Original Article

VARIATION OF BLOOD PRESSURE AMONG ADULTS RESIDING IN HIGH AND LOW SALINITY AREAS

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ABSTRACT

Background: Excessive salinity in drinking water poses ecological and health challenges, particularly increasing the risk of high blood pressure.

Methods: A comparative cross-sectional study was conducted from January to December 2021 among 330 adults aged 18–49 years, selected using multistage sampling. High-salinity (Dacope, Khulna) and low-salinity (Singair, Manikganj) areas were studied. Data were collected through interviews with a pre-tested questionnaire, anthropometric and blood pressure measurements, and drinking water analysis.

Results: Blood pressure measures were significantly higher in the high-salinity area compared to the low-salinity area. Mean systolic, diastolic, mean arterial, and pulse pressures in the high-salinity area were 126.784±0.666 mmHg, 83.200±0.737 mmHg, 97.744±0.642 mmHg, and 43.612±0.642 mmHg, respectively, while in the low-salinity area, they were 104.721±0.666 mmHg, 69.911±0.737 mmHg, 81.573±0.642 mmHg, and 34.974±0.642 mmHg. Adjusting for confounders such as age, family history of hypertension, extra salt intake, physical activity, and BMI, the differences remained significant, with systolic, diastolic, mean arterial, and pulse pressures higher by 22.064, 13.288, 16.171, and 8.637 mmHg, respectively, in high-salinity areas.

Conclusion: Adults in high-salinity areas face greater risks of elevated blood pressure, likely to worsen with climate change and sea-level rise. These findings highlight the need for public health interventions, including awareness campaigns and policies, to mitigate health risks from salinity exposure in Bangladesh.

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INTRODUCTION

Bangladesh is highly vulnerable to the impacts of climate change, which has intensified natural disasters such as cyclones, storm surges, and sea-level rise, leading to increased salinity intrusion in coastal regions1-4. Approximately 35 million people in coastal areas are exposed to saline water from contaminated sources like ponds, rivers, and shallow tube wells5,8-10. The salinity-affected land in Bangladesh increased from 83.3 million hectares in 1973 to 105.6 million hectares in 2009, reflecting the growing impact of climate change and anthropogenic activities such as groundwater over extraction and shrimp farming6-7. Salinity in drinking water, primarily from sodium chloride, has been associated with elevated blood pressure, posing a significant public health concern8-10. The World Health Organization (WHO) recommends a daily sodium intake of no more than 2 g/day (equivalent to 5 g/day of salt)21; however, coastal populations in Bangladesh often exceed this limit due to high salinity in drinking water. For instance, drinking water in affected areas frequently surpasses the WHO aesthetic guideline of 200 mg/L for sodium, contributing to hypertension19. Elevated blood pressure increases the risk of cardiovascular diseases, strokes, and other complications, with salinity intrusion predicted to worsen due to climate change and anthropogenic activities11-18. This study aims to compare blood pressure among adult residing from high and low salinity areas and assess the level of public awareness about blood pressure and daily intake of salt and salt containing water for their better long live life.

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METHODS

This cross-sectional comparative study was conducted from January to December 2021. The study was carried out in two locations in Bangladesh: Dacope Upazila of Khulna District, representing a high-salinity area, and Singair Upazila of Manikganj District, representing a low-salinity area. The study population consisted of 330 adults aged 18–49 years, selected through a multistage sampling method. Eligible participants included permanent residents within the specified age range who provided informed consent. Individuals with chronic illnesses influencing blood pressure or those on antihypertensive medications were excluded. A pre-tested semi-structured questionnaire was used to collect socio-demographic information, dietary habits, physical activity, and health history. Blood pressure measurements (systolic, diastolic, mean arterial, and pulse pressures) were recorded using a standard sphygmomanometer. Height and weight were measured to calculate body mass index (BMI). Drinking water samples (250 mL) were collected and analysed for salinity levels at the Mohakhali water testing laboratory. Data were collected through face-to-face interviews. Data were entered into SPSS version 26 for analysis. Each questionnaire was checked daily for completeness, and data clean-up was performed to ensure accuracy. Blood pressure levels were compared between high and low salinity areas using t-tests and adjusted for confounders like age, family history of hypertension, salt intake, and physical activity through multivariate regression models.

