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Short communication

The effects of drinks made from simple sugars on blood pressure in healthy older people

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The objective of the research was to determine the blood pressure (BP) lowering effects in older people of 50 g carbohydrate drinks with varying carbohydrate content using a randomised, cross-over study with ten (six females) healthy older subjects (mean age 72·20 (SEM 1·50) years). BP, heart rate and glucometer-derived blood glucose levels were determined at baseline and following the ingestion of equal volumes (300 ml) of water and carbohydrate drinks with varying nutrient content (glucose, sucrose and fructose). A significant decline in BP over the first 60 min was seen following glucose (systolic BP (SBP) $P<0·01$, diastolic BP (DBP) $P<0·01$, mean arterial BP (MAP) $P=0·03$) and sucrose (SBP $P<0·01$, DBP $P<0·01$, MAP $P<0·01$) ingestion, although the decrease occurred earlier after glucose than sucrose ingestion (SBP 7·33 (SEM 2·19) *v.* 21·00 (SEM 4·30) min ($P=0·03$) and MAP 11·22 (SEM 3·10) *v.* 17·00 (SEM 3·78) min ($P=0·03$)). BP increased after water ingestion (SBP $P=0·04$, DBP $P=0·18$, MAP $P=0·02$) but did not change after fructose ingestion (SBP $P=0·36$, DBP $P=0·81$, MAP $P=0·34$). *Post hoc* analyses revealed that the BP (SBP, DBP and MAP) decrease following glucose and sucrose ingestion were similar but significantly greater than following fructose or water ingestion. Sucrose, which is used widely (table sugar), reduces BP as much as glucose. In contrast to this, fructose ingestion causes no change in BP. Further studies are required to determine if the substitution of glucose or sucrose with fructose may be beneficial in the medical management of older people with severe symptomatic postprandial hypotension.

Glucose: Sucrose: Fructose: Postprandial hypotension: Elderly

Blood pressure (BP) normally falls slightly after food ingestion in older people. When the fall is excessive it can produce postprandial hypotension (PPH), which is defined as a decrease in systolic blood pressure (SBP) of 20 mmHg or more within 2 h from the start of a meal. The nadir is usually reached between 30 and 60 min after the start of eating (Jansen & Lipsitz, 1995; Smith *et al.* 2003). PPH is associated with an increased incidence of falls, syncope, angina and transient ischaemic attacks, particularly in older people and patients with autonomic neuropathy; the latter most frequently due to diabetes mellitus (Jansen & Lipsitz, 1995). Despite a reported prevalence between 20 and 45 %, PPH in older people is an under-recognised problem (Vaitkevicius *et al.* 1991; Aronow & Ahn, 1994; Grodzicki *et al.* 1998; Le Couteur *et al.* 2003; Puisieux *et al.* 2002).

The pathophysiology of PPH is poorly understood, but is likely to be multifactorial (Jansen & Lipsitz, 1995). Meal composition is thought to be an important determinant of the degree of postprandial BP decrease (Jansen & Lipsitz, 1995). Ingestion of carbohydrates, particularly glucose and to a lesser degree complex carbohydrates (starch) but not fructose or xylose, lowers BP more than ingestion of protein, fat or water (Heseltine *et al.* 1991; Jansen *et al.* 1987, 1990; Mathias *et al.* 1989; Robinson, 1995). The addition of guar, a naturally occurring, non-absorbed, gel-forming carbohydrate of vegetable origin attenuates the fall in BP seen following the ingestion of a glucose drink (Jones *et al.* 2001). Reducing the total carbohydrate amounts in meals has also recently been shown to reduce the magnitude, duration and symptoms of PPH (Vloet *et al.* 2001). Thus, modification of meal composition, particularly its carbohydrate content and type, could provide a means of reducing excessive postprandial BP falls in people with PPH.

