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Mediating effect of BMI on the association of economic status and coexistence of hypertension and diabetes in Bangladesh: A counterfactual framework-based weighting approach

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Abstract

Background and Aims: Non-communicable diseases such as hypertension and diabetes are matters of huge concern worldwide, with an increasing trend in prevalence over the previous decade. First of all, this study aimed to evaluate the association between economic status (ES) and body mass index (BMI), ES and comorbidity of hypertension and diabetes, and BMI and comorbidity independently. Second, it explored the mediating role of BMI in the association between ES and comorbidity of hypertension and diabetes. Finally, it investigated whether the mediating effect differs with the place of residence, gender, and education levels.

Methods: A total of 11,291 complete cases from the Bangladesh demographic and health survey 2017–18 were utilized for this study. Survey-based binary logistic regression or multiple logistic regression was used to find the association among outcome, exposure, and mediator variables, and a counterfactual framework-based weighting approach was utilized for mediation analysis.

Results: Middle-income (adjusted odds ratio [AOR]: 1.696, 95% confidence interval [CI]: 1.219, 2.360) and rich (AOR: 2.770, CI: 2.054, 3.736) respondents were more likely to have comorbidity of hypertension and diabetes compared to the poor. The odds of comorbidity increased with the increase in BMI. A positive association was observed between ES and BMI. A significant mediating role of BMI in the association between ES and comorbidity was found. We observed that 19.85% (95% CI: 11.50%, 49.6%) and 20.35% (95% CI: 14.9%, 29.3%) of total effect was mediated by BMI for middle and rich respondents, respectively, compared to the poor.

Conclusions: The mediating role of BMI was greater for female, no or primary educated respondents, and respondents from rural areas. Therefore, the study will facilitate policymakers of Bangladesh and other countries with a similar set-up to decide on health policies regarding hypertension and diabetes.

KEYWORDS
Bangladesh, Bangladesh demographic and health survey (BDHS) 2017-18, diabetes, hypertension, obesity, overweight

1 | INTRODUCTION

Obesity and overweight have become great threats to global public health. It was reported that people with higher body mass index (BMI) (overweight or obese) were more likely to succumb to death earlier than others. Higher BMI was associated with a more extended hospital stay and more likelihood of using mechanical ventilation.[1–3] Since 1980, the prevalence of obesity in the world has doubled. From 1980 to 2008, the global prevalence of obesity and overweight increased by 5.6% (from 6.4% to 12.0%) and 9.8% (from 24.6% to 34.4%), respectively.[4,5] According to the World Health Organization (WHO), 39 million children aged below 5 years and 340 million children and adolescents aged 5–19 years fall under the purview of obesity in the 2020s. It was noted that 13% (650 million) of adults aged 18 years or above are obese, and 39% of them (1.9 billion) are overweight.[6] It was also reported to be linked to various comorbidities, including hypertension, diabetes, and dyslipidemia.[7] Several studies indicated that a good economic status (ES) was almost always a prerequisite for sound health and nutrition. It was reported that economically disadvantaged people were more likely to suffer from chronic diseases, and they showed a higher risk of death.[8,9] Reports also indicated that if a child faced such adverse conditions, it was more likely to face adverse health situations in adult life despite its adult ES. Hence, adverse ES is a cause of health inequality[10,11]

Hypertension was reported to be a severe risk factor for acute and chronic cardiovascular disorders, including stroke, coronary heart disease, and myocardial infarction. Primary hypertension (also known as essential hypertension) is the most common type. It does not have a single known cause; its risk has been linked to genetics, high cholesterol levels, increased sodium intake, and higher BMI.[12,13] Secondary hypertension has known causes and usually results from kidney diseases, lung diseases, endocrine disorders, etc. BMI is one of the most discussed modifiable risk factors for hypertension.[14] According to the WHO, the global frequency of hypertension is 22%. This prevalence is 25% in South-East Asia. An estimated 1.13 billion people had hypertension worldwide in 2019, most of whom (two-thirds) were living in poor economic conditions, and the number is projected to rise to 1.6 billion by 2025.[15,16]

Diabetes is an endocrine disorder manifested by persistent high blood glucose levels. This is of two major types: type I and type II, where type II diabetes is primarily associated with obesity, high BMI, and a sedentary lifestyle.[17,18] The prevalence of diabetes has been increasing in recent years, as well as that of high BMI.[19] According to the 2021 International Diabetes Federation report, around 537 million people worldwide had diabetes, accounting for roughly 10.5% of the global population. This condition incurred healthcare costs of $966 billion. Projections suggest diabetes cases will rise to 783 million by 2045, with associated costs surpassing $1054 billion.[20,21] In Southeast Asia, especially in Bangladesh, diabetes cases are rising rapidly.[4]

Highlights

- Non-communicable diseases (NCD) like hypertension and diabetes are matters of enormous concern worldwide.
- The study used the BDHS 2017–18 data set to investigate the link of economic status (ES) and body mass index (BMI) with comorbidities of hypertension and diabetes.
- The mediating role of BMI was greater for female, no or primary educated respondents, and respondents from rural areas. BMI significantly mediates the association between ES and the coexistence of hypertension and diabetes.