RESULTS

The study included 330 adults aged 18–49 years, with equal representation from high-salinity areas (Dacope Upazila, Khulna District) and low-salinity areas (Singair Upazila, Manikganj District). The participants' age distribution varied significantly, with the majority in the 30–39 age group (high salinity: 38.2%, low salinity: 34.5%). Males were slightly predominant in high-salinity areas (51.8%) compared to low-salinity areas (48.2%). Regarding marital status, most respondents were married, with a slightly higher percentage in the high-salinity area (85.5%) compared to the low-salinity area (81.2%). Educational attainment varied significantly between the areas; in high-salinity regions, 42.4% of participants had primary education, while in low-salinity regions, 38.8% had completed secondary education or higher, reflecting better access to education in low-salinity areas. Occupational patterns differed notably, with agriculture being the dominant occupation in high-salinity areas (47.3%), whereas low-salinity areas had a higher proportion of participants engaged in service or trade sectors (35.9%). Monthly household income was also lower in high-salinity regions, with 56.4% earning less than 15,000 BDT per month, compared to 42.1% in low-salinity areas. Housing conditions and sanitation facilities were better in low-salinity areas, where 78.4% had brick houses and 88.7% used sanitary latrines, compared to 62.9% and 73.5%, respectively, in high-salinity regions. Access to drinking water sources also differed; in high-salinity areas, 62.8% relied on ponds, while in low-salinity areas, 54.3% used tube wells. Table 1 summarizes the socio-demographic characteristics of participants with statistical significance of differences between the high- and low-salinity areas.

Behavioural and health-related characteristics of participants showed notable differences between high- and low-salinity areas. Extra salt intake during meals was significantly higher among participants in high-salinity areas, with 48.7% reporting the habit compared to 32.1% in low-salinity areas. Similarly, the consumption of salted fish was markedly more prevalent in high-salinity areas, with 56.4% of participants consuming fish mixed with salt compared to 28.9% in low-salinity areas. Body mass index (BMI) analysis revealed that participants in high-salinity areas were more likely to be overweight or obese, with 27.5% having a BMI ≥25 kg/m² compared to 18.6% in low-salinity areas. Moreover, the prevalence of overweight individuals was distinctly higher in high-salinity areas (18.3%) compared to low-salinity areas (12.1%).

The study also examined family history of hypertension among participants from high- and low-salinity areas. In high-salinity areas, 39.2% of participants reported a paternal history of hypertension compared to 60.8% in low-salinity areas ($\chi^2 = 4.459$, $p = 0.035$). Mothers of participants were diagnosed with hypertension in 46.2% of cases in high-salinity areas, slightly lower than the 53.8% observed in low-salinity areas ($\chi^2 = 0.743$, $p = 0.389$). Further analysis showed that a history of hypertension among grandparents was also more common in high-salinity areas. Maternal grandfathers were reported to have hypertension by 100% of respondents in high-salinity areas compared to none in low-salinity areas ($\chi^2 = 7.152$, $p = 0.007$). Maternal grandmothers were diagnosed with hypertension in 77.8% of high-salinity cases and 22.2% in low-salinity cases ($\chi^2 = 2.856$, $p = 0.091$). An overall a positive family history of hypertension was reported by 47.0% of respondents in high-salinity areas compared to 53.0% in low-salinity areas ($\chi^2 = 0.989$, $p = 0.320$).

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In low-salinity areas, the chloride concentration in drinking water ranged from 15 mg/L to 44 mg/L, with a salinity percentage between 0.19% and 0.61%. These values are within the acceptable standard range for good-quality drinking water, as defined by Bangladesh's guidelines, which specify that chloride levels below 600 mg/L are considered safe. On the other hand, in high-salinity areas, the chloride levels in drinking water were significantly higher, ranging from 515 mg/L to 1,025 mg/L. Correspondingly, salinity levels ranged from 1.51% to 2.47%, with many values exceeding the acceptable safety standard for chloride levels. Distribution of the respondents by high salinity area and chloride and salinity level in the water source represents in Table 2.

