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Unveiling the effects of living standards on diabetes and hypertension with the mediating role of overweight and obesity: a cross-sectional study in Bangladesh

Kanchan Kumar Sen, Ahsan Rahman Jamee, Ummay Nayeema Islam, Wasimul Bari

ABSTRACT
Objective  The purpose of the study was to ascertain how the standard of living is associated with the likelihood of developing diabetes and hypertension directly as well as indirectly through overweight and obesity. Study design The study used 2017–2018 Bangladesh Demographic and Health Survey data. It examined the household living standard (LSD) as the main factor, and body mass index (BMI) as a mediator. Outcomes included diabetes status, hypertension status and their co-occurrence. Structural equation modelling with logistic regression and bootstrapping were used for mediation analysis and computing bias-corrected SEs. Setting The research was carried out in Bangladesh and included both male and female adults. Participants The study encompassed a total of 11,961 adults (5124 males and 6837 females) aged 18 years or older. Results  Among the participants, 10.3% had diabetes, 28.6% had hypertension and 4.9% had both conditions. The prevalence of diabetes, hypertension or both conditions was 18.5%, 33.5% and 9.7%, respectively, among those with a high LSD. Regression analysis demonstrated that individuals with high LSD had significantly elevated risks of these conditions compared with those with low LSD: 133% higher odds for diabetes (OR 2.22, 95% CI 1.97 to 2.76), 25% higher odds for hypertension (OR 1.25, 95% CI 1.10 to 1.42) and 148% higher odds for both conditions (OR 2.48; 95% CI 1.96 to 3.14). Moreover, the indirect effects of high LSD through obesity surpassed its direct effects for developing diabetes, hypertension or both conditions. Conclusion  This study emphasises that with the enhancement of LSD, individuals often experience weight gain, resulting in elevated BMI levels. This cascade effect significantly amplifies the risks of diabetes, hypertension or both conditions. To counteract this concerning trajectory, policy interventions and targeted awareness campaigns are imperative. These efforts must prioritise the promotion of heightened physical activity and the mitigation of the overweight/obesity surge associated with rising LSD.

INTRODUCTION
Non-communicable disease (NCD) is an emerging threat to the current world as approximately 41 million people die from NCDs annually, which is proportional to 74% of worldwide total deaths; 17 million people experience early deaths due to NCDs. A striking 86% of these early deaths occur in low-income and middle-income countries (LMICs). By 2030, it is projected that NCDs will be responsible for 52 million deaths on a global scale. Among the foremost NCDs, cardiovascular diseases (CVD), diabetes, cancer and chronic respiratory diseases stand out as the major causes of death, jointly contributing to 70% of global mortality, with CVD exerting the most significant impact. Unhealthy diets, lack of physical activity, high body mass index (BMI) and alcoholism are the causal factors of NCDs, operating through intermediate risk factors such as high blood pressure (BP), elevated blood glucose and plasma lipid concentrations. Diabetes and hypertension are two of the leading causes of cardiovascular death and disability-adjusted
life-years (DALYs).\textsuperscript{5, 6} Raised BP is responsible for 7.5 million deaths and 57 million DALYs.\textsuperscript{7} Additionally, 54% of strokes and 47% of coronary heart disease are caused due to high BP.\textsuperscript{8} The number of people with high BP has risen to 1 billion in 2000, and it is predicted that globally around 1.56 billion adults would be hypertensive by 2025.\textsuperscript{9} Again, the number of patients with diabetes is rising at an alarming rate from 108 million in 1980 to 422 million in 2014.\textsuperscript{10} Moreover, LMICs are witnessing a rapid increase in NCDs including hypertension and diabetes mellitus than developed countries.\textsuperscript{10, 11}

Over the last decade, Bangladesh has been going through an epidemiological transition from communicable diseases to NCDs.\textsuperscript{12} According to WHO, NCDs account for an estimated 67% of total deaths in Bangladesh.\textsuperscript{13, 14} Some NCDs, such as stroke, heart disease, chronic obstructive pulmonary disease, diabetes and lung cancer, were the leading causes of death in Bangladesh.\textsuperscript{15} Due to their major role in causing deaths, these are the major public health concern in Bangladesh.\textsuperscript{14} The prevalence of hypertension showed an increasing trend between 2011 and 2017–2018.\textsuperscript{11, 15} Over the years, the occurrence of hypertension raised from 32% to 45% among women and from 20% to 34% among men with age at least 35 years.\textsuperscript{4} Bangladesh Demographic and Health Survey (BDHS) 2017–2018 collected biomarker measurements on BP and fasting blood glucose (FBG) from both men and women of age 18 years or older. The report revealed that the prevalence of diabetes increased modestly in both men (11%–14%) and women (12%–14%) between 2011 and 2018.\textsuperscript{4} It is projected that by 2045, Bangladesh will be burdened with almost 15 million people suffering from diabetes.\textsuperscript{16}

The WHO Global Action Plan has set a voluntary global target of achieving a relative reduction of 25% in NCD-related premature deaths by 2025.\textsuperscript{17} For this purpose, it is essential to identify the potential factors associated with the NCDs. Several studies revealed the fact that raised fat levels in the blood, inadequate consumption of fruit and vegetables, overweight or obesity, physical inactivity, poor diet, smoking, alcohol use, age, sex, marital status, education, geographical region, etc are the significant risk factors for the development of diabetes, hypertension and other NCDs.\textsuperscript{14, 18–23}