Bangladesh, a country of limited ES, has also seen a rise in obese and overweight people in recent years. According to the Bangladesh demographic and health survey (BDHS) 2011 report, married women aged 15–49 years had an overweight and obesity prevalence of 13.6% and 2.9%, respectively, while 9.1% males aged 35 years and older had an overweight or obesity. Furthermore, among women and men aged 35 and older, the prevalence of hypertension was 32% and 20%, respectively, while the prevalence of diabetes mellitus was 11.2% and 11.7%, respectively.[22] More than 32% of married women between the ages of 15 and 49 were overweight or obese in 2017–18, whereas about 18% of men over the age of 18 were overweight or obese. Also, the prevalence of hypertension was 28.4% and 26.2%, respectively, among women and men over the age of 18, and the prevalence of diabetes mellitus was 9.5% and 10.5%, respectively.[23] Notably, the fraction of ever-married women (15–49 years old) who are overweight or obese increased from 3% in 1996–1997 to 32% in 2017–2018.[23] Additionally, over 20% of adults in Bangladesh are found to have hypertension, a common chronic condition.[24] In Bangladesh, 8.4 million adults had diabetes as of 2019, and by 2045, that figure is projected to rise to 15.0 million.[25] According to the Global Health Estimates 2020, the deaths in Bangladesh related to noncommunicable illnesses grew from 43.1% in 2000 to 70.2% in 2019.[4]

Several previous studies revealed the association between ES and BMI, ES and comorbidity, and BMI and comorbidity in Bangladesh.[4,19] There is no such study that explored the mediating effect of BMI on the association of ES and comorbidity. To the best of our knowledge, this study is the very first study of its kind that used a counterfactual weighting approach for mediation analysis to determine the role of BMI on the association of ES and comorbidity. So, the primary objective of the study was to independently assess the correlation between ES and BMI, as well as the relationship between ES and the co-occurrence of hypertension and diabetes, and the association between BMI and comorbidity. Furthermore, it sought to delve into the potential mediating effects of BMI in the association between ES and the coexistence of hypertension and diabetes. Additionally, the investigation aimed to ascertain whether the mediating impact varied across different demographic factors, including place of residence, gender, and levels of education.

Moreover, this study utilized a recent nationally representative BDHS 2017–18 survey data that collected biomarker measurements for adults aged greater than 18 years. Therefore, this study will facilitate policymakers of Bangladesh and other countries with similar socioeconomic characteristics to make decisions on health policies considering hypertension and diabetes.

2 | METHODS

2.1 | Data and sampling

This study used the data obtained from BDHS 2017–18. BDHS used a two-stage stratified cluster random sampling using the list of enumeration areas (EAs) or primary sampling units or clusters available from the 2011 population and household census of Bangladesh. In the first stage, 672 EAs/clusters (urban: 249, rural: 423) were selected from 293,579 EAs using a probability proportional to EAs size. Each of the EA has on an average 120 households. In the second stage, 20,160 households (urban: 7470, rural: 12,690) were selected (30 from each EAs) with an equal probability systematic selection. A total of 19,457 households were interviewed. More detail on sampling is available from the publicly available survey report.[23] Of the selected households, 14,704 (men: 6691, women: 8013) respondents (age 18+) were eligible for biomarker sample. Among the respondents, information on both blood glucose and blood pressure were available for 12,290 cases after excluding missing and implausible cases. After excluding currently pregnant women, non-residents, missing in BMI, and missing in other covariates, a total of 11,291 complete cases were selected for this study (Figure 1).

2.2 | Ethics approval

The study is based on the secondary data set which is publicly available from the BDHS 2017–18. The original survey was performed in accordance with relevant guidelines and regulations of Declaration of Helsinki. The purpose of the study was explained to every participant, and data were only collected with their informed written consent. The National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare, Bangladesh, provided ethical approval for conducting the survey. After requesting the website www.dhsprogram.com, we were able to access data there. It is noted that the work documentation adheres to the guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist, as evidenced by its inclusion as a supplemental file.

