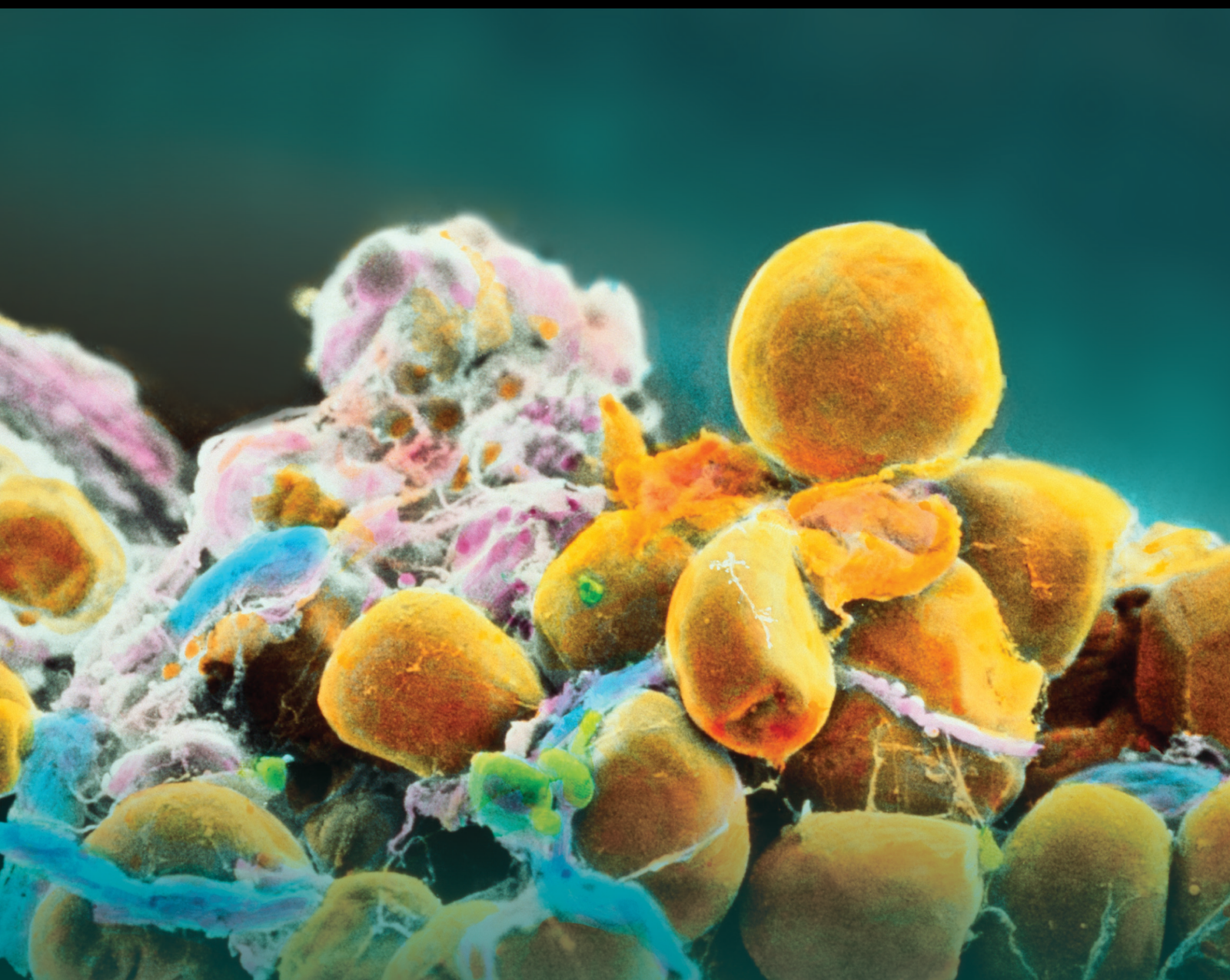


# Obesity in Asians: Predisposition, Noncommunicable Diseases, and Preventive Strategies

Lead Guest Editor: Tazeen H Jafar

Guest Editors: KM Venkat Narayan, Nikhil Tandon, and Naveed Sattar





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## Research Article

# Linkage between Neighborhood Social Cohesion and BMI of South Asians in the Masala Study

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**Introduction.** South Asians in the United States have a high prevalence of obesity and an elevated risk for cardiometabolic diseases. Yet, little is known about how aspects of neighborhood environment influence cardiometabolic risk factors such as body mass index (BMI) in this rapidly growing population. We aimed to investigate the association between perceived neighborhood social cohesion and BMI among South Asians. **Methods.** We utilized cross-sectional data from the MASALA study, a prospective community-based cohort of 906 South Asian men and women from the San Francisco Bay area and the greater Chicago area. Multivariable linear regression models, stratified by sex, were used to examine the association between perceived level of neighborhood social cohesion and individual BMI after adjusting for sociodemographics. **Results.** Participants were 54% male, with an average age of 55 years, 88% had at least a bachelor's degree, and the average BMI was 26.0 kg/m<sup>2</sup>. South Asian women living in neighborhoods with the lowest social cohesion had a significantly higher BMI than women living in neighborhoods with the highest cohesion ( $\beta$  coefficient = 1.48, 95% CI 0.46–2.51,  $p = 0.02$ ); however, the association was not statistically significant after adjusting for sociodemographic factors ( $\beta$  coefficient = 1.06, 95% CI –0.01–2.13,  $p = 0.05$ ). There was no association between level of neighborhood social cohesion and BMI in South Asian men. **Conclusion.** Perceived neighborhood social cohesion was not significantly associated with BMI among South Asians in our study sample. Further research is recommended to explore whether other neighborhood characteristics may be associated with BMI and other health outcomes in South Asians and the mechanisms through which neighborhood may influence health.

## 1. Introduction

Obesity rates continue to rise in the United States (US), with some studies estimating that more than 78 million adults, or 1 in 3 adults, in the United States were obese in 2009–2010 [1, 2]. Obesity is linked to multiple preventable diseases and some of the leading causes of preventable deaths including type 2 diabetes, heart disease, stroke, and certain types of cancer [1, 3]. Cardiovascular disease accounts for nearly a quarter (23%) of the deaths of the South Asian and is the

leading cause of death in populations aged 45 and above [4]. South Asians' incidence rate is 6 per 1,000 population and 11.2% population 12.2%, and 10.0% for type 2 diabetes [4]. The staggering rates of obesity across the US are a significant public health concern with significant biomedical, psychosocial, and economic implications [1]. While obesity is a serious problem for many people in general, it does affect some groups more than others [1].

Together, South Asians (from India, Pakistan, Bangladesh, Nepal, and Sri Lanka) make up one of the largest and

fastest growing immigrant Asian subgroups in the United States [3]. While Asian Americans overall have a relatively low body mass index (BMI) compared with other race/ethnic groups in the US, South Asians specifically have the highest rates of overweight/obesity among all Asians in the US [5, 6]. In addition, South Asians are more prone to develop abdominal fat, [7, 8] have lower lean body mass, and have a higher proportion of overall body fat than non-Hispanic whites [7, 9]. Accordingly, South Asians have high rates of obesity-related chronic disease, such as type 2 diabetes and cardiovascular disease [8, 10, 11]. Since South Asians are a rapidly growing population in the US, it is important to identify the social and cultural factors that may underpin the increased obesity and related risks.

Given the continuing population trends of rising obesity rates and the serious health implications, there has been a growing focus on better understanding the related social determinants of health, and specifically, on how neighborhood environment influences individual's overall well-being and weight fluctuation [12]. While the association between neighborhood-built environment and obesity risk has been widely examined, studies suggest neighborhood social context may be equally important in understanding obesity risk [12, 13]. One important feature of the neighborhood social environment is social cohesion, which captures a central aspect of a neighborhood's social environment. In previous studies, neighborhood social cohesion has been defined by constructs such as perceived connectedness, solidarity, and shared resources that allow people to act together [13]. Studies in other racial/ethnic groups suggest that social cohesion may mediate the effects of other neighborhood factors [14], such as residential segregation and poverty, on obesity. In addition, there may be differential effects in how social cohesion impacts obesity risk in different racial and ethnic groups [15]. Higher neighborhood social cohesion was associated with lower obesity risk in non-Hispanic whites [14], but the literature on neighborhood cohesion and obesity risk in racial/ethnic minorities is sparse and inconsistent [16]. A study of South Asian and white European men in the United Kingdom found that South Asian men lived in more disadvantaged neighborhoods with lower social cohesion, and they also had a higher waist circumference than white men [17]. Even less is known about neighborhood social cohesion and women's health. In a prior paper, neighborhood social cohesion was associated with hypertension prevalence in South Asian women in the U.S., but not men, underscoring the need to examine the applicability of social cohesion in the context of sex [18].

The existing literature has highlighted the need for research that focuses on the influence of the neighborhood on South Asian men and women's health and more specifically on how social cohesion may link to obesity and obesity-related factors [19]. In response to this need, using data collected as part of the community-based Mediators of Atherosclerosis in South Asians Living in America (MASALA) study, we examined the association between perceived neighborhood social cohesion and individual BMI. We hypothesized that higher levels of neighborhood social cohesion would be associated with a lower BMI.

## 2. Methods

**2.1. Participants.** The MASALA study is a prospective community-based cohort of South Asian men and women from two clinical sites (San Francisco Bay area at the University of California, San Francisco and the greater Chicago area at Northwestern University). The baseline MASALA study examination was conducted by trained bilingual (English, Hindi, or Urdu) study staff from October 2010 through March 2013, and a total of 906 participants were enrolled [20]. For participants to be eligible for MASALA, participants had to be of South Asian ancestry and have at least three grandparents born in one of the following countries: India, Pakistan, Bangladesh, Nepal, or Sri Lanka, be between the ages of 40–84 years, and be able to speak and/or read English, Hindi, or Urdu [20–23]. Exclusion criteria included a physician-diagnosed heart attack, stroke or transient ischemic attack, heart failure, angina, use of nitroglycerin, a history of cardiovascular procedures, current atrial fibrillation, active treatment for cancer, life expectancy < 5 years due to a serious medical illness, impaired cognitive ability, plans to move out of the study region in the next 5 years, and living in a nursing home. The study protocol was approved by the institutional review boards at the University of California, San Francisco, Northwestern University, and Loma Linda University.

### 2.2. Measures

**2.2.1. Predictor Variable.** Our primary independent variable of interest was perceived neighborhood social cohesion, which was measured using a five-item Likert scale tool ranging from 1 (strongly agree) to 5 (strongly disagree) that had been previously validated [23–25]. Respondents were asked to report their levels of agreement with the following statements: (Item 1) “people around here are willing to help their neighbors,” (Item 2) “people in this neighborhood generally do not get along with each other,” (Item 3) “people in this neighborhood can be trusted,” (Item 4) “people in this neighborhood do not share the same values,” and (Item 5) “most people in this neighborhood know each other” [18, 21, 23]. Items 1, 3, and 5 were “positive” constructs; therefore, we had to reverse code so that a higher score would indicate higher level of social cohesion. Items 2 and 4 are worded as “negative” constructs, so the strongly agree score of 1 does indicate lower levels of social cohesion. Cronbach's alpha for the items was 0.65.

We used principal component factor analysis with orthogonal rotation on the five items of the neighborhood questionnaire to construct the measure of social cohesion [16]. The first factor had an eigenvalue >1 and explained 43% of the variance. The results of the principal component factor analysis, factor loadings for factor 1, and scoring coefficients are shown in Supplementary Table 1. The factor score was created as the standardized weighted average using the scoring coefficients from Supplementary Table 1 and have a mean 0 and standard deviation 1. Factor scores were then divided into tertiles and defined as lowest (first tertile),

TABLE 1: Characteristics of the MASALA study participants by neighborhood social cohesion, 2010–2013,  $N = 906$ .

	Women ( $N = 420$ )				$p$ value	Men ( $N = 486$ )				$p$ value
	Lowest tertile ( $N = 151$ ) $N$ (%)	Middle tertile ( $N = 149$ ) $N$ (%)	Highest tertile ( $N = 120$ ) $N$ (%)	Total $N$ (%)		Lowest tertile ( $N = 151$ ) $N$ (%)	Middle tertile ( $N = 207$ ) $N$ (%)	Highest tertile ( $N = 128$ ) $N$ (%)	Total $N$ (%)	
Age, mean (SD)	55.58 (9.28)	54.53 (8.50)	52.63 (7.68)	54.37 (8.63)	0.0185	57.36 (9.47)	54.92 (9.90)	56.69 (10.35)	56.14 (9.93)	0.0555
BMI*, mean (SD)	27.34 (4.19)	26.43 (4.35)	25.85 (4.02)	26.59 (4.30)	0.0156	26.29 (4.19)	26.08 (3.35)	26.60 (4.23)	26.28 (3.87)	0.4873
Income**					0.0013					0.0133
Less than \$50,000	38 (26.21)	20 (13.89)	12 (10.26)	70 (17.24)		39 (27.08)	28 (13.66)	18 (14.4)	85 (17.93)	
\$50,000 to \$99,999	33 (22.76)	29 (20.14)	19 (16.24)	81 (19.95)		27 (18.75)	39 (19.02)	22 (17.6)	88 (18.57)	
\$100,000 or more	74 (51.03)	95 (65.97)	86 (73.50)	255 (62.81)		78 (54.17)	138 (67.32)	85 (68)	301 (63.5)	
Education					0.0036					
Less than a bachelor's degree	35 (23.18)	15 (10.07)	12 (10.0)	62 (14.76)		17 (11.26)	21 (10.14)	10 (7.81)	48 (9.88)	
Bachelor's degree	49 (32.45)	45 (30.20)	44 (36.67)	138 (32.86)		50 (33.11)	49 (23.67)	24 (18.75)	123 (25.31)	
More than a bachelor's degree	67 (44.37)	89 (59.73)	64 (53.33)	220 (52.38)		84 (55.63)	137 (66.18)	94 (73.44)	315 (64.81)	
Marriage					0.0234					0.0387
Married or living as married	120 (79.47)	133 (89.26)	107 (89.17)	360 (85.71)		141 (93.38)	202 (97.58)	126 (98.44)	469 (96.5)	
Others	31 (20.53)	16 (10.74)	13 (10.83)	60 (14.29)		10 (6.62)	5 (2.42)	2 (1.56)	17 (3.5)	

\*Missing for 3 participants (one woman and two men).