Although various risk factors for diabetes and hypertension were investigated in earlier studies, no research has yet looked at how a level of living standard (LSD) affects these problems.\textsuperscript{24, 25} The healthy lifestyle of an individual depends on their standard of living which in turn can affect their life expectancy. Therefore, to lower the prevalence of diabetes, hypertension or both, the current study concentrates on the standard of living for policy initiatives. In addition, the study also hypothesises that the LSD not only has a direct impact on diabetes or hypertension, but it can also have an indirect impact through other channels like overweight or obesity (figure 1). Earlier studies revealed that being overweight or obese is the major cause of developing both diabetes and hypertension.\textsuperscript{26–30} However, no studies have yet examined the relationships of LSD with obesity. This study is the first that investigated the relationships of LSD with overweight/obesity, diabetes and hypertension as well as explored the indirect impact of LSD on diabetes and/or hypertension through overweight and obesity.

**METHODS**

**Study population and data source**

A nationally representative cross-sectional data obtained from BDHS, 2017–2018 has been used in this study to explore the association of LSD with diabetes, hypertension or both. The National Institute of Population Research and Training conducted the survey from 24 October 2017 to 15 March 2018 under the Ministry of Health and Family Welfare of Bangladesh and Mitra and Associates to investigate the socioeconomic and demographic characteristics such as health, education, housing, wealth, child nutrition, family planning, maternal healthcare, mortality, etc at the national level. The study encompassed Bangladeshi adults aged 18 years or older.

**Sampling method and sample size**

The 2017–2018 BDHS used a stratified probability sampling approach to collect the data in two stages. In the first stage, 675 enumeration areas (EAs) (urban areas: 250, rural areas: 425) known as primary sampling units were randomly chosen from a lot of EAs listed in the ‘Bangladesh Population and Housing Census 2011’ with probability proportional to EA size. In the second stage, an average of 30 households was chosen using a systematic random sampling approach from each selected EAs. The details of the sample design can be found in the BDHS, 2017–2018 final report.\textsuperscript{4} A total of 89457 households were counted from a successful interview of 19457 households in the survey. As per the survey report, 14704 respondents (6691 men and 8013 women) met the eligibility criteria for BP and blood glucose tests, all of whom were 18 years of age or older.\textsuperscript{1} Finally, BP measurements were taken for 7452 women and 5687 men, while blood glucose tests were administered to 6971 women and 5286 men in the BDHS, 2017–2018. However, for

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**Figure 1** Conceptual path diagram for the empirical association between living standard and diabetes or hypertension.
the current study, 11961 adults (5124 males and 6837 females) were selected after removing missing observations from the dataset.

Outcome measures
The study focused on three distinct outcome variables: diabetes status, hypertension status and the combined presence of both diabetes and hypertension. The study followed the WHO guidelines to define diabetes status. A person was considered to have diabetes if, at the time of the survey, his or her FBG equivalent level was at or above 7.0 mmol/L or if it was reported that the individual was taking a prescribed medicine to treat their diabetes or high blood sugar. Again, for hypertension status, the BDHS, 2017–2018 measured BP three times of a person during the survey interview, with an interval of at least 5 min between successive measurements, and then took the average of second and third measurements to report the respondent’s both systolic BP (SBP) and diastolic BP (DBP) values. It is noted that the BDHS, 2017–2018 report and the seventh report of the Joint National Committee were followed to define hypertension status in the study, where a respondent was considered to have hypertension if, at the time of the survey, he or she had SBP of ≥140 mm Hg or DBP of ≥90 mm Hg, or if he/she reported any of the following during the survey’s interview: a doctor or nurse diagnosed high BP or taking prescribed medication to lower BP. Moreover, a binary variable was established to categorise individuals as 1 if they had both diabetes and hypertension and as 0 otherwise. This variable was employed to assess the impact of LSD on individuals with concurrent diabetes and hypertension. Existing research underscores the interconnectedness of hypertension and diabetes, with hypertension frequently manifesting among individuals diagnosed with diabetes.

Main exposure
The respondent’s standard of living in the household was considered as a main exposure in the study. The LSD is a composite index that is measured through some household characteristics. The Oxford Poverty and Human Development Initiative, carried out in 2011 by Alkire and Foster, was used in the study to calculate LSD. Following a prior study, six indicators across six different dimensions were employed in calculating the LSD. Lighting, cooking, sanitation facility, drinking water, housing and asset ownership are the six dimensions (see online supplemental table S1 for indicators and weights). For measuring the LSD index, the deprivation score for each household was calculated giving equal weights to each indicator, so that the sum of a household’s weights across the dimensions is exactly 1. Before calculating the deprivation score, the indicator variables were categorised as 1 or 0, indicating 1 being deprived. Therefore, mathematically, the deprivation score in LSD can be calculated as follows:

\[ Z_i = \sum_{j=1}^{d} w_j I_{ij}, \]

where \( Z_i \) is the deprivation score for the \( i^{th} \) household, \( I_{ij} \) is the value of \( j^{th} \) indicator in the \( i^{th} \) household, \( w_j \) indicates the weighting value of \( j^{th} \) indicator with \( \sum_{j=1}^{d} w_j = 1 \) and \( d \) is the number of dimensions. The deprivation score varies from 0 to 1, with 0 indicating no deprivation and 1 indicating completely deprived in LSD. Following the cutoffs suggested by Alkire and Foster and other research, the deprivation score in LSD was categorised into three groups. A household was categorised as low LSD if its deprivation score was greater than 0.5, moderate LSD if it was between 0.33 and 0.5, and high LSD if it was below 0.33.