Interestingly, the effects of sucrose, the main constituent of table sugar, on postprandial BP have not been reported before. Therefore, the aim of this study was to determine the effects of drinks with equal volume and carbohydrate content (50 g), but differing carbohydrate types (glucose *v.* sucrose *v.* fructose) on post-ingestion BP in healthy older people.

Abbreviations: BP, blood pressure; bpm, beats per minute; DBP, diastolic blood pressure; HR, heart rate; MAP, mean arterial blood pressure; PPH, postprandial hypotension; SBP, systolic blood pressure.

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Methods

Subjects

Ten healthy, older subjects (six female), aged 65–78 years (mean 72·20 (SEM 1·50) years), mean BMI 26·14 (SEM 0·95) kg/m^2 were recruited by advertisement. All subjects were non-smokers and had no history of gastrointestinal disease or surgery, diabetes mellitus, significant respiratory or cardiovascular disease, autonomic dysfunction, chronic alcohol abuse or epilepsy. No subject was on any medications known to influence BP and all medications remained unchanged during the study.

Protocol

Each subject had BP, heart rate (HR) and plasma blood glucose measurements taken on four separate study days before and after ingestion of the following drinks in random order: (1) 50 g glucose in 270 ml of water and 30 ml of lemon juice; (2) 50 g sucrose in 270 ml of water and 30 ml of lemon juice; (3) 50 g of fructose in 270 ml of water and 30 ml lemon juice; and (4) 270 ml of water and 30 ml of lemon juice (control). The studies were not blinded and were separated by at least 72 h. The study room was air-conditioned with the temperature set at 22 ± 3°C. All drinks were served at a temperature of 22°C to avoid the potential effect of temperature on BP (Kuipers *et al.* 1991).

Subjects attended the Department of Medicine following an overnight fast (10 h for solids and 6 h for liquids), at the same time for all studies. A cannula was placed in the left antecubital vein for blood sampling and subjects were seated comfortably in a chair to mimic normal physiological conditions during a meal. A BP cuff was attached to the right upper arm. Cardiovascular autonomic function was evaluated on one of the study days. Each subject gave written, informed consent and the study was approved by the Research Ethics Committee of the Royal Adelaide Hospital.

Measurements

Blood pressure and heart rate. BP (SBP, diastolic BP (DBP) and mean arterial BP (MAP)) and HR were measured using an automated oscillometric BP monitor (DINAMAP ProCare, GE Medical Systems, NSW, Australia). Following a 20 min rest post cannula insertion, three measurements were obtained at 9, 6 and 3 min before drink ingestion. The mean of these three readings formed the baseline value (t 0). The study drink was consumed within 3 min. BP and HR measurements were then measured every 3 min for the first 60 min (to t 60) post drink ingestion and then every 15 min to 120 min.

Blood glucose measurements. Venous blood was obtained from the intravenous cannula for glucose estimation at baseline and t 15, 30, 45, 60, 90 and 120 min. Blood glucose levels from these venous samples were immediately determined at the bedside, using a glucometer (True Sense; Abbott Diagnostic Division, NSW Australia).

Cardiovascular autonomic function. Autonomic nerve function was evaluated using standardised cardiovascular reflex tests (Ewing & Clarke, 1982; Piha, 1991). Parasympathetic function was evaluated by the variation (R-R interval) of the HR during deep breathing and the response to standing from a lying position. The maximum and minimum R-R interval for each respiratory cycle (converted to beats per minute (bpm)) was determined. The ratio of the longest R-R interval (around the thirtieth beat) to the shortest R-R interval (around the fifteenth beat) upon standing was also determined (30:15). Sympathetic function was assessed by the fall in SBP in response to standing. Each of the test results was scored according to age-adjusted predefined criteria as 0 = normal, 1 = borderline and 2 = abnormal for a total maximum score of 6. A score ≥3 was considered to indicate autonomic dysfunction (Ewing & Clarke, 1982; Piha, 1991).

