Dietary sodium, erythrocyte sodium concentration, sodium-stimulated lithium efflux and blood pressure

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Summary
1. There was a significant positive relationship between sodium-stimulated lithium efflux and systolic blood pressure \( r = 0.512 \) in erythrocytes of black school children. Weight was also positively and significantly correlated with blood pressure. Although erythrocyte sodium concentration did not bear any significant relationship with blood pressure, it did bear significant inverse relationship with urinary sodium excretion.

2. High-school students were randomly assigned to either the experimental or the control group. In the former a reduction of about 70% in salt intake was achieved. After 24 days, the erythrocyte sodium concentration was significantly reduced in the experimental group. A non-significant decline in systolic blood pressure was observed in the experimental group; no change was detectable in the control group for either erythrocyte sodium concentration or systolic blood pressure.

Key words: erythrocyte, lithium, sodium.

Introduction
There is evidence for a relationship between intracellular sodium metabolism and blood pressure in the adult population. Although epidemiological, clinical and animal-experimental research implicates dietary sodium in the aetiology and pathogenesis of hypertension, no systematic studies have been reported on the effects of dietary sodium on intracellular sodium metabolism. Two studies, one observational and one experimental, were carried out to explore the relationships between dietary sodium, erythrocyte sodium metabolism (intracellular sodium concentration, sodium-stimulated lithium efflux) and blood pressure in pre-adolescent and adolescent youngsters.

Methods
Observational study
The study was an extension of a blood pressure survey among children in the parochial schools of Chicago [1]. Twenty-nine black school children (10 boys and 19 girls), age 11–15 years, enrolled in the study. After careful instruction all were asked to collect 24 h urine specimens for 7 consecutive days. Blood pressure was measured on two occasions during the week of urinary collection. On each occasion the blood pressure was measured twice, 1 min apart, a random zero sphygmomanometer being used after 5 min rest. Cuff size was assigned based on arm circumference. Weight was measured in light street clothes without shoes. Urine sodium excretion was determined by flame photometry. Erythrocyte sodium concentrations \( ([\text{Na}]_{\text{RBC}}) \) was determined after washing the packed cells three times with an iso-osmotic cold solution of \( \text{MgCl}_2 \) (115 mmol/l). All values were corrected for volume concentration of erythrocytes by comparing the sample haemoglobin with that of the original whole blood corrected to a packed cell volume of 100% (M. Trevisan, D. Ostrow, R. Cooper, K. Liu, S. Sparks & J. Stamler, unpublished method).

Sodium-stimulated lithium efflux \( (\text{Li efflux}) \) was determined by using the method of Canessa
et al. [2], after loading the cells with a solution containing LiCl (150 mmol/l), glucose (15 mmol/l) and Tris-MOPS buffer (10 mmol/l), pH 7.4. Both techniques have an acceptable degree of precision (coefficients of variation \(\frac{\sqrt{\sum d^2/2N}}{100 \times \text{mean}, \text{where } d \text{ is the difference in value between duplicate samples, and } N \text{ is the number of duplicate pairs}) \) are 2.5% and 6.4% for \([\text{Na}]_{\text{RBC}}\) and Li efflux respectively.

Statistical analyses were performed by using simple and partial correlation techniques.

**Experimental study**

In a Seventh Day Adventist boarding high school, 21 students consuming a lacto-ovo vegetarian diet completed a trial on moderate salt restriction of 24 days' duration. After collection of baseline data, the participants were randomly assigned to either the experimental or the control group. While the control group continued to eat the school cafeteria meals, the experimental group consumed a special diet of similar composition except for a decrease in sodium of about 70% (from 216 to 72 mmol of sodium a day). During the study random 24 h urine collections and random duplicate meals were collected for sodium analysis. Blood pressure was measured on the first and last days of the study with an automatic device (VITA-STAT). The values reported here are the means of two successive readings, 1 min apart, after a 5 min rest.

\([\text{Na}]_{\text{RBC}}\) was determined by using the same technique as in the observational study. Statistical analyses were performed with paired \(t\)-testing within each group and \(t\)-testing across the two groups.

