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## Malnutrition and associated factors affecting the nutritional status of adult rural population in Bangladesh

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# Malnutrition and associated factors affecting the nutritional status of adult rural population in Bangladesh

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## Abstract

**Introduction:** The burden of malnutrition is widely evaluated in Bangladesh in different contexts. However, most of them determine the burden of sociodemographic factors that have limited scope to modify and design intervention. Hence, this study attempted to assess the current burden of malnutrition and sought its association with various modifiable risk factors.

**Method:** This study was part of a cross-sectional study that applied the WHO Package of Essential Noncommunicable Disease Interventions (WHO PEN) in a rural area of Bangladesh to assess the burden of diabetes, hypertension and their associated risk factors. The sampling technique was census, and anthropometric measurement was taken following the standard protocol described in the WHO STEPS-wise approach to Surveillance for Noncommunicable Diseases risk factors survey of Bangladesh.

**Result:** The mean BMI of the study population was 21.9 kg/m<sup>2</sup> (95% CI = 21.8-22.0). About 20.9% were underweight, and 16.4% were overweight, and 3.5% obese. Underweight was most predominant among people above 60 years of age, while overweight and obesity were predominant among people between 31-40 years' age group. Higher overweight and obesity were noted among females. Consumption of added salt and inactivity increased the odds of being underweight by 0.32 and 0.20, respectively. On the other hand, the odds of being overweight or obese increased by 0.96, 0.55, and 0.63 if a respondent was married, literate, and female; and by 0.25 and 0.18 if a respondent consumed red meat and took inadequate amounts of fruits and vegetables respectively. Consumption of added salt decreases the odds of being overweight or obese by 0.37.

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3 **Conclusion:** The study once again emphasized malnutrition to be of public health concern in spite  
4 of the dynamic sociodemographic scenario. Specific health messages for targeted population may  
5 help to improve the nutritional status. Findings from further explorations may support policies and  
6 programs in future.  
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13 **Keywords:** Obesity, overweight, underweight, physical activity, Bangladesh, body mass index  
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### 16 17 **Strengths and limitations of this study** 18 19

- 20  
21 • This study attempted to assess the current burden of malnutrition and look at its association  
22 with different modifiable risk factors among adults in a selected rural population of  
23 Bangladesh  
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- 26 • The sampling technique was census and data was collected from all adults except those  
27 institutionalized in a hospital, prison, nursing home, or other similar institutions  
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- 30 • People who are already diagnosed tend to visit health facilities more often than those who  
31 remain undiagnosed  
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- 34 • Some of the subjects included in the study were already on medication or received lifestyle  
35 modification counseling  
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# 1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.<sup>1, 2</sup> Near about one-third of people in any community have at least one form of malnutrition, which include disorders caused by excessive and/or imbalanced intake leading to obesity and overweight, and disorders caused by deficient intake of energy or nutrients leading to stunting, wasting, and micronutrient deficiencies. Both over- and under-nutrition are caused by intake of unhealthy and poor quality diets.<sup>1</sup> Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.<sup>2</sup> Studies show that prevalence of obesity and overweight are increasing over time.<sup>3</sup> Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.<sup>4</sup> At least 2.8 million people die each year due to causes related to obesity and overweight.<sup>5</sup> Data from a national survey show that in Bangladesh, about 30.4%, 18.9%, and 4.6% of adults were underweight, overweight, and obese respectively.<sup>6</sup>

Unhealthy dietary behavior, low physical activity, genetics, family history of certain diseases, community environment, and usage of some drugs can lead to obesity and overweight.<sup>7</sup> Obesity and overweight are two of the key risk factors for noncommunicable diseases such as cardiovascular diseases, and diabetes mellitus, which are known major public health concerns.<sup>8, 9,</sup>  
<sup>10</sup> Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.<sup>1, 11</sup> Diabetes and hypertension have some common and important risk factors, such as unhealthy diet, inadequate physical inactivity, tobacco use, abnormal lipid profiles and overweight/obesity.<sup>12</sup> About 85.0% of premature deaths from NCDs now occur in low- and middle-income countries, where greater burden of undernutrition and infectious diseases also exist.<sup>1, 13</sup> In economically well-off countries, NCDs are noted disproportionately among vulnerable