2.3 | Outcome variables

For this study, the outcome variable of our interest is the co-morbidity of hypertension and diabetes. Therefore, co-morbidity was recorded as "1" for respondents with both hypertension and diabetes.[26] Respondents were reported to have hypertension if they had systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg and/or if taking medication to lower the BP, following the guidelines of the American Heart Association (AHA) and WHO.[23,27] On the other hand, individuals who had fasting plasma glucose ≥7 mmol/L and/or were taking medication for controlling diabetes during the survey were reported to have diabetes.[23,28]

2.4 | Exposure variables

ES is the exposure variable for this study. BDHS used the principle component analysis to construct the respondents' wealth index based on the households' resources and categorized them into five wealth quintiles (first to fifth quintile).[23] For our study, we constructed the variable ES, recoding the first and the second quintile as poor, the third quintile as middle, and the fourth and fifth quintile as rich.

2.5 | Mediator variable

BMI is the mediator variable for our study, which was calculated as the ratio of weight in kilogram to height in squared meters. We classified BMI following the classification suggested for Asian people: underweight (<18.5 kg/m^2), normal (18.5 ≤ BMI < 23 kg/m^2), overweight (23 ≤ BMI < 27.5 kg/m^2), and obese (≥27.5 kg/m^2).[29]

2.6 | Effect modifiers

As effect modifiers, we considered place of residence (urban and rural), sex of the respondents (male and female), and educational status (≤ primary and ≥ secondary).

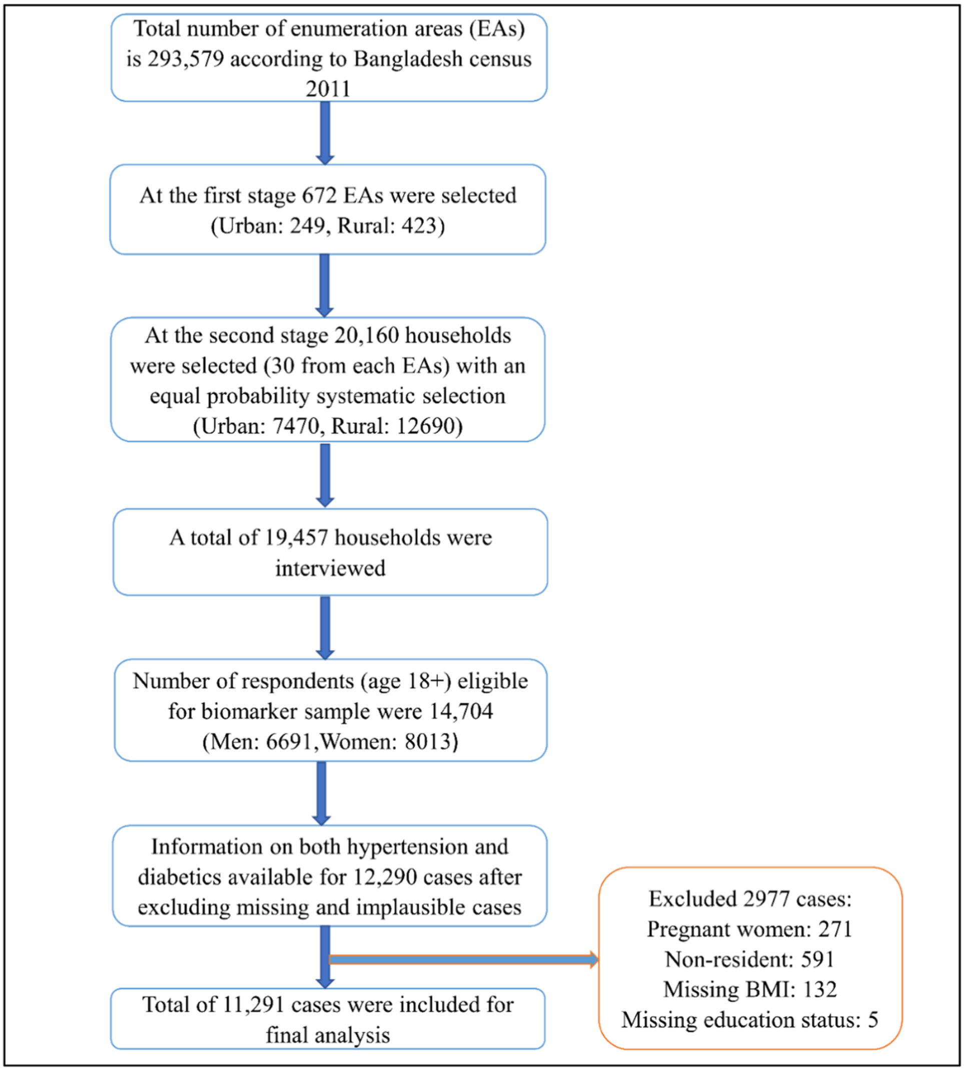

FIGURE 1 Flowchart showing the steps to select the study sample.

