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Original article

Vitamin intake in obesity and hypertension: A population-based study from Haryana, North India

Neha Yadav [1], Vineet Chaudhary [1], Kallur Nava Saraswathy, Naorem Kiranmala Devi [*]

Department of Anthropology, University of Delhi, Delhi, 110007, India

A R T I C L E I N F O

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A B S T R A C T

Background: Obesity and hypertension are two highly prevalent health conditions and important risk factors for several health adversities. Adequate intake of certain vitamins has been reported to play a protective role in obesity and hypertension. Since dietary pattern, among other factors, delineates the status of vitamin intake in a population, it is pertinent to validate the relationship between vitamin intake, obesity, and hypertension in populations with unique dietary patterns. This study aimed to explore the interrelationship between intake of selected vitamins, obesity, and hypertension among adults of a lacto-vegetarian population.

Methods: A total of 488 participants, aged 30–70 years of either sex, were recruited from Palwal, Haryana, India. Data on socio-demographic variables and dietary intake was collected using a pretested interview schedule & food-frequency questionnaire (FFQ) respectively. Body mass index (BMI), and blood pressure (BP) were determined using standard techniques. Statistical analysis was performed using SPSS.

Results: While inadequacy in vitamin B9 intake was found to be positively associated with hypertension, inadequate vitamin C intake was found to be positively associated with both overweight/obesity and hypertension. In stratified analyses for BMI and BP categories, adequate intake of vitamin B9 and C was found to be protective against hypertension only among non-overweight/obese individuals; however, regardless of BP status, adequate vitamin C intake was inversely associated with overweight/obesity.

Conclusions: Adequate intake of vitamin C can help in reducing the burden of obesity in general and hypertension among non-obese individuals. Further, adequate intake of vitamin B9 may be protective against hypertension.

1. Introduction

Obesity and hypertension are two of the widely prevalent health conditions and leading causes of morbidity and mortality worldwide.[1,2] While obesity has been associated with an increased risk of diabetes mellitus, cardiovascular diseases (CVDs), several cancers, and poor mental health, hypertension is an important risk factor for CVDs.[1,2] As per estimates, 39.0% of the world's population is either obese or overweight, and 31.1% of the global adult population is hypertensive.[1,2]

The situation in India is no different. According to the national family health survey-5, 22.8% of Indian males are overweight/obese and 24% of them are hypertensive, likewise, 24% of Indian women are overweight/obese and 21.3% are hypertensive.[3] Other studies have reported higher prevalences of both obesity (up to 31.3%) and hypertension (up to 30.7%).[4–6] In fact, the rates at which obesity and hypertension have increased in India over the past few decades are among the highest in the world.[5,7]

The epidemic of obesity and hypertension in India warrants immediate population-level intervention. To design effective interventions, it is important to identify population-specific modifiable risk factors. Both obesity and hypertension have complex etiologies and are thought to be caused by a combination of genetic and environmental factors.[8,9] Genetic predisposition along with imbalances in energy intake (high dietary content in fat and carbohydrate) and expenditure (physical inactivity) have been identified as the main factors behind weight gain and obesity.[10] Dietary factors and physical inactivity have also been found to be involved in the etiology of hypertension both independently as well as through weight gain and obesity.[11] Apart from energy intake, due attention is being given to micronutrient deficiencies in general and vitamins in particular as risk factors for obesity and hypertension.[12,13]

* Corresponding author.
E-mail addresses: yadavneha97111@gmail.com (N. Yadav), vineetchaudhary.vc@gmail.com (V. Chaudhary), knsaraswathy@yahoo.com (K.N. Saraswathy), kmaladevi@gmail.com (N.K. Devi).

[1] Both authors contributed equally and share the first authorship.

