Original Article

Association between salt and hypertension in rural and urban populations of low to middle income countries: a systematic review and meta-analysis of population based studies

Asvini K Subasinghe PhD[1], Simin Arabshahi PhD[1], Doreen Busingye PhD[1], Roger G Evans PhD[2], Karen Z Walker PhD[3], Michaela A Riddell PhD[1], Amanda G Thrift PhD[1,4]

[1]*Department of Medicine, School of Clinical Sciences at Monash Health, Monash University, Melbourne, Australia*
[2]*Department of Physiology, Monash University, Melbourne, Australia*
[3]*Department of Nutrition and Dietetics, Monash University, Melbourne, Australia*
[4]*Florey Neuroscience Institutes, Heidelberg, Victoria, Australia*

Background and Objectives: The prevalence of hypertension, the greatest contributor to mortality globally, is increasing in low-and-middle income countries (LMICs). In urban regions of LMICs, excessive salt intake is associated with increased risk of hypertension. We aimed to determine whether this is the case in rural regions as well. **Methods and Study Design:** We performed a meta-analysis of studies in rural and urban areas of LMICs in which the association of salt and hypertension were assessed using multivariable models. **Results:** We identified 18 studies with a total of 134,916 participants. The prevalence of high salt intake ranged from 21.3% to 89.5% in rural and urban populations. When salt was analysed as a continuous variable, a greater impact of salt on hypertension was found in urban (n=4) (pooled effect size (ES) 1.42, 95% CI 1.19, 1.69) than in rural populations (n=4) (pooled ES 1.07, 95% CI 1.04, 1.10, *p* for difference <0.001). In studies where salt was analysed continuously, a greater impact of salt on hypertension was observed in lean rural populations (BMI <23 kg/m^2) than in non-lean rural populations (BMI ≥23 kg/m^2, *p* for difference <0.001). **Conclusions:** The prevalence of high salt intake is similar in rural and urban regions. Excessive salt intake has a greater impact on the prevalence of hypertension in urban than rural regions. BMI appears to modify the relationship between salt and hypertension in rural populations.

Key Words: hypertension, salt, rural, urban, meta-analysis

INTRODUCTION

Approximately two thirds of the 972 million people with hypertension live in low-and-middle income countries (LMICs).[1-3] The prevalence of hypertension in LMICs is increasing rapidly,[1-3] due in large part to economic and demographic transitions.[4-6] These transitions have led to the adoption of westernised lifestyles and the increased prevalence of smoking, alcohol, sedentary activity, obesity, poor dietary habits, and other risk factors for chronic disease.[7]

There is compelling evidence that high salt intake is an important driver of hypertension.[8-14] Investigators in the landmark INTERSALT study, which included more than 10,000 adults in 32 countries, found a quasi-linear relationship between salt-intake and blood pressure.[15] High salt intake was only observed in one of the four INTERSALT cohorts from non-urban regions, and this cohort may not have been representative of non-urban populations subjected to high salt intake because the population centre was located nearly 4000 metres above sea level.[16] This highlights the limited information regarding the relationship between salt intake and hypertension in rural populations of LMICs compared with urban regions.

A noteworthy observation in the INTERSALT study was that the relationship between sodium and blood pressure attenuated when BMI was introduced into multiple regression models.[17] An explanation for this attenuation is that the blood pressure of obese individuals is sensitive to the effects of sodium, and results in an increased activity of the sympathetic nervous system.[18] Even though there is limited evidence for this relationship in populations of

Corresponding Author: Dr Asvini K Subasinghe, Department of Medicine, School of Clinical Sciences at Monash Health, Monash University Level 1, 43-51 Kanooka Grove Clayton VIC 3168, Melbourne, Australia.
Tel: +613 95947572; Fax: +613 9902 4245
Email: asvini.subasinghe@gmail.com
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LMICs, obesity related salt-sensitivity may underscore the sodium-blood pressure relationship in LMICs as well. If so, obesity related salt-sensitivity might be expected to be more evident in urban regions, as the prevalence of obesity is greater than in rural regions.[19] There is evidence that salt intake is high in LMICs.[20,21,14] In urban populations, excessive salt intake is attributed to a nutritional shift from cereal and millet based diets to a diet comprising processed foods with added sugars, fats, and sodium.[22] In rural populations, salt is mostly derived from its addition during the preparation of meals, as it is the cheapest form of flavour.[23,24] The lack of processed foods in rural populations might lead one to expect that salt intake would be less in rural areas than in urban areas.

We undertook a systematic review and meta-analysis to determine whether (1) the prevalence of excessive salt intake, and (2) the relationship between salt intake and the risk of hypertension, differs between rural and urban populations of LMICs. We also aimed to determine whether BMI modified the association between salt and hypertension in these populations. We hypothesised that (1) salt intake in rural areas of LMICs is less than that in urban areas, (2) the contribution of salt intake to the risk of hypertension is greater in urban than in rural regions (3) The impact of BMI on salt intake and hypertension differs between these two settings.

METHODS

Search strategy and selection criteria

We searched three databases (PubMED, Web of Science (WOS), and Scopus) until July 2014. Search terms used were "poverty areas" or "vulnerable population*" or "rural population*" or "rural health" or "developing countries" or "rural" or "disadvantaged areas" or "disadvantaged population*" or "urban" or "urban population" and "low-income countries" or "middle-income countries" or "low income countries" or "low AND middle-income countries" and ("risk factor(s)" or "determinant(s)" or "predictor(s)" or "blood pressure determination(s)" or "nutritional status" or "nutrition" or "salt" or "sodium" or "sodium/urine*" or "DASH diet") and ("hypertension" or "high blood pressure" or "blood pressure") or "WHO steps"). Each search included publications written in English and other languages.