**Table 1.** Dietary sodium, erythrocyte sodium concentration, sodium-stimulated lithium efflux from cells and blood pressure

<table>
<thead>
<tr>
<th>Observed study ((n = 29))</th>
<th>Correlation coefficient</th>
<th>([\text{Na}]_{\text{RBC}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mmHg)</td>
<td>0.512**</td>
<td>-0.107</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>0.285</td>
<td>-0.085</td>
</tr>
<tr>
<td>Urinary Na (mmol/24 h)</td>
<td>0.060</td>
<td>-0.321*</td>
</tr>
<tr>
<td>([\text{Na}]_{\text{RBC}}) (mmol/l of cells)</td>
<td>-0.056</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervent study</th>
<th>Experimental ((n = 12))</th>
<th>Control ((n = 9))</th>
</tr>
</thead>
<tbody>
<tr>
<td>([\text{Na}]_{\text{RBC}}) (mmol/l of cells)</td>
<td>8.01 ± 1.1</td>
<td>8.70 ± 1.9</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>108.42 ± 11.6</td>
<td>110.67 ± 10.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.05 ± 8.3</td>
<td>61.74 ± 8.4</td>
</tr>
<tr>
<td>([\text{Na}]_{\text{RBC}}) (mmol/l of cells)</td>
<td>7.41 ± 1.0**</td>
<td>8.60 ± 2.1</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>107.17 ± 13.1</td>
<td>110.67 ± 7.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.32 ± 8.1</td>
<td>61.70 ± 8.3</td>
</tr>
</tbody>
</table>

**Results**

**Observational study**

In the group of 29 children, mean weight was 53.5 ± 14.0 kg, systolic blood pressure 105.5 ± 9.8 mmHg, \([\text{Na}]_{\text{RBC}}\) 8.9 ± 2.0 mmol/l of erythrocytes, Li efflux 3.2 ± 0.9 \(\mu\)mol min\(^{-1}\) l\(^{-1}\) of erythrocytes (means ± SD). Li efflux was positively and significantly correlated with systolic blood pressure (Table 1). The correlation remained significant with control for weight \((r = 0.487, P < 0.05, \text{partial correlation coefficient})\). Li efflux was not significantly related to \([\text{Na}]_{\text{RBC}}\) or urinary sodium excretion.

Urinary sodium excretion was negatively and significantly correlated with \([\text{Na}]_{\text{RBC}}\). Urinary potassium excretion did not significantly relate to any of the variables except urinary sodium excretion \((r = 0.673)\). Weight was significantly and directly correlated with blood pressure \((r = 0.645)\).

**Experimental study**

There was a significant decrease in \([\text{Na}]_{\text{RBC}}\) in the experimental group at the end of the study period, and virtually no difference was detectable in the control group (Table 1). The difference between the differences for the two groups was statistically significant. Changes in systolic blood pressure and weight did not reach statistical significance.

**Discussion**

Cellular handling of water and ions has been studied in hypertension for a number of years. Impaired movement of water and ions in skeletal
muscle was reported in dogs with Goldblatt hypertension in 1943 [3]. Since that time both static and dynamic aspects of intracellular ion metabolism have been found to be altered in a variety of experimental models of hypertension in animals, as well as in human hypertension [4–10]. Unfortunately, the use of different techniques and incomplete knowledge of cellular ion pathways make it difficult to compare the results of different studies. Among the ion pathways which have been reported as abnormal in essential hypertension are total Na efflux which have been reported as abnormal in static and dynamic aspects of intracellular ion metabolism. Changes in systolic blood pressure observed in the intervention study did not achieve statistical significance. In view of the small sample size and short duration, this finding must be interpreted with caution. Sizeable reduction in dietary sodium was associated with a significant fall in intracellular sodium level at the end of the 24 day experiment.

In conclusion, data presented here support the hypothesis that a relationship exists between intracellular Na metabolism and blood pressure, and that some aspects of intracellular Na metabolism are influenced by dietary Na intake.

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References


