JAMA Cardiology | Original Investigation

Sodium Reduction Legislation and Urinary Sodium and Blood Pressure in South Africa

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IMPORTANCE Reductions in dietary salt are associated with blood pressure reductions; however, national governments that have passed laws to reduce sodium intake have not measured these laws' impact.

OBJECTIVE To determine if South African regulations restricting sodium content in processed foods were associated with reductions in sodium consumption and blood pressure.

DESIGN, SETTING, AND PARTICIPANTS The HAALSI (Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa) study is a population-based cohort study among adults aged 40 years or older randomly selected from individuals living in rural Mpumalanga Province in South Africa. This study incorporated 3 waves of data (2014/2015, 2018/2019, and 2021/2022) from the HAALSI study to examine how 24-hour urine sodium (24HrNa) excretion changed among a population-based cohort following mandatory sodium regulations. Spot urine samples were collected across 3 waves, and data analysis was performed from 2023 to 2024.

EXPOSURES South African regulations introduced in 2013 that reduced levels for the maximum amount of sodium in milligrams per 100 mg of food product by 25% to 80% across 13 processed food categories by 2019.

MAIN OUTCOMES AND MEASURES 24HrNa was estimated using the INTERSALT equation, and generalized estimating equations were used to assess changes in sodium excretion and blood pressure.

RESULTS Among 5059 adults 40 years or older, mean (SD) age was 62.43 years (13.01), and 2713 participants (53.6%) were female. Overall mean (SD) estimated 24HrNa excretion at baseline was 3.08 g (0.78). There was an overall reduction in mean 24HrNa excretion of 0.22 g (95% CI, −0.27 to −0.17; *P* < .001) between the first 2 waves and a mean reduction of 0.23 g (95% CI, −0.28 to −0.18; *P* < .001) between the first and third waves. The reductions were larger when analysis was restricted to those with samples in all 3 waves (−0.26 g for both waves 2 and 3 compared to wave 1). Every gram of sodium reduction was associated with a −1.30 mm Hg reduction (95% CI, 0.65-1.96; *P* = .00) in systolic blood pressure. The proportion of the study population that achieved ideal sodium consumption (<2 g per day) increased from 7% to 17%.

CONCLUSION AND RELEVANCE In this cohort study, following South African regulations limiting sodium in 13 categories of processed foods, there was a significant reduction in 24HrNa excretion among this rural South African population, which was sustained with reductions in blood pressure consistent with levels of sodium excreted. These results support the potential health effects anticipated by effective implementation of population-based salt reformulation policies.

Editorial

Related article

Supplemental content

JAMA Cardiol. doi:10.1001/jamacardio.2024.5410
Published online February 5, 2025.

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Cardiovascular disease (CVD) remains the leading cause of death globally.[1] Hypertension is responsible for over 50% of CVD deaths and is a major risk factor for chronic kidney disease and dementia.[2] Furthermore, there is generally poor management of hypertension, with less than 10% of hypertensive individuals achieving control in low-income and middle-income countries.[3]

Sodium intake has been associated with increases in blood pressure (BP)[4,5] and CVD mortality when mean consumption is greater than 2 g per day as estimated by spot urine collection.[6,7] Further, reductions in consumption are associated with declines in BP.[8] Worldwide, mean daily consumption for adults is nearly 4 g of sodium (10 g of salt), or 2-fold the World Health Organization (WHO)-recommended amount of 2 g of sodium (5 g of salt).[9] Sodium consumption above 2 g is estimated to account for 1.65 to 1.8 million deaths, or about 1 in 10 of all CVD deaths, each year.[10] The WHO has recommended 4 strategies to reduce sodium consumption as best buys: (1) mass media campaigns; (2) reformulation of food products either voluntarily or by national legislative mandates; (3) front-of-package labeling; and (4) procurement of public sector food products with reduced sodium.

In 2013, South Africa became one of the first countries—and the first in Africa—to introduce legislation mandating maximum levels of sodium in different food categories.[11,12] Furthermore, South Africa targeted 13 categories, the most of any country, and is 1 of only 4 countries to set targets on more than 5 food categories, along with Slovakia, Argentina, and Iran. While there have been assessments of changes in the food contents on store shelves to assess industry compliance in some of these countries, to date there have been no complete evaluations of the impact of the legislation on 2 key clinical parameters: urinary sodium excretion as a measure of sodium intake and, most importantly, potential impact on BP.

We therefore undertook an impact evaluation using spot urine sodium samples collected in 2014, 2018, and 2021 from the population-based cohort of the HAALSI (Health and Aging in Africa: a Longitudinal Study of an INDEPTH community in South Africa) study, composed of participants 40 years and older in rural South Africa. This allowed for assessment of urinary sodium excretion prior to regulation, between the 2 regulatory target dates, and after the second date, when salt content was further restricted. This timing also allowed for an investigation of the association between change in urinary sodium excretion and BP.

Key Points

Question Is there an association between South African regulations to reduce sodium content in processed foods and sodium consumption and blood pressure in adults 40 years and older?

Findings In this cohort study among adults in a rural community, mandated reductions in sodium content in processed products were associated with a reduction in urinary sodium excretion in a cohort of rural South African adults aged 40 years or older. This reduction in sodium excretion was associated with modest but significant reductions in blood pressure.