We included population-based studies (with either a case-control, cross-sectional or longitudinal design) in which the association between salt and hypertension was assessed in adults using multivariable analysis. We excluded studies in which only univariable associations between potential risk factors and hypertension were assessed, in which only genetic analysis was undertaken, or which were limited to investigation of only younger (<24 years) or older (≥65 years) participants.

Classifications of countries developed by the World Bank[25] were used to define the LMICs. Rural and urban populations were classified according to the reports by the authors of each published article. Where there were multiple reports from one study, the most recent publication was included.

The following information was extracted from each study included in the analysis: study type; region and country; year/s of data collection (cross-sectional studies); sample size; age-range and mean age of participants; definition of hypertension used; mean and standard deviation (SD) of arterial blood pressure (BP); prevalence of hypertension; categories of salt intake and sodium intake; point estimates (odds ratios (ORs)) and 95% confidence intervals (CIs), and variables for which statistical adjustments were performed. When estimates from multiple models were reported, we used the model that provided adjustment for the greatest number of variables.

Definitions

Only studies in which both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were used to define hypertension were considered for inclusion in the meta-analysis. Hypertension was defined as a SBP ≥140 mmHg and/or DBP ≥90 mmHg and/or prescription of antihypertensive medication, as well as a SBP ≥130 mmHg and/or DBP ≥85 mmHg. 'Not lean' populations were defined by a mean population BMI of ≥23 kg/m^2 and 'lean' populations by a mean population BMI of <23 kg/m^2.

Statistical analysis

Hypertension was the outcome variable used in this study. Studies were pooled according to whether salt (NaCl) and/or sodium intake had been assessed as a categorical variable or continuous variable. The pooled effect sizes (ESs) for studies were calculated based on the weighting of the number of participants in each study. We pooled studies according to whether salt intake was assessed as a continuous or a categorical variable. We report the ESs and 95% CIs for the impact of salt on the prevalence of hypertension. A ratio of the two odds ratios was used to detect statistical differences between urban and rural regions. A p value ≤0.05 was deemed statistically significant.

When we pooled categorical analyses for the meta-analyses, categories of salt were compared to the given reference category in each study. We further stratified the meta-analysis by sex when such data were available. A random effects model was used rather than a fixed model because of the expected heterogeneity across studies. In the random effects model we attempted to integrate the heterogeneity among studies into a pooled estimate using the method of DerSimonian and Laird.[26] Publication bias was not assessed by conducting funnel plot asymmetry tests because these tests would lack sufficient power to identify bias in meta-analyses with fewer than 10 studies identified.[27] Sensitivity analyses were conducted by removing each study from the meta-analysis and comparing the point estimates before and after each study was excluded. Analyses were performed using STATA Version 11.2 (Stata Corporation, College Station, Texas).

RESULTS

Search results and study characteristics

Guidelines from MOOSE[28] and PRISMA[29] were followed for this review and meta-analyses. Of the 1567 publications that were identified, 1066 remained after duplicates were removed (Figure 1). After excluding articles by reviewing titles and abstracts, 161 full text articles were assessed for eligibility. After assessing the data presented in articles that met the eligibility criteria, one study was