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As per the existing literature, deficiencies in the intake of several vitamins are independently associated with both obesity and hypertension and their adequate intake has been reported to be associated with a reduced risk of obesity and hypertension.[14–18]

A vitamin-based population-level intervention for obesity and hypertension would be particularly meaningful in India as such an intervention would have three folds benefits. Besides the high prevalence of obesity and hypertension in India, there is a huge burden of vitamin deficiencies.[19] Apart from possible benefits in obesity and hypertension, a vitamin-based intervention can help address rampant vitamin deficiencies and related disorders in India. However, for the intervention to be effective, population-based studies exploring population-specific patterns of vitamin intake and their role in obesity and hypertension are prerequisites.

Dietary intake of vitamins is bound to vary with varying dietary patterns across populations. Therefore, it is pertinent to explore the status of dietary intake of vitamins and their impact on obesity and hypertension in populations with unique dietary patterns. Given the dietary diversity in India,[20] it's rather surprising that very few population-based studies have been taken on this topic. Further, studies have mostly investigated the association between one vitamin and one health condition. However, there is a growing realization that nutrients often interact with each other in influencing related health conditions. To address these research gaps, the present study was undertaken with an aim to explore the interrelationship between the intake of selected vitamins (A, B1, B2, B3, B5, B6, B7, B9, C, and D), obesity, and hypertension in a lacto-vegetarian population of Palwal district of Haryana, North India.

2. Materials and methods

Study design and participants

The present study is a population-based cross-sectional study conducted among a total of 488 lacto-vegetarian adult participants (aged 30–70 years; mean age 52.47 ± 10.06 years) of either sex (59.63% females) from 15 villages of Palwal district, Haryana, North India. Those villages (within the Palwal district) that were primarily inhabited by a lacto-vegetarian community were purposively selected. Individuals from the selected villages were conveniently recruited through household surveys. The number of recruited participants from each village was in proportion to the population of the village. Individuals having any terminal illnesses, pregnant women, and individuals on any long-term medication or micronutrient supplements were excluded from the study.

Ethical approvals

The present study was approved by the departmental ethics committee, Department of Anthropology, University of Delhi (reference number: Anth/2010/455/5). Prior to recruitment, informed written consent, typed in the local language, was obtained from each participant.

Data collection

Sociodemographic variables: Data on sociodemographic variables (age, sex, marital status, education status, employment status, and family income) were collected by using a pretested and modified interview schedule.

Blood pressure: Left-hand blood pressure was measured while the participant was at rest using Omron digital Sphygmomanometer. Three BP readings were taken, each after a gap of 5 min, and average of the three readings of SBP and DBP was considered to estimate the hypertension status. The categorization of hypertension was done by using AHA cut-off (normal = SBP<120 mmHg and DBP<80 mmHg; elevated = SBP 120–129 mmHg and DBP<80 mmHg; Stage I = SBP 130–139 mmHg or DBP 80–89 mmHg; Stage II = SBP≥140 mmHg or DBP ≥90 mmHg).[21] For various analyses in this study, normal (n = 109) and elevated (n = 28) categories of BP have been merged as normotensives, and stage-I (n = 165) and Stage-II hypertension (n = 184) categories as hypertensives. Blood pressure could not be obtained from two of the participants due to injury in their left hand.

General obesity: The height and weight of participants were measured using an anthropometry rod and weighing balance respectively for BMI calculation. The BMI was calculated using the standard formula (weight in kilogram divided by height in meter square) and categorized using the Asian Indian cut-off as underweight (BMI <18.5 kg/m^2), normal (BMI = 18.0–22.9 kg/m^2), overweight (BMI = 23.0–24.9 kg/m2), and obese (BMI ≥25 kg/m^2).[22] Asian cut-off for BMI was preferred over WHO cut-offs because the Asian classification of BMI is a better predictor of insulin resistance and cardiovascular risk factors among Indians.[22] Again, for various statistical analyses, underweight (n = 91) and normal weight (n = 225) categories have been merged as non-obese and overweight (n = 137) and obese (n = 35) categories as overweight/obese.

Dietary intake: Dietary intake levels of studied vitamins were estimated by administering a validated (for rural Haryana) semi-quantitative food frequency questionnaire (FFQ) to the study participants.[23] FFQ is a widely employed nutritional assessment method in epidemiological studies.[24] FFQ consists of a list of food items consumed in a region along with a frequency section to record the frequency of intake of various food items over a period.[24] For the present study, the dietary history of the past one year was recorded.