Statistical analysis

All values are expressed as mean with the standard error of the mean. Two-way repeated measures ANOVA was used to examine the overall effects of time and drinks type (treatment) and the treatment × time interaction on BP and plasma glucose changes from baseline. *Post hoc* analysis using the Bonferroni/Dunn (all means) correction was performed when significant treatment effects were seen. One-way repeated measures ANOVA was conducted to evaluate the effects of each drink type on changes of BP and HR measurements from baseline over the first 60 min and a one-way ANOVA was conducted to compare the differences between the baseline BP, HR and whole blood glucose values between the study days. The time to BP decrease was the first time point after drink ingestion at which the BP was below the baseline value. The time values derived for glucose and sucrose were then compared using a paired t-test. All analyses were performed using Statview version 5.0 and SuperANOVA. P values $<0·05$ were considered statistically significant.

Results

The drinks were well tolerated. One person had sub-clinical autonomic dysfunction (score 3) without overt symptoms and so was not excluded from the study.

Blood pressure

There was no significant difference in the baseline BP (SBP, DBP and MAP) values between any of the four study days (Table 1). One person had an asymptomatic (≥ 20 mmHg) systolic BP decrease following both glucose and sucrose.

A significant treatment ($P=0·04$) and time ($P\leq0·01$) effect on SBP (change from baseline values) over the first 60 min was seen. In the first 60 min, the SBP (Fig. 1(a)) decreased significantly from baseline following glucose ($P<0·01$; −3·96 (SEM 1·38) mmHg (mean of 30–60 min post-ingestion values when nadir reached; Jansen & Lipsitz, 1995)) and sucrose ($P\leq0·01$; −3·03 (SEM 1·37) mmHg) ingestion, increased non-significantly following fructose ingestion ($P=0·36$; 2·59 (SEM 1·62) mmHg) and increased significantly from baseline following water ingestion ($P=0·04$; 2·96 (SEM 2·39) mmHg). The decrease in SBP occurred earlier after glucose than sucrose ingestion (7·33 (SEM 2·19) *v.* 21·00 (SEM 4·30) min; $P=0·03$).

For DBP (change from baseline) there was a significant treatment effect ($P<0·01$) and treatment × time ($P<0·01$) interaction. In the first 60 min, the DBP (Fig. 1(b)) decreased significantly from baseline following glucose ($P<0·01$; −4·07 (SEM 1·09) mmHg) and sucrose ($P<0·01$; −4·491 (SEM 1·092) mmHg) ingestion, and increased slightly but not significantly following fructose ($P=0·81$; 0·97 (SEM 0·69) mmHg) and water