Mediator
The primary aim of this study was to examine the empirical correlation between LSD and the presence of diabetes or hypertension. Additionally, the investigation delved into how LSD might influence diabetes or hypertension through alternative pathways. To comprehensively explore both direct and indirect effects, the study incorporated a mediator: overweight/obesity. Overweight and obesity were assessed using specific BMI thresholds. BMI is calculated as the ratio of weight in kilograms to the square of height in metres (kg/m²). According to WHO guidelines, adults were categorised as follows: normal or underweight (BMI < 25 kg/m²), overweight (BMI 25–29.9 kg/m²) and obese (BMI ≥ 30 kg/m²). The study treated BMI as a multinomial mediator variable considering these three distinct categories for mediation analysis.

Control variables
Following the literature, gender (male, female), current age (18–30, 30–40, 40–50, 50+ years), level of education (no education, primary, secondary, college/higher), marital status (unmarried, ever married), place of residence (rural, urban) and division (Barisal, Chattagong, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, Syylhet) were adjusted for examining the effect of LSD on the study outcome.

Statistical analysis
The exploratory results were carried out using univariate and bivariate analysis. Percentage frequencies were computed for the univariate analysis, and the differences in the prevalence of diabetes and/or hypertension by different categories of the selected covariates were estimated in the bivariate analysis (table 1). To examine the unadjusted relationship between outcome measures and selected covariates, a \( \chi^2 \) test was performed, confirming \( p<0.05 \) as statistically significant. According to the conceptual framework (figure 1), it might be revealed that LSD has an impact on diabetes, hypertension, or both directly and indirectly via overweight/obesity (O). As a result, a
Mediation analysis was performed for getting mediated impacts of LSD overweight/obesity. First, a multinomial logistic regression model was applied for overweight/obesity as this measure has three categories, and finally, the binary logistic regression models were used for three different outcome measures of diabetes, hypertension, and diabetes and hypertension statuses. The structural equations with logit link functions are given as follows:

### Table 1: Background characteristics and their bivariate association with diabetes and hypertension

<table>
<thead>
<tr>
<th>Backgrounds</th>
<th>Frequency percentage</th>
<th>Diabetes (PR [95% CI])</th>
<th>Hypertension (PR [95% CI])</th>
<th>Diabetes &amp; hypertension (PR [95% CI])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living standard (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Low</td>
<td>59.8</td>
<td>07.0 (06.2 to 07.7)</td>
<td>26.4 (25.2 to 27.7)</td>
<td>02.9 (02.5 to 03.4)</td>
</tr>
<tr>
<td>Moderate</td>
<td>16.2</td>
<td>10.5 (08.8 to 12.2)</td>
<td>29.2 (26.5 to 31.9)</td>
<td>04.8 (03.5 to 06.1)</td>
</tr>
<tr>
<td>High</td>
<td>24.0</td>
<td>18.5 (16.8 to 20.3)</td>
<td>33.5 (31.4 to 35.6)</td>
<td>09.7 (08.4 to 11.0)</td>
</tr>
<tr>
<td>Body mass index (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Normal or underweight</td>
<td>75.9</td>
<td>08.3 (07.6 to 09.1)</td>
<td>23.6 (22.5 to 24.8)</td>
<td>03.3 (02.9 to 03.7)</td>
</tr>
<tr>
<td>Overweight</td>
<td>20.0</td>
<td>15.8 (14.2 to 17.4)</td>
<td>43.4 (41.1 to 45.7)</td>
<td>09.1 (07.8 to 10.4)</td>
</tr>
<tr>
<td>Obesity</td>
<td>04.1</td>
<td>20.3 (16.2 to 24.4)</td>
<td>47.1 (42.4 to 51.9)</td>
<td>13.6 (10.0 to 17.2)</td>
</tr>
<tr>
<td>Current age (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>18–30</td>
<td>33.0</td>
<td>04.6 (03.8 to 05.5)</td>
<td>11.2 (10.0 to 12.4)</td>
<td>0.8 (0.05 to 01.1)</td>
</tr>
<tr>
<td>30–40</td>
<td>23.6</td>
<td>09.5 (08.2 to 10.8)</td>
<td>24.6 (22.7 to 26.5)</td>
<td>03.6 (02.8 to 04.3)</td>
</tr>
<tr>
<td>40–50</td>
<td>17.1</td>
<td>13.2 (11.5 to 14.9)</td>
<td>35.1 (32.6 to 37.5)</td>
<td>06.8 (05.6 to 08.1)</td>
</tr>
<tr>
<td>50+ years</td>
<td>26.3</td>
<td>16.3 (14.7 to 17.9)</td>
<td>50.0 (47.7 to 51.7)</td>
<td>09.9 (08.6 to 11.1)</td>
</tr>
<tr>
<td>Gender (p value)</td>
<td></td>
<td>0.765</td>
<td>&lt;0.001</td>
<td>0.078</td>
</tr>
<tr>
<td>Male</td>
<td>42.8</td>
<td>10.8 (09.8 to 11.8)</td>
<td>26.9 (25.3 to 28.4)</td>
<td>04.6 (04.0 to 05.3)</td>
</tr>
<tr>
<td>Female</td>
<td>57.2</td>
<td>09.9 (09.0 to 10.8)</td>
<td>29.8 (28.5 to 31.1)</td>
<td>05.0 (04.4 to 05.7)</td>
</tr>
<tr>
<td>Level of education (p value)</td>
<td></td>
<td>0.834</td>
<td>&lt;0.001</td>
<td>0.630</td>
</tr>
<tr>
<td>No education</td>
<td>26.2</td>
<td>10.2 (08.9 to 11.4)</td>
<td>36.6 (34.5 to 38.7)</td>
<td>05.0 (04.2 to 06.0)</td>
</tr>
<tr>
<td>Primary</td>
<td>30.1</td>
<td>10.4 (09.1 to 11.7)</td>
<td>27.7 (26.0 to 29.4)</td>
<td>04.6 (03.8 to 05.3)</td>
</tr>
<tr>
<td>Secondary</td>
<td>29.7</td>
<td>10.7 (09.4 to 11.9)</td>
<td>24.8 (23.1 to 26.6)</td>
<td>05.2 (04.3 to 06.1)</td>
</tr>
<tr>
<td>College or higher</td>
<td>14.0</td>
<td>09.6 (08.1 to 11.1)</td>
<td>23.4 (21.1 to 25.6)</td>
<td>04.4 (03.4 to 05.5)</td>
</tr>
<tr>
<td>Marital status (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unmarried</td>
<td>09.7</td>
<td>05.1 (03.5 to 06.8)</td>
<td>11.5 (09.6 to 13.3)</td>
<td>0.9 (0.3 to 01.5)</td>
</tr>
<tr>
<td>Ever married</td>
<td>90.3</td>
<td>10.9 (10.1 to 11.6)</td>
<td>30.4 (29.2 to 31.6)</td>
<td>05.3 (04.8 to 05.8)</td>
</tr>
<tr>
<td>Place of residence (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urban</td>
<td>26.6</td>
<td>13.7 (12.3 to 15.1)</td>
<td>30.1 (28.2 to 32.1)</td>
<td>06.5 (05.5 to 07.5)</td>
</tr>
<tr>
<td>Rural</td>
<td>73.4</td>
<td>09.1 (08.2 to 10.0)</td>
<td>28.0 (26.7 to 29.3)</td>
<td>04.3 (03.7 to 04.8)</td>
</tr>
<tr>
<td>Division (p value)</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Barisal</td>
<td>05.5</td>
<td>10.4 (08.1 to 12.7)</td>
<td>34.0 (30.7 to 37.2)</td>
<td>04.9 (03.5 to 06.4)</td>
</tr>
<tr>
<td>Chittagong</td>
<td>17.2</td>
<td>11.8 (09.7 to 13.9)</td>
<td>30.7 (27.9 to 33.4)</td>
<td>06.6 (05.2 to 08.1)</td>
</tr>
<tr>
<td>Dhaka</td>
<td>23.2</td>
<td>14.9 (12.7 to 17.0)</td>
<td>25.3 (22.4 to 28.1)</td>
<td>06.0 (04.7 to 07.3)</td>
</tr>
<tr>
<td>Khulna</td>
<td>12.4</td>
<td>08.7 (07.3 to 10.2)</td>
<td>30.8 (27.8 to 33.8)</td>
<td>05.2 (04.0 to 06.4)</td>
</tr>
<tr>
<td>Mymensingh</td>
<td>08.1</td>
<td>08.0 (06.2 to 09.9)</td>
<td>23.7 (20.8 to 26.6)</td>
<td>03.4 (02.2 to 04.6)</td>
</tr>
<tr>
<td>Rajshahi</td>
<td>14.5</td>
<td>08.2 (06.5 to 10.0)</td>
<td>28.8 (25.8 to 31.8)</td>
<td>03.6 (02.6 to 04.6)</td>
</tr>
<tr>
<td>Rangpur</td>
<td>12.6</td>
<td>05.6 (04.3 to 06.9)</td>
<td>31.1 (28.7 to 33.5)</td>
<td>02.7 (01.8 to 03.5)</td>
</tr>
<tr>
<td>Sylhet</td>
<td>06.5</td>
<td>09.6 (07.2 to 12.1)</td>
<td>26.5 (23.5 to 29.5)</td>
<td>04.4 (03.0 to 05.7)</td>
</tr>
<tr>
<td>Total</td>
<td>n=11961</td>
<td>10.3 (09.6 to 11.1)</td>
<td>28.6 (27.5 to 29.7)</td>
<td>04.9 (04.3 to 05.3)</td>
</tr>
</tbody>
</table>