\*\*Missing for 26 participants (14 women and 12 men).

\*\* $P > 0.05$ .

middle (second tertile), and highest (third tertile) levels of neighborhood social cohesion.

**2.2.2. Outcome Variable.** The primary outcome was BMI, which was calculated from measured weight in kilogram divided by height in square-meter. Participant weight was measured on a standard balance beam scale or digital weighing scale, and height was measured using a stadiometer. We used BMI as a continuous variable to examine the association of BMI with social cohesion tertiles.

**2.2.3. Covariates.** Our sociodemographic covariates included age, education, income, and marital status. Age was kept as a continuous variable in the model to preserve accuracy. Highest educational attainment was categorized as [1] less than a Bachelor's degree, [2] Bachelor's degree, and [4] more than a Bachelor's degree. In the original dataset, household income had 15 categories which we collapsed into three categories: [1] less than \$50,000, [2] \$50,000–\$99,999, and [4] \$100,000 or more. Marital status was also dichotomized as [1] married or living as married or [2] others (single, divorced, separated, or widowed).

**2.3. Statistical Analysis.** We first used descriptive statistics to assess sociodemographic characteristics (age, BMI, income,

education, and marriage) by neighborhood social cohesion tertiles stratified by sex. Theoretical and empirical evidence suggests that women are more likely to be influenced by community social environment [24–27]; therefore, we conducted all analyses stratified by sex. Mean  $\pm$  standard deviation or frequencies and percentages were presented. We compared sociodemographic characteristics by neighborhood social cohesion tertile using Chi-squared tests for categorical variables and ANOVA for continuous variables. Linear regression models stratified by sex were created to examine the associations between the categorical social cohesion tertile (reference category was high neighborhood cohesion) and continuous BMI outcome. For this analysis, we built two different models: model 1, where we examined the relationship between neighborhood cohesion tertile and BMI without adjusting for any covariates and model 2, where we adjusted for covariates (age, education, family income, and marital status). Statistical analyses were performed using SPSS Version 22 [28], and a two-sided  $p$  value of  $<0.05$  was considered to be statistically significant.

### 3. Results

Characteristics of MASALA study participants by neighborhood cohesion tertile stratified by sex are shown in Table 1. There were differences in average BMI across neighborhood social cohesion tertile ( $\text{BMI}_{\text{lowest social cohesion tertile}} = 27.3 \text{ kg/m}^2$ ,

BMI<sub>middle social cohesion tertile</sub> = 26.4 kg/m<sup>2</sup>, and BMI<sub>highest social cohesion tertile</sub> = 25.9 kg/m<sup>2</sup>,  $p = 0.015$ ). This was not evident in men (BMI<sub>lowest social cohesion tertile</sub> = 26.3 kg/m<sup>2</sup>, BMI<sub>middle social cohesion tertile</sub> = 26.1 kg/m<sup>2</sup>, and BMI<sub>highest social cohesion tertile</sub> = 26.6 kg/m<sup>2</sup>,  $p = 0.480$ ). Among both men and women, there were differences in the distribution of education category, income category, and marital status by neighborhood social cohesion tertile (see Table 1).

In unstratified analyses, neighborhood social cohesion tertile was not associated with BMI in South Asian adults ( $\beta_{\text{lowest vs highest}} = 0.58$ , 95% CI (-0.11, 1.26),  $p = 0.099$ ;  $\beta_{\text{middle vs highest}} = -0.02$ , 95% CI (-0.68, 0.65),  $p = 0.962$ ) from the unadjusted model.

In models stratified by sex, in the unadjusted models, living in neighborhoods with the lowest social cohesion tertile compared with the highest social cohesion tertile was associated with a higher BMI in women ( $\beta = 1.48$ , 95% CI (0.46, 2.51),  $p = 0.02$ ), but not in men ( $\beta = -0.31$ , 95% CI (-1.22, 0.61),  $p = 0.51$ ) (refer Table 2). For women, this association was no longer statistically significant after adjusting for age, education, income, and marital status ( $\beta = 1.06$ , 95% CI (-0.02, 2.13),  $p = 0.05$ ) (refer Table 2). In the adjusted model in men, education and age were associated with BMI, having less than a bachelor's degree compared with having more than a bachelor's degree being associated with higher BMI ( $\beta = 1.67$ , 95% CI (0.29–3.05),  $p = 0.020$ ) and increasing age associated with lower BMI ( $\beta = -0.06$  for each year increase in age, 95% CI (-0.10 to -0.03),  $p = 0.001$ ).

#### 4. Discussion

The overall objectives of this study were to help fill a gap in existing literature and examine whether neighborhood social cohesion was associated with body mass index among South Asians in the US. Our study found that neighborhood social cohesion was not associated with BMI among South Asians in the MASALA study.

Studies looking at the association between neighborhood social cohesion and BMI have produced mixed results. A number of studies have found a significant association between higher neighborhood social cohesion and lower BMI [24, 25, 29]. In the MESA (Multi-Ethnic Study of Atherosclerosis) study, Mujahid et al. found that BMI was lower for women living in neighborhoods with a better social environment (which included social cohesion, aesthetics, crime, and safety), but that in men living in a neighborhood with a better social environment was associated with higher BMI [26, 29]. Literature from Carrillo et al. and others have had suggested that social capital and social cohesion can shape health behaviors and outcomes through “(i) informal control and the normalization of health-related behaviors, (ii) collective efficacy, and (iii) exchange of social support” [30]. There remain knowledge gaps in how neighborhood environment and mediating pathways, such as social norms, may create or mitigate health risks in South Asians [31, 32].

Although we did find an association between neighborhood social cohesion and BMI in women, the association was attenuated after controlling for individual-level

socioeconomic factors. There may be possible mediation; for example, higher education may be associated with a better diet, more exercise, and a lower BMI, but it may also be associated with living in a neighborhood with higher cohesion [33, 34]. Having a higher education and family income may help one to live in a place with higher social cohesion which influences factors on the pathway for BMI.

A number of other factors may have contributed to the null finding. First, it may be important to integrate social cohesion environment and other community-level factors. Our study population included residents in two major urban and outlying suburban areas in the US, where social cohesion with neighbors may be high, but the built environment (such as apartment buildings, or densely populated city dwellings/surroundings) may not allow for physical activity. Another important aspect of the neighborhood environment is neighborhood racial/ethnic composition which is an important correlate of obesity risk and is likely to impact social cohesion [32].

Additionally, the social cohesion measure itself could also have contributed to the null finding. Although our study uses a well-validated neighborhood social cohesion scale in general US population, the psychometric properties of this scale have not been evaluated in South Asian populations. The current study had a Cronbach's alpha of 0.65 for the social cohesion variable, which is acceptable in exploratory research, but should be further explored for improvement in future studies. To this end, additional questions regarding neighborhood social cohesion should be explored because South Asians may have different values and beliefs about what constitutes social cohesion compared with other racial/ethnic groups. In an analysis of National Health Interview Survey Data, the association of social cohesion with physical activity differed by race/ethnicity and was not associated with physical activity in several Asian American groups, including Asian Indians [35]. This suggests that the relevance of social cohesion on health must be examined within the context of race/ethnicity.

Furthermore, studies indicate that specific aspects of the neighborhood social environment, such as social capital, collective efficacy, and crime, are associated with obesity among both adults and children [25]. Safety, crime, and violence have been shown to have consistent associations with obesity; greater neighborhood safety is associated with lower BMI, and higher neighborhood crime is associated with higher BMI [32, 35, 36]. Specifically, neighborhood safety and crime might influence social cohesion among residents by limiting opportunities for social interaction and promoting distrust among residents [31, 32]. Studies have also identified physical activity as a potential pathway of the neighborhood safety and obesity association [33, 37, 38].

**4.1. Limitations.** Although the MASALA study cohort's demographics are similar to those of South Asians in the 2010 US Census, there are limitations [39]. The MASALA sample largely comprises Asian Indian immigrants living in the San Francisco and Chicago areas, and thus the results may not be generalizable to all South Asians in the U.S.



TABLE 2: Association between neighborhood social cohesion and BMI stratified by sex, MASALA study (2010–2013).

Model 1 unadjusted items	Women (N = 419)				Men (N = 484)			
	Standardized coefficients B	95% confidence interval for $\beta$		<i>p</i> value	Standardized coefficients B	95% confidence interval for $\beta$		<i>p</i> value
		Lower bound	Upper bound			Lower bound	Upper bound	
BMI (constant)	25.85	25.09	26.62		26.60	25.93	27.27	
Neighborhood cohesion								
Lowest tertile	1.48	0.46	2.51	0.02 <sup>a</sup>	−0.31	−1.22	0.61	0.51
Middle tertile	0.57	−0.46	1.60	0.27	−0.52	−1.38	0.33	0.23
Highest tertile	Ref	—	—	—	Ref	—	—	—
Model 2 adjusted items	Women (N = 405)				Men (N = 472)			
	Standardized coefficients B	95% confidence interval for $\beta$		<i>p</i> value	Standardized coefficients B	95% confidence interval for $\beta$		<i>p</i> value
		Lower bound	Upper bound			Lower bound	Upper bound	
BMI (constant)	27.77	24.69	30.84	<0.0001	29.98	27.57	32.39	<.0001
Neighborhood cohesion								
Lowest tertile	1.06	−0.01	2.13	0.05	−0.23	−1.16	0.70	0.63
Middle tertile	0.47	−0.58	1.52	0.38	−0.63	−1.49	0.22	0.15
Highest tertile	Ref	—	—	—	Ref	—	—	—
Age in years	−0.04	−0.09	0.01	0.15	−0.06	−0.10	−0.03	0.001 <sup>a</sup>
Education								
Less than a bachelor's degree	1.25	−0.10	2.60	0.07	1.67	0.29	3.05	0.02 <sup>a</sup>
Bachelor's degree	−0.16	−1.10	0.79	0.75	0.42	−0.44	1.28	0.34
More than a bachelor's degree	Ref	—	—	—	Ref	—	—	—
Income								
Less than \$50,000	1.39	−0.01	2.78	0.05	−0.61	−1.82	0.60	0.32
\$50,000 to \$99,999	Ref	—	—	—	Ref	—	—	—
\$ 100,000 or more	−0.10	−1.24	1.03	0.86	−0.14	−1.08	0.80	0.77
Marriage								
No (ref = yes)	0.35	−0.92	1.61	0.59	0.59	−1.42	2.61	0.56

<sup>a</sup>*p* < 0.05.

Additionally, the study sample had a high SES, which does not capture the bimodal distribution of SES in different South Asian groups. Because this is a cross-sectional study, our ability to make causal inferences is limited. Longitudinal follow-up of the MASALA cohort will allow for further investigations about neighborhood effects and changes in BMI or other outcomes.

## 5. Conclusion

Our research provides important information regarding the relationship between social cohesion and obesity-related risk factors among South Asian Americans. We did not find an association between neighborhood social cohesion and BMI in South Asian adults. Future studies should examine other aspects of the built and social environment that may be associated with weight in South Asians and include individuals with greater variation in socioeconomic status and neighborhood environment.

## Data Availability

The Mediators of Atherosclerosis South Asians Living in America (MASALA) data used to support the findings of this study are restricted by the University of California, San Francisco, and Northwestern University in order to protect

patient privacy. Data are available by request and approval by the MASALA steering committee for researchers who meet the criteria for access to confidential data and must require further addition IRB approval with a signed data use agreement. Please contact [masala@ucsf.edu](mailto:masala@ucsf.edu) and [masalastudy@northwestern.edu](mailto:masalastudy@northwestern.edu).

## Disclosure

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung, and Blood Institute or the National Institutes of Health.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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## Supplementary Materials

Supplementary Table 1: principal component factor analysis. Supplementary Table 2: factor loadings and unique variances. Supplementary Table 3: scoring coefficients (method = regression; based on varimax rotated factors). (Supplementary Materials)

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## Review Article

# Health Promotion and Obesity in the Arab Gulf States: Challenges and Good Practices

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This debate paper focuses on available strategies, policies, and challenges of health promotion for combating obesity in the Arab Gulf states (Saudi Arabia, Bahrain, Kuwait, Oman, and Qatar). The paper focuses on the abovementioned countries due to their similarity on many aspects and because of their alarming obesity rates that are on the rise and keep increasing. The paper argues that there are significant efforts to be made in sectors such as policies, intersectoral work, primary healthcare, health promotion strategies development, and qualified personnel for health promotion and health education. Among the six states, Qatar, United Arab Emirates, and to a degree Oman have shown some development with regard to the implementation and evaluation of obesity-related health promotion policies, and thus other Arab Gulf countries could be inspired by existing good practices and move from good intentions to using their available wealth to invest in the implementation and evaluation of published policies and strategies. All Arab Gulf countries are in need of more qualified personnel and the development of infrastructure that can help tackle the growing obesity challenge that such countries are experiencing.