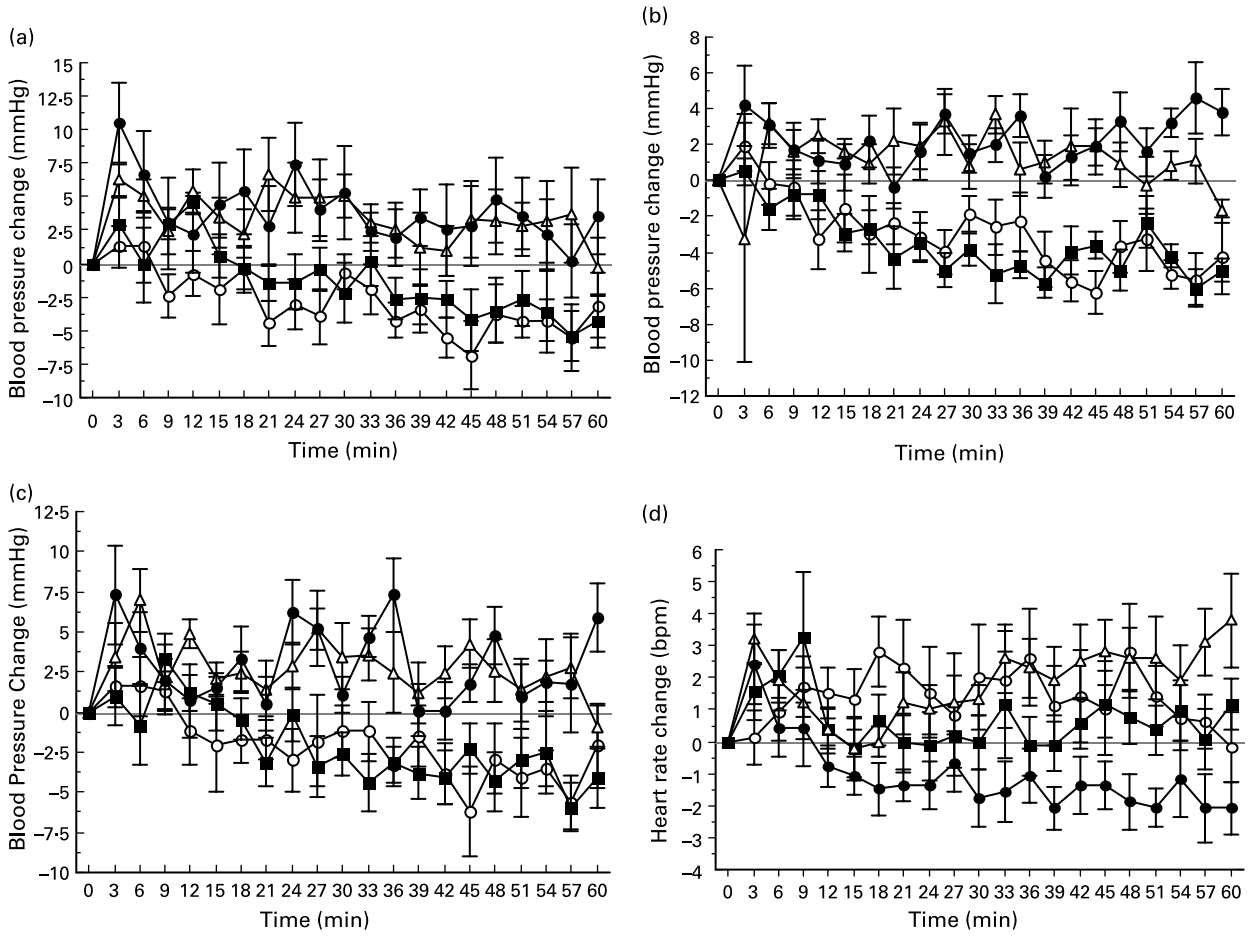

Fig. 1. Blood pressure (systolic (a); diastolic (b); mean arterial (c)) and heart rate (d) changes from baseline following ingestion of the four different study drinks (O,glucose; ■, sucrose; △, fructose; ●, water) in ten healthy older people. Values are means with their standard errors of the means depicted by vertical bars. bpm, Beats per minute.

($P=0{\cdot}18$; 2·46 (SEM 0·54) mmHg) ingestion. The decrease in DBP occurred at a similar time following glucose and sucrose ingestion (8·70 (SEM 2·12) *v.* 8·70 (SEM 1·81) min; $P=1{\cdot}00$).

For MAP (change from baseline) there was a significant treatment ($P<0{\cdot}01$) and time ($P<0{\cdot}01$) effect and a treatment × time ($P=0{\cdot}01$) interaction. MAP (Fig. 1(c)) decreased significantly from baseline following glucose ($P=0{\cdot}03$; −3·22 (SEM 1·35) mmHg) and sucrose ($P<0{\cdot}01$; −3·46 (SEM 1·05) mmHg) ingestion, increased non-significantly following fructose ($P=0{\cdot}34$; 2·30 (SEM 0·92) mmHg) ingestion and increased significantly following water ingestion ($P=0{\cdot}02$; 2·77 (SEM 0·78) mmHg). The decrease in MAP occurred sooner after glucose ingestion than sucrose ingestion (11·22 (SEM 3·10) *v.* 17·00 (SEM 3·78) min; $P=0{\cdot}03$).