Dietary intake data analysis

Data obtained by FFQ was analyzed by using DietCal software to generate the nutrient profile of the study participants.[25] The recommended dietary allowances (RDA) values for each of the vitamins were used as cutoffs to categorize the intake levels of vitamins into adequate and inadequate (RDA, per day, for vitamin A = 1000 μg for males, 840 μg for females; vitamin B1 = 1.8 mg for males, 1.7 mg for females; vitamin B2 = 2.5 mg for males, 2.4 mg for females; vitamin B3 = 18 mg for males, 14 mg for females; vitamin B5 = 5 mg for both males and females; vitamin B6 = 2.4 mg for males, 1.9 mg for females; vitamin B7 = 40 μg for both males and females; vitamin B9 = 300 μg for males, 220 μg for females; vitamin C = 80 mg for males, 65 mg for females; and vitamin D = 600 IU for both males and females).[26]

Statistical analysis

SPSS version 22 was used for the statistical analysis. The chi-square test was used to determine any significant difference in the distribution of categorical variables. The linear regression analysis was performed to estimate the association between two continuous variables. Binary logistic regression has been used to calculate the odds ratio. Participants were divided into quartiles based on the dietary intake of Vitamin B9 and C, and the prevalence of obesity and hypertension was determined in each quartile. Statistical tests computed in this study were considered significant at a two-tailed p-value <0.05.

3. Results

Socio-demographic characteristics of the study participants

The proportion of individuals in normotensive versus hypertensive categories as well in non-obese versus overweight/obese categories were not found to be significantly different for any of the studied socio-demographic variables (age, sex, marital status, education status, employment status, and annual family income) (Table 1).

Table 1
Socio-demographic characteristics of the study participants with respect to obesity and hypertension status.

Socio-demographic Variables		Non-obese (N = 316)	Overweight/Obese (N = 172)	*p*-value	Normotensive (N = 137)	Hypertensive (N = 349)	*p*-value
		n (%)	*n* (%)		*n* (%)	*n* (%)	
Age group (years)	30–39	37 (11.7)	20 (11.6)	0.27	17 (12.4)	40 (11.5)	0.47
	40–49	102 (32.3)	51 (29.7)		36 (26.3)	115 (33.0)	
	50–59	74 (23.4)	54 (31.4)		41 (29.9)	86 (24.6)	
	≥60	103 (32.6)	47 (27.3)		43 (31.4)	108 (30.9)	
Sex	Males	130 (41.1)	67 (39.0)	0.64	53 (38.7)	143 (41.0)	0.65
	Females	186 (58.9)	105 (61.0)		84 (61.3)	206 (59.0)	
Marital Status	Married	293 (92.7)	155 (90.1)	0.60	125 (91.2)	321 (92.0)	0.27
	Unmarried	3 (9)	2 (1.2)		3 (2.2)	2 (0.6)	
	Widowed	20 (6.3)	15 (8.7)		9 (6.6)	26 (7.4)	
Employment status	Employed	32 (10.1)	14 (8.1)	0.47	17 (12.4)	29 (8.3)	0.17
	Unemployed	284 (89.9)	158 (91.9)		120 (87.6)	320 (91.7)	
Education status	Literate	141 (44.6)	79 (44.9)	0.78	63 (46)	154 (44.1)	0.71
	Non- literate	175 (55.4)	93 (54.1)		74 (54)	195 (59.9)	
Per-capita annual family income (INR)	≥50,000	28 (8.9)	24 (14.0)	0.82	12 (8.8)	39 (11.2)	0.43
	<50,000	288 (91.2)	148 (86.0)		125 (91.2)	310 (88.8)	

N = category wise sample size; INR= Indian national rupees.

