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ESTIMATION OF TOTAL SALT CONSUMPTION FROM DIETARY SODIUM INTAKE AND ITS ASSOCIATION WITH BLOOD PRESSURE AMONG ADULTS OF MARDAN

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Abstract

Background: Excessive dietary salt intake is a major modifiable risk factor for hypertension and cardiovascular disease, particularly in developing countries where dietary habits are changing rapidly. This study estimated total dietary salt intake from sodium consumption among adults of District Mardan and examined its association with blood pressure. **Methods:** In this cross-sectional study, data were collected from 200 adults aged 20–65 years using a 24-

hour dietary recall and a food frequency questionnaire (FFQ). Anthropometric measurements and blood pressure were also recorded, and nutrient intake was analyzed using NutriSurvey software. Statistical analysis, including multivariate general linear modeling, was performed in SPSS version 20. **Results:** The mean dietary sodium intake was 2079 ± 685.94 mg/day, corresponding to an estimated salt intake of 4.91 ± 1.39 g/day; 55% of participants exceeded the WHO-recommended limit of 5 g/day. Nearly half of the respondents (46.0%) were classified as likely hypertensive. Salt intake was positively associated with systolic blood pressure ($\beta = 0.74$, $p < 0.05$), whereas potassium intake was inversely associated with both systolic and diastolic blood pressure. Likely-hypertensive individuals also showed higher body weight, BMI, waist circumference, and energy intake, alongside lower intake of fiber, potassium, calcium, magnesium, and vitamins D, B9, and B12. Age, gender, salt intake, and potassium intake emerged as significant independent predictors of blood pressure. **Conclusion:** Elevated blood pressure among adults of Mardan is driven largely by excessive salt intake and poor overall diet quality, underscoring the need for community-based salt-reduction and dietary-quality interventions.

Keywords: Dietary salt; Sodium intake; Blood pressure; Hypertension; Sodium–potassium ratio; Mardan

1. Introduction

Hypertension remains a leading cause of cardiovascular morbidity and mortality worldwide, contributing to an estimated 7.6 million deaths annually (Ravi et al., 2016). Although its precise etiology remains multifactorial, established modifiable risk factors include obesity, physical inactivity, high dietary fat intake, alcohol use, and, most notably, excessive salt consumption (Mansouri et al., 2019). Sodium is naturally present in many foods and is added extensively during cooking and food processing, with dietary patterns and cultural food preferences strongly shaping intake levels (Ravi et al., 2016).

A substantial body of evidence links high sodium intake with elevated blood pressure, increased cardiovascular risk, and higher mortality. The World Health Organization (WHO) recommends limiting daily sodium intake to below 2000 mg (equivalent to 5 g of salt), yet global mean intake remains roughly twice this level (Stern et al., 2021). Reduction in dietary salt has consistently been shown to lower blood pressure in both hypertensive and normotensive populations and to reduce the incidence of stroke and cardiovascular death (Erdem et al., 2010). Beyond sodium, dietary potassium exerts a protective, opposing effect on blood pressure by promoting sodium excretion and improving vascular function, making the sodium–potassium (Na/K)

ratio an important composite indicator of cardiovascular risk (Mohammadifard et al., 2017).

Because 24-hour urinary sodium analysis — the gold-standard method for assessing sodium intake — is costly and impractical for large community-based studies, diet-based approaches such as 24-hour dietary recall and food frequency questionnaires (FFQ) are widely used alternatives, and combining the two enables both quantitative estimation and identification of principal dietary sources of salt (McLean et al., 2014; Matsuno et al., 2022). Despite the well-documented burden of hypertension in Pakistan, locally generated data on dietary salt intake and its relationship with blood pressure remain limited, particularly for District Mardan.

This study, therefore, aimed to (i) estimate dietary salt consumption among adults of Mardan using the 24-hour dietary recall and FFQ, (ii) determine the sociodemographic correlates of salt intake, and (iii) examine the extent to which dietary salt intake, together with related demographic, anthropometric, and nutrient factors, explains variation in systolic and diastolic blood pressure in this population.

2. Materials and Methods

2.1 Study Design and Setting

A cross-sectional study was conducted in District Mardan, Khyber Pakhtunkhwa, Pakistan.