For all BP measures, BP returned to baseline by 120 min following glucose, sucrose and fructose ingestion but remained mildly elevated following water ingestion. *Post hoc* analyses using the Bonferonni/Dunn correction found that glucose and sucrose ingestion had similar effects on post-ingestion BP (SBP, DBP and MAP) to each other ($P>0{\cdot}05$), water and fructose ingestion had similar effects on BP to each other ($P>0{\cdot}05$), and glucose and sucrose ingestion were each associated with a greater decline in BP than both fructose and water ingestion ($P<0{\cdot}01$).

Heart rate

There was no significant difference in the baseline HR values between the four study days (Table 1). There was a significant treatment effect ($P=0{\cdot}04$) and treatment × time interaction ($P<0{\cdot}01$). The HR (Fig. 1(d)) did increase non-significantly from baseline following glucose ($P=0{\cdot}49$; 1·43 (SEM 1·06) bpm) and sucrose ($P=0{\cdot}33$; 0·54 (SEM 0·72) bpm) ingestion, increased significantly following fructose ingestion ($P=0{\cdot}01$; 2·49 (SEM 0·75) bpm) and decreased significantly following water ingestion ($P<0{\cdot}01$; −1·68 (SEM 0·67) bpm).

Blood glucose

There was no significant difference in the baseline blood glucose values between the four study days (Table 1). The blood glucose (Fig. 2) values increased significantly from baseline following the glucose ($P<0{\cdot}01$), sucrose ($P<0{\cdot}01$) and fructose drinks but did not change from baseline over time (120 min) following water ($P=0{\cdot}51$) ingestion. The change in blood glucose value from baseline was greater following the glucose drink and lesser following the fructose drink in comparison to the changes seen following the sucrose drink ($P<0{\cdot}01$).

Table 1. Subject characteristics and baseline blood pressure, heart rate and glucose measurements (Mean values with their standard errors for ten subjects)

	Mean	SEM
Age (years)	72·20	1·50
Female (%)	60	
BMI (kg/m^2)	26·14	0·95
Autonomic nerve function score	0·8	0·2
Baseline systolic BP (mmHg)		
Glucose drink	117·43	5·35
Sucrose drink	118·20	5·63
Fructose drink	116·37	5·24
Water	119·40	7·38
Baseline diastolic BP (mmHg)		
Glucose drink	65·19	3·25
Sucrose drink	65·80	3·27
Fructose drink	65·00	3·59
Water	63·90	4·23
Baseline mean arterial BP (mmHg)		
Glucose drink	83·60	3·98
Sucrose drink	84·93	3·79
Fructose drink	83·83	5·24
Water	84·40	5·80
Baseline heart rate (bpm)		
Glucose drink	65·47	1·78
Sucrose drink	65·13	1·72
Fructose drink	63·30	1·42
Water	62·57	2·01
Baseline blood glucose (mmol/l)		
Glucose drink	5·87	0·23
Sucrose drink	5·63	0·09
Fructose drink	5·89	0·16
Water	5·93	0·17

bpm, Beats per minute.

Discussion

In agreement with the results of previous studies of healthy, young and older adult subjects, the BP of healthy, older subjects in this study decreased in the hour after glucose ingestion, increased after water ingestion and did not change after fructose ingestion (Jansen & Lipsitz, 1995; Lu *et al.* 2003). Sucrose ingestion was followed by a significant BP decrease, similar in degree to that following glucose, but later in onset. During the 60 min after drink ingestion, SBP decreased on average between 3 and 4 mmHg following glucose and sucrose ingestion and one subject had a > SBP decrease 20 mmHg following both sucrose and glucose, fulfilling the criteria for PPH. To our knowledge, this is the first report of the effect of sucrose ingestion on BP in any age group.