Obesity and hypertension with respect to levels of vitamin intake

Of all the studied vitamins (A, B1, B2, B3, B5, B6, B7, B9, C, and D), the proportions of individuals consuming inadequate levels of vitamin B9 or vitamin C were found to be significantly higher in the hypertensive category than in the normotensive category (Table 2). Further, the proportion of individuals with vitamin C inadequacy was found to be significantly higher in the overweight/obese category than in their non-obese counterparts (Table 2) (for further details on the distribution of participants consuming adequate and inadequate levels of vitamins in underweight, normal weight and overweight/obese BMI categories, refer to Supplementary Table 1).

Since the proportion of participants consuming adequate levels of several of the studied vitamins was very low (less than 10% in the case of vitamins A, B1, B2, B3, B6, B7, and D) regardless of obesity and hypertension status, linear regression analyses, with intake levels of studied vitamins as independent variables, and BMI and blood pressure (SBP & DBP) as dependent variables, were performed to understand the association of BMI and blood pressure with the intake of the studied vitamins (Supplementary Table 2). This analysis revealed a significant negative association of vitamin C intake with both BMI and blood pressure. Other studied vitamins were not found to be associated with BMI or blood pressure among the study participants. Based on the findings of distribution and linear regression analyses, further analyses have been performed only on vitamins B9 and C.

Odds ratio analysis

Odds ratio analysis showed that inadequate vitamin B9 intake posed 1.57-folds significantly increased risk for hypertension and inadequate vitamin C intake posed 2.72- and 2.77- folds significantly increased risk for overweight/obesity and hypertension respectively. The combined inadequate intake of vitamin B9 and C posed 1.65- and 2.25-folds increased risk for overweight/obesity and hypertension respectively (Table 3).

Distribution of overweight/obese & hypertensive individuals in quartiles of vitamins B9 & C intake

Due to the observed relationship of vitamin B9 and C intake with blood pressure and vitamin C intake with obesity, the distribution of overweight/obesity and hypertension was further seen in different

Table 2
Distribution of participants consuming adequate and inadequate levels of vitamins with respect to obesity and hypertension status.

Vitamins	Status	Non-obese	Overweight/obese	*p*-value	Normotensive	Hypertensive	*p*-value
		n (%)	*n* (%)		*n* (%)	*n* (%)	
Vit A	Adequate	1 (0.3)	0 (0.0)	0.76	1 (0.7)	0 (0.0)	0.63
	Inadequate	315 (99.7)	172 (100)		136 (99.3)	349 (100)	
Vit B1	Adequate	24 (7.6)	12 (7)	0.06	15 (10.9)	21 (6)	0.06
	Inadequate	292 (92.4)	160 (93)		122 (89.1)	328 (94)	
Vit B2	Adequate	18 (5.7)	6 (3.5)	0.28	8 (5.8)	15 (4.3)	0.47
	Inadequate	298 (94.3)	166 (96.5)		129 (94.2)	334 (95.7)	
Vit B3	Adequate	5 (1.6)	4 (2.3)	0.56	2 (1.5)	7 (2)	0.69
	Inadequate	311 (98.4)	168 (97.7)		135 (98.5)	342 (98.0)	
Vit B5	Adequate	82 (25.9)	36 (20.9)	0.22	38 (27.7)	80 (22.9)	0.29
	Inadequate	234 (74.1)	136 (79.1)		99 (72.3)	269 (77.1)	
Vit B6	Adequate	22 (7)	10 (5.8)	0.63	12 (8.8)	20 (5.7)	0.23
	Inadequate	294 (93)	162 (94.2)		125 (91.2)	329 (94.3)	
Vit B7	Adequate	6 (1.9)	1 (0.6)	0.24	3 (2.2)	4 (1.1)	0.39
	Inadequate	310 (98.1)	171 (99.4)		134 (97.8)	345 (98.9)	
Vit B9	Adequate	95 (30.1)	53 (30.8)	0.86	51 (37.2)	98 (28.1)	**0.049**[a]
	Inadequate	221 (69.9)	119 69.2)		86 (62.8)	251(71.9)	
Vit C	Adequate	121 (38.3)	33 (19.2)	**<0.01**[a]	66 (48.2)	89 (25.5)	**<0.01**[a]
	Inadequate	195 (61.7)	139 (80.8)		71 (51.8)	260 (74.5)	
Vit D	Adequate	0 (0)	0 (0)	–	0 (0)	0 (0)	–
	Inadequate	316 (100)	172 (100)		137(100.0)	349 (100.0)	

[a] Significant at *p*-value < 0.05.