2.7 | Covariates

A set of variables were found to be associated with high blood pressure and high blood glucose level from literature review were considered as covariates in this study.[30–34] These variables are division, place of residence, sex of the respondents, educational status, age of the respondents, marital status, and working status.

2.8 | Statistical analysis

As descriptive statistics, we have reported the frequency and percentage distribution of the respondents. These analyses were adjusted for survey weights, clusters, and strata to consider the complex survey design. We also constructed the Lorenz curve and calculated the Gini coefficient to measure the inequality in the prevalence of comorbidity with the ES.[32] Lorenz curve demonstrates the cumulative proportion of households' wealth against the cumulative proportion of the prevalence. The Gini coefficient was measured as the ratio of the area between the perfect equality line and the inequality line. A design-based binary logistic regression was utilized to find the crude and adjusted effects of ES and BMI on comorbidity, and a design-based multiple logistic regression was applied to find the association between ES and BMI.[35]

For mediation analysis, a counterfactual framework-based weighting approach was applied, where the total effect (TE) of ES on comorbidity was separated as natural direct effect (NDE) and natural indirect effect (NIE).[36,37] NDE is the direct effect of ES on comorbidity not mediated through BMI, and NIE is the indirect effect of ES on comorbidity mediated through BMI (Figure 2). As confounders, division, place of residence, sex of the respondents, educational status, age of the respondents, marital status, and working status were considered. Bootstrap 95% confidence interval (CI) was constructed using 500 replications as a robust approach for TE, NDE, NIE, and proportion mediated.[37,38] Analysis has been conducted using Microsoft Excel V.13.0, STATA V.15.0, and R version 4.0.3.

3 | RESULTS

3.1 | Characteristics of study sample

Among the respondents, after adjusting the survey weight, 10.76% (CI: 10.20%, 11.35%) had diabetes, 28% (CI: 27.24%, 28.91%) had hypertension, and 4.94% (CI: 4.54%, 5.35%) had coexistence of hypertension and diabetes. Descriptive statistics and cross-tabulation of background characteristics by comorbidity were constructed in Table S1. In our analytical sample, Dhaka division had the highest percentage of respondents (23%), Barisal division had the lowest percentage of respondents (5.44%), 26.56% of respondents were from urban areas, 26.30% had no education, 14.54% of respondents had higher education, 80.75% of respondents were married, 44.56% of respondents were male, 63% of respondents were employed, 39.91% of respondents were overweight and obese, 40% of respondents were rich, 40% of respondents were poor, and about 43% of respondents were less than 35 years old. Prevalence of comorbidity was the highest among respondents of Chattogram division, urban area, uneducated, female, unemployed, overweight/obese, and those who were rich in ES.

3.2 | Association of ES and BMI with comorbidity

Survey design-based binary logistic regression results showed that ES and BMI were significantly associated with comorbidity. Crude estimates showed that middle and rich respondents had about 95.3% (crude odds ratio [COR] = 1.953, CI: 1.419, 2.689) and 270.8% (COR = 3.708, CI: 2.863, 4.804) higher odds of comorbidity, respectively, compared to the poor respondents (Table 1). Adjusted odds ratios showed that odds of comorbidity were 69.6% (adjusted odds ratio [AOR] = 1.696, CI: 1.219, 2.360) and 177% (AOR = 2.770, CI: 2.054, 3.736) higher for middle and rich ES, respectively, than that of poor ES (Table 1). Respondents with higher BMI were found to be more likely to have comorbidity in both crude and adjusted models. For instance, in the adjusted model, overweight/obese respondents had 374.2% (AOR = 4.742, CI: 3.090, 7.277) higher odds of comorbidity than the underweight respondents (Table 1).

3.3 | Inequality in the prevalence of comorbidity

Inequality in the prevalence of comorbidity was evident from the Lorenz curve (Figure 3). The Gini coefficient value corresponding to comorbidity was 0.345, implying the inequality in ES for comorbidity. Figure 3 also displayed the Lorenz curves and Gini coefficients for hypertension and diabetes. However, income inequality was the highest for comorbidity, followed by diabetes mellitus and hypertension.