Meaning South African national regulations to reduce sodium content in processed foods were associated with reductions in sodium consumption and blood pressure in a population with high sodium consumption and high prevalence of hypertension.

Methods

Extent and Timing of the Salt Regulation Implementation

Two different dates were set to implement the targets in South Africa[9]: the first target for the designated food categories was in 2016 and the second in 2019 (eFigure 1 in Supplement 1). The legislation defined maximum amounts of sodium allowed by each of the target dates for each of the 13 categories: bread; breakfast cereals; butter and fat spreads; 3 types of crisps or savory snacks; raw sausage; 2 types of processed meats; 3 types of soup powders and sauces; and stock cube concentrate. eTable 1 in Supplement 1 lists the amounts for several of the categories, with the 2010 baseline values compared to the target values. The 2016 target date included an amount of sodium anywhere from 20% to 70% less than that currently available. The 2019 date required further reductions of anywhere from 5% to 46% in the same categories.

Study Setting and Sampling

HAALSI is a population-based cohort study of health and aging initiated in 2014 among a random sample of 5059 adults aged 40 years or older living in rural northeastern South Africa.[13] HAALSI is closely linked with the US-based Health and Retirement Study (HRS) and is the first HRS-linked study in Africa. The study is situated in the Agincourt-Bushbuckridge subdistrict of Mpumalanga Province, South Africa (hereafter called Agincourt), which contains approximately 117 000 people living in 31 distinct and contiguous villages who have been annually followed up in a census update since 1992.[13,14]

All participants had anthropometric measures collected at baseline and completed a computer-assisted personal interviewing program (CAPI) for additional survey measures. Details on the community, the original sampling design, and the full survey elements can be found in prior publications.[13,14] The second wave of data collection occurred between November 2018 and November 2019 and was completed by 4176 respondents (93.6% of surviving cohort members). A third wave of data collection, conducted between July 2021 and March 2022, was completed by 3707 respondents (94.1% of survivors). From the original HAALSI cohort, all participants aged 40 to 60 years and a random sample of participants older than 60 years, stratified by age, were invited to enroll in a complementary study, the AWI-Gen (Africa Wits-INDEPTH Partnership for Genomics Studies) subcohort in 2015. A total of 2486 individuals were enrolled, and of these participants, urine samples were successfully collected from 1947 individuals and phenotyped through HAALSI. All surviving individuals within this subsample were eligible for the collection of spot urine samples in waves 2 and 3 of data collection.

Table 1. Profile of Characteristics for Those With Samples at Each Wave and the Full HAALSI (Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa) Cohort

Characteristic	Participants, No. (%)			
	Wave 1 (n = 1918)	Wave 2 (n = 1002)	Wave 3 (n = 1064)	Overall (N = 5059)
Respondent age, mean (SD), y	54.52 (8.16)	58.36 (8.40)	60.75 (8.21)	62.43 (13.01)
Years of education				
No formal education	629 (32.8)	340 (33.9)	355 (33.4)	2314 (45.7)
Some primary (1-7 y)	766 (39.9)	396 (39.5)	437 (41.1)	1724 (34.1)
Some secondary (8-11 y)	303 (15.8)	159 (15.9)	161 (15.1)	574 (11.3)
Secondary or more (≥12 y)	220 (11.5)	107 (10.7)	111 (10.4)	447 (8.8)
Alcohol consumption (past 30 d)				
No	1525 (79.5)	808 (80.6)	931 (87.5)	3887 (76.8)
Yes	393 (20.5)	187 (18.7)	128 (12.0)	1169 (23.1)
Missing	0	7 (0.7)	5 (0.5)	3 (0.1)
Smoking status				
No	1719 (89.6)	897 (89.5)	992 (93.2)	4594 (90.8)
Yes	197 (10.3)	97 (9.7)	66 (6.2)	460 (9.1)
Missing	2 (0.1)	8 (0.8)	6 (0.6)	5 (0.1)
Body mass index, mean (SD)[a]	27.86 (6.95)	28.00 (6.86)	28.38 (7.20)	27.25 (6.88)
Systolic blood pressure, mean (SD), mm Hg	135.50 (21.76)	126.37 (18.68)	129.59 (19.53)	137.99 (23.34)
Diastolic blood pressure, mean (SD), mm Hg	83.45 (12.18)	80.63 (11.35)	80.96 (11.09)	82.14 (12.71)
Hypertension status				
No	772 (40.3)	356 (35.5)	338 (31.8)	1808 (35.7)
Yes	1136 (59.2)	593 (59.2)	716 (67.3)	3145 (62.2)
Missing	10 (0.5)	53 (5.3)	10 (0.9)	106 (2.1)
Taking blood pressure medications				
No	1450 (75.6)	695 (69.4)	655 (61.6)	3620 (71.6)
Yes	467 (24.3)	304 (30.3)	409 (38.4)	1434 (28.3)
Missing	1 (0.1)	3 (0.3)	0	5 (0.1)

[a] Calculated as weight in kilograms divided by height in meters squared.