Table 3
Odds ratio (Adjusted) analysis for vitamin B9 and C intake in obesity and hypertension.

Independent variable	Dependent variable	Adjusted OR (CI)	*p*-value
Inadequate vitamin B9 intake	Overweight/ Obesity[b]	0.97 (0.65–1.46)	0.89
	Hypertension[c]	1.57 (1.03–2.39)	**0.035**[a]
Inadequate vitamin C intake	Overweight/ Obesity[b]	2.72 (1.80–4.10)	**<0.01**[a]
	Hypertension[c]	2.77 (1.81–4.22)	**<0.01**[a]
Inadequate vitamin B9 + inadequate vitamin C	Overweight/ Obesity[b]	1.65 (1.12–2.43)	**0.01**[a]
	Hypertension[c]	2.25 (1.50–33.95)	**<0.01**[a]

[a] Significant at *p*-value < 0.05; OR = odds ratio; CI = confidence interval.
[b] adjusted for blood pressure.
[c] adjusted for BMI.

quartiles of vitamin B9 and C intake levels. No significant difference in the proportion of overweight/obese or hypertensive individuals was found in various quartiles of vitamin B9 intake. For vitamin C, non-obese and normotensive individuals were found to be significantly higher in the fourth quartile of vitamin C intake, whereas overweight/obese and hypertensive participants were significantly higher in the first quartile (*p*-value <0.001) (Table 4).

Vitamin B9 and C intake in obesity (stratified for BP) and hypertension (stratified for BMI)

Stratified analysis was undertaken to understand the effect of vitamin B9 and C intake on overweight/obesity in the different BP categories and on hypertension in different BMI categories. Since more than 50% of participants were consuming inadequate levels of both the vitamins, inadequate intake status was taken as the reference category, and the relationship between adequate consumption of these vitamins, obesity, and hypertension was explored. Adequate intake of vitamins B9 and C was found to be negatively associated with hypertension in the non-obese group, but not in the overweight/obese group. As far as the association of overweight/obesity with intake levels of vitamins B9 and C among normotensive and hypertensive individuals is concerned, regardless of blood pressure status vitamin B9 intake showed no significant association with overweight/obesity, and adequate vitamin C intake showed a significant inverse association with overweight/obesity (Table 5).

Table 4
Distribution of BMI categories and BP categories in various quartiles of Vitamin B9 and C intake.

Vitamin intake quartiles →		I	II	III	IV	*p*-value
		n (%)	*n* (%)	*n* (%)	*n* (%)	
Vitamin B9						
BMI	Non-obese	79 (65.3)	81 (64.8)	78 (63.4)	73 (65.2)	0.99
	Overweight/ obese	42 (34.7)	44 (35.2)	45 (36.6)	39 (34.8)	
BP	Normotensive	29 (24.4)	30 (24)	35 (28.9)	38 (33.3)	0.33
	Hypertensives	90 (75.6)	95 (76)	86 (71.1)	76 (66.7)	
Vitamin C						
BMI	Non-obese	74 (60.7)	77 (62.6)	64 (52.0)	100 (84.0)	**<0.01**[a]
	Overweight/ obese	48 (39.3)	46 (37.4)	59 (48.0)	19 (16.0)	
BP	Normotensive	28 (23.3)	23 (18.9)	27 (22.0)	58 (48.3)	**<0.01**[a]
	Hypertensives	92 (76.7)	99 (81.1)	96 (78.0)	62 (51.7)	

[a] Significant at *p*-value < 0.05.