3.4 | Mediating effect of BMI on the association of ES and comorbidity

From the binomial logistic regression models, we have found that ES and BMI were significantly associated with comorbidity (Table 1). Results obtained from the design-based multinomial logistic regression model showed that ES was also significantly associated with BMI in both crude and adjusted models (Table 2). For instance, the relative adjusted odds of overweight/obesity for the middle and rich were 94.2% (AOR = 1.942, $p < 0.001$) and 282% (AOR = 3.820, $p < 0.001$) higher, respectively, compared to the poor. However, we found exposure was associated with both mediator and outcome variables, and the mediator was also associated with the outcome variables. Therefore, we utilized the

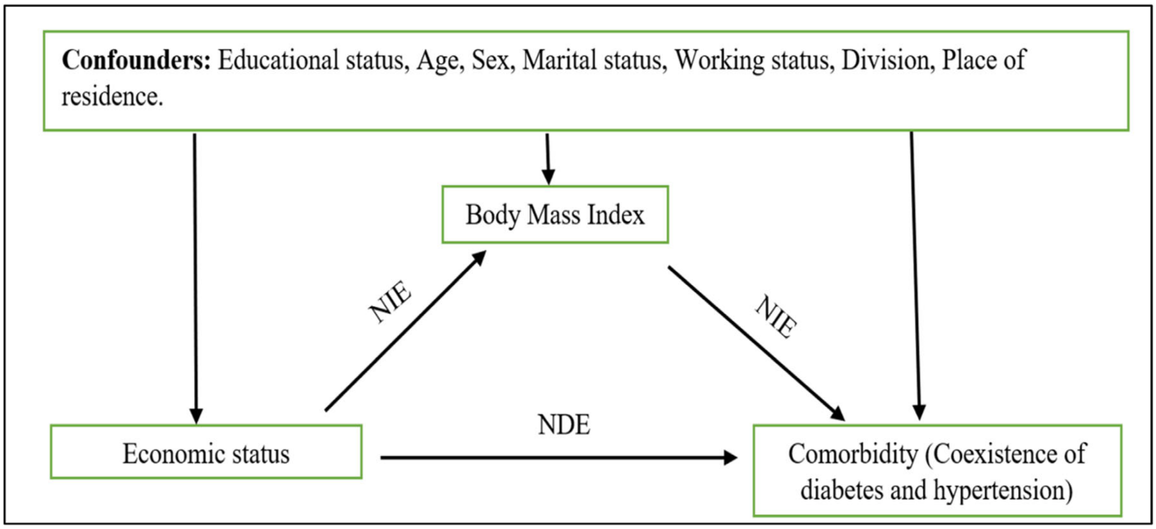

FIGURE 2 Diagram showing the decomposition of the effect of Economic Status on the co-morbidity of diabetics and hypertension mediating through body mass index. NDE stands for natural direct effect and NIE stands for natural indirect effect.

TABLE 1 Crude odds ratio (COR) and adjusted odds ratio (AOR) with their confidence intervals and *p*-values obtained from design-based logistic regression.

Exposure/mediator	COR (95% CI)	*p*-value	AOR (95% CI)	*p*-value
Economic status (ES)				
Poor	Ref		Ref	
Middle	1.953 (1.419, 2.689)	<0.001	1.696 (1.219, 2.360)	0.002
Rich	3.708 (2.863, 4.804)	<0.001	2.770 (2.054, 3.736)	<0.001
Body mass index (BMI)				
Underweight	Ref		Ref	
Normal	1.804 (1.193, 2.727)	0.005	1.950 (1.264, 3.007)	0.003
Overweigh/obese	5.273 (3.540, 7.854)	<0.001	4.742 (3.090, 7.277)	<0.001

Abbreviation: CI, confidence interval.