Data Collection

Spot urine samples were collected by trained and supervised local field staff according to best practice outlined by the WHO.[15] In each of the 3 waves, 10 to 15 mL of midstream urine was collected after the initial volume was voided. Detailed methods for urine sample processing, storage, devices, and techniques for assays and sodium measurement are described in eMethods 1 in Supplement 1. For BP measurement, participants were seated for at least 5 minutes and asked to remove all outer layers of clothing. Three BP measurements were then taken by the carefully trained and monitored field worker at 2-minute intervals using an Omron M6W automated cuff (Omron).

In addition to the individual-level data, a basket of salt-containing foods targeted in the legislation was sampled from local stores in all the Agincourt communities at waves 1 and 3. Their labeling was evaluated to assess any changes in the salt content. The sodium content on the labels was then compared to the legislative targets to assess for changes and compliance.

Sodium Consumption Estimation

Assessing sodium consumption by dietary recall has limitations either due to recall bias in food frequency questionnaires and 24-hour dietary recall studies (with errors up to 30%) or due to the expense, burden, challenges with literacy, and time needed to provide detailed dietary records.[16,17] The more reliable tools for estimating population-level mean consumption are urinary sodium excretion studies, wherein consumption is assumed to equal urinary excretion. Estimating 24-hour urine sodium (24HrNa) excretion based on spot urine tests for population-based mean estimates has been shown to be reliable in many countries.[18]

In a previous analysis,[19] 24HrNa excreted from individuals in this sample was estimated based on spot urine samples using 3 well-known equations: Tanaka,[20] Kawasaki,[21] and INTERSALT.[22] Results showed that INTERSALT equations yielded the best estimates, and the means based on spot urine samples for this population were not statistically different to those calculated from the 24-hour samples (n = 399). Given that spot urine samples are both easier to collect and less expensive than 24-hour samples and that the INTERSALT without potassium equation was reliable in this population, INTERSALT was used in the current study to assess mean changes in 24HrNa excretion in the larger population over 3 waves in 2014 to 2015, 2018 to 2019, and 2021 to 2022. Details of the equations for the 24-hour estimates by sex and the handling of extreme or missing values are detailed in eTable 2 and eMethods 2 in Supplement 1.

Outcomes

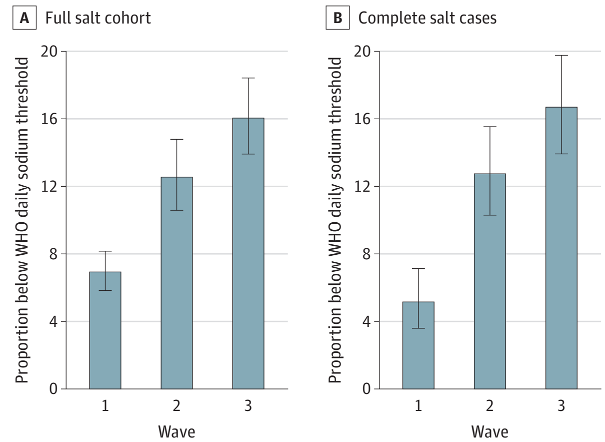
The primary outcome of interest was the change in mean population estimated 24HrNa excretion between study waves using the INTERSALT equation (without potassium). Additional

Table 2. Generalized Estimated Equation of Reductions (Milligrams of Sodium Excreted per 24 Hours) Compared to Wave 1 Using INTERSALT Estimation

Study group	Coefficient (SE) [95% CI]	*P* value
All participants		
Study wave		
Wave 1 (Reference)	NA	NA
Wave 2	−0.224 (−0.026) [−0.274 to −0.174]	<.001
Wave 3	−0.232 (−0.025) [−0.281 to −0.183]	<.001
_cons	3.075 (−0.019) [3.038 to 3.113]	<.001
Participants with urine samples in all 3 waves		
Study wave		
Wave 1 (Reference)	NA	NA
Wave 2	−0.259 (−0.033) [−0.324 to −0.193]	<.001
Wave 3	−0.264 (−0.033) [−0.329 to −0.198]	<.001
_cons	3.099 (−0.032) [3.035 to 3.162]	<.001

Abbreviations: cons, intercept; NA, not applicable.

Figure 1. Proportion of Respondents Below the World Health Organization (WHO)–Recommended Daily Sodium Intake Threshold



The figure depicts those who gave a urine sample in any wave (A) or those who gave a sample in all 3 waves (B). The WHO-recommended daily sodium threshold is less than approximately 2 g of sodium, or less than approximately 5 g of sodium chloride.

analyses included the proportion of the population achieving WHO-recommended targets for daily consumption of sodium (<2 g/day). The secondary outcome was whether changes in sodium excretion levels were associated with changes in BP across the waves. Systolic and diastolic BP were calculated from 3 separate readings using the following system: (1) mean of the final 2 readings if all 3 readings were present; (2) the final reading if 2 readings were present; or (3) the available reading if only a single reading was present.