## 1. Obesity Prevention in the Arab Gulf States

The six Arab Gulf states are among the countries that have very high levels of obesity and overweight individuals. Around 30% or more of the population in these countries is obese ( $\geq 30 \text{ kg/m}^2$ ), and more than 60% have a weight range higher than normal ( $\geq 25 \text{ kg/m}^2$ ). Similar obesity and/or overweight levels are found also in other Middle Eastern countries, in the Maghreb countries, and also in the United States, New Zealand, Canada, Australia, and in some European countries [1]. Table 1 shows the prevalence of overweight and obesity for males and females in the Gulf States for 2016 [1]. It also shows the population for each country based on the latest estimate or census [2–7]. Table 1 also shows the prevalence of type 2 diabetes by gender. The highest rates are seen in KSA, Kuwait, and Qatar, and they are similar (more than 10%) to other Eastern Mediterranean countries such as Lebanon, Turkey, and Egypt as well as Morocco, Algeria, and Tunisia

but are higher than those rates recorded in the USA, Australia, or UK [8].

The alarming levels of obesity and overweight have awakened the Gulf countries to develop country- and community-level health promotion strategies in the last few years. For example, these kinds of strategies have been in place in the Nordic countries [9, 10] in Australia and New Zealand [11] and in Switzerland [12] for more than ten years.

The aim of this debate paper is to present and discuss the main challenges that the Arab Gulf states face in relation to health promotion and obesity. This debate is particularly important because of the rise of the obesity epidemic in these countries. Important aspects in health promotion are policy development, building up intersectoral work, establishing primary healthcare centers as settings [13], developing workforce capacity in health promotion as well as prioritizing health education, and health promotion at leadership and governance [14].

TABLE 1: General characteristics of the Gulf states.

	KSA	Kuwait	Bahrain	Qatar	United Arab Emirates	Oman
Population	32,612,641 (2017)	4,132,415 (2016)	1,423,726 (2016)	2,700,539 (2017)	9,121,167 (2016)	4,634,812 (2017)
Surface area (square km)	2,149,690	17,188	774	11,628	77,700	309,500
Obesity prevalence (male) 2016	31%	33%	26%	33%	28%	23%
Obesity prevalence (female) 2016	42%	46%	37%	43%	41%	34%
Overweight and obesity prevalence (male) 2016	68%	72%	64%	71%	66%	61%
Overweight and obesity prevalence (female) 2016	72%	75%	69%	73%	71%	66%
Type 2 diabetes prevalence (male) 2016	15%	15%	9%	13%	8%	7%
Type 2 diabetes prevalence (female) 2016	14%	15%	8%	13%	9%	8%

## 2. What Are the Main Challenges for the Arab Gulf States?

The Arab Gulf states share similar cultural, political, and geographical characteristics. They are all wealthy states with high standards of living (GDP for 2016 ranging from 32.179 billion for Bahrain to 646.438 billion for Saudi Arabia) [15] that have been particularly exposed to and influenced by the western way of life, including eating habits (fast food and processed food) and physical inactivity (ways of commuting, working environments, and types of work). A study showed that physical inactivity, for example, in Saudi Arabia is not related to sociocultural factors but rather to lack of facilities for women to practice sports [16]. On the contrary, the Arab Gulf states are also quite different in terms of size, population, and governance from a centralized system in Saudi Arabia, to a decentralized system in Oman, and to local governance, like a city state in all other Gulf states due to their small size and population.

It is very common that health promotion is seen/interpreted as awareness campaigns and that dietary choices as well as physical activity are purely individual choices. The dominant concept worldwide has been that of risk, and the individual is put in the position of personal responsibility to reduce this risk [13]; the Arab Gulf states are no exception to this interpretation. However, there are other wider social and environmental determinants for obesity such as marketing, taxes, pricing, and availability of healthy food, physical activity facilities, and cultural traditions. Only targeting individuals and neglecting these wider, social, and ecological determinants of behaviors and consumption is not sufficient to curb the obesity epidemic in the Arab Gulf states. This debate paper identifies central areas of challenges, including policies, intersectoral work, the role of primary healthcare, and lack of qualified staff, which all require further development in the Arab Gulf countries to curb the obesity epidemic. A more elaborate work on the strategies and policies of the Gulf states will be presented in a future book chapter [17].

**2.1. Policies.** Policies are an integral part of health promotion, and some policies relating to school environments [18], food labeling [19], and others are very important for

combating obesity. Evidence also exists that catering services in schools and workplaces contribute to healthy eating habits in the population [20]. Good examples of healthy meal policies implemented in schools and workplace canteens come from Sweden and Finland [9, 20, 21].

All Arab Gulf states have made some efforts with regard to prevention and health promotion policies and meant implementation such as (1) soft drink taxation adopted by Saudi Arabia [22] and United Arab Emirates [23], (2) banning soft drinks and junk food in hospitals in Qatar [24], (3) workplace health promotion in Qatar [25] and United Arab Emirates where it mostly focused on government entities [26], and (4) nutrition and/or physical activity at the school setting in Qatar [27], United Arab Emirates [28–30], Bahrain [31], and Oman [32]. Qatar and United Arab Emirates are the most advanced when it comes to developing and implementing policies at the school setting, e.g., when it comes to introducing physical education courses for all schools [33, 34].

However, most of the Arab Gulf countries lack important local policies in schools, for example, the availability of healthy food and beverages in school canteens, regular screening for obesity and overweight, and extracurricular activities. In addition to the above, work environment policies and food labeling policies are needed. Saudi Arabia showed an example by introducing a mandatory regulation to mark calories in all restaurant menus as of 2019 [35]. Food labeling both in restaurants and (packaged) food items for sale is urgently needed for the population to make informed food choices. Furthermore, the Arab Gulf countries could also establish a food database for the use of all citizens in line with the Finnish food database [36].

**2.2. Intersectoral Work.** Intersectoral work is the backbone of health promotion and for applying the principle of “Health in All Policies.” This strategy aims to include health considerations in policymaking across different sectors that influence health, such as transportation, agriculture, land use, housing, public safety, and education [37]. “Health in All Policies” is adopted in Nordic countries [9], in Australia [38], and in the Netherlands [39].

The approach “Health in All Policies” has been initiated in Oman [40], United Arab Emirates [41], and Qatar [42]



which has involved the collaboration of the Ministry of Education, Municipalities, academia, sports councils, etc. A clear example is the development of the National Healthcare Strategy 2011–2016 for Qatar as a common effort of many stakeholders (Ministry of Interior, Supreme Council for Family Affairs, and Permanent Population Committee) [42]. However, the Oman strategy is still in the implementation stage.

On the contrary, Saudi Arabia, Bahrain, and Kuwait do not show established intersectoral work. These countries often do not mention intersectoral work in their national healthcare strategies [43–45].

In light of the current situation of the Arab Gulf states, it is time for them to introduce the “Health in All Policies” approach to create dynamic interactions across different societal sectors and on different levels of the society (national, regional, and local) to create the infrastructures and environments which could enable healthy choices and an active lifestyle for citizens.

**2.3. Primary Healthcare.** Primary healthcare should be the main healthcare entry point for citizens and also a major actor in promoting health and evaluating the status of the population. Primary healthcare contributions have shown positive results in obesity reduction [46, 47], for example, Finland with its Health Care Act of 2010 that included health-promoting activities as part of primary healthcare purposes [48] and Canada with many examples of health promotion incorporated in primary healthcare [49].

Primary healthcare is not yet established as an entry point for all Arab Gulf states. In addition, in most of them, the primary healthcare centers do not even play a significant role in health promotion, and future plans for them in current healthcare reforms (all Arab Gulf states are going through them) do not suggest enhancing this role [43, 44]. Qatar is the only example that puts primary healthcare at the forefront of action for health promotion [25]. In Abu Dhabi, primary healthcare centers have facilitated the screening of the population for noncommunicable disease risk factors (Weqaya program) [50]; however, they do not have any further roles and tasks in health promotion.

Definitely, some of the Arab Gulf states such as Oman and Saudi Arabia have different priorities for primary healthcare since they strive to ensure basic services before even considering health-promoting activities [40, 43]. However, with the increasing obesity problem, the above argument is no longer sufficient for neglecting these services. There is a need for primary healthcare in both countries to increase awareness of structural health promotion, including disease prevention strategies, the policy level, and contextually salient and setting-based interventions.

**2.4. Qualified Personnel and the Specialization Issue.** Appropriate human resources are crucial in fulfilling tasks and functions related to health promotion in the primary care sector and in the health sector in general [13]. Examples of countries with highly qualified health promotion professionals are the USA [51] and Canada [52].

A common problem for all of the Arab Gulf states is the current limited number of specialized personnel in health promotion and health education especially for Saudi Arabia that needs to cover a big population (32,612,641 for 2017) [2]. In general, healthcare is lacking competent and qualified personnel that are nationals and sufficient in numbers to cover current needs. Such states majorly depend on foreign specialists for different areas. For example, Saudi Arabia requires foreign staff for all specializations in public health due to its size [53], whereas Kuwait is lacking professionals mostly for policy, strategy, and plan development as well as in the fields of nursing and dentistry [414]. Bahrain [54] and Oman [55] are exceptions in their capacity for public health professionals (such as nutritionists and health educators although not health promoters).

With regard to health education, there are some bachelor-level health education programs, e.g., in Saudi Arabia [56, 57], but there is a clear need for more focused and prioritized university departments/units/curricula for health promotion/health education at the national levels in the Arab Gulf States. One solution is to offer tailor-made professional level courses in evidence-based, multilevel, contextual health promotion interventions.

Training professionals will require time and resources but would be very important in building the needed competences and infrastructure for health promotion to comprehensively tackle the regional obesity challenge.

**2.5. National Programs and Action Plans.** National obesity programs with concrete action plans and follow-ups are needed.

A solid national strategy for nutrition/physical activity/health promotion with specific goals, targets, actors involved, procedures, implementation, and evaluation processes is needed to create changes in health promotion and obesity [14]. Examples of national programs related to obesity exist from different countries such as France [58] and UK [59].

All Arab Gulf states have developed at least one document on health promotion that focuses on nutrition and physical activity. However, with the exception of Qatar [41] and Abu Dhabi [50] that have several concrete strategy documents, all other countries only have issued documents that are limited with time-specific goals, ways of follow-up, tangible expected outcomes, specific procedures, etc. This makes the efforts of each country somehow arbitrary and not enough focused on specific actions/programs.

Implementation and evaluation are very important for health promotion strategies as they are for any strategy. The major problem in most cases in the Arab Gulf states is that the strategies are often not implemented or followed up, and also health educators and health promoters often are not at the backbone of these strategies. Due to these two factors, the strategies remain good intentions with little value even if they are well articulated and developed on paper. There is a need to establish an institutional system, which links intersectoral work, prioritizes tasks, and gives a framework for health promotion initiatives at different levels and the



possibility to develop standards for implementation and evaluation. For this kind of system to function cost-effectively, accountability must be assigned to certain actors.

The Arab Gulf states need to consider seriously the development of such programs and action plans with the support of policymakers, health promoters, and other professionals that are experts in different fields related to health. One way of addressing this challenge can be through providing more significant budgets for health promotion programs and employing experienced (foreign or local if available) professionals. In the same direction, it is important to strengthen the presence of health promotion departments that are often nonexistent and the presence of health promotion in departments of other ministries as a part of a "Health in All Policies" approach.

### 3. Conclusion

For the Arab Gulf states, the biggest challenges are as follows: (1) the development of substantial health promotion strategies, especially their implementation and evaluation and the administrative structure around health promotion, (2) the availability of national competent professionals for health promotion, and (3) the development of multilevel and intersectoral work and in general applying a "Health in All Policies" approach. These are important challenges that require serious consideration because they are at the root of developing a solid and consistent health promotion strategy to combat the challenges of obesity. Qatar and the United Arab Emirates provide examples of some efforts in that direction but need more focused and elaborate work and a more institutional system to create sustainability. On a final note, the Arab Gulf countries need to focus their efforts more towards these aspects of their health strategy or else will face the increasing costs of diabetes care and the increase of other chronic conditions related to obesity more and more in the coming years.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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## Research Article

# Regional Variation in Comorbid Prediabetes and Diabetes and Associated Factors among Hypertensive Individuals in Rural Bangladesh, Pakistan, and Sri Lanka

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We aimed to explore the cross-country variation in the prevalence of comorbid prediabetes or diabetes and determine the sociodemographic, lifestyle, and clinical factors, especially body mass index (BMI) and waist circumference, associated with comorbid diabetes in individuals with hypertension in rural South Asia. We analyzed cross-sectional data of 2426 hypertensive individuals of  $\geq 40$  years from 30 randomly selected rural communities in Bangladesh, Pakistan, and Sri Lanka. Prediabetes was defined as fasting plasma glucose (FPG) between 100 and 125 mg/dL without use of antidiabetic treatment and diabetes as FPG  $\geq 126$  mg/dL or use of antidiabetic medication. The prevalence (95% CI) of prediabetes or diabetes (53.5% (51.5%, 55.5%)) and diabetes (27.7% (25.9%, 29.5%)) was high in the overall hypertensive study population in rural communities in 3 countries. Rural communities in Sri Lanka had the highest crude prevalence of prediabetes or diabetes and diabetes (73.1% and 39.3%) with hypertension, followed by those in Bangladesh (47.4% and 23.1%) and Pakistan (39.2% and 20.5%). The factors independently associated with comorbid diabetes and hypertension were residing in rural communities in Sri Lanka, higher education, international wealth index, waist circumference, pulse pressure, triglyceride, and lower high-density lipoprotein. The association of diabetes with waist circumference was stronger than with BMI in hypertensive individuals. Prediabetes or diabetes are alarmingly common among adults with hypertension and vary among countries in rural South Asia. The high prevalence of comorbid diabetes in Sri Lanka among hypertensives is not fully explained by conventional risk factors and needs further etiological research. Urgent public health efforts are needed to integrate diabetes control within hypertension management programs in rural South Asia, including screening waist circumference.