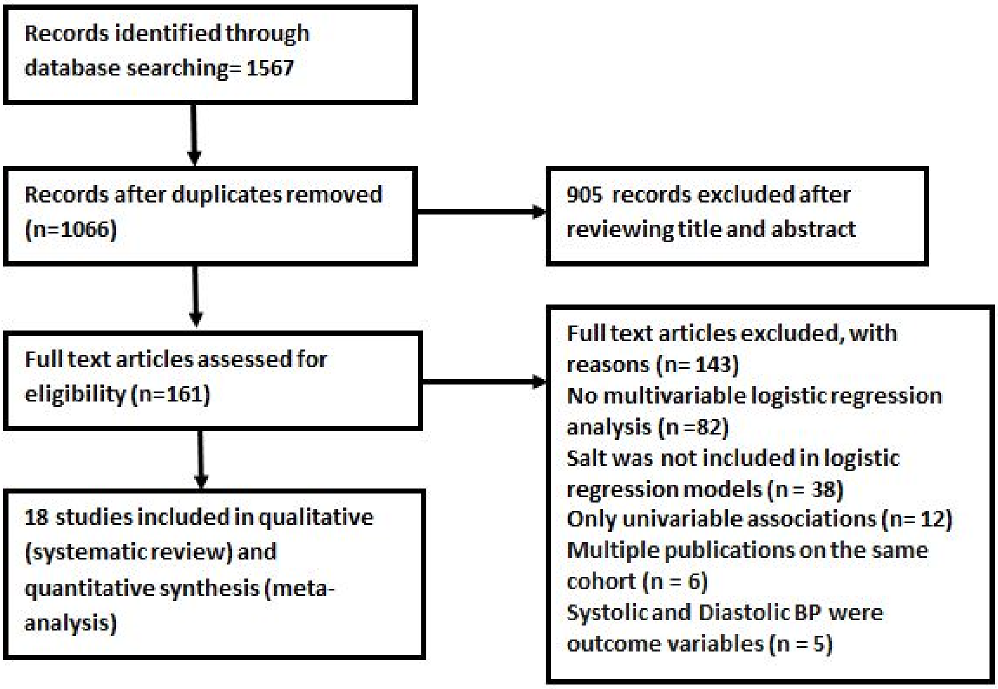

Figure 1. Flowchart of search strategy and selection process

further excluded because the authors failed to provide information about whether or not they had log transformed the variable of salt, nor did they explain which variables were adjusted for in the multivariable logistic model.[30] Subsequently, 18 studies,[31-48] in which the association of salt intake with hypertension had been assessed in LMICs, were included in this review. Eleven of these studies were conducted in rural populations, six were conducted in urban populations, and one was conducted in both rural and urban populations. Overall, these 18 studies, with sample sizes ranging from 255 to 36,154, provided data for a total of 134,916 participants (Table 1).

Individual consumption of salt was estimated by various methods between the studies (Table 2), including reports of the total amount of salt consumed by a family for one year;[32-35,47] by a direct question about salt added to food;[36,37,45,46,48] or by a dietary method (seven day food records,[38,40,43,44] food frequency questionnaire (FFQ),[42] household questionnaire,[21] or 24 hour recall).[39,41] In addition, different characteristics were adjusted for in the multivariable logistic regression models (Table 2).

Hypertension

The mean prevalence of hypertension was reported for the total population in the majority of studies.[33-37,39-46,48] From these estimates, the prevalence of hypertension ranged from 7.2% to 42% (Table 1). The greatest prevalence of hypertension reported in urban populations was 36.7% and in rural populations it was 42%.

Salt intake

Estimates of mean daily salt intake were reported for nine populations, and ranged from 6.9 g/day to 42.3 g/day. The average salt and sodium intake reported in all of these populations were greater than the daily allowance recommended (RDA) by the WHO (<5 g/day).[49] The prevalence of high salt intake ranged from 21.3% to 89.5% in both rural and urban populations (Figure 2). The greatest prevalence of high salt intake reported was in urban India (87.8%)[43] and in rural Nepal (89.5%).[45]

Salt intake and hypertension

Studies in which salt was assessed as a categorical variable

We were unable to detect a significant difference in the relationship between high salt intake and hypertension in studies conducted in rural populations (n=8) (pooled ES 1.36 95% CI 1.24, 1.48) and urban populations (n=3) (pooled ES 1.28 95% CI 1.13, 1.45, p for difference= 0.34, Figure 3).

Studies in which salt was assessed as a continuous variable

When salt was analysed continuously there was a greater association between salt intake and hypertension in urban (pooled ES 1.42 95% CI 1.19, 1.69) per one gram increase in salt (Figure 4) than in rural populations (pooled ES 1.07 95% CI 1.04, 1.10, p for difference <0.001).

BMI, salt intake and hypertension

The mean BMI for rural populations ranged from 19.5 kg/m^2 to 24 kg/m^2 and between 22.4 kg/m^2 and 32.5 kg/m^2 for urban populations. We found a greater impact of salt on hypertension in lean rural populations than non-lean rural populations when salt was analysed as a continuous variable (p for difference <0.001, Figure 5). We were unable to assess the impact of salt on hypertension according to BMI in studies conducted in urban populations as few investigators reported measures of BMI.

Sensitivity analyses

In sensitivity analyses, when we removed each study individually, no single study significantly changed the pooled effect sizes for high salt intake and hypertension

Table 1. Summary of studies where multivariable analysis was used to assess the relationship between salt and hypertension in rural and urban populations of low to middle income countries

Location	Survey year	Sample size (n)	Age range (year)	Mean age (SD)	Mean BMI	Prevalence of hypertension (%)			Mean blood pressure mmHg (SD)	
						Total	Men	Women	SBP	DBP
Rural populations of LMICs										
Nandan County, China[39]	NR									
Bai Ku Yao		485	40-85	54 (11)	22.2	21.9	25.3	17.7	123 (18)	77 (10)
Han Chinese		501	40-89	55 (11)	22.7	28.9	33.7	23.8	127 (18)	79 (11)
Fuxin, Liaoning, China[33]	2004-06		≥35	51.2 (11.8)						
Mongolian		9236			23.1	42	41.7	42.2	136 (23.2)	83.7 (12.8)
Han		36,154			23.6	36.7	35.8	37.7	134 (22.6)	82.5 (12.7)
Hubei, China [37]	NR	3054	>35	51.4 (12.2)	22.1	26.9	–	–	127 (20.2)	77.2 (11.4)
Chirai Goan, Varanasi, India[34]	NR	316	≥30	–	4.7†	7.2	5.6	8.8		
Assam, India[36]	NR	3180	≥30	–	10.2†	33.3	33.2	33.4		
Rishi Valley, South India[31]	2006	1479	≥18	39.7 (15.6)	19.5	11.4	16.2	7.3	115 (114, 116)	70.9 (70.3, 71.5)
Moradabad, India[38]	NR	255	60-84		21.5	13	16	10		
Fuxin County, Liaoning, China[35]	2004-06									
Mongolian		8320	≥35	50.4 (11.6)	23.5	11.6	–	–		
Han		33,036	≥35	50.6 (11.7)	23.0	14.7	–	–		
Liaoning Province, China[32]	2004-06	23,178F	≥35	–	24	–	–	38.6		
Bhadrabas, Nepal[45]	2006	1218	≥21		–	33.8	38.3	30.8		
Moradabad, India [44]	NR	1769	25-64		11†	17.7	17.4	17.9		
Nanning, China [48]	NR	2036	–	≥18	–	11.6	12.5	11	–	–
Urban populations of LMICs										
Trivandrum, India[40]	NR	1497	25-64	–	24.2		34.6	30.7		
Hyderabad, India[41]	NR	165	30-50		–					
Moradabad, Trivandrum, Calcutta, Nagpur, Bombay, India[43]		3212F	25-64		23.2	25.6			125 (17)	82 (11)
Moradabad, India[38]	NR	311	60-84		22.4	–	58	48		
Chennai, India [42‡]	NR	1902	≥20		25					
West Bengal, India[46]	NR	1609	>18		–	32.5				
Lomé, Togo[47]	2011	2002				36.7	34.6	38.4		