Statistical Analysis

Descriptive statistics (means, proportions, and frequencies) were calculated for the full wave 1 HAALSI cohort and separately for the wave 1 subset of participants giving urine samples and for the remaining participants that did not give a urine sample. Standard differences were calculated to assess the differences between the main cohort and the sample subset. Distribution of variables was assessed for normality by histograms. Generalized estimating equations were used to assess the change in mean sodium excretion, measured as the unadjusted difference in mean INTERSALT estimates across each of the 3 waves. Exploratory analysis of possible confounders, including sample wave, sex, body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), age, baseline excretion, and use of BP medications, was assessed by stepwise linear regression. *P* value tests were 2-tailed, and any variables with a significant *P* value less than .05 were included in an adjusted model. The proportion and 95% confidence intervals of the population who achieved the estimated ideal sodium consumption recommended by the WHO of less than 2 g per day of sodium in each of the waves were calculated and visualized with bar graphs. Generalized estimating equations were used to analyze and assess change in BP, first with only change in mean sodium concentration and then adjusted for covariates collected in the CAPI survey previously associated with BP. These included the following sociodemographic measures: sex, marital status (never married; separated or divorced; widowed; or currently married or cohabitating), and continuous age. Additional health-related measures included respondent BMI, smoking status (yes, no, or missing), alcohol consumption in the past 30 days, and change in self-reported BP medication usage. Details for these variables are described in a previous paper.[13] Models were compared adjusting for and excluding baseline outcome values. Analysis was performed using all available data from patients at each wave, and a sensitivity analysis was performed using only participants who had urine collected at each wave (complete data analysis). Statistical analysis were performed with Stata SE version 18.5 (StataCorp).

Results

Demographic, BP, and other covariate data at baseline are included in **Table 1**, which compares the population that gave urine samples in each wave with the overall cohort. The population for this study was slightly younger than the overall cohort at baseline. Among 5059 adults aged 40 years or older, mean (SD) age was 62.43 years (13.01), and 2713 participants (53.6%) were female. Overall, the participants that gave urine samples had similar educational status and BMI across the waves but were younger, more educated, and had higher BMI compared to the overall cohort at baseline. Alcohol consumption, smoking, and hypertension status declined, while use of medications increased across the 3 time waves. Missingness of key covariates was limited to less than 0.5% in the studied population. eTable 3 in Supplement 1 lists the characteristics of those eligible in the cohort but who did not give a sample. These individuals had slightly higher alcohol consumption and smoking rates than those that did provide samples. BMI, systolic and diastolic BP, and hypertension status were similar across groups who provided and did not provide urine samples.

Table 3. Generalized Estimating Equation Showing Reduction in Blood Pressure per Gram Sodium Excretion and Other Determinants

Determinants	Systolic		Diastolic	
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value
Sodium excretion reduction, g	−1.30 (0.65 to 1.96)	<.001	−0.45 (0.07 to 0.84)	.02
Study wave				
Wave 1 (Reference)	NA	NA	NA	NA
Wave 2	−9.04 (−10.10 to −7.97)	<.001	−2.35 (−2.99 to −1.71)	<.001
Wave 3	−5.48 (−6.54 to −4.43)	<.001	−1.96 (−2.59 to −1.33)	<.001
Systolic blood pressure at wave 1, mm Hg	0.72 (0.70 to 0.74)	<.001	0.71 (0.69 to 0.73)	<.001
Sex				
Female (Reference)	NA	NA	NA	NA
Male	0.12 (−1.10 to 1.35)	.85	0.01 (−0.72 to 0.73)	.99
Respondent age, y	0.10 (0.05 to 0.16)	<.001	−0.01 (−0.04 to 0.02)	.55
Alcohol consumption (in the past 30 d)				
No (Reference)	NA	NA	NA	NA
Yes	1.63 (0.31 to 2.94)	.02	0.73 (−0.05 to 1.52)	.07
Missing	−2.92 (−14.78 to 8.94)	.63	−0.14 (−7.20 to 6.93)	.97
Smoking status				
No (Reference)	NA	NA	NA	NA
Yes	−0.41 (−2.16 to 1.34)	.65	−0.07 (−1.11 to 0.97)	.89
Missing	−0.44 (−10.95 to 10.06)	.93	0.96 (−5.29 to 7.22)	.76
Taking blood pressure medications				
No (Reference)	NA	NA	NA	NA
Yes	−1.96 (−2.96 to −0.95)	<.001	−1.11 (−1.71 to −0.52)	<.001
Missing	0.07 (−18.93 to 19.08)	.99	−0.11 (−11.43 to 11.21)	.90
Body mass index[a]	0.07 (−0.01 to 0.15)	.07	0.05 (0.01 to 0.10)	.03
_cons	26.71 (22.14 to 31.28)	.00	21.93 (18.98 to 24.88)	<.001

Abbreviations: cons, intercept; NA, not applicable.

[a] Calculated as weight in kilograms divided by height in meters squared.