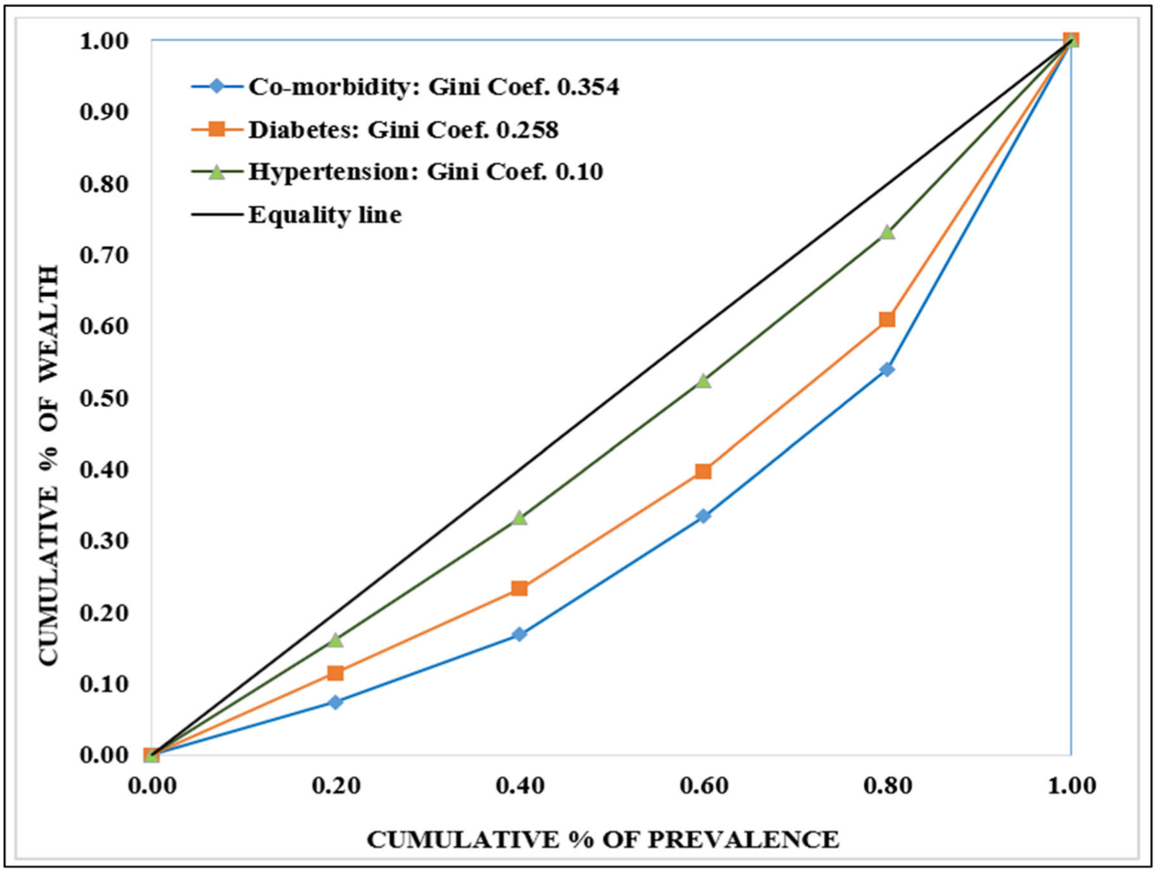

FIGURE 3 Concentration curves with Gini coefficients for the prevalence of diabetes, hypertension, and their co-morbidity.

TABLE 2 Design-based multinomial logistic regression model for finding association between economic status and BMI.

Exposure	Normal		Overweight/obese		Normal		Overweight/obese	
Economic status	COR	*p*-value	COR	*p*-value	AOR	*p*-value	AOR	*p*-value
Poor	Ref		Ref		Ref		Ref	
Middle	1.402	<0.001	2.197	<0.001	1.383	<0.001	1.942	<0.001
Rich	1.750	<0.001	5.179	<0.001	1.668	<0.001	3.820	<0.001

Abbreviations: AOR, adjusted odds ratio; BMI, body mass index; COR, crude odds ratio.

counterfactual framework-based weighting approach to find the mediating effect of BMI on the association of ES and comorbidity. The total AOR 1.662 (95% CI: 1.226, 2.160) for the middle compared to the poor was decomposed into the direct AOR 1.503 (95% CI: 1.106, 1.950), and the indirect AOR 1.106 (95% CI: 1.074, 1.150) through a mediator. Therefore, the proportion mediated through BMI in the log AOR scale was 19.85% (95% CI: 11.5%–49.6%). Similarly, the total AOR 2.866 (95% CI: 2.223, 3.807) for the rich compared to the poor was decomposed into the direct AOR 2.313 (95% CI: 1.754, 3.068) and the indirect AOR 1.239 (95% CI: 1.186, 1.301) through a mediator, and the proportion mediated through BMI in log AOR scale was 20.35 (95% CI: 14.9%–29.3%).

3.5 | Effect modification by gender, education level, and place of residence

Results obtained from effect modification are reported in Table 3. It was observed that respondents who lived in urban areas were more likely to have comorbidity compared to the respondents who lived in rural areas. For instance, the total AOR for rich and urban respondents was 4.102 (95% CI: 2.586, 8.529) compared to poor and urban respondents. Male respondents had higher odds of comorbidity compared to the female respondents. Individuals with secondary and higher education were more vulnerable to comorbidity than respondents with primary and no education.

4 | DISCUSSION

This study examined the association between ES and BMI, ES with hypertension and diabetes, and the independent association of BMI with comorbidity of hypertension and diabetes by utilizing a nationally representative cross-sectional BDHS 2017–2018 survey data set. The study also investigated the role of BMI as a mediator in the ES-hypertension/diabetes link, exploring demographic variations like residence, gender, and education levels. To the best of our knowledge, this study is groundbreaking as this study is the first one of its kind. The ES was significantly associated with BMI and comorbidity. The mediation analysis estimated that the association

TABLE 3 Decomposition of the effect of economic status on coexistence of hypertension and diabetes mediating through body mass index (BMI).