LMICs: low-and-middle income countries; F: female; NR: not reported; SBP: systolic blood pressure; DBP: diastolic blood pressure.
†Overweight BMI ≥23 kg/m^2; BMI >25 kg/m^2.
‡>130/85 mmHg SBP/DBP.

Table 2. Studies of the association between salt intake and hypertension in rural and urban areas of LMICs: multivariable analyses

Location	Salt intake	OR (95% CI) Total	Adjustments	Prevalence of high salt intake	Individual daily salt intake calculated from
SBP ≥140 mmHg and/or DBP ≥90 mmHg or using antihypertensive medication					
China[33]					
Mongolian Han	Cont. g/d per increase in one gram	1.01 (1.00, 1.01) 1.01 (1.00, 1.01)	Age, sex, BMI, WC, education, smoking status, alcohol consumption, lipid disorder, diabetes, and FHX HT		Total amount of salt consumed by a family for 1 year was used to calculate individual consumption
China[32]	<14 g/d ≥14 g/d	1.0 1.2 (1.1-1.3)	Age, ethnicity, education, income, smoking status, drinking status, BMI, WC, lipid disorder, diabetes, and FHX HT		Total amount of salt consumed by a family for 1 year was used to calculate individual consumption
China[37]	≤6 g/d >6 g/d	1.0 1.15 (1.05, 1.25)	BMI, educational level, predominantly sedentary work, physical exercise, alcohol consumption, positive FHX HT, vegetable and fruit intake, animal insides intake, and dysarteriotony (pressure difference >60 mmHg or 20 mmHg between SBP and DBP), where appropriate		Dietary questionnaire. High salt intake defined as >6 g/d
India[31]	≤ median intake > median intake	1.0 2.39 (1.36, 4.21) M 0.85 (0.44, 1.64) F	Model 2: M: age, BMI, alcohol consumption, physical activity, education, and cholesterol F: age, BMI, smokeless tobacco, education, and triglyceride		Salt added to household cooking divided by the number of individuals in each family
SBP ≥140 mmHg and/or DBP ≥90 mmHg					
Moradabad, India[38]	<8 g/d ≥8 g/d	1.18 (1.12, 1.27) M 1.17 (1.12, 1.26) F	Age, BMI, WHR, SES, energy expenditure, 2 hour plasma insulin, and 2 hour blood glucose	54.1%	Seven day food intake records were obtained for all individuals in the household.
Assam, India[36†]	No extra salt intake Extra salt intake ≥ ¼ teaspoon	1.0 1.45 (1.21, 1.73) 1.36 (1.05, 1.77) M 1.51 (1.19, 1.92) F	Age, sex, BMI, WHR, type of work, smoking status, tobacco chewing, alcohol consumption, and marital status	50.1%	Direct question- daily intake ≥¼ teaspoon of salt or ≥½ teaspoon salt/d
China[35‡]					
Mongolian	<13.5 g/d ≥13.5 g/d	1.0 1.42 (1.26, 1.60)	Age, sex, BMI, smoking status, alcohol consumption, and FHX HT		Total amount of salt consumed by a family for one year to calculate individual consumption
Han	<14.6 g/d ≥14.6 g/d	1.0 1.31 (1.22, 1.40)	Age, sex, BMI, smoking status, alcohol consumption, and FHX HT		Total amount of salt consumed by a family for one year to calculate individual consumption
China[39§]					
Bai Ku Yao Han	Cont. g/d per increase in one gram	1.55 (1.30, 2.94) 1.57 (1.22, 2.56)	Age, BMI, WC, education level, physical activity, triglycerides, total energy, total fat, total dietary fibre		24 hour recall questionnaire

LMIC's: low to middle income countries; Cont: continuous; d: day; Ref: reference; M: males; F: females; BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; FFQ: food frequency questionnaire; WHR: waist/hip ratio; WC: waist circumference; SES: socioeconomic status; FHX HT: family history of hypertension.
†Participants who used antihypertensive medication were excluded from this analysis.
‡Participants did not take antihypertensive medications the last two weeks before they were examined.
§Sodium intake.
¶Odds ratio for the third tertile.

Table 2. Studies of the association between salt intake and hypertension in rural and urban areas of LMICs: multivariable analyses (cont.)

