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Research Article

Sodium and Potassium Intake, the First Step to Control Arterial Hypertension

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Abstract

In Portugal, Hypertension affects 43% of adults. Salt intake reduction and potassium increase are recommended for prevention and treatment of hypertension. This study was designed to determine how dietary sodium and potassium affects blood pressure (BP). Cross-sectional study of 41 patients was made in Centro Hospitalar de Coimbra. Patients BP, as well as their 24-hour urinary excretion of sodium (UNa) and potassium (UK); UNa/UK ratio was calculated. There were highly significant differences for both diastolic BP (DBP) and systolic BP (SBP) means according to 24h-UNa and UNa/UK values ($p < 0.001$). There was a highly correlation between BP and 24h-UNa, as well as, UNa/UK; stronger with this latest factor. Among BP values, SBP was strongly influenced by 24h-UNa and UNa/UK than DBP (Pearson $0.608 > 0.578$ and $0.675 > 0.633$, respectively). So, increased potassium intake should be considered as a recommendation for prevention and treatment of hypertension, especially in those who are unable to reduce their intake of sodium.

Keywords: Hypertension; Cardiovascular; Sodium; Potassium; Aldosterone; Renine

Introduction

Cardiovascular disease is the leading cause of death, hospitalization and disability in middle-aged and elderly European populations [1]. Arterial hypertension (HTA) is the major risk factor! In Portugal, HTA affects 43% of adults older than eighteen years old and rises

to 70% above seventy; only 11% are under control [2].

There is much evidence from animal, epidemiological, migration, intervention, genetic, and treatment studies that dietary salt (sodium chloride) plays an important role in regulating blood pressure (BP), and current high salt intake is largely responsible for the rise in BP with age [3]. This has important clinical implications because, unlike age, salt intake is a modifiable risk factor for cardiovascular disease. In the INTERSALT multi-national evaluation, differences in dietary sodium ingestion of 100 mmol (equal to 2,3 g, about 23% assuming an average salt consumption of 10 grams/

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day) per day were associated with differences in systolic BP of approximately 2.2 mmHg after adjustment for age, sex, potassium excretion, body mass index, and alcohol intake [3]. Meta-analyses of low-salt intervention trials indicate decreases in systolic BP of 3.7 to 7.0 mmHg and diastolic BP of 0.9 to 2.5 mmHg in hypertensive patients [4-7]. The World Health Organization recommends not more than 2 grams of sodium (5 grams of salt) per day. Ninety five percent of sodium is consumed in the form of salt. The current daily salt consumption in most European countries is estimated or measured to range between 8 to 12 grams per day [8,9].

Dietary potassium has been shown to exert a powerful, dose-dependent inhibitory effect on sodium sensitivity. Previous studies support the notion of inherent synergism in the activity of these two electrolytes [7]. The pressor effect of potassium depletion requires abundant consumption of sodium chloride [10]. High sodium and low potassium levels have complementary effects to reduce the availability of nitric oxide (NO) and increase asymmetrical dimethylarginine, leading to altered vascular smooth muscle cell contraction [11], with changes in vascular compliance and peripheral vascular resistance. So, increased potassium intake has also been recommended for prevention and treatment of hypertension, especially in those who are unable to reduce their intake of sodium [12,13].

Going further, the correlation between UNa/UK and BP, as well as, cardiovascular disease is also well known and has been found to be somewhat stronger than either of them alone [14-17]. The potassium content of the Dietary Approaches to Stop Hypertension (DASH) diet of fruits and vegetables was more than twice as high as that of the typical American diet [18]; therefore, a higher potassium/sodium ratio likely contributed to the observed benefits of the DASH diet.

Measurement of 24-hour urinary sodium (UNa) and urinary potassium (UK) is probably the most reliable and valid estimate of sodium and potassium intake in clinical practice [19,20].

As many hypertensive patients require several medications to reach target BP, it is of major importance to add lifestyle modifications as a support contributing

to the decrease of BP.