## 1. Introduction

Diabetes is a major global public health concern and a common comorbidity in individuals with hypertension

[1, 2]. About 425 million people had diabetes worldwide in 2017, and this number is expected to increase to 629 million by 2045 [3]. The excess costs due to diabetes on healthcare systems alone are tremendous, primarily due to the grave



consequences of microvascular and macrovascular complications (e.g., blindness, cardiovascular disease, myocardial infarction, stroke, and kidney failure) [2, 3]. The International Diabetes Federation estimated the global health expenditure on diabetes was 850 billion in 2017 [3]. Of all the individuals with diabetes worldwide, approximately 80% live in low- and middle-income countries [3].

South Asian countries have an increasing burden of diabetes [1, 4], with the estimated number of diabetic patients increasing from 58.7 million in 2010 to 101 million in 2030 [1]. The International Diabetes Foundation estimated diabetes-related healthcare expenditure in 2017 to be approximately US \$9.5 billion in the South Asian region [3]. The rising burden could be related to increased life expectancy, rapid population growth, unplanned urbanization, and limited healthcare expenditure [5].

Studies in the West have consistently shown that type 2 diabetes is more common in South Asian immigrants than other ethnic groups [6–9]. Moreover, prediabetes tends to progress faster to diabetes in South Asians, at an earlier age than in Europeans [10]. Diabetes is also associated with greater risk of retinal and cerebral microvascular disease in South Asians than Europeans [11, 12]. The susceptibility of South Asians to dysglycemia has been shown to be apparent since early childhood and is associated with low birth weight and adverse in utero environment due to poor maternal nutrition, followed by excessive relative weight gain during childhood that persists into adulthood [13].

A high prevalence of diabetes has been reported in urban South Asia and has been associated with sedentary lifestyle and greater consumption of fast food rich in sugar and saturated fats associated with progressive social, cultural, and economic globalization [14, 15]. However, health systems are weaker, and complications from diabetes have worse outcomes in rural than in urban areas [16].

Diabetes frequently coexists with hypertension and reportedly affects 7.5% to 32% hypertensive individuals [17–23]. Studies of people with hypertension [19, 20, 23–26] identified similar risk factors for diabetes to those in general population [27, 28] such as demographical factors (older age and male gender), unhealthy life style (smoking and physical inactive), and clinical factors (overweight or central obesity and dyslipidemia). However, there is a dearth of studies comparing cross-country prevalence and determinants of diabetes among hypertensive individuals living in rural South Asia.

We analyzed baseline data from the ongoing COBRA-BPS (Control of Blood Pressure (BP) and Risk Attenuation-Bangladesh, Pakistan, and Sri Lanka) trial on 2426 hypertensive individuals, to examine the prevalence and cross-country differences in comorbid prediabetes and/or diabetes in hypertensive individuals in rural communities in 3 South Asian countries [29]. We aimed to determine whether the sociodemographic characteristics, lifestyle factors, obesity, and other clinical risk factors accounted for potential differences in prevalence of comorbid diabetes among individuals with hypertension in rural areas across the 3 South Asian countries. We also sought to determine whether central or generalized obesity was a stronger determinant of

comorbid diabetes and hypertension. As an ancillary aim, we compared the awareness and management of diabetes in the 3 countries.

We hypothesized that (1) the prevalence of comorbid prediabetes or diabetes is high and varies among hypertensive individuals in rural communities across the three South Asian countries; (2) the cross-country variation in comorbid diabetes and hypertension will only partially be accounted for by differences in sociodemographic, lifestyle, and cardiovascular risk factors; and (3) waist circumference will be more strongly associated with comorbid diabetes and hypertension compared to body mass index (BMI).

## 2. Methods

**2.1. Population.** The present study was performed using baseline data from COBRA-BPS full-scale study. The detailed information on the study has been described earlier [29]. Briefly, COBRA-BPS full-scale study is an ongoing two-year cluster randomized controlled trial among 2643 hypertensive adults from 30 randomly selected rural clusters (communities), 10 clusters each, in Bangladesh, Pakistan, and Sri Lanka. In each country, cluster selection was stratified by distance ( $\leq 2.5$  km for near and  $> 2.5$  for far) from the government primary care clinics, such that there were 6 near and 4 far clusters in each country. Individuals in each cluster were screened using door-to-door sampling method. The inclusion criteria for COBRA-BPS were age  $\geq 40$  years, hypertension (defined as sustained elevation of systolic blood pressure (SBP) to  $\geq 140$  mmHg, or diastolic blood pressure (DBP) to  $\geq 90$  mmHg based on two readings from 2 separate days, or receiving antihypertensive medications), and residents in the selected clusters. Individuals were excluded if they had severe physical incapacity, were pregnant, had advanced diseases (on dialysis, liver failure, and other systemic diseases), or were mentally comprised leading to incapability of giving consent.

Supplementary Figure S1 shows the study flow diagram. Of the 2977 hypertensive individuals from 30 randomly selected clusters in 3 countries, 2643 were enrolled in the clinical trial after excluding 334 individuals for various reasons (Supplementary Figure S1). Of the 2643 hypertensives recruited, 217 (9.3%) were excluded because they missed laboratory data on fasting blood glucose and were not on antidiabetic medication. The study protocol was approved by respective Ethical Review Committee in Singapore, Bangladesh, Pakistan, Sri Lanka, and UK. All study participants provided written informed consent.

**2.2. Measurements.** Self-reported sociodemographic and economic status (age, gender, education, marital status, international wealth index (IWI) [30]), lifestyle characteristics (smoking and physical activity), cardiovascular disease (CVD) (self-reported heart disease or stroke), and current medication use were obtained at the baseline visit. Physical activity was evaluated by the short version of the International Physical Activity Questionnaire (IPAQ) [31].

Framingham CVD risk score was computed, and  $\geq 20\%$  indicated a high global CVD risk at 10 years [32].

An overnight fasting blood sample was collected to measure lipids, serum creatinine, and plasma glucose (measured on Roche Hitachi-Cobas c311 in Bangladesh, Siemens ADVIA 1800 in Pakistan, and Beckman Coulter in Sri Lanka). Urine albumin and creatinine excretion were measured on spot urine samples by nephelometry using the array systems method on the same equipment as for blood tests in each country. All tests were done in an accredited laboratory in each country. Glomerular filtration rate (GFR) was estimated using the original Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [33]. Urine albumin and creatinine ratio (UACR) was determined by urine albumin divided by urine creatinine. Chronic kidney disease was defined as the presence of estimated glomerular filtration rate (eGFR)  $\leq 60$  ml/min/1.73 m<sup>2</sup> or UACR  $\geq 30$  mg/g.

On enrolment, participants' weight, height, waist circumference, and BP were measured. BMI was calculated as weight (in kilogram)/height (in meters<sup>2</sup>). BP was measured four times every 5 minutes of rest in sitting position using an Omron HEM-7300 digital monitor. The mean of last 2 readings was used in the analysis. Pulse pressure (PP) was calculated as the difference between SBP and DBP.

**2.3. Analysis Methods.** The main outcome was diabetes defined as a fasting plasma glucose (FPG)  $\geq 126$  mg/dL or self-reported use of antidiabetic medication. Prediabetes was defined as an FPG between 100 and 125 mg/dL and not on antidiabetic treatment.

Comparison of characteristics between hypertensive individuals with and without comorbid diabetes was performed using *t*-test for continuous variables and chi-square test for categorical variables. When continuous variables were not normally distributed, the Mann-Whitney *U* test was used. Age- and gender-standardized prevalence of comorbid prediabetes or diabetes with hypertension and only comorbid diabetes with hypertension was computed using direct standardization, with the standards being the age (grouped as 40~50, 50~60, 60~70, and  $\geq 70$  years) and gender distribution of the total population. In addition, we examined the distribution of central obesity (waist circumference:  $\geq 90$  cm for male and  $\geq 80$  cm for female) [34] and categorical BMI (grouped as underweight or normal ( $< 23.0$  kg/m<sup>2</sup>) vs. overweight or generalized obesity ( $\geq 23.0$  kg/m<sup>2</sup>)) [35] for hypertensive individuals with prediabetes or diabetes, and only diabetes.

We performed logistic regression analysis to evaluate the association between risk factors and comorbid diabetes in the entire sample of hypertensive individuals from 3 countries, allowing for within-cluster correlation. Covariates were chosen for the analysis if they were reported to be risk factors for diabetes in previous studies or were associated with diabetes based on standard logistic regression ignoring clustering effects. Covariates in the initial standard logistic regression model were country, socioeconomic variables (age, gender, education, marital status, and IWI), smoking,

physical activity, BMI, waist circumference, PP, high-density lipoprotein (HDL), and triglycerides. We used stepwise method to select covariates with a significant level of 0.15 for retaining variables and of 0.10 for removing a variable. Country, education level, IWI, waist circumference, PP, HDL, and triglyceride were selected. We also retained all the excluded variables for final analysis because they were found to be risk factors for diabetes in previous studies [20, 25, 27, 28, 36].

Four models were constructed with these covariates. In model 1, only country was included; in model 2, we further introduced socioeconomic variables (age, gender, education, marital status, and IWI) and BMI (grouped as  $< 18.5$ ,  $18.5\sim 23.0$ ,  $23.0\sim 27.5$ , and  $\geq 27.5$  kg/m<sup>2</sup>) [35]; model 3 further included waist circumference (grouped via gender-specific quartiles: for male  $\leq 82$ ,  $82\sim 91$ ,  $91\sim 98$ , and  $\geq 98$  cm and for female  $\leq 79$ ,  $79\sim 88$ ,  $88\sim 95$ , and  $\geq 95$  cm); and the final model was adjusted for the variables in model 3 plus smoking, physical activity (grouped via tertiles:  $< 1381$ ,  $1381\sim 5544$ , and  $\geq 5544$  MET-min/week), PP, HDL, and triglycerides. All the models included cluster-specific random intercepts to account for within-cluster correlation.

We also investigated two-way interactions of country and gender with other variables to assess the presence of country- or gender-specific effect, respectively. Significant interactions were interpreted by the ratio of odds ratios (ROR) [37] and subgroup analysis. Finally, we computed the proportion (95% CI) of diabetic individuals with hypertension who (1) were aware of their diabetes status defined as self-reported doctor diagnosis of diabetes, (2) controlled BP to conventional target of  $< 140/90$  mmHg, (3) were receiving statin therapy, and (4) were receiving antidiabetic medications (number and different classes). All analyses were conducted using SAS version 9.4, and all hypothesis testing was 2-tailed with  $P < 0.05$  set as statistically significant.

### 3. Results

**3.1. Characteristics of Participants.** Of all the 2643 individuals with hypertension, 2426 (91.8%) were included in the study. The mean age ( $\pm$ SD) of the participants was 58.8 ( $\pm 11.3$ ) years, the mean ( $\pm$ SD) BMI was 24.8 ( $\pm 5.0$ ) kg/m<sup>2</sup>, and the mean ( $\pm$ SD) waist circumference was 90.5 ( $\pm 12.7$ ) cm for male and 87.1 ( $\pm 12.9$ ) for female (Table 1).

Compared with hypertensive individuals without comorbid diabetes, those with comorbid diabetes were older, had a higher education and wealth index score, lower level of physical activity, and higher BMI, waist circumference, and PP, and were more likely to be from Sri Lanka. Comorbid diabetes was also positively associated with higher levels of triglyceride, CVD, CKD, and a CVD risk of 20% or above (Table 1). No significant association was found between comorbid diabetes and other variables.

Compared with individuals included in the analysis ( $n = 2426$ ), those excluded ( $n = 217$ ) were more likely from Pakistan, had lower education and lower proportion of married persons, and were at lower socioeconomic level and more often physically inactive (Supplementary Table S1).



TABLE 1: Comparison of baseline characteristics between hypertensive individuals with and without diabetes in rural areas in Bangladesh, Pakistan, and Sri Lanka ( $n = 2426$ ).