Location	Salt intake	OR (95% CI) Total	Adjustments	Prevalence of high salt intake	Individual daily salt intake calculated from
Bhadrabas, Nepal[45]	<5 g/d ≥5 g/d	1.0 1.54 (1.0-2.35)	Age, sex, physical activity, tobacco, high waist circumference, BMI	89.5%	Visual aids (sachets of salt) were showed to participants to estimate amount of daily salt consumption
Varanasi, India[34]	≤75 g/d >75 g/d	1.0 2.68 (0.09-6.32)	BMI, fat intake, and energy intake	32.6%	Direct questions: how much salt was added during cooking, how much salt was bought and consumed by the household each month
Nanning, China[48]	Not a high salt diet High salt diet	1.0 1.48 (1.04-2.10)		21.3%	Direct questions: Do you consume a high salt diet?
Moradabad, India[44]	Cont. g/d per increase in one gram	1.0 1.31 (1.06-1.68) M 1.28 (1.20-1.46) F	Age	68%	Seven day food records
Urban					
Moradabad, India[38]	≤8 g/d >8 g/d	1.0 1.45 (1.15-1.65) M 1.47 (1.35-1.58) F	Age, BMI, energy expenditure, plasma insulin, blood glucose, SES	48.8%	Seven day food records
Trivandrum, India[40]	≤8 g/d >8 g/d	1.0 1.35 (1.02-1.65) M 1.38 (1.04-1.57) F	Age	38.2%	Seven day food records
Hyderabad, India[41]	Cont. g/d per increase in one gram	4.36¶ (1.11-17.12) M 3.43¶ (1.23-9.48) F	Energy, protein, fat, visible fat, energy fat and sodium: potassium ratio		24 hour recall method
Moradabad, Trivandrum, Calcutta, Nagpur, Bombay, India[43]	Cont. g/d per increase in one gram	1.45 (1.12-1.85)	Age, BMI, overweight, sedentary lifestyle	87.8%	Seven day food records
West Bengal, India[46]	No extra salt added to meal Extra salt added to meal	1.0 1.15 (0.87-1.50)	Age, occupation, BMI, smoking, diet, ischaemic heart disease	26.4%	Direct questions: how much salt was added during cooking and extra salt added to the meal
Lomé, Togo[47]	Moderate consumption of salt High consumption of salt	1.0 1.12 (1.07-1.98)	Age, sex		10 minute questionnaire
SBP ≥130 mmHg and/or DBP ≥85 mmHg					
Chennai, India[42]	Cont. g/d per increase in one gram	1.16 (1.12-1.21)	Age, gender, BMI, total energy and dietary fat intake		FFQ

LMIC's: low to middle income countries; Cont: continuous; d: day; Ref: reference; M: males; F: females; BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; FFQ: food frequency questionnaire; WHR: waist/hip ratio; WC: waist circumference; SES: socioeconomic status; FHX HT: family history of hypertension.
†Participants who used antihypertensive medication were excluded from this analysis.
‡Participants did not take antihypertensive medications the last two weeks before they were examined.
§Sodium intake.
¶Odds ratio for the third tertile.

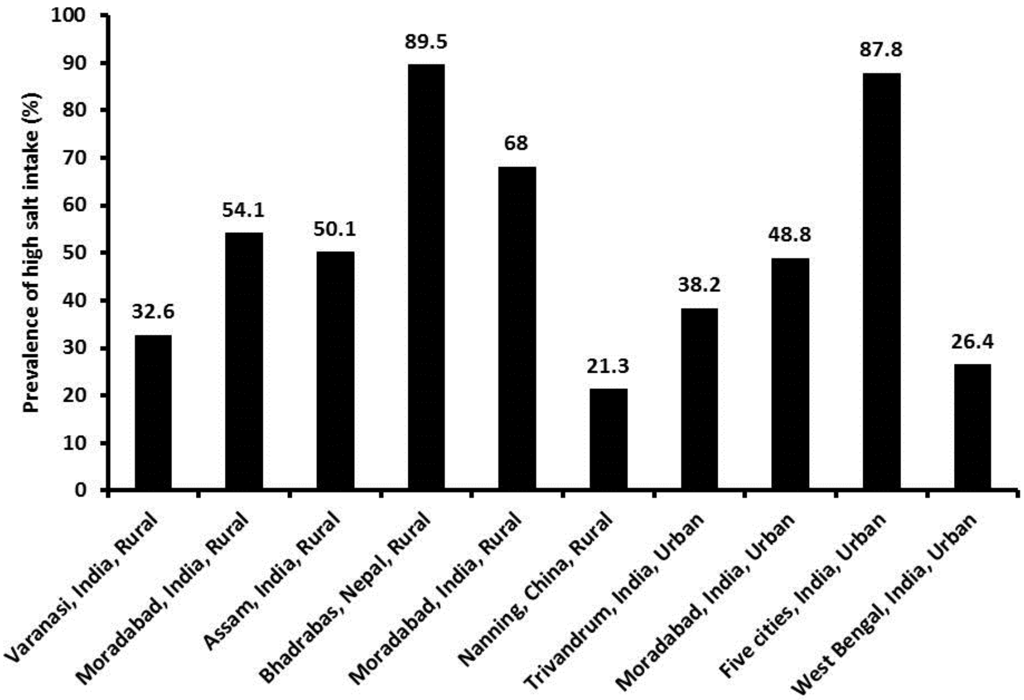

Figure 2. Prevalence of high salt intake in studies of hypertension in rural and urban populations (n=9)[34,36,38,40,43-46,48]