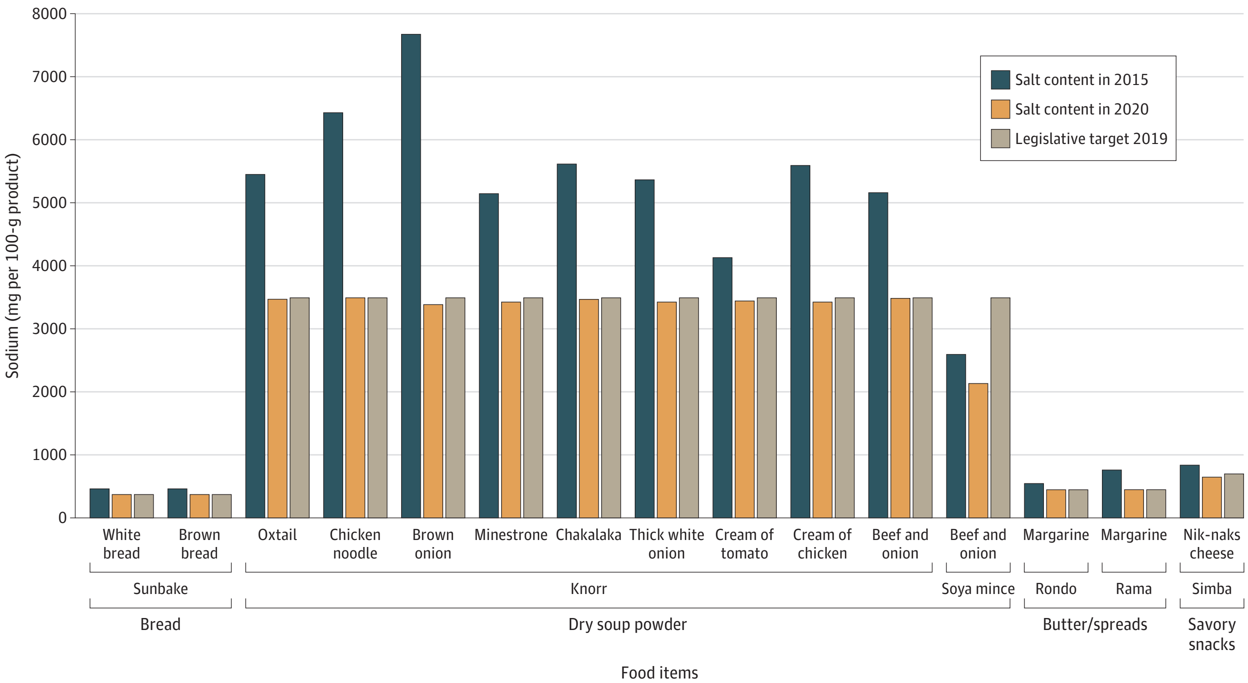
In 2014 (wave 1), 1918 individuals within the HAALSI cohort had spot urine measurements and 1899 had both systolic and diastolic BP measurements. Between waves 1 and 3, the number of samples declined due to both deaths and refusals. In 2019 (wave 2), 1002 individuals had spot urine samples and 895 had both systolic and diastolic BP measurements, and in 2021 (wave 3), 1064 individuals had spot urine samples and 1039 had both systolic and diastolic BP measurements. All participants with urine samples had matching data from the CAPI survey, and 51.8% of respondents who gave spot urine samples in wave 1 also gave spot urine samples in wave 2, while 54.4% of respondents with spot urine measurements in wave 1 also gave samples in wave 3. Additional data regarding details of samples are provided in Supplement 1.

Overall, the distribution of urine sodium estimates was normal as confirmed by histograms, with minimal outliers (eFigure 2 in Supplement 1). Overall baseline mean (SD) estimated 24HrNa excretion at wave 1 was 3.08 g (0.78). Using data from all who provided at least 1 sample, between waves 1 and 2 there was an overall reduction of 0.22 g (95% CI, −0.27 to −0.17; $P < .001$), and between waves 1 and 3, there was a reduction of 0.23 g (95% CI, −0.28 to −0.18; $P < .001$), both of which were statistically significant (**Table 2**). When the analysis was restricted to only those participants who gave samples in all 3 waves (n = 659), the reductions were greater from wave 1 to 2 (−0.26 g; 95% CI, −0.32 to −0.19) and wave 1 to 3 (−0.26 g; 95% CI, −0.33 to −0.20). When the sample was restricted in a sensitivity analysis to those who were not taking BP medications, the reductions were mildly attenuated in wave 2 (−0.18 g; 95% CI, −0.27 to −0.10) and wave 3 (−0.20 g; 95% CI, −0.28 to −0.11), yet remained significant.

Potential modifiers of change in estimated 24HrNa excretion were assessed in a sensitivity analysis using the generalized estimating equations model (eTable 4 in Supplement 1). Female sex was associated with a decrease of 0.74 g of urinary sodium per day. Each unit of BMI increase was associated with a 0.04 g per day greater increase in sodium excretion. Use of medications for hypertension was associated with 0.12 g per day decrease in estimated urinary sodium. Results were similar when the analysis was restricted to those who had samples in each of the 3 waves.

Figure 1A displays the proportion of all participants in each wave who achieved the estimated ideal sodium consumption recommended by the WHO (<2 g per day) in each of the waves.[9] In wave 1, only 7% of participants achieved ideal consumption; by wave 2, it was 13%, and the proportion increased to nearly 17% by wave 3. Male participants had no significant change over time, whereas the rates increased from 7% to 23% among female participants from wave 1 to wave 3. Similar results were seen when the cohort

Figure 2. Sodium Content on Packaging in a Basket of Food Products in the Agincourt-Bushbuckridge by Wave and Legislative Target



was restricted to just those with samples given in all 3 waves (Figure 1B).

