case of PW, a decrease in DBP was observed immediately after and throughout the 40 min observation time, although the differences were statistically not significant.

The mean arterial pressure (MAP) reflected the changes in blood pressure which showed sustained increase with ORS, transient increase up to 5 min with FJ, but a slight decrease in early minutes with PW (Figure 1).

DISCUSSION

This is an experimental study with a cross-over design, comparing the hemodynamic effects of acute ingestion of three types of commonly available fluids. Normotensive young adult subjects ingested different types of fluid in three different occasions and changes in their HR, SBP, and DBP in relation to baseline were compared. The baseline measurements being comparable indicated that carry-over effect, characteristically possible with cross-over study design, was negligible. The measurements made in the first few minutes were to evaluate the effect of fluid ingestion possibly mediated through the sympathetic reflex mechanism.[8]Later on, following intestinal absorption, ingested water begins to appear in plasma and blood cells within 5 minutes whereas absorption peaks at around 20 min.[12] This made the reason for timing of the later measurements.

The major finding of this study is the significant rise in SBP and DBP with ORS and FJ immediately and up to 5 minutes after fluid ingestion whereas with PW ingestion, the pressor effects were not significant. HR increased significantly with all three fluid types which lowered in 20 min.

Conditions such as postural hypotension, autonomic failure, post-exercise, spinal anesthesia, and blood donation are frequently associated with marked falls in blood pressure, which can often lead to syncopal incidences. In efforts to prevent the hypotensive state, different methods have been tried. Not all methods are applicable or suitable to every condition. These include parenteral hydration, oral prehydration with different fluids, periodic tensing of limb muscles, mental distraction, and others.[5,6,10,11,13-16] Regarding oral prehydration, most studies are on plain (tap) water but use of other types of fluid are reported scantily. While reporting the pressor effects of plain water ingestion in multiple system atrophy and pure autonomic dysfunction patients, Jordan et al (2000) initially reported a rise in SBP of as much as 33±5 to 37±7 mmHg after 30 to 35 min of ingestion of 480 mL of plain water. The pressor effect was also associated with raised plasma norepinephrine level; the magnitudes of norepinephrine level changes were comparable to classic sympathetic stimuli such as caffeine and nicotine, and indicated a sympathetic reflex as the mechanism of action.[8] The sympathetic reflex also incorporated increase in peripheral vascular resistance and attenuation of tachycardia-response in healthy subjects when challenged with head-up tilt postural change.[5] However, the effects have also been questioned by other studies.

Scott et al (2001) did not find significant changes in arterial blood pressure despite increased muscle sympathetic nerve activity and peripheral vascular resistance in normal subjects (n=9) in response to water drinking.[17] Routledge et al (2002) observed a fall in HR ($p<0.01$) and no significant changes in arterial blood pressure with 500 mL of PW ingestion in healthy subjects (n=10). In the same study, they observed a pressor response (range 13 to 29 mmHg) in cardiac transplant recipient patients (n=4). They concluded that in normal subjects undergoing water ingestion, the pressor effects of sympathetic activation is countered by an increase in cardiac vagal control.[9] This study, conducted in healthy young individuals, also did not find significant changes in SBP or DBP with ingestion of plain water although cardiac chronotropic effect was observed with a significant increase in HR for initial five minutes of water drinking. Thus, this study also supports the suggestion that pressor effect of plain water drinking has a variable response in healthy individuals and patients with autonomic dysfunction.

Comparison between effects of drinking plain water and other fluids are scantily reported. Differential patterns of fluid turnover after oral intake of 0.5 L of tap water, lemonade, and isotonic saline was observed in one cross-over study on ten healthy volunteers (age = 21-48 years), when measured in terms of blood hemoglobin, hematocrit, and glucose concentrations over 2 hours. Although absorbed fastest, tap water primarily hydrated peripheral tissues while a high rate of absorption and excretion was observed with lemonade. Lemonade also expanded the blood volume effectively.[18] These findings are in agreement with our findings too. Further, the study found a prolonged hydration response to isotonic saline which is again supported by this study. In another cross-over study on healthy volunteers (age = 18-20 years, n=16) undergoing voluntary dehydration challenge, Penggalih et al (2012) observed that banana isotonic drink better improved orthostatic tolerance as compared to plain water.[10]

Most studies assessed the effectiveness of fluid ingestion in preventing or attenuating hypotension associated with conditions such as postural change or autonomic failure. This study, conducted in healthy young adults, did not involve any such challenges and evaluated the responses in resting conditions. Also, the evaluation tools were limited to periodic and manual measurement of BP and

HR. Thus, this study could have missed transient and very small changes occurring in between the observed times or in other parameters such as heart rate variability, peripheral vascular resistance, and plasma norepinephrine levels. However, the larger number of participants in this study, compared to most other studies, along with the cross-over study design, should raise the reliability of the study findings.

CONCLUSION

Ingestion of 500 mL ORS or 400 mL FJ leads to immediate increases in HR as well as SBP and DBP but 500 mL PW ingestion does not have pressor effect. Further studies employing more sensitive and continuous HR and BP measurements, blood volume evaluation, and sympathetic activity measurements should be conducted to verify the findings. The findings could have clinical implications in choice of fluid for use in hypotension-associated conditions such as blood donation associated syncope, orthostatic syncope, and autonomic dysfunction. Comparative studies are recommended for evaluation of pressor effects of various fluids in these different clinical conditions separately.

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