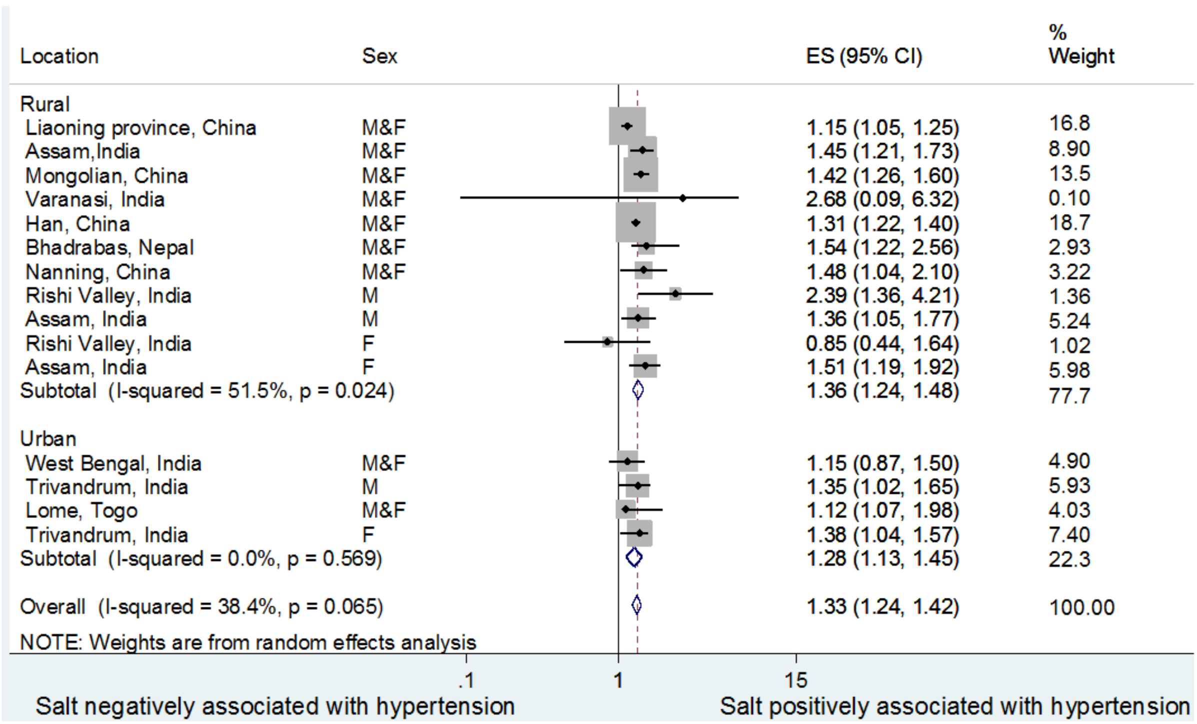

Figure 3. Meta-analysis of the association between salt intake (categorised high/low) and hypertension in studies conducted in rural populations (n= 8)[31,34-37,45,48] and urban populations (n=3).[40,46,47] ES: effect size; CI: confidence interval; I-squared: test for heterogeneity; M: male; F: female.

(data not shown).

DISCUSSION

From our meta-analysis of studies including 134,916 participants, we found that high salt intake was prevalent in both rural and urban populations of LMICs. The prevalence of high salt intake (26.4-89.5%) and hypertension (7.2-42%) reported in urban and rural populations of LMICs ranged widely. Our findings indicate that the prevalence of high salt intake in our study may even be as high as that has been reported in the UK and the US (77-95.4%).[50-51] Furthermore, we have shown that excess salt intake is associated with hypertension irrespective of whether populations are urban or rural.

We found that the prevalence of excessive salt intake was high in both rural and urban populations of LMICs. It has been argued that evidence for high salt intake in urban populations of LMICs further reflects their nutritional