We then explored the association between sodium consumption and BP across the waves in a full model of potential confounders (**Table 3**). Every gram of sodium reduction from wave 1 to wave 3 was associated with a 1.44 mm Hg reduction (95% CI, 0.93-1.94; $P < .001$) in systolic BP. This association was attenuated only slightly (1.30 mm Hg per gram sodium) controlling for age, sex, alcohol consumption, smoking status, BMI, and the initiation of self-reported BP medications. Diastolic BP declined by nearly 0.5 mm Hg per gram urinary sodium excretion in the full model. When the analysis was restricted to those with samples in each wave, the reduction in systolic BP was greater, at 1.75 mm Hg per gram sodium (95% CI, 0.95-2.55; $P < .001$), and similar (1.27 mm Hg per gram sodium) when controlling for other variables (eTable 5 in Supplement 1). Similar changes were seen for diastolic BP.

An assessment of food labels from a basket of goods obtained from local grocery stores in the encatchment area of the study cohort is displayed in **Figure 2**. Products from the bread, dried soup, butter or spreads, and snack categories were sampled. All products had sodium reductions between wave 1 and wave 3, and all met the labeling requirements set in place for products sold after June 30, 2019.

Discussion

To our knowledge, this is the first evaluation of the potential impact of the salt legislation in South Africa across the full timeline of regulations. Consumption of salt remained above the recommended levels, at 2 g per day of sodium, or nearly 5 g per day of salt. However, when compared across the 3 waves of samples, there was a nearly 10% (0.23 g per day) reduction in sodium consumption in this rural cohort of adults aged 40 years and older. There did not appear to be any further reductions after the second round of regulations—however, the gains after the first round of mandatory salt reductions appear to have been maintained.

When the regulations were proposed, it was estimated that there would be a sodium reduction of approximately 0.34 g per day. The mean reduction found in this study was slightly less overall. However, reductions were greater for those with higher baseline values, meaning the association could be greater in populations with a higher baseline values. While much of Africa consumes around 3 g of sodium per day, other regions consume up to 6 g per day. These reductions appear to be less than the reduction estimated in another community sample[23] that was 75% urban and only evaluated the first round of the mandatory regulations, which found a reduction of 0.46 g of sodium per day. Both reductions found in their respective population studies were less than those seen in other countries with mandatory reformulation—a mean reduction of 0.58 g of sodium per day.[1] One study[23] used spot urine samples to evaluate urinary sodium excretion before and after the first target deadline (2016) in South Africa; this suggested a decline in the mean urinary sodium excretion across the 2 waves, while another study sampled young adults between 2015 and 2020 with similar results.[24]

The reductions in sodium intake were also associated with anticipated reductions in BP. The mean reduction in systolic BP (about 1.5 mm Hg for each 1-g reduction in sodium) is consistent with other estimates. This was similar to the results from the WHO SAGE study in South Africa.[23] In a large meta-analysis of 85 clinical trials[25] assessing the dose response of BP to sodium intake, there was a mean reduction of 2.42 mm Hg for each gram reduction of sodium in trials with a dietary intervention.

Limitations

Limitations to these analyses include the observational nature of the study. Thus, causality cannot be assumed between the legislation and the reductions in sodium excretion observed. The association is certainly in the right direction and of the magnitude expected from the regulations, but other secular trends may have also explained the association, as well as other unknowns this study was unable to measure. Further, we sampled adults predominantly between the ages of 40 and 69 years. Whether these results would be seen in different South African populations or ages or in other countries with different sources of sodium intake needs to be studied further.

Another limitation is the use of spot urine samples to estimate sodium consumption levels. The criterion standard for measuring sodium consumption has historically been 24-hour urine excretion.[9] However, this is expensive for investigators or regulators, time-consuming, difficult to administer at scale in resource-limited environments, and inconvenient for participants, leading to low levels of use and compliance. Further, spot urine estimates tend to be less reliable at the individual level. However, it has been shown that spot urine estimates for population means tend to be quite reliable,[26] especially when mean consumption is above 2 g of sodium per day.[27]

Furthermore, the ability to assess a population mean around the WHO target goal of 2 g of sodium per day using spot urine tests has sensitivity of 97% and specificity of 100%.[18] Given their reliability to measure population means accurately, spot urine samples are suitable for evaluating changes in national policies. In previous work, no statistical differences were found between the 24-hour measurements and spot urine samples using the INTERSALT equation with and without potassium in a comparison of 400 samples.[19] A further limitation is the extent to which the HAALSI cohort is representative of the overall South African population. However, a nonsignificant difference between 24-hour sodium and estimates from the INTERSALT equation estimate was found in another study that included White and Indian-origin South African individuals,[28] suggesting the spot urine method is a reliable measure for population means throughout South Africa.

Lastly, the impact of medications could have influenced the association. Thiazide diuretics are widely prescribed and their use may have an impact due to blocking of sodium reabsorption, but we do not have individual-level medication usage to model this potential impact. However, when examining self-reported medication use for hypertension, it appeared to only have a modest impact, even though thiazide diuretics are usually first-line or second-line choices.