In the present study, we analyzed the quality of BP control defined by office BP, the 24-hour UNa and UK excretion as well as the corresponding dietary intakes of the patients.

Material and Methods

Cross sectional study of 41 patients was conducted in Centro Hospitalar de Coimbra. Seated clinic BP was measured manually with a manometric sphygmomanometer and an appropriate size cuff after five minutes of rest according to AHA guidelines. Three readings were made at the appointment, and the average was calculated. HTA was defined according to European Societies of Hypertension and Cardiology Guidelines (2007): normal blood pressure when diastolic BP (DBP) $\leq$ 89 mmHg and systolic BP (SBP) $\leq$ 139 mmHg; HTA stage 1 when DBP 90-99 mmHg or SBP 140-159 mmHg; HTA stage 2 when DBP 100-109 mmHg or SBP 160-179 mmHg; HTA stage 3 when DBP $\geq$ 110 mmHg or SBP $\geq$ 180 mmHg.

The 24-hour urinary excretion specimens were analyzed for both UNa and UK; urinary sodium/potassium (UNa/UK) ratio was calculated. Glomerular filtration rate was estimated by the Modification of Diet in Renal Disease (MDRD) formula.

No medications were discontinued or started during the previous month. All patients were queried about their dietary salt intake.

Exclusion criteria were any secondary cause of HTA, impaired renal function with plasma creatinine >150 $\mu\text{mol/L}$, hepatic failure and cardiac failure $>$ stage II New York Heart Association (NYHA).

Statistical Analysis

Statistical analysis was performed by SPSS 20.0 Statistical Analysis (SPSS Inc., Chicago, IL). In the descriptive analysis data were presented by mean $\pm$ standard deviation for continuous variables. Frequency (percent) and graphs were presented for

qualitative variables. For investigating the relationship of hypertension and the dietary characteristics groups were made for these. In the multivariate analyses Crosstabs tables were made. Chi square test with kendalls tau b was made (BP classification groups and urinary measurements). T Test and Pearson's correlation coefficients were used. Two-sided $P < 0.05$ was considered as statistically significant.

Results

This study included a sample of 41 patients. About two thirds were women (67.7%). The mean age was 51 ± 15 years. Clearance of creatinine was 118.3 ± 27.5 ml/min. The means of BP were 87.2 ± 10.4 mmHg for DBP and 148.0 ± 24.1 mmHg for SBP. 24 hour urinary sodium and potassium were 191.6 ± 88.6 mEq and 61.8 ± 21.4 mEq, respectively. The ratio between urinary sodium and potassium was 3.3 ± 1.4 and it ranged from 0.8 to 6.3.

The majority of patients answered to the interview as having an half salt diet (83.4%); only 6.5% answered that have a salt-free diet and 9.7% admitted a diet without restrictions. The majority of the patients were under anti-hypertensive drugs (93.5%). Among these, Angiotensin Converting Enzyme Inhibitors and Angiotensin II Receptor Blockers were the most used drugs (83.9%), followed by thiazide diuretics (64.5%). About one third of the patients were under an association of two drugs (35.5%). None of the type or dose of these drugs was changed in the previous month and patients under potassium-sparing diuretics were excluded.

According to the European Society of Cardiology, stage 1 HTA was the most common (38.7%), followed by normal BP (32.3%) and after that by stage 2 HTA (22.6%). Urinary measurements were divided in two groups: $24\text{h-UNa} \leq 150$ mEq was found in 38.7% and > 150 mEq in 61.3%; $24\text{h-UK} \leq 60$ mEq in 45.2% and > 60 mEq in 54.8%. Na/K Urinary ratio was divided in two groups, ≤ 3 and > 3 , and their distribution was similar to the 24h-UNa.