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3 and disadvantaged groups.<sup>2</sup> On the other hand, in less developed economies, childhood  
4 undernutrition affects health, survival, growth and development in rural population.<sup>1</sup> Globally,  
5 undernutrition contributes to around 45% of deaths among under-five children, the majority of  
6 which occur in low- and middle-income countries.<sup>1</sup>  
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13 Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical  
14 outcome of the dramatic shift in current food systems, which focus on increasing availability of  
15 inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets.  
16 Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts)  
17 has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat,  
18 sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely  
19 available.<sup>1</sup> Studies show that reduction in risk factors through lifestyle modifications help greatly  
20 in reducing the burden of most non-communicable diseases including hypertension, diabetes,  
21 malnutrition, and mental disorders.<sup>14, 15</sup> Studies in rural Bangladesh found that 55% of women  
22 ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly  
23 and monthly basis respectively.<sup>16, 17</sup>  
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40 Under these circumstances, developing countries like Bangladesh can benefit from interventions  
41 that help the primary health care facilities to be ready to tackle different noncommunicable diseases  
42 that are predisposed by overweight, obesity, and undernutrition. This study provides an  
43 opportunity to find the influencing factors and predictors of malnutrition in the current changing  
44 lifestyle among selected communities. This study was conducted to determine the prevalence of  
45 underweight, overweight and obesity, and their predictors in a rural population of Bangladesh.  
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3 different socio-demographic characteristics.<sup>18-26</sup> This study builds up on the previous studies by  
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5 examining the association of various risk factors with underweight, overweight and obesity on a  
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7 large dataset of adult population.  
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## 10 11 **2. Methods**

### 12 13 14 15 16 **2.1 Study design, setting, and participants**

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20 This was a cross-sectional study that incorporated quantitative methods to fulfill the study  
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22 objectives. It was a part of an implementation research in a randomly selected union (smallest rural  
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24 administrative and local government units), Dhangora, among the three unions (Brammagachha,  
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26 Chandaikona, and Dhangara) of Raiganj sub-district under Sirajganj district of Bangladesh. The  
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28 three unions of Raiganj are under active health and demographic surveillance system of the  
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30 implementing organization – Centre for Injury Prevention and Research Bangladesh (CIPRB),  
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32 since 2006. Dhangara union has 12323 households with a population size of 51759, of whom  
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34 35704 were adult population ( $\geq 18$  years old) during the data collection.  
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40 The sampling technique was a census that included all adults except those who were mentally  
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42 challenged or institutionalized in a hospital, prison, nursing home, or other similar institutions. The  
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44 duration of the study was six months from January to June 2019, while data was collected from  
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46 March to June 2019.  
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## 2.2 Data collection instrument and procedure

As a part of an implementation research, this study collected data by screening out the sociodemographic and cardio-metabolic risk factors of chronic diseases (hypertension, diabetes), and determine their prevalence. The study adapted the procedure as described in the WHO Package of Essential Noncommunicable Disease Interventions (WHO PEN) model.<sup>27</sup>

The data was collected electronically at the household level, using an Android-based mobile platform software. Interviewer administered face-to-face interview was used to collect data. The questionnaire was prepared based on the STEP-wise approach to Surveillance (STEPS) of NCD risk factors by the World Health Organization (WHO, Version 3.2). The STEPS questionnaire was modified and used to ask questions on sociodemographic characteristics, behavioral risk factors (such as tobacco and alcohol consumption, physical activity, dietary habits, added salt intake), occurrence of chronic disease, and to measure physical and biochemical parameters (height, weight, blood glucose, blood pressure). The English STEPS questionnaire was first translated to Bangla and then finalized after necessary modification following pre-testing on a suitable population. Data collectors having requisite background were recruited and intensively trained before the commencement of data collection.

Screening at community level posed specific challenges that were identified and addressed, such as, the time of a day or day of a week to reach a particular population like office goers, farmers, homemakers, especially for males. The use of active surveillance provided the advantage of having a full list of households and addresses, which ensured full coverage of the survey area. Data collectors were provided with the list and information required to track each household. If the respondent was unable to provide information when the data collector visited, a new time was