Note. p-values resulting from the chi-square test are denoted in bold within the respective rows of the independent variables. PR, prevalence rate.
In Eq. (3), \( \Pr(\Omega = 1) \), \( \Pr(\Omega = 2) \) and \( \Pr(\Omega = 3) \) represent the probabilities of having normal/overweight, overweight and obesity, respectively so that \( \sum_{j=1}^{3} \Pr(\Omega = j) = 1 \), and \( \Pr(\Omega = 3) \) is considered as baseline probability. In Eq. (3), \( p_1 \), \( p_2 \) and \( p_3 \) indicates the probabilities of developing diabetes, hypertension and both, respectively. In both equations, \( \alpha_j(j=2,3) \) and \( \beta_{ij} \) \((i=1,2,3)\) are the constants; \( X \) = vector of control variables; \( \alpha_j, \beta_k, \eta_j, \delta_{ij} \) and \( \gamma_k \) are the regression coefficients. One may express the probabilities as follows:

\[ p_k = \left[ 1 + \beta_{0k} + \beta_k \cdot \text{LSD} + \eta_k \cdot O + \gamma_k \cdot X \right]^{-1}, \quad k = 1, 2, 3 \]

\[ \Pr(\Omega = 1) = \left[ 1 + \exp \left( \sum_{j=2}^{4} a_j' Z \right) \right]^{-1}, \quad \text{and} \]

\[ \Pr(\Omega = j) = \exp \left( a_j' Z \right) \times \Pr(\Omega = 1); \quad j = 2, 3 \]

Note that the regression coefficient \( \beta_k \) is the direct effect of LSD on the \( k^{th}(k = 1, 2, 3) \) outcome variable (diabetes, hypertension and both). The indirect effect of LSD via overweight/obese on the \( k^{th} \) outcome is the product of the regression coefficient of LSD obtained from model (2) and the regression coefficient of overweight/obese obtained from model (3), that is, \( \alpha_j \times \tau_k \). The direct and indirect effects of LSD are added together to create its total effect on diabetes and/or hypertension, that is, total effect = \( \beta_k + \alpha_j \times \tau_k \). A number of 10000 bootstrap sampling samples were used to estimate the bias-corrected SEs of the indirect. Stata V.18 was used for all analyses.

Patient and public involvement

The research question, outcome measurement and study design were not developed with the involvement of any patients. As a result, we are unable to directly disseminate the research findings to the study participants.

RESULTS

Exploratory data analysis

The percentage distribution of study participants among different categories of selected outcome, mediator and control variables has been reported in Table 1. A total of 11961 adults participated in the study. Among them 10.3% had only diabetes, 28.6% were suffering from hypertension, and 4.9% had both diabetes and hypertension. The majority of the participants (59.8%) belong to low LSD and approximately one-fourth (24.0%) were from high LSD. It has been found that one-third of the individuals were in the age group 18–30 years, and more than one-fourth (26.3%) were 50 years or older. More than half of the respondents (57.2%) were female, and a few of the respondents (9.7%) were not married. Only 14% of adults were highly educated, whereas 26.2% of the individuals had no institutional education. The majority of participants (73.4%) lived in urban areas, and the highest number (23.2%) participated in the study from the Dhaka division, with the lowest (5.5%) being from Khulna.

Table 1 further presents an overview of the prevalence of diabetes, hypertension and the coexistence of both diabetes and hypertension across various selected exposure variables. Notably, a distinct pattern emerges as the LSD of the participants increases, with the prevalence exhibiting a significant rise (p<0.001). For instance, among individuals with a low level of LSD, the rates of diabetes, hypertension and both conditions were 7.0%, 26.4% and 2.9%, respectively. In contrast, among those with a high level of LSD, these rates saw a substantial increase to 18.5%, 33.5% and 9.7%, respectively. This stark contrast in prevalence emphasises the noteworthy influence of LSD on the occurrence of diabetes, hypertension and their coexistence. Similar results were also found for overweight/obese adults as the prevalence of diabetes and hypertension was significantly (p<0.001) higher for overweight and obese persons compared with normal or underweighted adults.

Figure 2 illustrates the variation in the prevalence of the diabetes–hypertension combination across different levels of BMI among individuals categorised under low, moderate and high LSD. The data in Figure 2 distinctly highlight that the prevalence of overweight and obesity is notably elevated among individuals with high LSD, whereas it is lowest among those with low LSD. Furthermore, the occurrence of diabetes and hypertension was observed to be most pronounced among individuals classified as overweight or obese within households with high LSD. For instance, among individuals who are obese and maintain a low standard of living, the prevalence of diabetes was recorded at 9.2%. However, when examining individuals with both obesity and a high standard of living, the prevalence of diabetes escalated almost threefold to reach 26.4%. Similar trends were also apparent for individuals classified as overweight and maintaining a high standard of living. This observation underscores the pivotal role played by the standard of living in influencing diabetes and hypertension through the amplification of BMI levels among individuals.