Conclusions

Implementation of regulations to encourage healthy levels of sodium consumption is achievable. Information about the source of sodium is important. In South Africa, 55% of the food comes from processed foods that were subject to these regulations. Efforts to change salt added during cooking or at the table require different solutions. There are 154 countries that have some policy commitment to reducing sodium in the diet. Some policies are easier to implement, such as sodium substitutes, mass media campaigns, or request for voluntary reformulations. Proposals for mandatory reformulation are more challenging, but in the countries where such policies were implemented, key ingredients to overcome barriers included reliable data about key sources of sodium, multisector collaboration (including manufacturers), strong government leadership, and adequate resources to implement.[29]

Hypertension remains a leading cause of death globally. It is clear that improvements, both at the clinical level and the population level, will be necessary to reduce its burden, which can lead to reductions in overall CVD mortality, as well as related conditions, such as kidney disease and even emerging dementias. In this study, it appears that at the population level, legislation enacted in South Africa may have been associated with the reformulation of many products containing high levels of sodium. Our findings noted an observed reduction in estimated urinary sodium excretion at the population level, which was associated with the time course of the implementation of the regulations, which in turn was associated with expected reductions in BP.

ARTICLE INFORMATION

Accepted for Publication: October 31, 2024.

Published Online: February 5, 2025. doi:10.1001/jamacardio.2024.5410

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Statistical analysis: Kapaon, du Toit, Fabian, Roberts-Toler.
Obtained funding: Gaziano, Wade.
Administrative, technical, or material support:

Gaziano, du Toit, Riumallo-Herl, Tollman. *Supervision:* Gaziano.

Conflict of Interest Disclosures: Dr Gaziano reported grants from AstraZeneca and Novartis and personal fees from Multiply Labs outside the submitted work. Dr du Toit reported grants from National Institute on Aging at the National Institutes of Health and from the Department of Science and Innovation, South Africa, during the conduct of the study. Dr Wade reported grants from the Fogarty International Center at the National Institutes of Health during the conduct of the study and nonfinancial support from Novo Nordisk outside the submitted work. No other disclosures were reported.

Funding/Support: The HAALSA (Health and Ageing in Africa: Longitudinal Studies in South Africa) study is supported by the US National Institute on Aging of the National Institutes of Health (P01 AG041710). The HAALSI (Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa) study is nested within the SAMRC/Wits University Rural Public Health and Health Transitions Research Unit (Agincourt Health and socio-Demographic Surveillance System), which is supported by the University of the Witwatersrand, the Medical Research Council, and the Department of Science and Innovation, South Africa.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Data Sharing Statement: See Supplement 2.

Additional Contributions: This article is dedicated to Profs Krisela Steyn and Lionel Opie who devoted a significant part of their professional lives to the prevention of hypertension and its sequalae among their fellow South Africans. They passed away in 2019 and 2020 respectively.

REFERENCES

1. Roth GA, Mensah GA, Johnson CO, et al; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global Burden of Cardiovascular Diseases and Risk Factors, 1990-2019: update from the GBD 2019 study. *J Am Coll Cardiol*. 2020;76(25):2982-3021. doi:10.1016/j.jacc.2020.11.010

2. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1923-1994. doi:10.1016/S0140-6736(18)32225-6

3. Geldsetzer P, Manne-Goehler J, Marcus ME, et al. The state of hypertension care in 44 low-income and middle-income countries: a cross-sectional study of nationally representative individual-level data from 1·1 million adults. *Lancet*. 2019;394(10199):652-662. doi:10.1016/S0140-6736(19)30955-9

4. Grillo A, Salvi L, Coruzzi P, Salvi P, Parati G. Sodium intake and hypertension. *Nutrients*. 2019;11(9):1970. doi:10.3390/nu11091970

5. He FJ, Tan M, Ma Y, MacGregor GA. Salt reduction to prevent hypertension and cardiovascular disease: JACC State-of-the-Art Review. *J Am Coll Cardiol*. 2020;75(6):632-647. doi:10.1016/j.jacc.2019.11.055

6. Welsh CE, Welsh P, Jhund P, et al. Urinary sodium excretion, blood pressure, and risk of future cardiovascular disease and mortality in subjects without prior cardiovascular disease. *Hypertension*. 2019;73(6):1202-1209. doi:10.1161/HYPERTENSIONAHA.119.12726

7. Mente A, O'Donnell M, Rangarajan S, et al. Urinary sodium excretion, blood pressure, cardiovascular disease, and mortality: a community-level prospective epidemiological cohort study. *Lancet*. 2018;392(10146):496-506. doi:10.1016/S0140-6736(18)31376-X

8. Gupta DK, Lewis CE, Varady KA, et al. Effect of dietary sodium on blood pressure: a crossover trial. *JAMA*. 2023;330(23):2258-2266. doi:10.1001/jama.2023.23651

9. WHO global report on sodium intake reduction. World Health Organization. Accessed June 23, 2023. https://www.who.int/publications-detail-redirect/9789240069985

10. Mozaffarian D, Fahimi S, Singh GM, et al; Global Burden of Diseases Nutrition and Chronic Diseases Expert Group. Global sodium consumption and death from cardiovascular causes. *N Engl J Med*. 2014;371(7):624-634. doi:10.1056/NEJMoa1304127

11. Tighter regulations for salt, tobacco use. South African Government News Agency. Accessed June 26, 2023. https://www.sanews.gov.za/south-africa/tighter-regulations-salt-tobacco-use

12. Kaldor JC, Thow AM, Schönfeldt H. Using regulation to limit salt intake and prevent non-communicable diseases: lessons from South Africa's experience. *Public Health Nutr*. 2019;22(7):1316-1325.