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3 scheduled for the screening as per convenience of the household members and data collector. All  
4 possible measures were taken to ensure full coverage of the population.  
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9 During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.)  
10 among the members was explored. Each participant was interviewed for approximately 25 to 30  
11 minutes. Treatment and other medical documents were reviewed to confirm the disease  
12 conditions, and show-cards were used for food and physical activity to ensure quality data. In some  
13 cases, where a person was not able to respond to data collectors' queries (those who were ill or  
14 had some form of disability), an appropriate person from the household, for example- the caregiver  
15 was asked to answer on behalf provided he/she could give the exact information.  
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26 The household survey participants were advised to visit the nearby community clinic (CC) on the  
27 next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and  
28 biochemical parameters. In the community clinic, standard weight scale, height measurement  
29 scales, measuring tape, and automated digital BP machine were used to record their weight, height,  
30 waist circumference, and blood pressure respectively. Fasting capillary glucose was measured by  
31 a standard glucometer maintaining all necessary aseptic precautions. Blood pressure was measured  
32 twice – first, after 15 minutes' rest time, and second one 3 minutes after the first measurement.  
33 The mean of the two measurements was used to determine the actual BP. Physical measurements  
34 were carried out by well-trained male and female assistants maintaining adequate privacy. The  
35 data collected at the CC were synced with those collected at the household level. The Flow Chart  
36 of study methods applied to collect data is shown in Figure 1.  
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53 **Figure 1: Flow Chart of study methods applied to collect data from selected rural population of**  
54 **Bangladesh**  
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## 2.3 Ascertainment of key variables

**Added salt intake:** The respondents who said they took extra dietary salt while eating any cooked meal were categorized as consumers of added dietary salt.

**Adequate amount of fruit and vegetable (FAV):** Respondents whose dietary intake of FAV corresponded to WHO recommended 5 servings were considered as taking adequate amount of FAV.<sup>28</sup>

**Physical activity:** The respondents were asked about their work-related physical activities, the number of days a week, and the amount of time (in minutes) per day that they spend on vigorous and moderate activities. This was then converted to the metabolic equivalent of task-minutes (MET-minutes) to find out the intensity of physical activity, which were then categorized. The categories were: less active or sedentary ( $\leq 600$  MET-minutes per week), moderately active (between 600 and 3000 MET-minutes per week), and highly or vigorously active ( $\geq 3000$  MET-minutes per week).<sup>29</sup>

**Underweight:** The respondents were considered as underweight when their body mass index (BMI) was less than  $18.5 \text{ kg/m}^2$ .<sup>30</sup>

**Normal weight:** The respondents were considered as normal weight when their BMI was between  $18.5$  and  $25.0 \text{ kg/m}^2$ .<sup>30</sup>

**Overweight:** The respondents were considered overweight when their BMI was between  $25.0$  and  $29.9 \text{ kg/m}^2$ .<sup>30</sup>

**Obese:** The respondents were considered obese when their BMI was over  $30.0 \text{ kg/m}^2$ .<sup>30</sup>

## 2.4 Data analysis

Double entry of raw data was done following careful cleaning and editing for consistency and to preserve for longer time. Descriptive, and relevant statistical analysis were performed on the cleaned data set using SATA version 12. The results were then presented in tables and illustrations. Of the 22270 respondents at the household level, a total of 11244 respondents visited community clinic for the required physical measurements. After cleaning the data, the final analysis was done with a sample of 11,064 respondents.

## 2.5 Patient and public involvement

Data was collected from all adults at household level. Further anthropometric data was collected at the health facilities from those who visited the community clinics. However, the public were not directly involved in the research. They did not play any role during the establishment of the research questions, designing or implementing the study, measuring the study outcomes, or interpretation of the results.

## Ethical consideration

Ethical approval was obtained from the Ethical Review Board of the Center for Injury Prevention and Research, Bangladesh (ERC number: CIPRB/ERC/2019/003). Participants had the right to withdraw at any point after starting the interview. Rigor, accuracy, and impartiality were ensured during data collection through in-person and digital monitoring systems.

## 3. Results

### 3.1 Anthropometric measurements

The mean anthropometric measurements of the respondents and the standard deviations with 95% confidence interval are shown below in Table 1. The mean weight, height, and BMI of the respondents were 51.4 kg, 153.4 cm., and 21.9 kg/m<sup>2</sup>, respectively. The mean waist circumference, hip circumference, and waist-hip ratio were 79.9 cm, 87.2 cm, and 0.9, respectively.

**Table 1: Mean anthropometric measurements of respondents with standard deviation and 95% confidence interval (N = 11,064)**

Mean measurements	Mean (SD)	95% CI
Weight (kg)	51.4 (0.1)	51.2-51.6
Height (cm)	153.4 (0.1)	153.2-153.5
BMI (kg/m <sup>2</sup> )	21.9 (0.0)	21.8-22.0
Waist circumference (cm)	79.9 (0.1)	79.6-80.0
Hip circumference (cm)	87.2 (0.1)	87.1-87.4
Waist-hip ratio	0.9 (0.0)	0.9-0.9

Considering body mass index (BMI), 59.2% of the respondents were within normal range, that is, between 18.5 – 25.0 kg/m<sup>2</sup>. Underweight was found in 20.9% respondents, while that of overweight and obesity was found to be 16.4% and 3.5%, respectively (Figure 2).