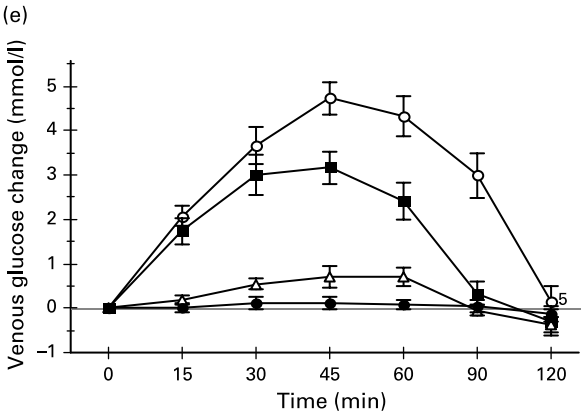

Fig. 2. The changes in blood glucose values over 120 min following the ingestion of the four different study drinks (○, glucose; ■, sucrose; Δ, fructose; ●, water) in ten healthy older people. Values are means with their standard errors of the means depicted by vertical bars.

Sucrose (molecular weight 342) is a disaccharide widely present in the diet as a component of food and also as table sugar. After ingestion it is hydrolysed by sucrase in the brush border of the small intestine to release an equimolar mixture of glucose and fructose, both with a molecular weight of 180. Sasaki *et al.* (2001) have reported that the use of oral acarbose, a sucrase inhibitor, reduced the fall in postprandial SBP in an elderly man with severe symptomatic PPH, from 45–50 mmHg to 18 mmHg, with resolution of symptoms. This suggests that sucrose must be broken down to glucose and fructose to exert its full hypotensive effect, as does the delayed onset of the BP decrease after sucrose compared to glucose ingestion in the present study. The results of this study also support this observation in that glucose ingestion results in a decrease in BP sooner than sucrose. It is unlikely that this difference is due to differences in gastric emptying rates as there is no evidence to suggest that gastric emptying is quicker following glucose ingestion than sucrose ingestion (Murray *et al.* 1994). Although the presence of glucose in the small intestine is thought to be an important prerequisite for the development of postprandial BP decreases, the changes in measured plasma glucose values are not predictive of subsequent postprandial BP changes. A recent study by our group found that the BP response to carbohydrate drinks could not be reliably predicted from their glycaemic index (glycaemic effect; Visvanathan *et al.* 2004).

The BP decrease after 50 g sucrose was not different from that after 50 g glucose, despite the former only delivering 25 g glucose to the gut, together with 25 g fructose which has no BP-lowering effect. Sucrose may therefore exert a hypotensive effect additional to that of its glucose content. Alternatively, the hypotensive effect of glucose may be saturable at a dose of less than 25 g. The results of a recent study by Vloet *et al.* (2001) support this possibility. They found no increase in the BP-lowering effect of a liquid meal when its carbohydrate content was increased from 65 g (−39 (SEM 7) mmHg) to 100 g (−40 (SEM 5) mmHg). A glucose dose–response study would be required to distinguish between these possibilities.

This study was performed in healthy older subjects, whose BP fell approximately 7·5 mmHg lower after sucrose and glucose than after fructose. There could be possible therapeutic implications for older people with PPH if they have similar (or greater) BP responses to these sugars. The substitution of fructose for sucrose (table sugar) is potentially an inexpensive and convenient treatment option in the management of symptomatic PPH. Further studies are required to assess the efficacy and safety of such a strategy, particularly in older people with symptomatic PPH.

In conclusion, the decrease in BP in older people after the consumption of 50 g carbohydrate-containing drinks of equal volume was determined by the nature of the sugars in the drink, with glucose and sucrose, but not fructose, lowering BP. Manipulation of the carbohydrates in a meal to increase fructose and decrease glucose and sucrose content may be a relatively simple and inexpensive management strategy for symptomatic PPH and this requires further evaluation.

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