Bivariate analysis with crosstabs tables showed a positive relationship between lower BP stages and

$24\text{h-UNa} \leq 150$ mEq, as well as, Na/K Urinary ratio ≤ 3 (75% of the patients with normal BP having a lower 24h-UNa and lower Na/K Urinary ratio). No patient with stage 3 HTA had a $24\text{h-UNa} \leq 150$ mEq or a Na/K Urinary ratio ≤ 3 . Chi-Square Tests didn't found a significant association between 24h-UK alone and HTA stages (p-value 0.968). On the contrary, we found a highly significant association for 24h-UNa and UNa/UK ratio (Kendall's tau-b 0.607 for 24 h-UNa and 0.676 for UNa/UK ratio; both p-values < 0.001).

T-test was performed and there were highly significant differences for both DBP and SBP means in the two groups of 24 h-UNa and Na/K Urinary ratio (Table 1). Through Pearson's, a stronger, positive and significant correlation was found between BP values and UNa/UK ratio. Among these, Pearson coefficient was also higher for SBP values than DBP (Table 2).

Discussion

For thousands of years, daily salt (sodium chloride) intake in man was about 1g. Then recently, about 10,000 years ago, salt intake increased by about ten-fold [21] because of the practice of using salt as a food preservative. Because of this, humans got used to the taste of salt and enjoyed the benefits of non-perishable food. However, the human genome could not adapt so quickly. Genetically, humans are well-equipped with mechanisms that retain even tiny amounts of salt, a pre-requisite for survival at those times when salt was scarce and intake was low. In keeping with this background, humans have less efficient excretory mechanisms when challenged with large salt loads, and the limiting factor is the rate of renal salt excretion. If salt intake exceeds the kidneys' ability for salt excretion, then salt is deposited in the body, which, in synergy with aldosterone, affects heart, blood vessels and kidneys [22]. Arterial hypertension, stroke and cardiac infarction are often the end result. Nowadays, about 30% of hypertension (approximately 300 million people) and 1 in 5 cardiovascular events, are estimated to be caused by excess dietary sodium [23,24].

In our study, most participants were consuming excessive amounts of sodium, in disagreement to their

Table 1: T Test for diastolic and systolic blood pressure vs 24h Urinary Sodium and Na/K Urinary Ratio.

	24h UNa	Mean	SD	Mean Dif.	p value	UNa/ UK	Mean	SD	Mean Dif.	p value
DBP	≤ 150 mEq/L	80.2	7.5	-11.4	.001	≤ 3	78.8	7.8	-13.7	.000
	> 150 mEq/L	91.6	9.5			> 3	92.5	8.0		
SBP	≤ 150 mEq/L	131.6	16.4	-26.7	.001	≤ 3	128.8	13.4	-31.2	.000
	> 150 mEq/L	158.3	22.7			> 3	160.1	21.5		

Table 2: Correlation between BP and 24h-UNa, UK and UNa/UK Ratio.

		24h Urinary Na	Na/K Urinary Ratio
SBP	Pearson Correlation	,608**	,675**
	Sig. (2-tailed)	,000	,000
DBP	Pearson Correlation	,578**	,633**
	Sig. (2-tailed)	,001	,000

** . Correlation is highly significant at the 0.01 level (2-tailed).

answers about their salt consumption, which appears to be making a significant contribution to elevated BP and increased rates of hypertension.

According to the results above, we found a positive, highly significant correlation between sodium intake (estimated by 24 h-UNa) and higher BP values. This relationship was stronger for SBP than DBP.

Sodium homeostasis depends on both, sodium intake and renal function. The response to a high salt intake is an increased urinary loss of sodium, in order to maintain total body sodium balance. The molecular mechanism for this response is a down regulation of ENaC-β and ENaC-γ in the renal cortical collecting duct. It was demonstrated that the sodium channel function in endothelium was regulated by the mineralocorticoid hormone aldosterone, as much as it is in the kidney [25]. Therefore sodium and aldosterone act synergistically, and aldosterone is viewed as a hormone that facilitates sodium retention and epithelial sodium channel expression in the vascular endothelium [26] and kidney. At cellular level, small changes in plasma sodium

concentration can have a large impact on endothelial function as long as aldosterone (or aldosterone receptor function) is available [27]. Even a 5% increase in plasma sodium concentration mechanically stiffens endothelial cells by about 25%, leading to cellular dysfunction (decreased nitric oxide release/increased vascular smooth muscle tone). A major component of this high sodium sensitivity is the sodium channel in the endothelial plasma membrane [25,28], which is identical to the epithelial sodium channel cloned from renal tissue [29]. This channel allows sodium to enter the endothelial cells [30] and, by yet unknown mechanisms, turn off endothelial nitric oxide synthase activity [31].