2.2 Sample Size and Sampling

Sample size was calculated using the single-population proportion formula (Cochran, 1977): $n = Z^2p(1-p)/d^2$, where $Z = 1.96$ (95% confidence level), $p = 0.30$ (estimated national hypertension prevalence of 25–35%), and $d = 0.065$ (margin of error). This yielded a minimum of 194 participants; accounting for possible non-response, the final sample comprised 200 adults. Written informed consent was obtained from all participants prior to enrolment.

2.3 Inclusion and Exclusion Criteria

Adults aged 20–65 years, of either gender, permanently residing in District Mardan, who provided informed consent, were not on a salt-restricted diet, and could reliably recall their dietary intake were included. Individuals below 20 or above 65 years, pregnant or lactating women, those with chronic renal, hepatic, or cardiac disease, those on antihypertensive medication for more than six months, and participants with incomplete data were excluded.

2.4 Anthropometric and Blood Pressure Measurement

Height, weight, and waist circumference were measured following WHO (1995) protocols, and body mass index (BMI) was calculated as weight (kg)/height^2 (m^2) and

classified per WHO cut-offs (underweight <18.5, normal 18.5–24.9, overweight 25.0–29.9, obese ⩾30.0 kg/m^2). Blood pressure was measured in duplicate using an automated sphygmomanometer with participants seated and relaxed, and the mean of the two readings was recorded. Participants were classified as normotensive (systolic <120 mmHg and diastolic <80 mmHg) or likely hypertensive (systolic ⩾120 mmHg and/or diastolic ⩾80 mmHg), consistent with WHO (2021) criteria.

2.5 Dietary Assessment and Estimation of Salt Intake

Dietary intake was assessed using a single 24-hour dietary recall, with portion sizes estimated using standard household measures and converted to gram weights using standard food-portion conversion tables. Data were analyzed using NutriSurvey software (based on standard food composition tables) to estimate daily energy, macronutrient, vitamin, and mineral intake, including sodium and potassium. Total daily sodium intake (mg/day) was converted to estimated salt intake using the standard conversion: Estimated salt intake (g/day) = Total sodium intake (mg/day) × 2.5 ÷ 1000, reflecting the molecular relationship between sodium and sodium chloride. Participants were classified as consuming normal (<5 g/day) or excessive (⩾5 g/day) salt per WHO (2012) guidelines.

A Food Frequency Questionnaire (FFQ) covering processed foods, canned foods, snacks, condiments, and fast foods was additionally used to classify habitual salt exposure as low, moderate, or high, based on weighted consumption frequency (rich-salt items weighted 3, moderate-salt home-cooked items weighted 2, and naturally low-sodium items weighted 1). The sodium–potassium ratio was calculated for each participant as daily sodium intake (mg/day) ÷ daily potassium intake (mg/day), with a ratio ⩾1 considered indicative of an unfavorable dietary balance associated with elevated cardiovascular risk.

2.6 Statistical Analysis

Data were analyzed using SPSS version 20. Continuous variables are presented as mean ± SD and categorical variables as frequencies and percentages. Independent-samples t-tests were used to compare continuous variables between normotensive and likely-hypertensive groups, and chi-square tests were used for categorical comparisons. A multivariate general linear model (GLM) was used to evaluate the independent associations of demographic, anthropometric, and dietary factors with systolic and diastolic blood pressure. A p-value <0.05 was considered statistically significant.

3. Results

3.1 Sociodemographic Characteristics

The mean age of participants was 43.27 ± 13.12 years, with no significant difference between males (42.36 ± 13.47 years) and females (43.79 ± 13.06 years, $p > 0.05$). Education level differed significantly by gender ($p < 0.001$): 56.7% of women were illiterate compared with 26.0% of men, while 41.1% of men were graduates compared with 7.9% of women. Monthly household income also differed significantly by gender ($p < 0.01$), with 53.5% of women reporting income below PKR 50,000 compared with 49.3% of men reporting income above PKR 100,000. Family size and family type did not differ significantly by gender (Table 1).