Mediation analysis

The findings of this study are presented in Table 2, obtained through mediation analysis using the structural equation modelling (SEM) technique. Covariate adjustments were made for gender, current age, level of education, marital status, place of residence and division. This analysis elucidated the direct impact of LSD, as well as the indirect effects mediated by overweight and obesity, on the occurrence of diabetes, hypertension or both conditions. To examine the relationship between LSD and overweight/obesity, a multinomial logistic regression model was employed. The model evaluated the influence of LSD on the likelihood of being overweight or obese.
Additionally, a binary logistic regression model was separately conducted to assess the effects of both LSD and overweight/obesity on the incidence of diabetes, hypertension, and the co-occurrence of both conditions. The assessment of the direct impact of LSD on overweight/obesity involved the use of relative risk ratios (RRRs) derived from a multinomial logistic regression model. The reference group was defined as those without overweight or obesity. The RRR for a specific category of a qualitative covariate within a particular outcome group was calculated as the ratio of the risk ratio of that category to the risk ratio of the reference category. The risk ratio represented the probability of belonging to a specific outcome group divided by the probability of being in the reference group.

Figure 2  Prevalence of having diabetes, hypertension or both among people belonging to different groups of living standard by their overweight or obesity levels.
**Table 2** Direct, indirect through overweight and obesity, and total effects of living standard on the status of diabetes-hypertension combination based on BDHS, 2017–2018 data

<table>
<thead>
<tr>
<th>Effects Channel</th>
<th>Exposures</th>
<th>Overweight</th>
<th>Obesity</th>
<th>Diabetes</th>
<th>Hypertension</th>
<th>Diabetes and hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>RRR (95% CI)</td>
<td>RRR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Direct effect of living standard</td>
<td>Living standard</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>1.56 (1.36 to 1.79)*</td>
<td>2.34 (1.73 to 3.17)*</td>
<td>1.40 (1.16 to 1.69)*</td>
<td>1.21 (1.07-1.38)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>2.72 (2.39 to 3.10)*</td>
<td>7.10 (5.46 to 9.22)*</td>
<td>2.33 (1.97 to 2.76)*</td>
<td>1.25 (1.10 to 1.42)*</td>
</tr>
<tr>
<td>Body mass index</td>
<td>Normal or underweight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overweight</td>
<td>1.68 (1.46 to 1.95)*</td>
<td>2.49 (2.24 to 2.77)*</td>
<td>2.25 (1.85 to 2.75)*</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Obesity</td>
<td>1.92 (1.50-2.46)*</td>
<td>2.75 (2.24-3.36)*</td>
<td>2.79 (2.04-3.80)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect effect of living standard</td>
<td>Overweight</td>
<td>Living standard</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>1.25 (1.14 to 1.38)*</td>
<td>1.47 (1.29 to 1.68)*</td>
<td>1.42 (1.23 to 1.64)*</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>1.69 (1.44 to 1.98)*</td>
<td>2.45 (2.10 to 2.86)*</td>
<td>2.26 (1.80 to 2.84)*</td>
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<tr>
<td>Obesity</td>
<td>Living standard</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>1.67 (1.26 to 2.22)*</td>
<td>2.28 (1.61 to 3.24)*</td>
<td>2.24 (1.50 to 3.37)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>3.54 (2.11 to 5.96)*</td>
<td>7.59 (4.81 to 11.99)*</td>
<td>7.29 (3.68 to 14.45)*</td>
<td></td>
</tr>
<tr>
<td>Total effect of living standard</td>
<td>Overweight</td>
<td>Living standard</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>1.75 (1.42 to 2.15)*</td>
<td>1.77 (1.48 to 2.12)*</td>
<td>2.21 (1.63 to 2.98)*</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>3.94 (3.17 to 4.90)*</td>
<td>3.13 (2.60 to 3.77)*</td>
<td>5.63 (4.14 to 7.66)*</td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>Living standard</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>2.34 (1.67 to 3.27)*</td>
<td>2.75 (1.90 to 3.98)*</td>
<td>3.48 (2.16 to 5.63)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>8.27 (4.90 to 13.96)*</td>
<td>9.67 (6.12 to 15.31)*</td>
<td>18.14 (9.12 to 36.09)*</td>
<td></td>
</tr>
</tbody>
</table>

Adjusted by gender, current age, level of education, marital status, place of residence and division.

*P<0.001; **p<0.01; ***p<0.05; ****p<0.10.

BDHS, Bangladesh Demographic and Health Survey; RRR, relative risk ratio.
The analysis revealed a noteworthy association between LSD and BMI levels. Specifically, the data indicated a significant increase in the likelihood of overweight and obesity among individuals with higher LSD in Bangladesh. For instance, individuals with moderate and high LSD were 1.56 and 2.72 times more likely to be overweight, and 2.34 and 7.10 times more likely to be obese, respectively, compared with those with no overweight or obesity. Furthermore, LSD exhibited a significant impact on the occurrence of diabetes, hypertension or both conditions. Individuals with moderate LSD had a 40% higher likelihood (OR 1.40; 95% CI 1.16 to 1.69) of having diabetes, a 21% higher likelihood (OR 1.21; 95% CI 1.07 to 1.38) of having hypertension, and a 55% higher likelihood (OR 1.55; 95% CI 1.19 to 2.02) of having both conditions, compared with those with low LSD. Similarly, individuals with high LSD exhibited even more substantial probabilities of developing these conditions: 133% (OR 2.22; 95% CI 1.97 to 2.76) for diabetes, 25% (OR 1.25; 95% CI 1.10 to 1.42) for hypertension and 148% (OR 2.48; 95% CI 1.96 to 3.14) for both conditions. Moreover, the study emphasised the role of increased BMI levels, denoting overweight and obesity, as potential risk factors for diabetes, hypertension and both conditions. In comparison to individuals with normal or underweight BMI, those with overweight had 1.68, 2.49 and 2.25 times higher odds of developing diabetes, hypertension and both conditions, respectively. Similarly, individuals with obesity faced even greater risks: 1.92, 2.75 and 2.79 times higher odds for diabetes, hypertension and both conditions, respectively. This highlights a clear connection between higher BMI levels and increased susceptibility to diabetes and hypertension.