Economic status (ES)	Total effect AOR (95% CI)	Natural direct effect (NDE) AOR (95% CI)	Natural indirect effect (NIE) AOR (95% CI)	Proportion mediated (PM)
Overall				
Poor → Middle	1.662 (1.226, 2.160)	1.503 (1.106, 1.950)	1.106 (1.074, 1.150)	0.1985
Poor → Rich	2.866 (2.223, 3.807)	2.313 (1.754, 3.068)	1.239 (1.186, 1.301)	0.2035
Urban				
Poor → Middle	1.667 (0.777, 3.337)	1.529 (0.725, 3.07)	1.09 (1.031, 1.168)	0.169
Poor → Rich	4.102 (2.586,8.529)	3.457 (2.17, 7.334)	1.186 (1.104, 1.287)	0.121
Rural				
Poor → Middle	1.604 (1.162, 2.177)	1.441 (1.044, 1.977)	1.113 (1.067, 1.173)	0.227
Poor → Rich	2.365 (1.687, 3.242)	1.853 (2.17, 7.334)	1.277 (1.194, 1.373)	0.284
No education/primary				
Poor → Middle	1.667 (1.141, 2.423)	1.463 (0.986, 2.125)	1.14 (1.084, 1.199)	0.256
Poor → Rich	3.001 (2.213, 4.132)	2.276 (1.734, 3.223)	1.319 (1.224, 1.415)	0.252
Secondary/higher				
Poor → Middle	1.826 (0.987, 3.7)	1.667 (0.898, 3.368)	1.096 (1.043, 1.163)	0.152
Poor → Rich	3.212 (1.985, 6.236)	2.665 (1.626, 5.211)	1.205 (1.121, 1.32)	0.16
Male				
Poor → Middle	2.062 (1.29, 3.955)	1.847 (1.132, 3.629)	1.116 (1.057, 1.186)	0.152
Poor → Rich	4.105 (2.698, 7.695)	3.222 (2.086, 6.052)	1.274 (1.179, 1.369)	0.171
Female				
Poor → Middle	1.48 (0.875, 2.176)	1.344 (0.765, 2.01)	1.101 (1.052, 1.155)	0.245
Poor → Rich	2.382 (1.6, 3.296)	1.957 (1.307, 2.739)	1.217 (1.134, 1.311)	0.226

Abbreviation: CI, confidence interval.

between the ES and the comorbidity was mediated by about 20% for both middle and rich classes compared to the poor class. The analysis also revealed a higher mediation effect of BMI among adult populations residing in rural areas compared to urban areas, among individuals with primary education or lower in contrast to those with secondary education or higher, and among females relative to males.

Hypertension and diabetes are independently as well as jointly become a public health burden because of their effects on severe health consequences, including cardiovascular disease, microvascular and macrovascular health complications, and renal and other diseases.[39–43] Our study demonstrated a positive correlation between increased BMI and the likelihood of experiencing comorbid hypertension and diabetes. Several studies also supported that BMI is an independent risk factor for hypertension[4,44–47] and diabetes[44,48] and their comorbidity.[49] This direction of the relationship conforms to the mechanism that insulin resistance due to obesity influences other cardiovascular risk factors, including hypertension and diabetes.[50]

The current findings showed that the extent of income inequality was highest for the comorbid status of hypertension and diabetes compared to each health outcome individually. The analysis exhibited that the respondents from the middle and rich classes had nearly twofold and threefold, respectively, higher likelihood of hypertension and diabetes comorbidity compared to the respondents from the poor class. In the context of Bangladesh, a limited number of studies[51,52] investigated this association between ES and comorbid hypertension and diabetes. Our findings are consistent with these studies. A study in the Korean population also found a similar directional association.[53] More studies focused on the independent association between ES and hypertension and diabetes separately, especially in developing countries, and reported a positive association.[34,54–57] Obesity rates have risen with urbanization and gross domestic product growth, accompanied by shifts in diet and reduced activity. Increased consumption of animal products and processed foods likely contributed to higher fat and sugar intake, primarily through sugary drinks, which adversely affect cardiometabolic health.[58] However, in developed countries, the reverse pattern in association between ES and the comorbidity was evident.[59–63] This reverse pattern in association between socioeconomic status (SES) and diabetes was also evident from the study by Xu and colleagues.[64] Thus, it is imperative that any policy interventions must be approached with a comprehensive understanding and careful consideration of the economic circumstances pertaining to the individuals affected and the broader macroeconomic conditions of the nation.