Table 1. *Sociodemographic Characteristics of Study Participants (n = 200)*

Variable	Category	Male (n=73)	Female (n=127)	Total (n=200)	p-value
Age (years), mean ± SD	—	42.36 ± 13.47	43.79 ± 13.06	43.27 ± 13.12	>0.05
Age group	20–35	29 (39.7%)	37 (29.1%)	66 (33.0%)	—
	36–50	20 (27.4%)	44 (34.6%)	64 (32.0%)	>0.05
	51–65	24 (32.9%)	46 (36.3%)	70 (35.0%)	—
Education	Illiterate	19 (26.0%)	72 (56.7%)	91 (45.5%)	—
	Schooling certificate	24 (32.9%)	45 (35.4%)	69 (34.5%)	<0.001
	Graduate	30 (41.1%)	10 (7.9%)	40 (20.0%)	—
Family size	<8 members	27 (37.0%)	50 (39.4%)	77 (38.5%)	>0.05
	⩾8 members	46 (63.0%)	77 (60.6%)	123 (61.5%)	—
Family type	Nuclear	31 (42.5%)	60 (47.2%)	91 (45.5%)	>0.05
	Joint	42 (57.5%)	67 (52.8%)	109 (54.5%)	—
Monthly income (PKR)	<50,000	24 (32.9%)	68 (53.5%)	92 (46.0%)	—
	50,000–100,000	13 (17.8%)	28 (22.0%)	41 (20.5%)	<0.01

>100,000	36 (49.3%)	31 (24.4%)	67 (33.5%)	—

SD = standard deviation; PKR = Pakistani Rupees.

3.2 Salt consumption status

Based on the 24-hour dietary recall, mean total dietary sodium intake was 2079 ± 685.94 mg/day, equivalent to an estimated salt intake of 4.91 ± 1.39 g/day. While the population mean fell just under the WHO threshold, 55.0% of individual participants exceeded the recommended limit of 5 g/day. FFQ-based classification indicated that 44.0% of participants had low, 29.0% moderate, and 27.0% high exposure to salt-rich foods (Table 2). A clear positive relationship was observed between FFQ-based exposure category and estimated salt intake from the 24-hour recall, rising from approximately 3.5–3.7 g/day in the low-exposure group to 6.3–6.5 g/day in the high-exposure group (Figure 1), confirming good agreement between the two dietary assessment tools.

Table 2. *Salt consumption status of respondents by dietary assessment method*

Estimated daily salt intake		Mean ± SD / n (%)
Based on 24-hr recall	Total sodium intake (mg/day)	2079 ± 685.94
	Estimated salt intake (g/day)	4.91 ± 1.39
	Normal (<5 g/day)	90 (45.0%)
	High (⩾5 g/day)	110 (55.0%)
Based on FFQ	Low exposure	88 (44.0%)
	Moderate exposure	58 (29.0%)
	High exposure	54 (27.0%)

FFQ = Food Frequency Questionnaire.

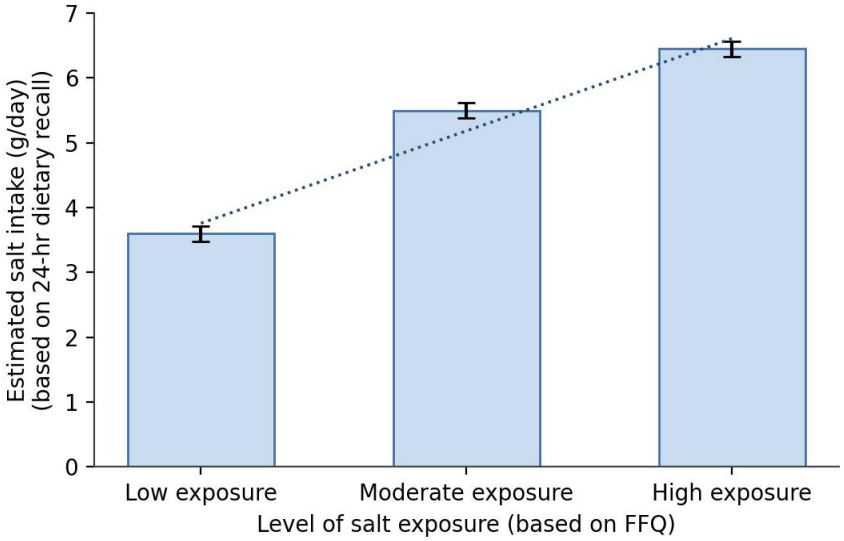

Figure 1. Estimated daily salt intake (24-hr recall) by level of salt exposure (FFQ).