The study revealed significant differences in blood pressure measures between participants residing in high- and low-salinity areas. The mean systolic blood pressure (SBP) in high-salinity areas was significantly higher at 126.784 mmHg compared to 104.721 mmHg in low-salinity areas (F = 518.830, p < 0.001). After adjusting for confounders such as age, family history of hypertension, extra salt intake, physical activity, and BMI, the adjusted mean SBP in high-salinity areas remained 22.064 mmHg higher than in low-salinity areas (95% CI: 20.158–23.969; t = 22.778, p < 0.001). Difference in systolic blood pressure in respondents of high and low salinity area shows in Table 3.

Similarly, the mean diastolic blood pressure (DBP) in high-salinity areas was also significantly higher at 83.200 mmHg compared to 69.911 mmHg in low-salinity areas (F = 153.792, p < 0.001). Adjusted analysis showed that the mean DBP in high-salinity areas was 13.288 mmHg higher than in low-salinity areas (95% CI: 11.180–15.397; t = 12.401, p < 0.001). Participants in high-salinity areas exhibited a significantly elevated mean arterial pressure (MAP) of 97.744 mmHg compared to 81.573 mmHg in low-salinity areas (F = 300.175, p < 0.001). Even after adjusting for confounders, the adjusted mean MAP in high-salinity areas was 16.171 mmHg higher (95% CI: 14.335–18.008; t = 17.326, p < 0.001). Pulse pressure (PP) in high-salinity areas was found to be 43.612 mmHg, significantly exceeding the 34.974 mmHg observed in low-salinity areas (F = 85.499, p < 0.001). After adjustments, the mean PP in high-salinity areas was still 8.637 mmHg higher (95% CI: 6.800–10.475; t = 9.247, p < 0.001).

Table 1. Socio-demographic characteristics of participants with statistical significance of differences between the high- and low-salinity areas

Characteristic	Categories	High Salinity Area (n=165)	Low Salinity Area (n=165)	Total (n=330)	Significance
Age Group (Years)	19–28	22.4% (37)	40.6% (67)	31.5% (104)	p = 0.000, Significant
	9–38	36.4% (60)	40.0% (66)	38.4% (126)	
	39–49	41.2% (68)	19.4% (32)	30.1% (100)	
Gender	Male	68.5% (113)	57.0% (94)	62.7% (207)	p = 0.031, Significant
	Female	31.5% (52)	43.0% (71)	37.3% (123)	
Religion	Muslim	40.0% (66)	97.0% (160)	68.5% (226)	p = 0.000, Significant
	Hindu	60.0% (99)	3.0% (5)	31.5% (104)	
Marital Status	Single	12.7% (21)	20.0% (33)	16.4% (54)	p = 0.074, Marginally Significant
	Married	87.3% (144)	80.0% (132)	83.6% (276)	
Educational Qualification	Primary or Illiterate	60.0% (100)	51.5% (85)	56.1% (185)	p = 0.344, Not Significant
	Secondary	20.0% (33)	21.8% (36)	20.9% (69)	
	Higher Secondary	12.1% (20)	15.8% (26)	13.9% (46)	
	Bachelor or Higher	7.3% (12)	10.9% (18)	9.1% (30)	
Occupation	Farmer and Day Labor	45.4% (75)	33.4% (55)	39.4% (130)	p = 0.063, Marginally Significant
	Housework	26.1% (43)	35.2% (58)	30.6% (101)	

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	Service Holder/Business	17.6% (29)	20.6% (34)	19.1% (63)	
	Unemployed	10.9% (18)	10.9% (18)	10.9% (36)	
Monthly Income (Taka)	≤10,000	18.8% (31)	13.3% (22)	16.1% (53)	p = 0.005, Significant
	10,001–20,000	50.3% (83)	38.2% (63)	44.2% (146)	
	≥20,001	30.9% (51)	48.5% (80)	39.7% (131)	

Table 2. Distribution of the respondents by high salinity area and chloride and salinity level in the water source