13. Gómez-Olivé FX, Montana L, Wagner RG, et al. Cohort profile: health and ageing in africa: a longitudinal study of an INDEPTH community in South Africa (HAALSI). *Int J Epidemiol*. 2018;47(3):689-690j. doi:10.1093/ije/dyx247

14. Kahn K, Collinson MA, Gómez-Olivé FX, et al. Profile: Agincourt health and socio-demographic surveillance system. *Int J Epidemiol*. 2012;41(4):988-1001. doi:10.1093/ije/dys115

15. World Health Organization Department of Communicable Disease Surveillance and Response. Guidelines for the collection of clinical specimens during field investigation of outbreaks. Accessed April 20, 2023. https://iris.who.int/handle/10665/66348

16. Freedman LS, Commins JM, Moler JE, et al. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for potassium and sodium intake. *Am J Epidemiol*. 2015;181(7):473-487. doi:10.1093/aje/kwu325

17. Ginos BNR, Engberink RHGO. Estimation of sodium and potassium intake: current limitations and future perspectives. *Nutrients*. 2020;12(11):3275. doi:10.3390/nu12113275

18. Huang L, Crino M, Wu JH, et al. Mean population salt intake estimated from 24-h urine samples and spot urine samples: a systematic review and meta-analysis. *Int J Epidemiol*. 2016;45(1):239-250. doi:10.1093/ije/dyv313

19. Du Toit JD, Kapaon D, Crowther NJ, et al. Estimating population level 24-h sodium excretion using spot urine samples in older adults in rural South Africa. *J Hypertens*. 2023;41(2):280-287. doi:10.1097/HJH.0000000000003327

20. Tanaka T, Okamura T, Miura K, et al. A simple method to estimate populational 24-h urinary sodium and potassium excretion using a casual urine specimen. *J Hum Hypertens*. 2002;16(2):97-103. doi:10.1038/sj.jhh.1001307

21. Kawasaki T, Itoh K, Uezono K, Sasaki H. A simple method for estimating 24 h urinary sodium and potassium excretion from second morning voiding urine specimen in adults. *Clin Exp Pharmacol Physiol*. 1993;20(1):7-14. doi:10.1111/j.1440-1681.1993.tb01496.x

22. Brown IJ, Dyer AR, Chan Q, et al; INTERSALT Co-Operative Research Group. Estimating 24-hour urinary sodium excretion from casual urinary sodium concentrations in Western populations: the INTERSALT study. *Am J Epidemiol*. 2013;177(11):1180-1192. doi:10.1093/aje/kwt066

23. Charlton KE, Corso B, Ware L, et al. Effect of South Africa's interim mandatory salt reduction programme on urinary sodium excretion and blood pressure. *Prev Med Rep*. 2021;23:101469. doi:10.1016/j.pmedr.2021.101469

24. Strauss-Kruger M, Wentzel-Viljoen E, Ware LJ, et al. Early evidence for the effectiveness of South Africa's legislation on salt restriction in foods: the African-PREDICT study. *J Hum Hypertens*. 2023;37(1):42-49. doi:10.1038/s41371-021-00653-x

25. Filippini T, Malavolti M, Whelton PK, Naska A, Orsini N, Vinceti M. Blood pressure effects of sodium reduction: dose-response meta-analysis of experimental studies. *Circulation*. 2021;143(16):1542-1567. doi:10.1161/CIRCULATIONAHA.120.050371

26. Huang L, Woodward M, Stepien S, et al. Spot urine samples compared with 24-h urine samples for estimating changes in urinary sodium and potassium excretion in the China Salt Substitute and Stroke Study. *Int J Epidemiol*. 2018;47(6):1811-1820. doi:10.1093/ije/dyy206

27. Belanger MJ, Lorinsky MK, Pankayatselvan V, Juraschek SP. A new method to estimate dietary sodium intake from a spot urine sample: context and caution. *Am J Hypertens*. 2021;34(7):686-688. doi:10.1093/ajh/hpab036

28. Swanepoel B, Schutte AE, Cockeran M, Steyn K, Wentzel-Viljoen E. Monitoring the South African population's salt intake: spot urine v. 24 h urine. *Public Health Nutr*. 2018;21(3):480-488. doi:10.1017/S1368980017002683

29. Webster J, Santos JA, Hogendorf M, et al. Implementing effective salt reduction programs and policies in low- and middle-income countries: learning from retrospective policy analysis in Argentina, Mongolia, South Africa and Vietnam. *Public Health Nutr*. 2022;25(3):805-816. doi:10.1017/S136898002100344X