## Figure 2: Nutrition status of respondents (N = 11,064)

### 3.2 Sociodemographic characteristics

The socio-demographic characteristics of the respondents are stratified by nutritional status and shown in Table 2 and Table 3, respectively. Irrespective of age, normal nutritional status was noted in about 55-61% respondents as shown in Table 2. Underweight was reported to be highest at 31.3% among  $\geq 60$  years, while overweight and obesity were highest at 21.0% and 5.1% respectively among 31-40 years age group. About 62.5% male and 57.5% female were within the normal range of weight. About 24.7% of men and 19.0% of females were underweight. Higher overweight and obesity were noted among females with 18.8% and 4.6%, respectively. Irrespective of years of schooling, normal weight was recorded in 59.2% of the respondents. Underweight was more with 26.8% among those with no schooling, while overweight (20.3%) and obesity (4.6%) was more among those with education up to or above secondary level. Normal weight was seen in about 60.0%, irrespective of marital status. Underweight was more (20.3%) in those never married, while overweight (17.0%) and obesity (3.7%) was more in those ever married. Underweight was more among unemployed and farmers with 31.3% and 31.9% respectively, overweight was 23.8% among service holders, and 4.8% obesity among homemakers.

### 3.3 Behavioral risk factors

Nutritional status with respect to behavioral risk factors is shown in Table 3. Irrespective of the risk factors considered, normal weight was noted in 57.3% to 60.5% respondents. Considering each risk factor, underweight was noted to be more among those who led sedentary lifestyle

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3 (25.1%), took red meat (21.9%), ate fried food (21.3%), took sugary drinks (21.7%), took added  
4 salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand,  
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6 overweight and obesity were noted as more among those who did moderate to vigorous exercise  
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8 (16.7% & 3.3% - 3.9 % respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8%  
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10 & 3.7%), did not consume processed food (16.5% & 3.4%), did not take sugary drinks (16.9% &  
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12 3.6%), did not take added salt (19.3% & 4.7%), and those who did not take inadequate (took  
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14 adequate) fruits and vegetables (18.2% & 4.3%).  
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**Table 2: Sociodemographic characteristics of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status % (95% CI)			
			Underweight	Normal weight	Overweight	Obese
Age (years)	<=30	2,184	23.7 (21.9–25.5)	61.2 (59.1–63.2)	12.9 (11.6–14.4)	2.2 (1.7 – 3.0)
	31 to 40	2,419	14.4 (13.0–15.8)	59.5 (57.5–61.4)	21.0 (19.5–22.7)	5.1 (4.3 – 6.0)
	41 to 50	2,482	16.3 (14.9–17.8)	59.3 (57.3–61.2)	20.1 (18.5–21.7)	4.4 (3.6 – 5.2)
	51 to 60	2,097	21.7 (20.0–23.5)	59.9 (57.8–62.0)	15.3 (13.8–16.9)	3.1 (2.4 – 3.9)
	> 60	1,882	31.3 (29.3–33.5)	55.5 (53.3–57.8)	10.6 (9.3 – 12.1)	2.5 (1.9 – 3.3)
Sex	Male	3,715	24.7 (23.3–26.1)	62.5 (60.9–64.0)	11.5 (10.5–12.6)	1.3 (1.0 – 1.8)
	Female	7,349	19.0 (18.2–20.0)	57.5 (56.4–58.6)	18.8 (17.9–19.7)	4.6 (4.2 – 5.1)
Education	No schooling	3,969	26.8 (25.5–28.2)	59.2 (57.6–60.7)	11.6 (10.7–12.7)	2.4 (1.9 – 2.9)
	Primary	3,171	19.8 (18.4–21.2)	59.2 (57.5–60.9)	17.4 (16.1–18.7)	3.7 (3.1 – 4.4)
	Secondary and above	3,924	15.9 (14.8–17.1)	59.2 (57.6–60.7)	20.3 (19.1–21.6)	4.6 (4.0 – 5.3)
Marital status	Never married	771	29.3 (26.2–32.6)	61.6 (58.1–65.0)	7.5 (5.9 – 9.6)	1.6 (0.9 – 2.7)
	Ever married	10,293	20.3 (19.5–21.1)	59.0 (58.0–60.0)	17.0 (16.3–17.8)	3.7 (3.3 –4.1)
Occupation	Unemployed	1,057	31.2 (28.5–34.1)	57.6 (54.6–60.6)	8.7 (7.1 – 10.6)	2.5 (1.7 – 3.6)
	Service holder	307	11.1 (28.5–34.1)	62.2 (56.6–67.5)	23.8 (19.3–28.9)	2.9 (1.5 – 5.5)
	Farmer	1,353	31.9 (29.4–34.4)	61.6 (58.9–64.1)	5.9 (4.8 – 7.3)	0.7 (0.3 – 1.3)
	Self-employed	2,416	18.5 (17.0–20.1)	62.7 (60.7–64.6)	16.1 (14.7–17.7)	2.6 (2.1 – 3.4)
	Housewife	5,931	18.1 (17.1–19.1)	57.3 (56.1–58.6)	19.8 (18.8–20.8)	4.8 (4.3 – 5.3)