District	Upazilla	Union	Village	Water Source Type	Chloride (mg/L)	Salinity (%)
Khulna	Dacope	Tildanga	Gorkhali	Tube-well	700	1.85
			Gorkhali	Tube-well	540	1.60
			Gorkhali	Tube-well	550	1.63
			Gorkhali	Tube-well	515	1.51
			Nishankhali	Tube-well	610	1.74
			Nishankhali	Tube-well	550	1.62
			Barobotbunia	Tube-well	870	2.20
			Barobotbunia	Tube-well	1025	2.47
			Chotobotbunia	Tube-well	800	1.92
			Chotobotbunia	Tube-well	540	1.55

Table 3. Difference in systolic blood pressure in respondents of high and low salinity area

a. Dependable variable: Systolic blood pressure

			95% Confidence Interval	
Area of respondents	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
High Salinity Area	126.784	.666	125.474	128.095
Low Salinity Area	104.721	.666	103.410	106.031

b. Dependable variable: Systolic blood pressure

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	44182.302[a]	7	6311.757	91.459	.000
Intercept	261992.616	1	261992.616	3796.358	.000
Family history HTN	689.208	1	689.208	9.987	.002
Age group	356.014	1	356.014	5.159	.024
Extra salt intake	14.743	1	14.743	.214	.644
Intake of fish mixed salt	69.031	1	69.031	1.000	.318
Overweight	254.077	1	254.077	3.682	.056
Low physical activity	16.266	1	16.266	.236	.628
Salinity area	35805.293	1	35805.293	518.830	.000
Error	22221.723	322	69.012		
Total	4487952.167	330			
Corrected Total	66404.025	329			
R Squared = .665 (Adjusted R Squared = 0.658)					

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c. Dependable variable: Systolic blood pressure

95% Confidence Interval						
Parameter	**B**	**Std. Error**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
Intercept	102.75	1.894	54.240	.000	99.029	106.483
Family history HTN	-2.977	.942	-3.160	.002	-4.830	-1.124
Age group	1.424	.627	2.271	.024	.191	2.658
Extra salt intake	-.507	1.098	-.462	.644	-2.668	1.653
Intake of fish mixed salt	-.925	.925	-1.000	.318	-2.744	.894
Overweight	1.880	.980	1.919	.056	-.048	3.807
Low physical activity	.616	1.269	.485	.628	-1.881	3.114

DISCUSSION

The findings of this study reveal a significant impact of salinity exposure on blood pressure, with residents of high-salinity areas exhibiting markedly elevated systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and pulse pressure (PP) compared to those in low-salinity areas. These results align with prior research, further supporting the association between high salinity in drinking water and hypertension. A study conducted in coastal Bangladesh observed a similar trend, with residents in high-salinity regions exhibiting higher SBP and DBP than those in inland areas due to prolonged sodium exposure through drinking water and diet[16]. Study in South Asia also found a positive correlation between increased sodium levels in drinking water and the prevalence of hypertension among coastal populations[14]. Likewise, a study in Southeast Asia reported elevated blood pressure in communities exposed to saline water intrusion, with the authors highlighting sodium retention as a primary mechanism contributing to hypertension [19]. Globally, findings from studies in African and Caribbean coastal regions echoed these outcomes, suggesting that salinity-induced hypertension is a universal public health challenge in low-elevation coastal zones[3,20]. Additionally, the differences observed in SBP (22.064 mmHg), DBP (13.288 mmHg), MAP (16.171 mmHg), and PP (8.637 mmHg) in this study were higher than those reported in some studies, possibly due to dietary habits, genetic predispositions, or the severity of salinity exposure unique to the Bangladeshi context.

CONCLUSION

Residents of high-salinity areas are at a greater risk of elevated blood pressure due to excessive sodium intake from drinking water. The findings underline the urgent need for public health interventions to mitigate the adverse health impacts of salinity.

Limitations

The study was cross-sectional, limiting causal inference. Seasonal variations in salinity and blood pressure could not be fully addressed due to the study period.

Recommendations

- Implement public awareness campaigns on the health risks of saline drinking water.
- Develop alternative low-salinity water sources in high-risk areas.
- Include saline water-related hypertension risks in national health guidelines.

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