3.3 Blood Pressure Status

Mean systolic blood pressure (SBP) was 116.98 ± 7.13 mmHg (range 105–134) and mean diastolic blood pressure (DBP) was 78.69 ± 6.85 mmHg (range 68–92). Overall, 46.0% of participants were classified as likely hypertensive and 54.0% as normotensive (Table 3).

Table 3. *Blood pressure status of respondents*

Indicator	Category	Mean ± SD / n (%)
SBP (mmHg)	Mean (range)	116.98 ± 7.13 (105–134)
DBP (mmHg)	Mean (range)	78.69 ± 6.85 (68–92)
SBP category	Raised (⩾120 mmHg)	70 (35.0%)
	Normal	130 (65.0%)
DBP category	Raised (⩾80 mmHg)	90 (45.0%)
	Normal	110 (55.0%)
Overall BP status	Normotensive	108 (54.0%)
	Likely hypertensive	92 (46.0%)

SBP = systolic blood pressure; DBP = diastolic blood pressure; mmHg = millimetres of mercury.

3.4 Anthropometric, sociodemographic, and nutrient correlates of blood pressure

Likely-hypertensive participants were significantly older (46.36 ± 13.60 vs. 40.63 ± 12.30 years, $p < 0.05$) and more often male (55.4% vs. 20.4% among normotensives, $p < 0.001$). Lower household income and joint family living were also significantly associated with likely-hypertensive status (both $p < 0.05$), while education level and family size were not significantly associated ($p > 0.05$).

Likely-hypertensive participants had significantly higher body weight, BMI, and waist circumference, and higher total energy intake, but significantly lower intake of dietary fiber, potassium, magnesium, calcium, and vitamins D, B9, and B12 (all $p < 0.05$; Table 4). Dietary sodium intake was significantly higher among likely-hypertensive participants (2183.01 ± 726.68 mg) than normotensive participants (1990.94 ± 639.41 mg, $p < 0.05$).

Table 4. *Selected anthropometric, dietary, and nutrient variables by blood pressure status*

Variable	Normotensive (n=108)	Likely hypertensive (n=92)	p-value
Weight (kg)	68.14 ± 11.92	75.68 ± 13.40	<0.001
BMI (kg/m^2)	26.07 ± 4.25	27.72 ± 4.39	<0.01
Waist circumference (cm)	80.69 ± 6.27	83.97 ± 5.72	<0.001
Energy intake (kcal)	1338.43 ± 372.67	1454.47 ± 383.48	<0.05
Dietary fiber (g)	26.27 ± 3.79	24.16 ± 4.45	<0.001
Sodium intake (mg)	1990.94 ± 639.41	2183.01 ± 726.68	<0.05
Potassium intake (mg)	2865.16 ± 418.53	2616.51 ± 407.16	<0.001
Magnesium intake (mg)	294.69 ± 43.03	269.09 ± 41.87	<0.001
Calcium intake (mg)	818.68 ± 119.56	752.28 ± 107.47	<0.001
Vitamin D (µg)	4.09 ± 0.59	3.78 ± 0.50	<0.001
Vitamin B9 (µg)	327.50 ± 47.88	311.53 ± 49.07	<0.05
Vitamin B12 (mg)	1.96 ± 0.28	1.77 ± 0.29	<0.001

SD = standard deviation; BMI = body mass index.

3.5 Blood pressure by salt intake level and sodium–potassium ratio

Participants consuming more than 5 g/day of salt had modestly higher SBP (118 vs. 115 mmHg) and DBP (77–78 vs. 75–76 mmHg) than those consuming less than 5 g/day

(Figure 2). Similarly, participants with an unfavorable sodium–potassium ratio (Na/K ⩾1) showed higher SBP (118–120 vs. 115–116 mmHg) and DBP (79–80 vs. 77–78 mmHg) than those with Na/K <1 (Figure 3), consistent with the protective role of dietary potassium against elevated blood pressure.