4. Discussion

The present study was aimed at exploring the relationship between dietary intake of ten vitamins, obesity, and hypertension in a lacto-vegetarian population. Of all the studied vitamins, inadequate intake of vitamin C was found to be positively associated with both obesity and hypertension, whereas inadequate intake of vitamin B9 (folate) was found to be positively associated with hypertension. Intake levels of other studied vitamins were not found to be associated with either obesity or hypertension. Vitamin C or ascorbic acid sufficiency has been reported to be protective against obesity,[27–29] and hypertension.[14,30] Similarly, B9 or folate sufficiency has been associated with a lower risk of hypertension.[31,32] Though no association between levels of vitamin C and obesity,[33] as well as folate and hypertension,[34] have also been reported. Reports on the inverse relationship between vitamin C levels and blood pressure have been more consistent.[30]

Regarding the mechanism of action, probably all the metabolic roles of vitamin C can be accounted for by its ability to donate electrons and hence act as an anti-oxidant or a reducing agent.[35] Vitamin C is an important scavenger of reactive oxygen species and prevents cellular damage by neutralizing free radicals.[36] Vitamin C is believed to act on obesity through various mechanisms. Oxidative stress, produced due to the accumulation of reactive oxygen species, is a possible cause of obesity and vitamin C, being an antioxidant, can reduce systemic oxidative stress.[36] Further, studies have shown adipose tissue to produce

Table 5
Intake of vitamins B9 & C in hypertension (stratified for BMI) & obesity (stratified for BP).

Stratification level	Status of dependent variable	Vitamin intake levels		*p*-value
		Inadequate	Adequate	
Vitamin B9				
Non-obese	Normotensive	58 (26.4)	36 (37.9)	**0.04**[a]
	Hypertensive	162 (73.6)	59 (62.1)	
	OR (CI)	Reference	0.59 (0.33–0.98)	**0.04**[a]
Overweight/ obese	Normotensive	28 (23.9)	15 (29.4)	0.45
	Hypertensive	89 (76.1)	36 (70.6)	
	OR (CI)	Reference	0.76 (0.36–1.58)	0.46
Normotensive	Non-obese	58 (67.4)	36 (70.6)	0.70
	Overweight/obese	28 (32.6)	15 (29.4)	
	OR (CI)	Reference	1.16 (0.55–2.46)	0.70
Hypertensive	Non-obese	162 (64.5)	59 (62.1)	0.67
	Overweight/obese	89 (35.5)	36 (37.9)	
	OR (CI)	Reference	0.90 (0.55–1.47)	0.67
Vitamin C				
Non-obese	Normotensive	39 (20.1)	55 (45.5)	**<0.01**
	Hypertensive	155 (79.9)	66 (54.5)	
	OR (CI)	Reference	0.30 (0.18–0.50)	**<0.01**[a]
Overweight/ obese	Normotensive	32 (23.5)	11 (34.4)	0.21
	Hypertensive	104 (76.5)	21 (65.6)	
	OR (CI)	Reference	0.59 (0.26–1.35)	0.21
Normotensive	Non-obese	39 (54.9)	55 (83.3)	**<0.01**[a]
	Overweight/obese	32 (45.1)	11 (16.7)	
	OR (CI)	Reference	0.24 (0.11–0.54)	**0.01**[a]
Hypertensive	Non-obese	155 (59.8)	66 (75.9)	**0.01**[a]
	Overweight/obese	104 (40.2)	21 (24.1)	
	OR (CI)	Reference	0.474 (0.27–0.82)	**0.01**[a]

[a] Significant at *p*-value < 0.05; OR = odds ratio; CI = confidence interval.

adipokine, which in turn can lead to oxidative stress and systemic inflammation.[37] Vitamin C may have a role to play in reducing systemic inflammation and hence body fat.[36] Additionally, hypoxia has also been shown to accelerate obesity, and vitamin C may help in inhibiting hypoxia.[36] Vitamin C can also act against obesity by decreasing adipogenesis and glucose uptake, inhibiting lipolysis, and downregulating steroidogenesis and leptin genes.[36]