Variables	Total ( $n = 2426$ )	Without diabetes ( $n = 1753$ )	With diabetes ( $n = 673$ )	<i>P</i> value
Age (y), mean (SD)	58.8 (11.3)	58.4 (11.6)	59.9 (10.5)	0.003
Men, $n$ (%)	864 (35.6)	609 (34.7)	255 (37.9)	0.15
Formal education, $n$ (%) (vs. no formal)	1466 (60.4)	959 (54.7)	507 (75.3)	<0.001
Unmarried, $n$ (%) (vs. married)	638 (26.3)	468 (26.7)	170 (25.3)	0.47
International wealth index, mean (SD)	58.8 (21.0)	56.1 (21.2)	66.2 (18.4)	<0.001
Smoking, $n$ (%)	249 (10.3)	193 (11.0)	56 (8.3)	0.052
Physical activity (MET-min/week), $n$ (%)				0.001
<1381	791 (33.0)	558 (32.2)	233 (35.0)	
1381~5544	810 (33.8)	562 (32.4)	248 (37.3)	
≥5544	798 (33.3)	614 (35.4)	184 (27.7)	
BMI ( $\text{kg}/\text{m}^2$ ), mean (SD)	24.8 (5.0)	24.3 (5.1)	26.0 (4.7)	<0.001
BMI ( $\text{kg}/\text{m}^2$ ), $n$ (%)				<0.001
<18.5	214 (8.9)	194 (11.1)	20 (3.0)	
18.5~23	692 (28.8)	547 (31.3)	145 (22.1)	
23~27.5	890 (37.0)	617 (35.3)	273 (41.6)	
≥27.5	610 (25.4)	391 (22.4)	219 (33.3)	
Waist circumference <sup>†</sup> (cm), mean (SD)	88.3 (12.9)	86.5 (12.8)	93.2 (11.9)	<0.001
Waist circumference <sup>†</sup> (cm), $n$ (%)				<0.001
≤Q1	570 (23.5)	506 (28.9)	64 (9.6)	
Q1~Q2	611 (25.2)	460 (26.3)	151 (22.5)	
Q2~Q3	584 (24.1)	380 (21.7)	204 (30.5)	
≥Q3	657 (27.1)	406 (23.2)	251 (37.5)	
Systolic blood pressure (mmHg), mean (SD)	145.5 (21.6)	145.1 (21.9)	146.4 (20.9)	0.17
Diastolic blood pressure (mmHg), mean (SD)	88.2 (14.1)	88.5 (14.3)	87.5 (13.6)	0.09
Pulse pressure (mmHg), mean (SD)	57.2 (14.9)	56.6 (14.9)	59.0 (14.6)	<0.001
HDL (mg/dL), mean (SD)	45.2 (13.1)	45.4 (13.3)	44.8 (12.4)	0.38
Triglyceride (mg/dL), median (IQR)	129.4 (94, 183.1)	126.1 (90.7, 177.8)	139.3 (102.1, 202.7)	<0.001
Self-reported CVD, $n$ (%)	554 (23.4)	361 (21.1)	193 (29.1)	<0.001
CKD (stage 3 A1 or worse), $n$ (%)	899 (38.3)	567 (33.1)	332 (52.5)	<0.001
10-year Framingham CVD risk score 20% or more <sup>‡</sup> , $n$ (%)	1052 (44.0)	590 (33.7)	462 (72.1)	<0.001
Country, $n$ (%)				<0.001
Bangladesh	872 (35.9)	671 (38.3)	201 (29.9)	
Pakistan	740 (30.5)	588 (33.5)	152 (22.6)	
Sri Lanka	814 (33.6)	494 (28.2)	320 (47.6)	

The number of missing values were 8 for international wealth index, 1 for smoking, 27 for physical activities, 20 for BMI, 4 for waist circumference, 34 for HDL, 35 for triglyceride, 54 for self-reported CVD, 78 for CKD, and 35 for Framingham risk score. SD, standard deviation; Met, metabolic equivalent; BMI, body mass index; HDL, high-density lipoprotein; IQR, interquartile range; CVD, cardiovascular disease; CKD, chronic kidney disease. <sup>†</sup>Gender-specific quartiles were used: Q1, Q2, and Q3 were 79, 88, and 95 among female and 82, 91, and 98 among male. <sup>‡</sup>10-year Framingham CVD risk was estimated based on the sex-specific general CVD risk score sheets.

**3.2. Prevalence of Comorbid Prediabetes or Diabetes and Comorbid Diabetes with Hypertension Stratified by Country.** Table 2 summarizes the crude, and age- and gender-standardized prevalence (95% CI) of comorbid prediabetes or diabetes, and comorbid diabetes in the overall rural hypertensive sample and by each country. The crude prevalence (95% CI) of comorbid prediabetes or diabetes among hypertensive individuals was 73.1% (70.0%, 76.2%) in Sri Lanka, 47.4% (44.0%, 50.7%) in Bangladesh, and 39.2% (35.6%, 42.8%) in Pakistan.

Likewise, comorbid diabetes was the most prevalent among hypertensives in Sri Lanka (39.3% (35.9%, 42.7%)), followed by Bangladesh (23.1% (20.2%, 25.9%)), and then Pakistan (20.5% (17.6%, 23.5%)), with almost no change in prevalence after adjustment for confounding by age and gender.

Supplementary Tables S2 and S3 report baseline characteristics by country and by comorbid diabetes status in each country, respectively.

**3.3. BMI, Central Obesity, Comorbid Prediabetes or Diabetes and Hypertension.** Of all the hypertensive individuals with comorbid prediabetes or diabetes, 71.5% ( $n = 915$ ) were overweight or had generalized obesity; 75.8% ( $n = 981$ ) were centrally obese; and 65.1% ( $n = 833$ ) were both overweight/generalized obesity plus central obesity. Of all the hypertensive individuals with comorbid diabetes, 74.9% ( $n = 492$ ) were overweight or had generalized obesity; 82.4% ( $n = 552$ ) were centrally obese; and 70.3% ( $n = 462$ ) were both overweight/generalized obesity plus central obesity (data not shown in the table).

**3.4. Risk Factors for Comorbid Diabetes and Hypertension.** The factors associated with comorbid diabetes in multi-variable models are shown in Table 3. In model 1, compared with hypertensive individuals from rural areas in Pakistan, those from rural Bangladesh had similar odds of comorbid

TABLE 2: Overall and country-specific prevalence of diabetes and/or prediabetes among individuals with hypertension in rural communities in Bangladesh, Pakistan, and Sri Lanka ( $n = 2426$ ).

	Total ( $n = 2426$ )	Bangladesh ( $n = 872$ )	Pakistan ( $n = 740$ )	Sri Lanka ( $n = 814$ )
Prediabetes or diabetes				
Crude prevalence, $n$ (% , 95% CI)	1298 (53.5 (51.5, 55.5))	413 (47.4 (44.0, 50.7))	290 (39.2 (35.6, 42.8))	595 (73.1 (70.0, 76.2))
Age-standardized prevalence, % (95% CI)	—	47.4 (42.7, 52.1)	39.0 (34.4, 43.5)	72.3 (66.0, 78.6)
Age- and gender-standardized prevalence, % (95% CI)	—	47.7 (42.9, 52.5)	38.8 (34.3, 43.4)	72.2 (65.9, 78.6)
Prediabetes only				
Crude prevalence, $n$ (% , 95% CI)	625 (25.8 (24.0, 27.5))	212 (24.3 (21.4, 27.2))	138 (18.7 (15.8, 21.5))	275 (33.8 (30.5, 37.1))
Age-standardized prevalence, % (95% CI)	—	24.1 (20.7, 27.4)	18.5 (15.4, 21.6)	34.9 (30.3, 39.4)
Age- and gender-standardized prevalence, % (95% CI)	—	24.2 (20.8, 27.6)	18.7 (15.5, 21.8)	34.4 (29.9, 38.9)
Diabetes only				
Crude prevalence, $n$ (% , 95% CI)	673 (27.7 (25.9, 29.5))	201 (23.1 (20.2, 25.9))	152 (20.5 (17.6, 23.5))	320 (39.3 (35.9, 42.7))
Age-standardized prevalence, % (95% CI)	—	23.3 (20.0, 26.6)	20.5 (17.2, 23.8)	37.4 (33.0, 41.8)
Age- and gender-standardized prevalence, % (95% CI)	—	23.5 (20.2, 26.9)	20.2 (16.9, 23.4)	37.8 (33.3, 42.3)

95% CI, 95% confidence interval.

diabetes (OR = 1.16, 95% CI (0.84, 1.61)), while those from rural Sri Lanka had significantly greater odds of comorbid diabetes (OR = 2.55, 95% CI (1.86, 3.49)). Adjustment for sociodemographic and clinical factors in models 2, 3, and 4 did not alter the association.

BMI had a strong positive association with comorbid diabetes in model 2, but this association became non-significant with adjustment for waist circumference and other covariates in models 3 and 4.

Significant interactions were detected between country and marital status ( $P$  for interaction = 0.011), international wealth index ( $P$  for interaction = 0.038), and HDL ( $P$  interaction = 0.002), but no interaction with gender was significant. Table 4 presents the results of multivariate analysis stratified by countries. There was a protective effect of being unmarried (vs. married) on comorbid diabetes only among hypertensives in rural Pakistan (OR = 0.44, 95% CI (0.24, 0.82)) (Table 4). IWI had a stronger positive association with comorbid diabetes in Pakistan (ROR = 1.47, 95% (1.07, 2.01)) and Bangladesh (ROR = 1.36, 95% (0.99, 1.86)) than Sri Lanka (Supplementary Table S4), but no association in Sri Lanka (Table 4). The inverse association between HDL and comorbid diabetes was only observed in Sri Lanka (OR = 0.80, 95% CI (0.73, 0.88)) (Table 4).

**3.5. Awareness and Management of Comorbid Diabetes and Hypertension.** Of all the 673 individuals with comorbid diabetes in hypertension, 74.3% knew that they had diabetes. The rates of awareness of comorbid diabetes were comparable between Bangladesh (81.6%) and Sri Lanka (80.0%), being much higher than that of Pakistan (52.6%). Only 32.8% controlled their BP under 140/90 mmHg, and 23.8% were on statin (Supplementary Table S5). About 69% of all hypertensive individuals with comorbid diabetes were on glucose-lowering medication, with the lowest prevalence in

Pakistan (46%) (Supplementary Table S6). Overall, 48.7% of the hypertensive individuals with comorbid diabetes reported using biguanides, with 35.3% in Bangladesh, 32.2% in Pakistan, and 65% in Sri Lanka.

## 4. Discussion

Our analysis of data on 2426 hypertensive individuals from 30 randomly selected rural communities in Bangladesh, Pakistan, and Sri Lanka revealed a strikingly high prevalence of comorbid prediabetes or diabetes affecting 1 in 2 in hypertensive adults in 3 countries, and this was much higher in Sri Lanka (2 in 3 adults) than the other 2 countries. Similar cross-country variation was observed in the prevalence of comorbid diabetes with 1 in 4 hypertensive adults affected in all 3 countries and at least 1 in 3 in Sri Lanka. Formal education, higher IWI, higher waist circumference, elevated PP, increased levels of triglyceride, and residing in rural Sri Lanka (vs. in rural Pakistan), each, were significantly associated with higher odds of comorbid diabetes. Waist circumference was a stronger determinant of comorbid diabetes and hypertension than BMI. Higher HDL, by contrast, was associated with lower odds of comorbid diabetes and hypertension. These factors only partially explained the higher prevalence of comorbid diabetes among hypertensive individuals in rural Sri Lanka. Our findings of an alarmingly high prevalence of prediabetes and/or diabetes as a key comorbidity in individuals with hypertension call for integrating diabetes care with hypertension management program in rural areas in South Asia. Such efforts must be complemented with population-wide policy initiatives for reducing key risk factors especially obesity.

To our knowledge, this is the first report of cross-country comparison of prevalence of comorbid diabetes among rural

TABLE 3: Factors associated with diabetes among individuals with hypertension in rural communities in Bangladesh, Pakistan, and Sri Lanka.