Our study showed a positive association between ES and BMI. The statistically adjusted likelihood of being overweight or obese among participants in the middle and rich categories was 94.2% and 282% greater, respectively, in comparison to those in the poor category. This association is consistent with other Bangladesh-based studies.[65,66] This pattern is similar to other developing countries.[67] In the majority of low- and middle-income countries, there exists a notable trend wherein the prevalence of overweight and obesity tends to be disproportionately higher among individuals of higher SES compared to those of lower economic standing. Nevertheless, with the advancement of national economic prosperity, a discernible transition occurs whereby the burden of overweight and obesity gradually gravitates towards segments of lower-income people.[68] Therefore, at this stage, a global generalization of this positive association is still unclear because of its complexity and variability due to sex distribution and income by countries.[67,69]

The novel finding of the study from the Bangladesh context was the mediation effect (20%) of BMI in the association between ES and the comorbidity of hypertension and diabetes. No study has used the same exposure, mediator, and outcome variables as those involved in our study. However, one study based on Nepali populations considered only hypertension instead of its comorbidity with diabetes as the outcome variable and SES instead of ES as exposure to evaluate the BMI mediation effect.[70] They showed the mediation effect of BMI in the positive association between SES and hypertension. Some studies showed the significant mediation effect of BMI in the association between the same SES and different outcome variables, including untreated hypertension,[71] brain development,[72] glycemic control, and diabetes.[73] Hossain et al.[33] showed that the association between overweight and obesity and diabetes could be mediated by hypertension. Presently, the incidence of obesity and overweight has reached alarming proportions, with a corresponding rise in the susceptibility to obesity and overweight attributed to escalating levels of SES, encompassing education and wealth. Consequently, the recognition of BMI as a mediator in the heightened SES and the comorbidity of hypertension and diabetes underscores this adjustable risk element as a prospective focal point for initiatives aimed at mitigating cardiovascular disease and associated risk factors like hypertension and diabetes within the higher socioeconomic strata in LMICs.[70]

The study results with effect modifiers identified that BMI mediated the association between ES and the comorbidity of hypertension and diabetes more among adults in rural areas than urban areas, having primary or less education and secondary or higher and female versus male. A comparable study also demonstrated that place of residence and sex are significant effect modifiers.[70]

5 | STUDY LIMITATIONS

Despite having many strong points of the study, it also has some limitations. First, due to the observed relationship between ES and the prevalence of hypertension and diabetes, both individually and in combination, across developing nations, it is imperative to recognize that the findings of this study may not be readily applicable to populations residing in developed countries. Besides, some other confounding variables like physical activity, food habit, genetic and environmental factor could be included in the study to get more precise estimates. However, this survey collected no information on those variables. Furthermore, because of the cross-sectional study, we didn't have access to measure the temporal direction of the relationship among the exposure, mediator, and outcome variables, and we could not estimate the cause-and-effect relationship.

6 | CONCLUSIONS

In conclusion, this study, for the first time, showed the extent of the mediation effect of BMI in the positive association between ES and comorbidity between hypertension and diabetes and how they varied over the status of place of residence, education, and sex of the respondents. These findings suggest that maintaining a normal BMI and eliminating economic disparities may help to reduce the growing burden of hypertension and diabetes and their associated risk. Preventive policies should target adults from poor economic classes, especially those living in urban areas, primary or less educated people, and females compared to their counterparts.

AUTHOR CONTRIBUTIONS

Foyez Ahmmed: conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft; writing—review & editing. **Md Jamal Hossain**: conceptualization; project administration; software; supervision; validation; visualization; writing—original draft; writing—review & editing. **Md Tareq Ferdous Khan**: investigation; methodology; resources; software; validation; visualization; writing—original draft. **Muhammad Mahabub Rahaman Manik**: data curation; methodology; validation; visualization; writing—review & editing. **Saimon Shahriar**: resources; software; validation; visualization; writing—original draft. **Dulal Chandra Nandi**: software; validation; visualization; writing—review & editing. **Md Parvej Hussain**: data curation; resources; validation; visualization; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The raw data sets generated and/or analyzed data during the current study are available in the BDHS 2017-18 repository, [www.dhsprogram.com]. All authors have read and approved the final version of the manuscript. The corresponding authors had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

ETHICS STATEMENT

The study was performed in accordance with relevant guidelines and regulations of Declaration of Helsinki. The Bangladesh Demographic and Health Survey (BDHS) 2017–18 provided the secondary data sets used in this investigation. The purpose of the study was explained to every participant, and data were only collected with their informed consent. The National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare, Bangladesh, provided ethical approval for conducting the survey. After requesting the website www.dhsprogram.com, we were able to access data there.

TRANSPARENCY STATEMENT

The lead authors, Foyez Ahmmed and Md. Jamal Hossain, affirm that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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