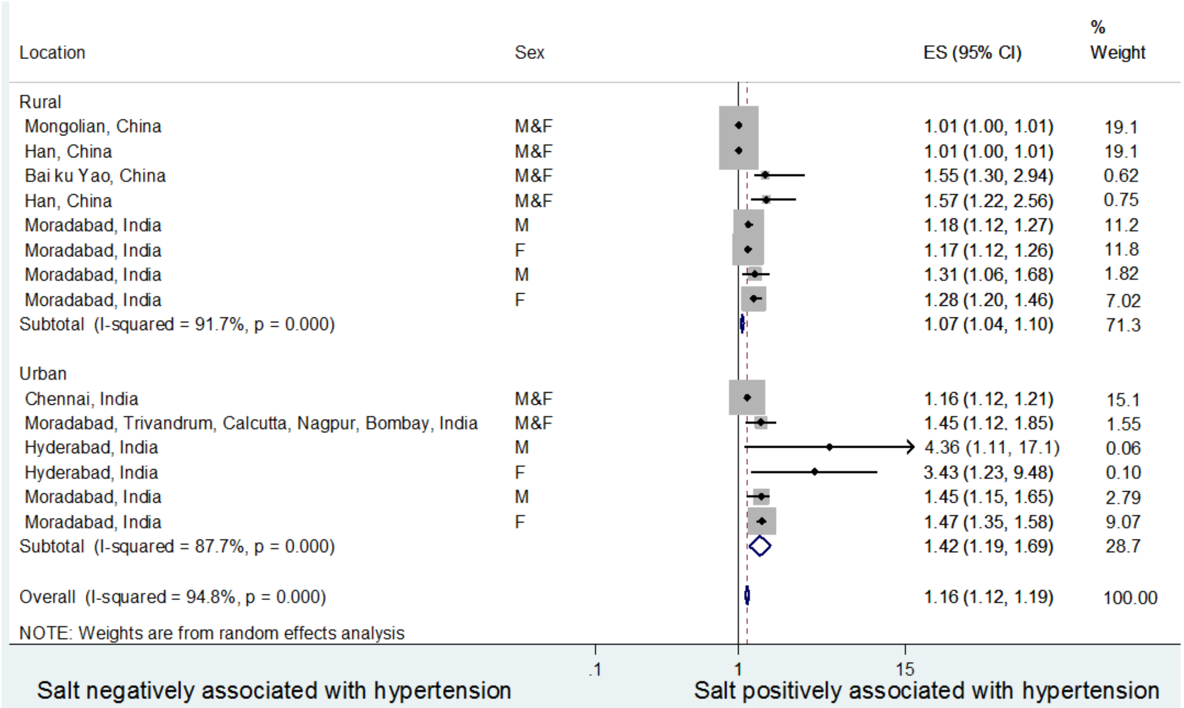

Figure 4. Meta-analysis of the association between salt intake as a continuous variable and hypertension from rural (n=4)[33,38,39,44] and urban populations (n=4).[38,41-43] ES: effect size; CI: confidence interval; I-squared: test for heterogeneity; M: male; F: female.

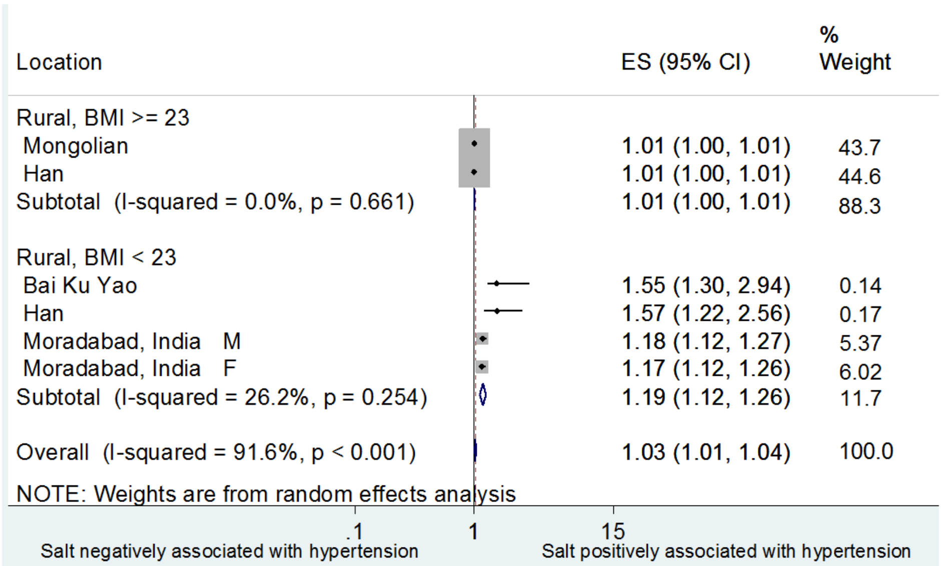

Figure 5. Populations in which the association between salt intake and hypertension was assessed in 'not lean' rural populations[33] compared with 'lean' rural populations (n=3).[38-39] ES: effect size; CI: confidence interval; I-squared: test for heterogeneity.

transition to 'Western-style' diets.[52] This nutritional transition is characterised by the increase in availability of food and adoption of westernised dietary habits such as a greater consumption of processed foods, fats, sodium, and sugars.[22] It might, therefore, seem surprising that salt intake is so high in rural populations of LMICs given the relative lack of processed foods documented in these areas in previous population based studies.[53-55] Possible explanations for this phenomenon include the fact that people who labour physically in hot climates require more salt than those who are not exposed to such conditions.[56] Salt is often still used as an important food preservative in communities with little or no access to refrigeration or other methods for safe storage and transport of food.[57] Additionally, limited available data indicate that most salt in rural India is added during cooking, and/or at the table, compared to urban populations and high income countries where processed foods largely contribute to overall population salt intake.[58] The high salt intake evident in rural populations of LMICs indicates that here, as in high income countries, the implementation of public health programs is germane.[11] However, importantly, the messages delivered by such programs should be tailored to the underlying causes of excessive salt intake in each population.

Because the intake of salt in urban and rural areas may be derived from different sources, interventions to reduce salt intake at a population level should be developed to target these populations separately. In urban areas, government initiatives aimed at developing greater individual awareness of salt intake, or public nutritional education campaigns may be successful in triggering a reduction in consumption of processed foods. Government run media campaigns, along with the provision of clear labelling of sodium content on the packaging of processed foods, are some of the approaches that have been successfully implemented in over ten countries in Europe and Asia.[59] In rural areas, initiatives to reduce salt intake should be implemented at a community level in order to galvanise a change in dietary behaviour. For example, local health-care practitioners could work together with communities to encourage restricting the amount of salt added to meals. If nutritional interventions are developed at a population level in urban areas, and at a grassroots level in rural areas, there would be a greater likelihood of reduced salt intake in LMICs.