Similarly, blood pressure in dialysis patients is known to decrease when sodium concentration in the dialysate is lowered [32]. There is also experimental evidence that the brain may be involved in the sodium-triggered increase of blood pressure [33].

Adding to this data, experimental studies observed that sodium balance is achieved in hypertensive

animals at higher pressures than in normotensive one, assuming that a shift in the pressure-natriuresis relationship to higher pressures is one of the central causal mechanisms of chronic hypertension in salt-sensitive hypertension [34]. Other investigators suggest that angiotensin II- and salt-induced increases in sympathetic nervous activity in the vasculature may be a primary causal factor in salt-sensitive hypertension [35,36].

Changing the ion factor, although not significant, it was seen an inversely correlation between potassium intake (estimated by 24h-UK) and higher BP values. Consistent with the Intersalt [16], Scottish Heart [37] and others, we also found that Na/K Urinary ratio had a stronger correlation with BP values, than 24h-UNa alone. Among BP values, SBP also had a higher correlation.

This effect may occur as a consequence of an enhanced activity of the Na-K-2Cl cotransporter in the distal tubule. Consequently, it is possible that Na⁺ excretion is more likely to be associated with an increase in BP in those individuals, whose K⁺ excretion decreases, thus indicating the presence of an active Na-K-2Cl cotransporter in response to Na⁺ intake.

The heterogeneity for the responses in BP is far from being completely elucidated; genetic predisposition might play an important role in determining individual variation. With no-lysine kinase 1 (*WNK1*) is a serine-threonine kinase and is predominantly expressed in the distal nephron of the kidney. It has been implicated as an important modulator of salt homeostasis, regulating the balance between renal sodium reabsorption and potassium excretion. Indeed, there is accumulated evidence of associations between the common variants of *WNK1* gene and BP level [38].

Under such evidence it has been proved that lowering the sodium intake of populations has been predicted to shift the population distribution curve of BP towards more optimal levels. Reducing dietary salt by 3 g per day has been projected to reduce mortality by 3%-11% for adults aged 35-64 years and to have cardiovascular benefits similar to population-wide reductions in tobacco use, obesity, and cholesterol levels [39]. In additional, in

developed, as well as in emerging countries, reducing dietary sodium is one of the few cost saving population based public health interventions available [40].

However, it is very difficult for individuals to effectively reduce dietary sodium intake, as over three-quarters of total intake is from sodium present in purchased foods [41]. Because of that the most effective strategy to achieve a significant reduction in population-wide salt intake would be to reduce the salt added to staple processed foods.

Limitations

There are a limited number of patients. Although BP values were an average from three measures of an appointment, we didn't performed an ambulatory blood pressure monitoring (ABPM) that, according to Practice Guidelines of the European Society of Hypertension, is a more reliable method to access the patient real BP.

We used a single urinary measure, which may be insufficient to estimate a participant's true usual sodium intake because does not account for daily variations in salt intake.

Conclusion

In agreement with our results, potassium intake is usually inversely related to sodium intake and associated with better BP control. Therefore, increased potassium intake with unprocessed food (fruits and vegetables) consumption should be considered as a recommendation for prevention and treatment of hypertension, especially in those who are unable to reduce their intake of sodium. However world health organization's should continue advocating the reduction of salt intake, and more targeted government and industry support is required to reduce the sodium content of processed foods, together with educational strategies to advise consumers to limit discretionary salt consumption [42].

Conflict of Interest

The authors have no conflict of interests.

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