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Estimating the effect of a reduction of sodium intake in childhood on cardiovascular diseases later in life

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Reducing sodium intake during childhood is recommended for the primordial prevention of hypertension, and cardiovascular diseases (CVD). There is however no estimation of the effect of sustained reduction on sodium intake beginning in childhood on CVD later in life. Based on a simple impact model, we estimated that a sodium intake reduction between 1 and 2 g per day in childhood could reduce coronary diseases by 3-6%, strokes by 3-5%, heart failures by 4-9%, and CVD mortality by 4-9% later in life.

Worldwide, cardiovascular diseases (CVD) cause 17.6 million deaths per year, and half would be attributable to high blood pressure (BP) (1, 2). Since experimental studies have shown that high sodium intake increases BP (3), a key public health strategy to reduce the burden of high BP, and its associated consequences, is to reduce dietary sodium intake at the population level (4). Sodium intake is high in most populations: The average sodium intake among adults has been estimated be around 4 g/day worldwide (corresponding to 10 g of salt) (5), with the majority of the world population having intakes above the maximum of 2 g/day recommended by the WHO (6). Because high BP has its roots in childhood and tracks to adulthood (7), it has been advocated that primordial prevention beginning as early as from the first years of life can have a large potential to reduce the global burden of high BP (8). Further, as dietary preferences and habits are largely ingrained during childhood, high sodium intake in childhood could lead to high sodium intake in adulthood, with associated higher BP levels and increased risk of CVD.

To the best of our knowledge, there is however no estimation of the long-term effect of sustained reduction on sodium intake beginning in childhood on CVD later in life. While several cohorts and trials have investigated the associations between sodium intake in childhood and BP later in childhood and in early adulthood (9, 10), no study has assessed the effect of reduced salt intake in childhood on BP after 25 years of age and associated CVD risk in adulthood. Using a simple impact model, we therefore indirectly estimated the percentage of CVD events and deaths prevented in adulthood by reducing sodium intake during childhood at the population level.

Assuming a causal relationship between sodium intake and BP during childhood, we modeled the effect of a reduction of sodium intake on BP and CVD incidence and mortality in adulthood. First, we chose two different levels of sodium intake reductions during childhood, i.e., 1 and 2 grams/day respectively. Second, we calculated the change in systolic BP in childhood caused each sodium intake reduction, using the findings from a recent systematic review on the effect of sodium intake on BP during childhood (11). Third, we extrapolated this systolic BP change in childhood to a change in systolic BP in adulthood, assuming that, a change in 1 mmHg in childhood would lead to a change in 2 mmHg in adulthood, based on the mean difference between the highest and lowest blood pressure trajectories reported in a cohort study (12). Fourth, we estimated the effect of this change in BP in adulthood on the risk of CVD later in life, using risk estimates from a recent systematic review (13). The equations used were the following:

1) $\Delta_{SBP\ child}\ [mmHg] = \Delta_{SBP/Na\ child}\ [mmHg/g\ sodium/d] \times \Delta_{Na\ child}\ [g/d]$
2) $\Delta_{SBP\ adult}\ [mmHg] = 2 \times \Delta_{SBP\ child}\ [mmHg]$
3) $\Delta_{CVD}\ (\%) = \Delta_{Risk}\ [\%/mmHg] \times \Delta_{SBP\ adult}\ [mmHg]$

where $\Delta_{SBP\ child}$ is the expected change in systolic BP in children; $\Delta_{SBP/Na\ child}$ is the change in systolic BP expected for one gram change in sodium intake in children, i.e., 0.8 mmHg/g (11); $\Delta_{Na\ child}$ is the reduction in sodium intake per day in children, i.e., 1 or 2 g; $\Delta_{SBP\ adult}$ is the expected change in systolic BP in adults; Δ_{CVD} is the relative reduction in fatal and non-fatal events of coronary heart disease, stroke, and heart failure, and CVD mortality; Δ_{Risk} is the percentage reduction in coronary heart disease, stroke, heart failure and CVD mortality per mmHg systolic BP (i.e. 1.7%, 2.7%, 2.8%, and 1.3% respectively (13)). To estimate the uncertainty around the estimates, we used the 95% confidence intervals (CI) of the expected change in systolic BP per gram change in sodium intake in children, i.e., 0.4 to 1.3 mmHg/g (11).