CI = confidence interval; Underweight = BMI less than 18.5 kg/m<sup>2</sup>; Normal weight = BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight = BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese = BMI is over 30.0 kg/m<sup>2</sup>

**Table 3: Behavioral risk factors of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status % (95% CI)			
			Underweight	Normal weight	Overweight	Obese
Physical activity	Sedentary	1,995	25.1 (23.2–27.0)	57.3 (55.2–59.5)	14.7 (13.2–16.4)	2.9 (2.2 – 3.7)
	Moderate	3,134	22.0 (20.6–23.5)	58.0 (56.2–59.7)	16.7 (15.5–18.1)	3.3 (2.7 – 4.0)
	Vigorous	5,935	19.0 (18.0–20.0)	60.4 (59.2–61.7)	16.7 (15.8–17.7)	3.9 (3.4 – 4.4)
Red meat intake	Yes	2,687	17.9 (16.5–19.4)	58.2 (56.3–60.0)	19.9 (18.4–21.5)	4.0 (3.3 – 4.8)
	No	8,377	21.9 (21.0–22.8)	59.5 (58.5–60.6)	15.2 (14.5–16.0)	3.4 (3.0 – 3.8)
Fried food intake	Yes	2,949	21.3 (19.9–22.8)	60.5 (58.7–62.2)	15.2 (13.9–16.5)	3.1 (2.5 – 3.7)
	No	8,115	20.8 (19.9–21.7)	58.7 (57.6–59.8)	16.8 (16.0–17.6)	3.7 (3.3 – 4.1)
Processed food intake	Yes	2,278	20.9 (19.2–22.6)	59.3 (57.3–61.3)	15.6 (14.2–17.2)	4.2 (3.5 – 5.1)
	No	8,786	20.9 (20.1–21.8)	59.2 (58.1–60.2)	16.5 (15.8–17.3)	3.4 (3.0 – 3.8)
Sugary drinks intake	Yes	4,044	21.7 (20.4–23.0)	59.6 (58.0–61.1)	15.4 (14.3–16.5)	3.4 (2.9 – 4.0)
	No	7,020	20.5 (19.6–21.4)	59.0 (57.8–60.1)	16.9 (16.1–17.8)	3.6 (3.2 – 4.1)
Added salt intake	Yes	6,946	23.2 (22.2 –24.2)	59.3 (58.2–60.5)	14.6 (13.8–15.5)	2.9 (2.5 – 3.3)
	No	4,118	17.1 (16.0–18.3)	58.9 (57.4–60.4)	19.3 (18.1–20.5)	4.7 (4.1 – 5.4)
Inadequate intake of fruits and vegetables	Yes	8,331	21.4 (20.6–22.3)	59.5 (58.5–60.6)	15.7 (15.0–16.5)	3.3 (2.9 – 3.7)
	No	2,733	19.4 (17.9–20.9)	58.1 (56.3–60.0)	18.2 (16.8–19.7)	4.3 (3.6 – 5.1)

CI, confidence interval; Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI is over 30.0 kg/m<sup>2</sup>

### 3.4 Factors affecting the malnutrition

Table 4 shows the multinomial logistic regression analysis of the data. For this analysis, overweight and obese were merged into one variable as overweight/obese. It was found that the odds of being underweight will decrease by 0.27, 0.24, 0.35, and 0.57 if a respondent is less than 45 years of age, female, literate, and married respectively. Consumption of added salt and inactivity increases the odds of being underweight by 0.32 and 0.20, respectively.