	Model 1 ( <i>n</i> = 2426)		Model 2 ( <i>n</i> = 2398)		Model 3 ( <i>n</i> = 2398)		Model 4 ( <i>n</i> = 2350)	
	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value
Country		<0.001		0.15		0.067		<0.001
Pakistan	1.00		1.00		1.00		1.00	
Bangladesh	1.16 (0.84, 1.61)	0.35	1.12 (0.85, 1.48)	0.41	1.21 (0.91, 1.61)	0.19	1.18 (0.85, 1.62)	0.31
Sri Lanka	2.55 (1.86, 3.49)	<0.001	1.37 (0.99, 1.89)	0.057	1.48 (1.07, 2.06)	0.021	2.32 (1.57, 3.41)	<0.001
Age (y, per 5 y increase)	—	—	1.10 (1.05, 1.16)	<0.001	1.10 (1.04, 1.15)	<0.001	1.05 (0.99, 1.11)	0.090
Women (vs. men)	—	—	0.93 (0.74, 1.16)	0.53	0.93 (0.74, 1.17)	0.53	0.96 (0.74, 1.23)	0.73
Formal education (vs. no formal education)	—	—	1.47 (1.12, 1.92)	0.005	1.35 (1.03, 1.78)	0.028	1.35 (1.02, 1.78)	0.036
Unmarried (vs. married)	—	—	0.87 (0.67, 1.13)	0.28	0.87 (0.67, 1.13)	0.30	0.83 (0.63, 1.08)	0.17
International wealth index (per SD increase)	—	—	1.32 (1.17, 1.50)	<0.001	1.30 (1.15, 1.47)	<0.001	1.30 (1.14, 1.48)	<0.001
BMI (kg/m <sup>2</sup> )	—	—		<0.001		0.55		0.84
<18.5			1.00		1.00		1.00	
18.5~23			2.29 (1.37, 3.85)	0.002	1.49 (0.86, 2.58)	0.16	1.29 (0.74, 2.26)	0.37
23~27.5			3.75 (2.25, 6.23)	<0.001	1.47 (0.81, 2.67)	0.20	1.27 (0.69, 2.33)	0.44
≥27.5			4.78 (2.84, 8.07)	<0.001	1.53 (0.81, 2.91)	0.19	1.31 (0.68, 2.52)	0.42
Waist circumference <sup>†</sup> (cm)	—	—	—	—		<0.001		<0.001
<Q1			—	—	1.00		1.00	
Q1~Q2			—	—	2.14 (1.47, 3.12)	<0.001	1.97 (1.34, 2.90)	<0.001
Q2~Q3			—	—	3.45 (2.29, 5.20)	<0.001	3.01 (1.97, 4.59)	<0.001
≥Q3			—	—	3.76 (2.40, 5.89)	<0.001	3.47 (2.18, 5.51)	<0.001
Smoking (vs. no smoking)	—	—	—	—	—	—	0.78 (0.53, 1.13)	0.19
Physical activity (MET-min/week)	—	—	—	—	—	—		0.096
<1381			—	—	—	—	1.00	
1381–5544			—	—	—	—	1.03 (0.80, 1.32)	0.82
≥5544			—	—	—	—	0.79 (0.61, 1.03)	0.083
Pulse pressure (mmHg, per 5 mmHg increase)	—	—	—	—	—	—	1.07 (1.03, 1.11)	<0.001
HDL (mg/dL, per 5 mg/dL increase)	—	—	—	—	—	—	0.90 (0.86, 0.96)	<0.001
Triglyceride (mg/dL, per 5 mg/dL increase)	—	—	—	—	—	—	1.01 (1.01, 1.02)	<0.001

OR, odds ratio; 95% CI, 95% confidence interval; SD, standard deviation; MET, metabolic equivalent task; BMI, body mass index; HDL, high-density lipoprotein. No interaction terms were included in the model. *P* trend for BMI was 0.68 and for waist circumference was <0.001 in model 4. <sup>†</sup>Gender-specific quartiles were used: Q1, Q2, and Q3 were 79, 88, and 95 among female and 82, 91, and 98 among male.

community dwellers with hypertension in South Asian countries using a common protocol. We found that adults with hypertension in rural Sri Lanka were older, better educated, more centrally obese and less physically active, had higher socioeconomic status, and higher pulse pressure compared to those in rural Pakistan or Bangladesh (Supplementary Table S2). However, these risk factors could not account for the higher prevalence of comorbid diabetes

among hypertensives in rural Sri Lanka compared to Pakistan or Bangladesh. An earlier study of urban hypertensive Pakistanis has shown that 27.6% had comorbid diabetes, which is higher than our finding of rural hypertensive Pakistanis (20.5%) and parallels that of all the three countries combined (28%) [18]. Ethnic differences in diabetes prevalence have previously been suggested among South Asian countries [9, 38–42]. Earlier studies of

TABLE 4: Factors associated with diabetes among individuals with hypertension in rural communities in Bangladesh, Pakistan, and Sri Lanka.

	Bangladesh ( <i>n</i> = 866)		Pakistan ( <i>n</i> = 706)		Sri Lanka ( <i>n</i> = 778)	
	OR (95% CI)	<i>P</i> Value	OR (95% CI)	<i>P</i> Value	OR (95% CI)	<i>P</i> Value
Age (y, per 5 y increase)	1.10 (0.99, 1.21)	0.077	0.98 (0.88, 1.11)	0.78	1.04 (0.94, 1.15)	0.43
Women (vs. men)	1.26 (0.76, 2.10)	0.37	0.67 (0.40, 1.12)	0.13	0.86 (0.57, 1.28)	0.45
Formal education (vs. no formal education)	1.15 (0.76, 1.72)	0.51	1.02 (0.61, 1.73)	0.93	3.72 (1.18, 11.77)	0.026
Unmarried (vs. married)	1.19 (0.71, 2.01)	0.50	0.44 (0.24, 0.82)	0.010	0.86 (0.57, 1.29)	0.47
International wealth index (per SD increase)	1.42 (1.10, 1.84)	0.008	1.64 (1.27, 2.12)	<0.001	1.03 (0.83, 1.28)	0.76
Smoking (vs. no smoking)	0.86 (0.44, 1.71)	0.67	1.02 (0.56, 1.87)	0.94	0.65 (0.29, 1.43)	0.28
Physical activity (MET-min/week)		0.81		0.30		0.043
<1381	1.00		1.00		1.00	
1381~5544	1.10 (0.70, 1.75)	0.68	0.68 (0.39, 1.18)	0.17	1.08 (0.73, 1.60)	0.70
≥5544	0.96 (0.57, 1.63)	0.88	0.74 (0.45, 1.23)	0.24	0.67 (0.44, 1.01)	0.056
BMI (kg/m <sup>2</sup> )		0.82		0.99		0.63
<18.5	1.00		1.00		1.00	
18.5~23	1.50 (0.39, 5.75)	0.55	1.16 (0.40, 3.34)	0.78	1.49 (0.65, 3.45)	0.34
23~27.5	1.69 (0.41, 7.05)	0.47	1.08 (0.35, 3.34)	0.89	1.18 (0.47, 2.98)	0.72
≥27.5	1.42 (0.31, 6.59)	0.65	1.07 (0.33, 3.50)	0.91	1.29 (0.48, 3.52)	0.61
Waist circumference <sup>†</sup> (cm)		0.002		0.019		0.038
<Q1	1.00		1.00		1.00	
Q1~Q2	2.50 (1.21, 5.14)	0.014	1.81 (0.72, 4.54)	0.21	1.81 (1.01, 3.25)	0.048
Q2~Q3	4.60 (2.03, 10.42)	<0.001	3.54 (1.38, 9.08)	0.009	2.38 (1.25, 4.52)	0.009
≥Q3	6.01 (2.35, 15.43)	<0.001	3.87 (1.46, 10.26)	0.007	2.72 (1.36, 5.43)	0.005
Pulse pressure (mmHg, per 5 mmHg increase)	1.06 (0.98, 1.14)	0.15	1.16 (1.07, 1.26)	<0.001	1.05 (0.99, 1.11)	0.090
HDL (mg/dL, per 5 mg/dL increase)	1.01 (0.91, 1.12)	0.85	0.91 (0.81, 1.01)	0.088	0.80 (0.73, 0.88)	<0.001
Triglyceride (mg/dL, per 5 mg/dL increase)	1.02 (1.01, 1.03)	0.001	1.01 (1.00, 1.02)	0.011	1.01 (1.00, 1.02)	0.077

OR, odds ratio; 95% CI, 95% confidence interval; SD, standard deviation; MET, metabolic equivalent task; BMI, body mass index; HDL, high-density lipoprotein. Adjusted ORs were reported based on the final model (model 4) in Table 3. *P* trend was 0.99 and <0.001 for BMI and waist circumference in Bangladesh, respectively; *P* trend was 0.95 and 0.005 for BMI and waist circumference in Pakistan, respectively; and *P* trend was 0.99 and 0.007 for BMI and waist circumference in Sri Lanka, respectively. <sup>†</sup>Gender-specific quartiles were used: Q1, Q2, and Q3 were 79, 88, and 95 among female and 82, 91, and 98 among male.

nationally representative samples of the general population have found the prevalence of diabetes was 10.3% among Sri Lankans [38], 9.7% among Bangladeshis [39], and 5.4% among Pakistanis [40], respectively. Using cross-sectional data of 1,122,771 immigrants aged ≥20 years from South Asia living in Canada, a higher age- and gender-standardized prevalence of diabetes has been reported in the diaspora from Sri Lanka than those from Pakistan and India [41]. In another study of 16,288 individuals aged 20 and above, higher prevalence of diabetes and prediabetes was reported in Chennai (22.8% and 37.9%, respectively) and Delhi (25.2% and 47.6%) than in Karachi (16.3% and 31.1%) [42]. A more recent study of 431,765 migrant South Asians in Canada reported that the diabetes prevalence was the highest in Sri Lankan immigrants (26.8%), followed by those from Bangladesh (22.2%) and Pakistan (19.6%) [9]. It is likely that some other unmeasured risk factors could explain the higher prevalence of comorbid diabetes among hypertensives in Sri Lanka. Decades of conflict from the civil war ending in 2009 has been shown to have an emotional and psychological impact with high rates of anxiety and depression in individuals in Sri Lanka [43]. Epidemiological studies have implicated psychological stresses such as depression and early-life adversity as risk factors for diabetes [44]. Psychological stress may affect the development of diabetes through the release of catecholamines and glucocorticoids such as cortisol, resulting in increased hepatic glucose output, decreased insulin secretion and sensitivity,

central accumulation of body fat, and inflammation, as well as through its adverse effects on behaviors including diet, physical activity, and adherence to medication [44, 45]. The observed difference could also result from differential distribution of other unmeasured factors such as inflammatory markers [46], unhealthy diet [28], family history of diabetes [27], organochlorine pesticide [47], or their interaction in this ethnic group. More etiological research is needed in Sri Lanka to understand the higher risk of comorbid diabetes in the population with hypertension. Nevertheless, our findings of an alarmingly high prevalence of comorbid diabetes (at least 1 in 4) in individuals with hypertension in communities in rural South Asia underscore the need for screening all adults with hypertension for diabetes and management of the latter in the primary care settings.

It is worth noting that central obesity (waist circumference) was a stronger determinant of comorbid diabetes than overweight/generalized obesity (BMI) in the overall population from 3 countries. Previous studies of hypertensive Chinese have shown that both BMI and waist circumference were correlates of diabetes with comparable strength of association [19, 23], but others reported similar results to ours [48, 49]. Notwithstanding the cross-sectional study design, our findings suggest the independent role of central obesity in diabetes development. BMI reflects total body mass, and waist circumference reflects abdominal obesity, largely a reflection of visceral fat. Abdominal adipose tissue has been shown to be metabolically active



especially when oxygenation patterns are dysfunctional leading to pathogenesis of insulin resistance, and glucose intolerance, which is associated with adverse cardiovascular risk profile [50–52]. For a given BMI, South Asians have higher amounts of abdominal adipose and are more insulin resistant than Caucasians [53, 54]. Our findings underscore the importance of including waist circumference as a risk marker for diabetes perhaps even preferentially than BMI in community screening programs in South Asian populations.

Our findings of the association between high triglycerides and comorbid diabetes are also consistent with evidence in other populations [26]. Recent post hoc analysis of the Diabetes Prevention Program suggested benefit of lowering triglyceride on reducing new-onset diabetes [55]. It is interesting to note that comorbid diabetes was more prevalent in individuals in the higher IWI strata. However, higher prevalence of diabetes in higher socioeconomic status has also been reported in previous studies in the region [56]. At the same time, it is important to highlight that even the higher socioeconomic strata households in these rural communities have low international purchasing power parity [57]. Thus, financial access to quality treatment is limited, and adverse outcomes of diabetes have been shown to be prevalent across all socioeconomic strata in South Asia.

BP control and lipid-lowering are key for preventing diabetes-related vascular complications [58, 59]. We found that the vast majority of hypertensive adults with diabetes had poor BP control (67%) using the conventional target of <140/90 mmHg. The American Diabetes Association (ADA) 2016 Standards of Medical Care in Diabetes Standards and the National Institute for Health and Care Excellence (NICE) guidelines recommend biguanides as first-line glucose-lowering drug for all individuals with type 2 diabetes needing drug therapy [60, 61], and statins for all patients aged  $\geq 40$  years with diabetes [61, 62]. However, we observed that biguanides and statins were underprescribed in all three countries, especially in Bangladesh and Pakistan. Our findings underscore the urgent need for comprehensive diabetes management program for all rural communities in Sri Lanka, Bangladesh, Pakistan, and other South Asian countries.

The major strengths of our study are that we used a uniform study design, door-to-door sampling of individuals, random selection of clusters, consistent definition of variables and outcomes, and standardized study procedures in all 3 countries. There are several limitations. First, our study is a cross-sectional study, precluding any cause-effect relationship inference between risk factors and comorbid diabetes. However, cross-sectional design is appropriate for determining cross-country variation in prevalence of comorbid diabetes and potential factors associated with the variation which was our main objective. Second, we defined diabetes using FBG only and did not complement with oral glucose test or HbA1c test, possibly underestimating diabetes prevalence in our sample. However, venous FBG is considered acceptable for diagnosis of diabetes in epidemiological studies [39]. Third, information on some important factors such as family history of diabetes, psychological stress, and exposure to pesticide was not

collected in the study. These and other unmeasured factors need to be evaluated in future studies. Fourth, chemistry analyzers and reagents used for our laboratory tests were different between the laboratories from each country. However, all laboratories were accredited to international standards (CAP accreditation for the laboratories in Bangladesh and Pakistan, and Bio-Rad for Sri Lanka), minimizing the cross-lab variation in these tests. Finally, our sample consisted of hypertensive participants aged  $\geq 40$  years sampled in a certain geographic location in each country. Regional differences in the prevalence of diabetes have been observed within a country in South Asia [4, 63, 64]. Therefore, the findings may not be generalizable to all the rural population, especially those free of hypertension or younger than 40 years in each country. However, the 30 clusters were randomly selected and were at least 7 km apart and stratified by distance from government clinic in each country ensuring a fair representation of varying access to healthcare and minimizing selection bias. Thus, we believe our findings are robust and generalizable to the regions where our study was conducted.