Besides obesity, evidence suggests that vitamin C intake can be protective against hypertension.[14,30] Vitamin C has been shown to increase the concentrations of tetrahydrobiopterin in cells, which in turn enhances the synthesis of nitric oxide.[38] Nitric oxide is a potent vasodilator and can reduce blood pressure.[14] Moreover, vitamin C has been reported to improve the bioactivity of nitric oxide as well as endothelial function.[38–40]

The relationship between adequate vitamin B9 intake and reduced hypertension is primarily explained through its effect on plasma homocysteine.[41] High homocysteine has been reported to be associated with endothelial dysfunction and hypertension.[41] Vitamin B9 can be beneficial in reducing plasma homocysteine concentrations and hence improving endothelial function and reducing blood pressure.[41,42]

Interestingly, in the analysis stratified for BMI levels, adequacy in intake of vitamins B9 and C was found to be negatively associated with hypertension among non-overweight/obese (normal-weight/underweight) participants, but not among overweight/obese participants. One of the possible reasons behind this observation could be that obesity is one of the major contributing risk factors for hypertension,[10] and the protection offered by adequate intake of vitamin B9 and C against hypertension is offset by obesity. Further, regardless of BP status, adequate intake of vitamin C, but not vitamin B9, was found to be negatively associated with overweight/obesity. This observation points towards an independent relationship (independent of BP) between adequate vitamin intake and healthy BMI. More studies should be taken up to explicate the biological pathways behind the observed relationships.

Apart from vitamin B9 and C, overweight/obesity or hypertension was not found to be associated with intake levels of other studied vitamins (i.e., vitamin A, B1, B2, B3, B5, B6, B7, and D). Obesity and hypertension have been reported to have both positive and negative as well as no associations with increased intake of these vitamins in other studies.[43–48] One of the possible reasons behind the lack of association between the intake of studied vitamins (other than vitamin C and B9) and studied health outcomes (obesity and hypertension) in the present study can be widespread inadequacy (among 90–100% of participants) in intake of these vitamins. More studies should be taken up to fully understand the relationship between intake levels of various vitamins, obesity, and hypertension in vegetarian populations.

There are a few limitations of the study that must be stated. First, the cross-sectional study design precludes causal association. Though available literature points towards causality between inadequate intake of vitamin C and obesity as well as hypertension, yet longitudinal study design would be required to establish the causal relationship. Secondly, due to widespread inadequacy in the intake of other studied vitamins, the relationship between their dietary intake and studied health conditions could not be meaningfully understood. Further, the inclusion of serum vitamin levels in the study could have helped in the validation of the observed relationships. Lastly, being a single-sited study, inferences of this study must be validated in other vegetarian populations before generalization.

5. Conclusion

Findings from the present study suggest that while adequate intake of vitamin B9 and C may be protective against hypertension (especially among non-obese individuals), adequate intake of vitamin C may be protective against obesity (regardless of BP status). Since the proportion of individuals consuming adequate levels of other studied vitamins was very small, not much can be said about their relationship with BMI and BP in this population. Promotion of local foods rich in vitamin C can be an effective intervention for hypertension among non-obese individuals and for obesity (which in turn may help in checking hypertension) in this population. Vitamin B9-rich food can additionally be beneficial for hypertension.

Data availability

The data supporting this study's findings are available on request from the corresponding author.

Ethics approval

The study was approved by Departmental Ethics Committee, Department of Anthropology, University of Delhi, Delhi-110,007, India (Ref No. Anth/2010/455/1).

Informed consent

Informed written consent, typed in the local language, was obtained from each participant before their recruitment.

Consent to publish

Not applicable.

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CRediT authorship contribution statement

Neha Yadav: Investigation, Formal analysis, Data curation, Writing-original draft. Vineet Chaudhary: Investigation, Formal analysis, Data curation, Writing-review & editing. Kallur Nava Saraswathy: Funding acquisition, Conceptualization, Methodology, Visualization. Naorem Kiranmala Devi: Project administration, Supervision; Validation, Visualization, Writing - review & editing.

Declaration of competing interest

The authors have no conflicts of interest to disclose.

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Appendix A. Supplementary data

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