The results are shown in **Table 1**. We estimated that a reduction of sodium intake by 1 g per day from childhood to adulthood would reduce BP during childhood by 0.8 mmHg, and during adulthood by

1.6 mmHg. Due to this reduction in BP in adults, 3% of coronary heart diseases, 3% of strokes, 4% of heart failures, and 4% of CVD deaths could be prevented. With a sodium reduction of 2 g per day, up to 6% of coronary heart disease, 5% of stroke, 9% of heart failure, and 9% of CVD deaths could be prevented.

Our simple model however has several limitations. First, the effect of sodium reduction in childhood was likely underestimated due to regression dilution bias in the available estimates due to measurement errors in sodium intake (14). Second, our analysis assumed a simple linear effect of sodium intake on BP in childhood, although it has been suggested that the dose-response relationship between sodium intake and BP could be J- or U- shaped (15, 16). Depending on the level of sodium intake, this could result in over- or under-estimation of the actual effect in some segments of the population. Third, we assumed that there was a causal relationship between sodium intake and BP and that there were no negative consequences of reducing sodium intake irrespective of the baseline sodium intake level and hypertension status of the individuals (17). Fourth, we assumed a difference in systolic BP in childhood of 1 mmHg resulted in a change of 2 mmHg in adulthood, although blood trajectories are much more complex and depend on other factors, such as overweight and smoking (12). Fifth, we did not consider the effect of a salt intake reduction on diastolic BP. Finally, the uncertainty around the estimates of the percentage of CVD events and deaths prevented is likely greater than reported, as our impact model does not account for several sources of uncertainties.

Nevertheless, this modeling study helps evaluate the impact of early life CVD preventive population based approach. Other studies have shown that population approaches to prevent CVD potentially can prevent more CVD events and deaths than targeted approaches. For instance, a modelling study using data from the Framingham Heart Study and the NHANES II found that a reduction of 2 mmHg diastolic BP at the population level could reduce the percentage of coronary heart diseases by 6% (18), similarly to what we have found in our analysis. By comparison, a targeted approach where individuals with diastolic BP above 95 mmHg are given anti-hypertension medication has been estimated to prevent 4% of the coronary heart disease events (18).

While limiting sodium intake during childhood would have a small impact from a clinical point of view, our analysis suggests that it could have a substantial impact on the burden of CVD later in life. Sodium intake can be limited during childhood by having more low-salt food options and reducing the amount of salt added during cooking and at the table both at home and at school. Primordial prevention of high blood pressure starting early in life, through a reduction in sodium intake in childhood, has the potential to have a substantial impact on the risk of CVD later in life.

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Table 1. Effect of reducing sodium intake by 1 and 2 g/day in childhood on blood pressure in childhood and on CVD risk and mortality in adulthood.

Reduction in sodium (g Na/d)	Equivalent in salt (g NaCl/d)	Change in systolic blood pressure in children (mmHg) (11)	Change in systolic blood pressure in adult (mmHg) (12)	Percentage of coronary heart diseases prevented (13)	Percentage of strokes prevented (13)	Percentage of heart failures prevented (13)	Percentage of CVD deaths prevented (13)
-1 g	-2.5 g	-0.8 (-0.4, -1.3)[1]	-1.6 (-0.8, -2.6)[2]	-3% (-2%, -5%)[2]	-3% (-1%, -4%)[2]	-4% (-2%, -7%)[2]	-4% (-2%, -7%)[2]
-2 g	-5 g	-1.6 (-0.8, -2.6)[1]	-3.2 (-1.6, -5.2)[2]	-6% (-3%, -10%)[2]	-5% (-3%, -9%)[2]	-9% (-4%, -14%)[2]	-9% (-4%, -15%)[2]

Abbreviations: CVD: cardiovascular diseases; Na: sodium; NaCl: salt. [1] 95% confidence interval; [2] lower and upper estimates.

Summary Table

What is known about topic
• Reducing sodium intake during childhood is advocated for the primordial prevention of hypertension, and cardiovascular diseases. • There is no estimation of the effect of sustained reduction on sodium intake beginning in childhood on CVD later in life.
What this study adds
• This modeling study helps evaluate the impact of sodium reduction in childhood for the primordial prevention of cardiovascular diseases incidence and mortality later in life. • Our findings suggest that a sodium intake reduction in childhood could prevent a substantial proportion of cardiovascular diseases later in life.