In conclusion, the prevalence of comorbid diabetes and prediabetes was alarmingly high among individuals with hypertension in rural communities in Bangladesh, Pakistan, and Sri Lanka. Formal education, higher IWI, higher waist circumference, elevated PP, increased levels of triglyceride, and lower HDL, each, were significantly associated with higher odds of comorbid diabetes. In addition, the higher prevalence of comorbid diabetes among hypertensives in rural Sri Lanka (compared to Pakistan) could not be explained by socioeconomic factors, lifestyle behaviors, or cardiovascular risk factors. Waist circumference was a stronger risk factor for comorbid diabetes than BMI. Moreover, lack of awareness of comorbid diabetes, poor BP control, and underprescription of statins and biguanides were common in all three countries. Further research is necessary to explore reasons for variation in the prevalence of comorbid diabetes across the countries, especially the high prevalence in rural Sri Lanka. Concerted efforts are needed to develop and implement effective and customized public health programs for prevention and management of comorbid diabetes integrated with hypertension care in rural South Asia.

## Data Availability

The data will be available to the public upon the approval of Trial Steering Committee for COBRA-BPS full-scale study.

## Conflicts of Interest

No potential conflicts of interest relevant to this article were reported.

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## Supplementary Materials

Table S1: comparison of baseline characteristics between hypertensive individuals included and excluded from the data analysis. Table S2: baseline characteristics of individuals with hypertension stratified by three countries ( $n = 2426$ ). Table S3: comparison of baseline characteristics between hypertensive individuals with and without diabetes in rural areas in Bangladesh ( $n = 872$ ), Pakistan ( $n = 740$ ), and Sri Lanka ( $n = 814$ ). Table S4: ratio of odds ratios (RORs) between countries for variables that had significant interactions with country. Table S5: management of diabetes among hypertensive individuals with diabetes ( $n = 673$ ). Table S6: use of glucose-lowering medications by hypertensive individuals with diabetes in rural communities in Bangladesh, Pakistan, and Sri Lanka ( $n = 673$ ). Figure S1: study flow chart of hypertensive individuals included in the study on prediabetes and diabetes. (Supplementary Materials)

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## Research Article

# Quality of Life in Yoga Experienced and Yoga Naïve Asian Indian Adults with Obesity

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**Background.** Obesity adversely affects quality of life which then acts as a barrier to weight loss and weight loss maintenance. Hence, those interventions which positively influence the quality of life along with weight reduction are considered useful for sustained weight loss in persons with obesity. An earlier study showed better quality of life in obese adults who had experience of yoga compared to yoga naïve obese adults. However, the main limitation of the study was the small sample size ( $n = 20$  in each group). **Objective.** The present study aimed to determine whether with larger sample sizes the quality of life would differ in yoga experienced compared to yoga naïve adults with obesity. **Methods.** There were 596 Asian Indian obese adults (age range 20 to 59 years; group mean age  $\pm$  SD;  $43.9 \pm 9.9$  years): of whom (i) 298 were yoga experienced (154 females; group mean age  $\pm$  SD;  $44.0 \pm 9.8$  years) with a minimum of 1 month of experience in yoga practice and (ii) 298 were yoga naïve (154 females; group mean age  $\pm$  SD;  $43.8 \pm 10.0$  years). All the participants were assessed for quality of life using the Moorehead–Ardelt quality of life questionnaire II. Data were drawn from a larger nationwide trial which assessed the effects of yoga compared to nutritional advice on obesity over a one-year follow-up period (CTRI/2018/05/014077). **Results.** There were higher participant-reported outcomes for four out of six aspects of quality of life in the yoga experienced compared to the yoga naïve ( $p < 0.008$ , based on  $t$  values of the least squares linear regression analyses, Bonferroni adjusted, and adjusted for age, gender, and BMI as covariates). These were enjoyment in physical activities, ability to work, self-esteem, and social satisfaction. **Conclusion.** Obese adults with yoga experience appear to have better quality of life in specific aspects, compared to yoga naïve persons with a comparable degree of obesity.

## 1. Introduction

As of June 2017, the Asia Pacific region had the largest absolute number of overweight and obese people equivalent to one billion [1]. In these regions, two out of every five adults are either overweight or obese [1]. Various aspects of quality of life are impaired in persons with obesity; these include low self-esteem, impaired psychosocial functions, disability, reduced physical activity, and sexual dysfunction [2–7]. It has been reported that the quality of life improves after intentional weight loss in persons with obesity [8, 9].

However, this is not always the case. For example, weight loss through severe calorie restriction, use of laxatives, diuretics, and excessive exercise is associated with decreased

health-related quality of life in persons with obesity [10–12]. Hence, those interventions which could positively influence health-related quality of life and measures of obesity (e.g., a reduction in BMI and waist circumference) are considered clinically useful for persons with obesity [13]. Examples of clinically useful interventions include increased physical activity and a healthy diet [13]. However, it is known that obese persons experience several challenges in initiating and adhering to increased physical activity [14, 15]. Therefore, pragmatic interventions which increase the level of physical activity and are easy to follow have been recommended for sustained weight loss in obese persons [13].

Yoga is one such intervention with studies reporting long-term adherence and benefits in various health

conditions including obesity [16, 17]. Effects of yoga on the quality of life were seen in a single-arm interventional study on 279 overweight and obese Asian Indian persons of both sexes aged between 20 and 60 years who showed a significant improvement in physical, psychological, and environmental domains of the quality of life based on the World Health Organization Quality of Life Instruments (WHOQOL-BREF) questionnaire, after 10 days of a yoga-based lifestyle intervention [18].

Apart from this, in a cross-sectional study, twenty obese Asian Indian obese adults of both sexes who had experience of yoga were compared with an equal number of yoga naïve obese persons of both sexes for six domains of quality of life in the Moorehead–Ardelt quality of life questionnaire II (i.e., enjoying physical activities, ability to work, self-esteem, social satisfaction, sexual pleasure, and approach towards food) and overall quality of life [19]. The yoga group showed significant improvements in three of the six domains (i.e., enjoying physical activities, ability to work, and self-esteem) and overall quality of life compared to the yoga naïve group. The main limitation of the study [19] was the small sample size ( $n = 20$ ; in each group).

Hence, the present cross-sectional study was planned primarily to compare the overall quality of life using the Moorehead–Ardelt quality of life questionnaire II in a larger sample of Asian Indian obese persons ( $n = 596$ ), of both sexes, of whom 298 had experience in practicing yoga, whereas 298 were yoga naïve. The secondary aim of the study was to compare the six different subdomains (i.e., general self-esteem, enjoyment in physical activities, satisfactory social contacts, satisfaction concerning work, sexual pleasure, and focus on eating behavior) of the Moorehead–Ardelt quality of life questionnaire II in the same sample of yoga experienced and yoga naïve obese adults ( $n = 596$ ).

## 2. Materials and Methods

**2.1. Study Design.** The present data were taken as part of a larger trial conducted across India to compare the effects of yoga with nutritional advice over a one-year follow-up period (CTRI/2018/05/014077). At the time of recruitment in 55 centers across India, participants were asked whether they had prior experience of yoga practice or not, as only yoga naïve persons who did not plan to adopt any other physical activity regimen were included in the larger trial. The present data were collected during the recruitment of participants for the larger trial, for which data analysis is still on-going.

The present study was a secondary analysis of data collected for screening eligibility criteria of an interventional trial designed to assess the effects of yoga and nutritional advice on obese adults. The screening for the interventional trial was done in two phases.

**Phase 1:** the participants were assessed for anthropometry (i.e., weight and height using standard methods) to determine their body mass index (BMI). Those with  $\text{BMI} \geq 25 \text{ kg/m}^2$  were considered for the second phase.

**Phase 2:** In this phase, the participants were screened for the following: (i) any metabolic abnormality

(e.g., hypothyroidism), (ii) obesity secondary to hormonal imbalance, secondary to medications such as steroids, or secondary to any other medical conditions, and (iii) any psychiatric illness (e.g., depression). At this stage, all the participants gave their signed informed consent to be included in the trial, and if they did not meet the criteria, their consent included using their data for research. All of them provided their sociodemographic details and filled in the Moorehead–Ardelt Quality of life questionnaire II at this stage. The sociodemographic form included their name, age, gender, occupation, years of education, and other details. Participants were asked a single question about yoga practice, viz., “Do you practice yoga? If “yes,” please mention the duration in months” (where yoga meant yoga postures (*asanas*), yoga breathing (*pranayamas*), and/or yoga meditation (*dhyana*)). Based on this response, the participants were categorized as yoga experienced or yoga naïve. Equal numbers of yoga experienced and yoga naïve participants were selected for comparison from the larger data set. The person who selected the participants had no access to the quality of life scores data, and hence, the selector was blinded to these scores but matched participants of both groups for their age, gender, and body mass index (BMI).

**2.2. Participants.** There were five hundred and ninety-six obese adults (age range between 20 and 59 years; group mean age  $\pm$  SD;  $43.9 \pm 9.9$  years): of whom 298 were yoga experienced (154 females; with group mean age  $\pm$  SD;  $44.0 \pm 9.8$  years) with a minimum of 1 month of experience in yoga practice, an mean of  $3.2 \pm 4.7$  years, and a range of experience from 1 to 480 months. The remaining 298 obese adults (154 females; group mean age  $\pm$  SD;  $43.8 \pm 10.0$  years) did not have any prior experience in yoga practice and were described as yoga naïve. In the present study, a priori calculation of the sample size was not done. However, the *post hoc* analyses showed that, for the present study, with the sample size of 298 in each group and Cohen’s  $d$  of 0.40 calculated from the mean and SD of the overall quality of life score, the power was 0.998201. Inclusion criteria were as follows: (i)  $\text{BMI} \geq 25 \text{ kg/m}^2$  [20] and (ii) age range between 20 and 59 years. Exclusion criteria were as follows: (i) any metabolic abnormalities (e.g., hypothyroidism), (ii) obesity secondary to hormonal imbalance, medication such as steroids or secondary to any other medical condition, (iii) any psychiatric illness (e.g., depression), and (iv) incompletely filled in Moorehead–Ardelt quality of life questionnaires II. None of the participants had to be excluded for these reasons. The study had the approval of the institution’s ethical committee (Approval number YRD-017/022).

### 2.3. Assessment

**2.3.1. Quality of Life.** The quality of life was assessed using the Moorehead–Ardelt quality of life questionnaire II [21]. The questionnaire has been used to assess the quality of life in overweight and obese persons in India [16, 19], where the present study was carried out. In addition, the questionnaire



is not culture sensitive [22] and has been used in different countries to assess the quality of life in obese persons [22, 23]. The questionnaire is designed to assess different aspects of quality of life such as general self-esteem, enjoyment in physical activities, satisfactory social contacts, satisfaction concerning work, sexual pleasure, and focus on eating behavior, on an equally weighted 10-point Likert scale with scores ranging from  $-0.5$  to  $+0.5$  [21]. The sum of these 6 scores provides an overall quality of life score. In the present study, English version of the questionnaire was used. However, for those who were not able to understand English, the questionnaire was translated in the local language, i.e., Hindi, by two language experts as follows: two independent bilingual experts translated the questionnaire from English to Hindi. Discrepancies between the two translators were discussed and resolved by the translators. After this, Hindi version was back translated to English by two independent translators to ensure the accuracy of the translation. Unclear wordings or any misunderstandings were again resolved by mutual discussion.

**2.4. Statistical Methods.** The analyses of the data were carried out using PASW (Version 18.0, SPSS Inc). Three types of analyses were performed which are mentioned below.

**2.4.1. Q-Q (Quantile-Quantile) Plots for Normal Distribution.** The data (overall quality of life scores and six subdomains) were tested for normal distribution using Q-Q plots.

**2.4.2. Chi-Square Test.** Ages and BMI values of the two groups were compared using the chi-square test.

**2.4.3. Regression Analysis**

**(1) Groups, Quality of Life Scores, and Three Covariates.** The data of the two groups (i.e., yoga and yoga naïve groups) were compared using the least squares regression analysis adjusted for three covariates, i.e., age, gender, and BMI. These covariates were selected based on the outcomes of the earlier studies [24–26]. Separate linear regression models were used to compare the two groups for (i) overall quality of life and (ii) the six subdomains of the quality of life (i.e., enjoying physical activities, ability to work, self-esteem, social satisfaction, sexual pleasure, and focus on eating behavior). In each model, scores of either overall quality of life or one of the six subdomains of the quality of life acted as the dependent variable. Statistical significance ( $\alpha$ ) and confidence interval (CI) were Bonferroni adjusted and set at 0.008 and 99.2 percent, respectively, when analyzing the six subdomains of the Moorhead–Ardelt Quality of Life Questionnaire II.

**(2) Yoga Experience in Months, Overall Quality of Life Scores, and Three Covariates.** The association between duration of yoga experience in months with overall quality of life scores was evaluated using least squares regression analysis adjusted for three covariates, i.e., age, gender, and BMI.

### 3. Results

The details of baseline characteristics of both groups are mentioned in Table 1.

**3.1. Q-Q (Quantile-Quantile) Plots for Normal Distribution.** Visual inspection of the Q-Q plots showed that data were not normally distributed. However, the parametric test (least squares regression) was used to compare the data of the two groups as parametric tests are considered robust enough for a large sample size [27].