The preceding discussion of results provides clear insights into the direct impact of LSD on the development of diabetes, hypertension or both, as well as its influence on elevated BMI levels. Furthermore, given the interplay between LSD and BMI levels, and the subsequent influence of BMI levels on diabetes and hypertension, the study underscores the potential for LSD to indirectly affect the occurrence of diabetes and hypertension, with BMI levels playing a crucial intermediary role. As a result, a mediation analysis was undertaken to validate the hypothesis that BMI serves as a significant mediator in the relationship between LSD and diabetes, hypertension or both. To assess the statistical significance of the mediating or indirect effects of LSD, a mediation analysis generated 10,000 bootstrap samples. The results pertaining to indirect effects, as presented in table 2, affirm the substantial mediating role of LSD through overweight or obesity in the context of diabetes, hypertension and their co-occurrence. Specifically, it was observed that among individuals with a high standard of living, the indirect odds of developing diabetes through overweight and obesity were 1.69 times higher and 3.54 times higher, respectively, compared with those with a low standard of living. Furthermore, individuals with a high standard of living exhibited increased likelihoods of hypertension through overweight and obesity, with ORs of 2.54 and 7.59, respectively, when compared with individuals with a low standard of living. This consistent and significant trend was similarly evident in cases of the co-occurrence of diabetes and hypertension. These findings underscore the intricate relationship between LSD, BMI levels and the development of diabetes and hypertension. The mediating effects of overweight and obesity on these conditions, particularly in the context of varying LSD, highlight the need for comprehensive interventions addressing both socioeconomic factors and health outcomes.

The graphical representation in figure 3 elucidates the contribution of direct and indirect effects of LSD on the development of diabetes, hypertension and

![Figure 3](https://bmjopen.bmj.com/content/13/1/e075370)
their co-occurrence, mediated through overweight and obesity. Notably, the indirect influence of LSD via obesity was more pronounced compared with its direct effect or the indirect effect mediated by overweight in relation to the occurrence of diabetes, hypertension or both conditions. For example, when examining the development of diabetes, moderate and high LSD exhibited direct effects of 0.34 and 0.85, respectively. However, the corresponding indirect effects through obesity were notably higher at 0.51 and 1.3, respectively. This indicates that the indirect impact of LSD on diabetes through obesity surpasses its direct impact by over 30%. Similarly, in the context of developing hypertension, the indirect effects of high LSD through overweight and obesity were substantially greater than the direct effect. While the direct effect of high LSD was 0.22, its indirect effects through overweight and obesity were 0.90 and 2.03, respectively, showcasing an indirect impact over 75% stronger than the direct impact. This noteworthy trend of higher indirect effects through obesity also held for the co-occurrence of diabetes and hypertension. The visual representation in figure 3 underscores that LSD not only have a direct influence on the likelihood of diabetes and hypertension but also exert an influence through intermediary factors such as BMI levels. Importantly, the study reveals that as BMI levels increase among adults in Bangladesh, the indirect effects of LSD on diabetes and hypertension become increasingly pronounced, surpassing the direct effects.

DISCUSSION
The prevalence of diabetes and hypertension has increased drastically over the past decade among adults in Bangladesh.44–46 It was found from this study that the prevalence of diabetes, hypertension, and both diabetes and hypertension was 10.3%, 28.6% and 4.9%, respectively. Several studies revealed that age, gender, BMI, wealth index, education, marital status and place of residence were the potential factors associated with diabetes and/or hypertension.44–46 The main aim of this study was to explore the adjusted direct association of LSD as well as indirect associations through overweight/obesity on diabetes, hypertension or both conditions among adults in Bangladesh using the mediation analysis technique.

A significant direct association of LSD with diabetes and/or hypertension was observed. Moreover, the LSD of individuals have indirect influences on diabetes and/or hypertension through overweight and obesity, respectively. Results obtained from this study showed that individuals with high LSD had a higher prevalence rate of diabetes and/or hypertension. In addition, overweight/obesity led an adult to a higher risk of experiencing diabetes and/or hypertension. Several earlier studies found that the wealth quintile plays a significant role in suffering from diabetes as well as hypertension, as people get wealthier, they had a higher rate of diabetes or hypertension.44–45 Individuals’ overweight/obesity led to a higher rate of diabetes or hypertension.46 Moreover, working people suffer less from diabetes as well as from hypertension47–48 because they are able to maintain their BMI levels. The current study indicated that LSD directly influenced overweight/obesity and through these, it influenced diabetes or hypertension. Interestingly, the indirect effect of LSD through obesity was greater than its direct effect on developing diabetes or hypertension. This may happen as people with higher LSD were less involved in physical activity and hence suffered more from diabetes, hypertension or both. Again, improvements in LSD resulted in becoming overweight among adults, which in turn increases the prevalence of diabetes–hypertension combination. Therefore, this study established the fact that overweight and obesity both play significant mediating roles to enhance the relationship between LSD and diabetes or hypertension among individuals.