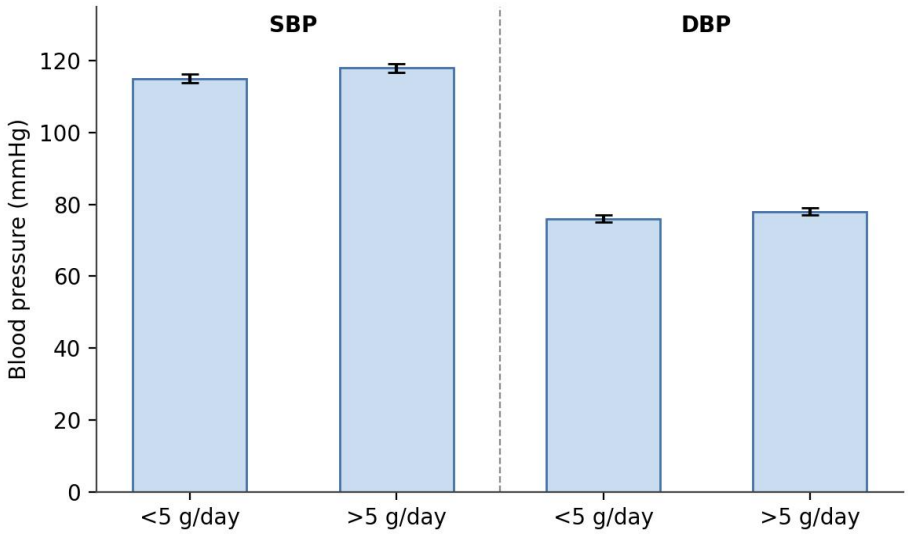

Figure 2. Systolic and diastolic blood pressure by estimated salt intake level.

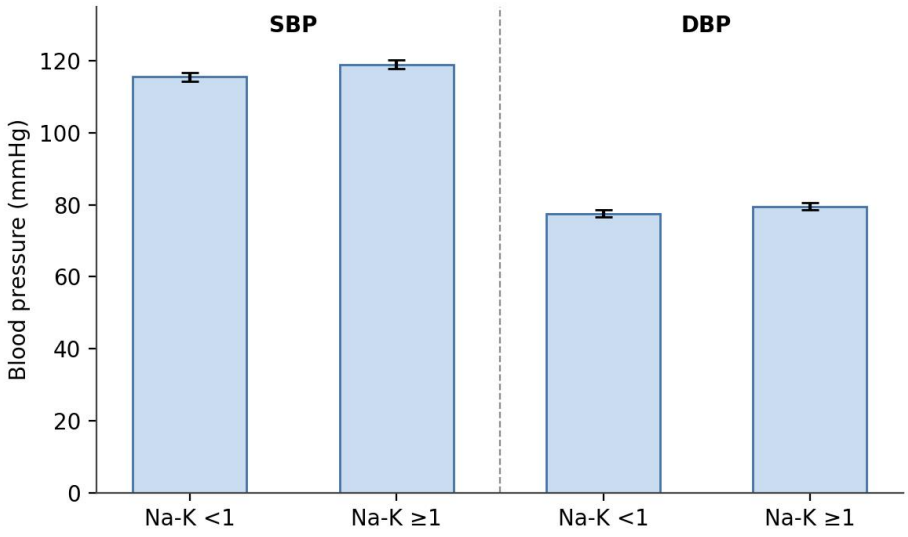

Figure 3. Systolic and diastolic blood pressure by sodium–potassium ratio category.

3.6 Predictors of blood pressure: multivariate GLM

In the multivariate general linear model, age (β = 0.07–0.08), male gender, estimated salt intake (β = 0.74 for SBP, $p < 0.05$), and dietary energy intake (for DBP) were significant

positive predictors of blood pressure, whereas potassium intake was a significant negative predictor of both SBP and DBP (Table 5). Education level and waist circumference were not statistically significant independent predictors after adjustment.