**3.2. Chi-Square Test.** At baseline, there were no statistically significant differences between the yoga ( $n = 298$ ) and yoga naïve ( $n = 298$ ) groups, for the following variables: (i) age ( $\chi^2 = 0.02$ ,  $p = 0.99$ ) and (ii) BMI ( $\chi^2 = 1.54$ ,  $p = 0.21$ ).

**3.3. Regression Analysis**

**3.3.1. Groups, Quality of Life Scores, and Three Covariates.** Least squares regression analysis adjusted for three covariates (i.e., age, gender, and BMI) showed that there was a statistically significant difference between the groups for overall quality of life ( $t = 4.825$ ,  $p < 0.001$ ) (Figure 1). Also, the least squares regression analyses adjusted for the three covariates showed a statistically significant difference between the groups for (i) enjoying physical activities ( $t = 4.172$ ,  $p < 0.001$ ), (ii) ability to work ( $t = 4.465$ ,  $p < 0.001$ ), (iii) self-esteem ( $t = 2.976$ ,  $p = 0.003$ ), and (iv) social satisfaction ( $t = 3.295$ ,  $p = 0.001$ ). The details of the analyses are provided in Table 2. Also, the group mean values  $\pm$  SD scores along with Cohen's  $d$  (an effect size used to indicate the standardized difference between two means) of quality of life for both groups are given in Table 3.

**3.3.2. Yoga Experience in Months, Overall Quality of Life Scores, and Three Covariates.** Least squares regression analysis adjusted for three covariates (i.e., age, gender, and BMI) showed no statistically significant association ( $F = 4.965$ ,  $df = 4, 293$ , adjusted  $R^2 = 0.05$ ) of yoga experience in months with overall quality of life scores ( $\beta = -0.075$ ,  $p = 0.202$ ).

### 4. Discussion

Higher participant-reported outcomes were found in the overall quality of life and in four subdomains of quality of life in persons with obesity who had experience in yoga compared to obese persons who were yoga naïve. These subdomains of quality of life were enjoyment in physical activities, ability to work, self-esteem, and social satisfaction.

The overall quality of life was significantly better in yoga experienced obese persons compared to the yoga naïve. The magnitude of difference between the two groups based on Cohen's  $d$  was 0.40, which is considered as average [28]. Given that four out of six subdomains of the Moorehead–



TABLE 1: Baseline characteristic profile of participants: yoga experienced and yoga naïve group.

Characteristics of participants	Yoga group	Yoga naïve group
Number ( <i>n</i> )	298	298
Age (years): mean $\pm$ SD	44.0 $\pm$ 9.8	43.8 $\pm$ 10.0
20 to 30 years, <i>n</i> (%)	35 (11.7)	34 (11.4)
31 to 50 years, <i>n</i> (%)	175 (58.7)	175 (58.7)
51 to 59 years, <i>n</i> (%)	88 (29.5)	89 (29.9)
Age range (years)	20–59	20–59
BMI (kg/m <sup>2</sup> ): mean $\pm$ SD	32.1 $\pm$ 4.5	32.3 $\pm$ 4.5
25.0 to 32.4 kg/m <sup>2</sup> : <i>n</i> (%)	178 (59.7)	163 (54.7)
$\geq 32.5$ kg/m <sup>2</sup> : <i>n</i> (%)	120 (40.3)	135 (45.3)
Gender		
Male : female	144 : 154	144 : 154
Percentage values	48.3 : 51.7	48.3 : 51.7
Years of education: <i>n</i> (%)		
<10 years	50 (16.8)	78 (26.2)
10–12 years	43 (14.4)	41 (13.8)
>12 years	205 (68.8)	179 (60.0)
Marital status: <i>n</i> (%)		
Married	264 (88.6)	262 (87.9)
Unmarried	29 (9.7)	23 (7.7)
Widow/widower	3 (1)	8 (2.7)
Occupation information: <i>n</i> (%)		
Business	87 (29.2)	82 (27.5)
Agriculture	7 (2.3)	19 (6.4)
Household	81 (27.2)	71 (23.8)
Professionals	52 (17.4)	40 (13.4)
Secretarial/clerical/officers	43 (14.4)	47 (15.8)
Self-employed	14 (4.7)	21 (7)
Skilled labour	1 (0.3)	2 (0.7)
Not mentioned	13 (4.4)	16 (5.4)
Socioeconomic information: <i>n</i> (%)		
Low income	43 (14.4)	52 (17.4)
Pre-middle income	98 (32.9)	103 (34.6)
Middle income	91 (30.5)	83 (27.9)
High income	52 (17.4)	48 (16.1)
Not mentioned	14 (4.7)	12 (4.0)
Dietary information: <i>n</i> (%)		
Vegetarian	211 (70.8)	187 (62.8)
Nonvegetarian	87 (29.2)	111 (37.2)
Consumption of addictive substances (alcohol and/or tobacco): <i>n</i> (%)		
Yes	26 (8.7)	39 (13.1)
No	253 (84.9)	248 (83.2)
Not mentioned	19 (6.4)	11 (3.7)

Ardelt quality of life questionnaire II (i.e., enjoyment in physical activities, ability to work, self-esteem, and social satisfaction) were higher in yoga experienced obese persons, the overall score of quality of life which is the sum of all the scores could be expected to be higher in yoga experienced obese persons.

Previously, a ten-day longitudinal trial reported the effects of an integrated yoga module which included yoga practice and theory for overweight and obese persons [18]. This single-arm interventional trial reported better physical, psychological, and environmental dimensions of the WHOQOL-BREF questionnaire following yoga. There was a

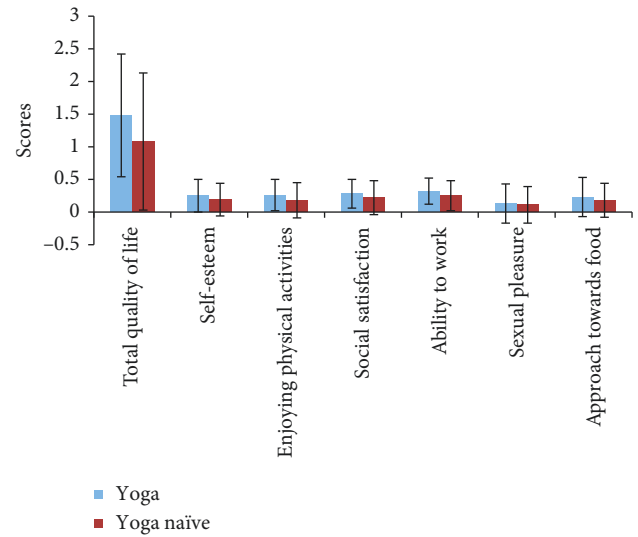


FIGURE 1: Graphical presentation of adjusted mean scores of quality of life of the yoga experienced and yoga naïve obese adults. Error bar showing the standard deviation of the quality of life scores.

single group of 279 participants of both sexes who did not differ significantly. The improvement in the physical dimension of quality of life is comparable to the increased enjoyment of physical activities seen in yoga practitioners in the present trial.

This higher self-reported enjoyment of physical activities in the present study could be explained by the outcomes of previous studies on yoga for obesity. In a fifteen-day comparative controlled trial, yoga reduced the body mass index and waist circumference, while the ability to balance and the handgrip strength increased [29]. A randomized controlled trial assessing the effects of yoga on female adults with abdominal obesity reported a reduction in perceived stress levels along with other favourable changes in mental health-related outcomes such as the health-related quality of life, self-esteem, better body awareness, and trust in bodily sensations following twelve weeks of yoga [30]. The results of these studies indicate that yoga decreases physical and psychological efforts required to be physically active in persons with obesity.

Obesity adversely affects workplace productivity [31]. Persons with obesity were more likely to be absent from their workplace and less productive while at work due to health-related conditions associated with obesity [32, 33]. Participation in a lifestyle intervention which included increased physical activity was reported to enhance workplace productivity by improving physical and mental health in the obese [34]. With these health benefits, absenteeism due to sickness decreases and enhances the ability to work better [31].

In an earlier study mentioned above [18], higher levels of psychological well-being in the WHOQOL-BREF questionnaire can be considered to be partially based on higher levels of self-esteem in yoga experienced persons compared to those who are yoga naïve. Practicing gives specific emphasis to body awareness and responsiveness to self-

TABLE 2: Details of the regression analyses adjusted for the three covariates (age, gender, and BMI) for overall quality of life and six subdomains.

Quality of life	<i>F</i>	df	Adjusted <i>R</i> <sup>2</sup>	Related to covariates		
				Covariates	$\beta$	<i>p</i> value
Total quality of life	8.547	1, 590	0.048	Age	0.024	0.557
				Gender	−0.029	0.479
				BMI	−0.116	0.005
Enjoying physical activities	5.253	1, 591	0.001	Age	0.007	0.869
				Gender	0.015	0.727
				BMI	−0.074	0.072
Ability to work	7.970	1, 591	0.045	Age	−0.075	0.066
				Gender	0.046	0.269
				BMI	−0.109	0.008
Self-esteem	4.953	1, 591	0.026	Age	0.070	0.090
				Gender	−0.020	0.641
				BMI	−0.104	0.012
Social satisfaction	3.634	1, 591	0.017	Age	0.052	0.211
				Gender	−0.026	0.532
				BMI	−0.039	0.350
Sexual pleasure	8.986	1, 591	0.051	Age	−0.810	0.418
				Gender	−5.435	<0.001
				BMI	−1.232	0.218
Approach towards food	4.237	1, 591	0.021	Age	0.095	0.021
				Gender	0.090	0.032
				BMI	−0.085	0.041

TABLE 3: Quality of life scores in yoga experienced and yoga naïve persons with obesity.

Overall quality of life and subdomains	Group as a whole				Cohen's <i>d</i>	Mean difference	<i>t</i> value	<i>p</i> value <sup>##</sup>
	Yoga ( <i>n</i> = 298)		Yoga naïve ( <i>n</i> = 298)					
	Mean ± SD	95% CI <sup>#</sup>	Mean ± SD	95% CI <sup>#</sup>				
Total quality of life	1.5 ± 0.94	1.39, 1.61	1.1 ± 1.05 <sup>@</sup>	0.98, 1.22	0.40	0.40	4.82	<0.001
Enjoying physical activities	0.27 ± 0.24	0.24, 0.3	0.18 ± 0.27 <sup>**</sup>	0.15, 0.21	0.35	0.09	4.17	<0.001
Ability to work	0.34 ± 0.2	0.32, 0.36	0.26 ± 0.23 <sup>**</sup>	0.23, 0.29	0.37	0.08	4.46	<0.001
Self-esteem	0.25 ± 0.25	0.22, 0.28	0.19 ± 0.25 <sup>*</sup>	0.16, 0.22	0.24	0.06	2.98	0.003
Social satisfaction	0.29 ± 0.22	0.27, 0.32	0.23 ± 0.26 <sup>*</sup>	0.2, 0.26	0.25	0.06	3.29	0.001
Sexual pleasure	0.15 ± 0.3	0.12, 0.18	0.13 ± 0.28	0.1, 0.16	0.07	0.02	0.87	0.384
Approach towards food	0.25 ± 0.3	0.22, 0.28	0.19 ± 0.26	0.16, 0.22	0.21	0.06	2.32	0.021

<sup>@</sup>*p* < 0.001 at the two-tailed level, level of statistical significance between the groups was analysed using separate least squares regression. <sup>\*</sup>*p* < 0.008 and <sup>\*\*</sup>*p* < 0.001 at the two-tailed level, level of significance between the groups was analysed using separate least squares regression. <sup>#</sup>95% CI was Bonferroni adjusted for the six subdomains of quality of life scores (i.e., 99.2%); <sup>##</sup>Bonferroni adjusted statistical significance level for the six subdomains of quality of life scores ( $\alpha = 0.008$ ). Values are group mean ± SD.

objectification [35]. When body awareness and responsiveness to how the body is viewed increases, there is a greater sense of body satisfaction and lesser chances of self-objectification. These factors could have contributed to the better self-esteem in yoga experienced obese persons. Improved self-esteem could in turn influence interaction with other persons. Yoga practice creates more interpersonal interactions [36, 37]. These factors also increase mental well-being associated with yoga practice [36, 37] which could explain the higher levels of social satisfaction in the yoga experienced compared to the yoga naïve participants. These findings, i.e., better social satisfaction were not observed in the earlier study conducted on smaller numbers (*n* = 20, each group) of yoga experienced and yoga naïve obese persons [19].

The significance of present findings is that if a person who is obese enjoys physical activities, they are likely to adhere to any physical activity program including yoga which would be definitely beneficial to maintain and possibly further weight loss.

A limitation of the present cross-sectional study is that factors other than yoga could have influenced the results. There was no association between the duration of yoga practice and overall quality of life scores. However, adequate details were not obtained about the frequency of yoga practice in terms of number of days in a week or the intensity of the yoga practice based on number of minutes of practice in a day. Also, while “yoga” included physical postures (*asanas*), regulated breathing (*pranayamas*), and yoga meditation (*dhyana*), the exact details about the school of

yoga followed were not obtained. It would have been ideal to know these details and take them into account. Hence, the results suggest that practicing yoga possibly influences the quality of life in obese persons though the quantum of practice does not appear to influence the results.

## Data Availability

The group mean data are given in the paper. The individual data are available in the archives of the laboratory and can be obtained from the corresponding author on request.

## Conflicts of Interest

The authors declare they have no conflicts of interest.

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