We found a greater impact of salt on hypertension in urban than rural populations when salt was analysed continuously. However, no differences were detected between the two populations when salt was analysed in a dichotomous fashion. A potential explanation for these disparate findings lies in the heterogeneity of definitions used to categorise high salt intake in categorical analyses. These definitions of high salt intake varied in the cut-point used to separate categories and in the units used. For example >6 grams per day was used to define high salt intake in one study, and >75 grams per day in another study. This means that for categorical analyses, the association between salt and hypertension was quantified in a different way in each study and so combined estimates would be expected to be heterogeneous. This heterogeneity may have further reduced the likelihood of finding a difference between urban and rural regions. In contrast, when salt was analysed continuously, our meta-analysis provides a more robust interpretation of pooled effect sizes because the same quantity of one gram of salt was used.

A noteworthy observation is that when salt was analysed continuously, in studies conducted in rural regions, we found that the association between salt and hypertension was greater in lean than in non-lean populations. This finding contradicts our hypothesis that the effect of BMI on the relationship between salt and hypertension would be more pronounced in non-lean than in lean populations. Given that lean populations have been accepted as a proxy for maternal malnutrition,[60] the prevalence of maternal malnutrition may be greater in the lean populations than in not-lean populations included in this meta-analysis. Maternal malnutrition appears to impede development of the fetal kidney, leading to deficient nephron endowment.[21,61] This deficient nephron endowment can pre-dispose individuals to the development of hypertension in adulthood, at least in part, by rendering their arterial pressure salt-sensitive.[21] This mechanism may provide an explanation for our findings for a greater effect of salt on hypertension in lean than in non-lean populations. However, this proposition is only speculative, as this hypothesis could only be tested in a prospective fashion.

A major limitation to our study was that data on salt intake were obtained from different methods of assessments in each of the studies included. Moreover, the majority of studies included the assessment of salt using self-report only. Because the validity of salt intake assessed using this method is highly questionable,[62] the estimates of salt intake reported in these studies may not be accurate. In addition, different definitions of hypertension were used in each study, and this may have introduced further heterogeneity in our analyses when salt was analysed categorically. Finally, there were only 18 population-based studies that met the eligibility criteria, revealing a considerable gap in the literature related to associations between salt and hypertension in LMICs.

Strengths to this review were that we only included studies in which multivariable models were used to assess independent associations between salt and hypertension and that the outcome of hypertension was directly measured in each study. Furthermore, to our knowledge no other systematic review and or meta-analyses have been conducted to investigate the relationship between salt and hypertension in rural and urban populations of LMICs, and so this summary addresses an important knowledge-gap.

Conclusion

In our meta-analysis of pooled results from 18 population based studies we found that high salt intake is very prevalent in rural and urban populations of LMICs. Furthermore, the impact of salt intake on hypertension appeared to be greater in urban than in rural regions of LMICs. Additionally, we found that salt had a greater impact on hypertension in lean compared with non-lean populations in rural regions. Public health initiatives are required to reduce salt intake in both rural and urban populations to potentially reduce the burden of hypertension in these regions.

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AUTHOR DISCLOSURES

All authors declared no conflict of interest.

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Original Article

Association between salt and hypertension in rural and urban populations of low to middle income countries: a systematic review and meta-analysis of population based studies

Asvini K Subasinghe PhD[1], Simin Arabshahi PhD[1], Doreen Busingye PhD[1], Roger G Evans PhD[2], Karen Z Walker PhD[3], Michaela A Riddell PhD[1], Amanda G Thrift PhD[1,4]

[1]*Department of Medicine, School of Clinical Sciences at Monash Health, Monash University, Melbourne, Australia*
[2]*Department of Physiology, Monash University, Melbourne, Australia*
[3]*Department of Nutrition and Dietetics, Monash University, Melbourne, Australia*
[4]*Florey Neuroscience Institutes, Heidelberg, Victoria, Australia*

低中收入国家城乡居民盐摄入量与高血压的关系：以人群为基础的系统性研究和 meta 分析

背景与目的：在全球高血压患病率对死亡率贡献最大，在低中等收入国家高血压的患病率呈增加的趋势。在低中收入国家的城市，过量的盐摄入与高血压患病风险的增加有关，我们旨在研究农村地区是否亦如此。**方法与研究设计：**使用多变量模型，我们进行了低中收入国家盐与高血压关系的 meta 分析。**结果：**共分析了来自 18 个研究的 134,916 名参与者。农村和城市居民高盐摄入的比例在 21.3%到 89.5%之间。当盐摄入量作为连续型变量分析时，发现城市地区（n=4）[合并效应尺度（ES）为 1.42，95% CI 为 1.19−1.69]比农村地区（n=4）[合并效应尺度（ES）为 1.07，95% CI 为 1.04−1.10，p<0.001]。当盐摄入量作为连续型变量分析时，体型偏瘦的农村人群（BMI <23 kg/m^2）比体型不偏瘦的农村人群（BMI ≥23 kg/m^2，p<0.001）盐摄入对高血压患病的影响更大。**结论：**农村和城市地区高盐摄入的比例相近。与农村居民相比，城市居民过多的盐摄入对高血压患病率的影响更大。在农村居民中，BMI 能调节盐摄入和高血压的关系。

关键词：高血压、盐、城市、农村、meta 分析