This is the first study that used mediation analysis using SEM and multinominal logistic regression to explore the intermediary of both overweight and obesity on the association between LSD and diabetes or hypertension status. Note that LSD was developed as a composite index considering six indicators associated with household wealth. However, there are some limitations. In this study, though the data were extracted from a nationally representative survey, the data are cross-section in nature. Therefore, it is not possible to draw a causal inference. Moreover, other potential covariates of diabetes and/or hypertension such as the family history of diabetes and hypertension (heredity), physical activity, and dietary habits were not adjusted due to unavailability of information. Physical activity may be one of the most important risk factors for overweight/obesity, diabetes and hypertension. In addition, the study’s findings are specific to the context of Bangladesh and might not be directly applicable to other populations or countries with different sociocultural, economic and healthcare settings.

CONCLUSION
This study sheds light on the complex interplay between LSD, diabetes, hypertension and the intermediary impact of overweight and obesity. The insights gleaned from this research carry significant implications for both public health and policy-making. The study emphasises the intricate nature of health outcomes, where socioeconomic circumstances intersect with lifestyle choices to mould the susceptibility to the chronic conditions of diabetes and hypertension. As societies make progress in terms of LSD, there is a tendency for individuals to adopt more sedentary routines and experience weight gain. This contributes to elevated BMI levels, ultimately raising the risk of diabetes and hypertension. The findings underscore that those belonging to the higher LSD households face an elevated risk of developing these health issues. This underlines the importance of reinforcing health promotion and early identification measures among these groups, aiming to halt the advancement of these conditions. Efforts to enhance the quality of LSD must
be supplemented with strategies that encourage regular physical activity, balanced nutrition and weight management. It is imperative to raise awareness about the potential risks associated with the confluence of raising LSD and the mediating effect of overweight and obesity. Informative campaigns have the potential to empower individuals to adopt healthier lifestyles and make well-informed decisions about their overall well-being. In crafting solutions, healthcare systems should embrace an integrated approach that takes into account the social determinants of health, including LSD, while devising strategies for the prevention and management of chronic diseases. Effective collaboration among healthcare, social services and other pertinent sectors is pivotal in addressing the multifaceted determinants that influence health outcomes. Through such collaborative endeavours, a comprehensive and lasting impact can be achieved in reducing the risks of developing diabetes and hypertension.

In order to address the current limitations of our study, future research endeavours could focus on several aspects. Specifically, an investigation could be conducted to delve deeper into the mediating role of physical activity in the intricate relationship between LSD and diabetes or hypertension. This would provide a more comprehensive understanding of how physical activity influences the impact of LSD on these health conditions. Furthermore, the establishment of a causal relationship between LSD and the development of diabetes and/or hypertension could be accomplished through a meticulous follow-up study. By tracking individuals over an extended period, researchers could obtain valuable insights into the long-term effects of varying LSD on the occurrence of these chronic conditions. Such a study design would enable a more robust exploration of causality, contributing significantly to the existing body of knowledge in this field.

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Contributors KKS and WB provided the concept and design for the study. The analysis or interpretation of data was done by KKS, AJ and UNI. The manuscript was first drafted by KKS, AJ and UNI. Critical revision of the manuscript for important intellectual content was done by KKS and AJ. Statistical analysis was conducted by KKS and AJ. UNI reviewed the literature. Study supervision was done by KKS and WB. Important intellectual content was done by KKS, AJ and WB. Statistical analysis was done by KKS, AJ and UNI. The manuscript or interpretation of data was done by KKS, AJ and UNI. The manuscript or interpretation of data was done by KKS, AJ and UNI. The manuscript or interpretation of data was done by KKS, AJ and UNI.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval No ethics approval was required as this study used cross-sectional data which is available freely and publicly with all identifier information removed. To access and analyse the dataset, we obtained official permission from the DHS programme. The Institutional Review Boards of Bangladesh Medical Research Council, Dhaka, Bangladesh, and ICF International, Rockville, MD, USA, approved the collection of demographic and health survey data for the BDHS, 2017–2018. With financial assistance from USAID/Bangladesh, the BDHS, 2017–2018 was carried out under the authority of the National Institute of Population Research and Training (NIPORT) of the Government of the People's Republic of Bangladesh. Prior to being questioned, informed consent was obtained from each survey participant. The responders who refused to consent were not included in the survey.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The Bangladesh Demographic and Health Survey (BDHS), 2017–2018 data used in this study are publicly available. Anyone can download the original data from the DHS website https://dhsprogram.com/methodology/survey/survey-display-536.cfm.

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ORCID iD Kanchan Kumar Sen http://orcid.org/0000-0001-7410-7490

REFERENCES


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