Table 5. *Multivariate GLM parameter estimates for demographic, anthropometric, and dietary predictors of blood pressure*

Variable	Category	SBP β (95% CI)	DBP β (95% CI)
Age	—	0.07 (0.00 – 0.13)	0.08 (0.02 – 0.15)
Gender	Female vs. Male	−5.30 (−7.85 – −2.76)	−3.38 (−5.86 – −0.92)
Estimated salt intake	—	0.74 (0.01 – 1.47)	0.51 (−0.19 – 1.23)
Potassium intake	—	−0.005 (−0.007 – −0.002)	−0.004 (−0.007 – −0.002)
Dietary energy	—	0.001 (−0.002 – 0.004)	0.004 (0.001 – 0.007)
Waist circumference	—	−0.02 (−0.20 – 0.16)	0.09 (−0.08 – 0.28)

β = unstandardized regression coefficient; CI = confidence interval; SBP = systolic blood pressure; DBP = diastolic blood pressure.

4. Discussion

The mean estimated salt intake in this study (4.91 ± 1.39 g/day) was lower than values reported from Islamabad (8.64 ± 4.43 g/day; Saqib et al., 2021), Kashmir (8.7 g/day; Mir et al., 1986), Turkey (18.01 g/day; Erdem et al., 2010), and Oman (10.3 g/day; Shaikh et al., 2022), and below the global average of approximately 10.8 g/day (WHO, 2023). Nonetheless, the finding that 55% of individual participants exceeded the WHO-recommended limit mirrors the broader international pattern of widespread excess salt consumption, suggesting that the population-level mean may mask considerable inter-individual variability, possibly reflecting under-reporting inherent to single-day 24-hour recall methodology.

The 46% prevalence of likely hypertension observed here is comparable to the 45% reported in urban Tanzania (Katalambula et al., 2017) and higher than the 36.4% reported among tribal populations in Rajasthan (Sachdev, 2011), reinforcing that hypertension is a substantial and possibly under-recognized burden in this community. Consistent with the SALTURK study (Erdem et al., 2010) and the INTERSALT study (Stamler, 1997), salt intake was positively and independently associated with systolic

blood pressure in the multivariate model, while potassium intake showed the expected inverse association, in line with the DASH trial (Appel et al., 1997) and findings by McCarron et al. (1984). The higher sodium–potassium ratio observed among likely-hypertensive participants further supports the view that cardiovascular risk is driven not by sodium alone but by the balance between sodium and potassium intake (Mohammadifard et al., 2017; Kelishadi et al., 2013).

Likely-hypertensive participants also exhibited higher BMI, waist circumference, and energy intake, corroborating earlier evidence linking obesity and central adiposity with elevated blood pressure (Kos et al., 2023; Katalambula et al., 2017; Sachdev, 2011). Lower intake of fiber, calcium, magnesium, and vitamins D, B9, and B12 among likely-hypertensive participants is consistent with reports that poor micronutrient status, low vitamin D, and elevated homocysteine may adversely affect vascular function and blood pressure regulation (Forman et al., 2007; Burgaz et al., 2011; Murphy, 2017). Older age and male gender were independent predictors of higher blood pressure, in agreement with findings from Tanzania (Katalambula et al., 2017) and the INTERSALT study (Stamler, 1997), while lower household income was associated with likely-hypertensive status, mirroring socioeconomic gradients reported in the SALTURK study (Erdem et al., 2010).

5. Conclusion and Recommendations

Adults of District Mardan show a high prevalence of excessive dietary salt consumption and a substantial burden of likely hypertension. Salt intake, sodium–potassium imbalance, higher BMI, and poor overall diet quality — characterized by low fiber, potassium, calcium, magnesium, and vitamin D, B9, and B12 intake — were significant correlates of elevated blood pressure, alongside older age, male gender, and lower household income. These findings support community-based nutrition education on salt reduction, promotion of potassium-rich foods (fruits, vegetables, legumes), targeted interventions for high-risk groups (males and lower-income households), integration of dietary counselling and blood pressure screening into primary healthcare, and policy-level measures such as food reformulation and sodium labelling to reduce population salt intake and the associated hypertension burden.

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