On the other hand, the odds of being overweight/obese increased by 0.96, 0.55 and 0.63 if the respondent was married, literate, and female; and by 0.25 and 0.18 if the respondent consumed red meat and took inadequate amount of fruits and vegetables, respectively. Consumption of added salt decreased the odds of being overweight/obese by 0.37.

**Table 4: Factors affecting the malnutrition among the study population using multinomial logistic regression analysis (N = 11,064)**

Malnutrition	Factors	B	p-value*	OR	95% CI for OR	
					Lower Bound	Upper Bound
Underweight	Age					
	< 45 years	- 0.268	< 0.001	0.765	0.685	0.855
	>= 45 years	<i>Ref</i>				
	Sex					
	Female	- 0.239	< 0.001	0.787	0.684	0.906
	Male	<i>Ref</i>				
	Education					
	Literate	- 0.350	< 0.001	0.704	0.632	0.786
	Illiterate	<i>Ref</i>				
	Marital status					
Married	- 0.568	< 0.001	0.566	0.468	0.685	
Unmarried	<i>Ref</i>					

	Added salt intake					
	Yes	0.319	< 0.001	1.376	1.239	1.527
	No	<i>Ref.</i>				
	Inadequate Physical activity					
	Yes	0.204	< 0.001	1.227	1.087	1.384
	No	<i>Ref.</i>				
Overweight/ obese	Sex					
	Female	0.630	< 0.001	1.878	0.600	2.204
	Male	<i>Ref.</i>				
	Education					
	Literate	0.552	< 0.001	1.738	1.541	1.959
	Illiterate	<i>Ref.</i>				
	Marital status					
	Married	0.961	< 0.001	2.615	1.997	3.425
	Unmarried	<i>Ref.</i>				
	Red meat intake					
	Yes	0.253	< 0.001	1.288	1.153	1.439
	No	<i>Ref.</i>				
	Added salt intake					
	Yes	- 0.373	< 0.001	0.689	0.623	0.762
No	<i>Ref.</i>					
Inadequate fruits and vegetables intake						
Yes	0.178	0.002	1.195	1.067	1.339	
No	<i>Ref.</i>					

Ref., reference; OR, odd-ratio; CI, confidence interval

\*Significant at the threshold of  $p < 0.05$

Only OR > 1 and CI for OR didn't contain 1 was considered

Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Overweight/obese, BMI is over 25.0 kg/m<sup>2</sup>

## 4. Discussion

This study found that underweight, overweight, and obesity are of similar concern among the adult rural population in Bangladesh. According to the WHO estimates, the age-standardized estimation of prevalence of overweight among adults in the South-east Asia was 21.9% in 2016, which was higher than that found in this study.<sup>17</sup> A study in South Africa found that the mean waist circumference for rural men and women was much higher, putting them at high risk of NCDs.<sup>31</sup> In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children was found to be less than ten percent.<sup>18</sup> Other studies among the rural and urban populations of Bangladesh found that prevalence of overweight and obesity were 15% – 18.9%, and 3% – 4.6%, respectively.<sup>6, 19, 20, 21</sup> The occurrence of overweight and obesity found in this study was near similar to the combined overweight and obesity as found in other studies in Bangladesh. However, the population of other studies included everyone in the study area, while this study included only adult population. It was noted in this study that factors such as extreme age, varied occupation, and other physio-demographic features influenced prevalence of obesity and overweight. Since this study was conducted in a surveillance population, the community members may already have been a little more aware of the importance of healthy lifestyles.

In this study, respondents in the age group 31 – 40 years were the most overweight and obese, while those 60 years and above were the most underweight. Females were found to be more overweight and obese than males, while males were found to be more underweight than females. The study also found that the likelihood of being overweight and obese increased among married and literate females, in contrast to unmarried and illiterate males. On the other hand, literate and married females less than 45 years were less likely to be underweight compared to illiterate and

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3 married males more than 45 years of age. Age between 33 – 37 years was also found significantly  
4 associated with obesity and overweight in other studies among rural women of Bangladesh (OR:  
5 3.71; 95% CI: 2.84 – 4.86;  $p < 0.001$ ).<sup>19</sup> Other studies have shown that urban women aged 30 to 39  
6 years were obese and/or overweight with a high association (OR: 3.9; 95% CI: 1.9 – 7.7;  
7  $p < 0.001$ ).<sup>23</sup> There are studies that also showed that the prevalence of underweight among males of  
8 more than 50 years of age was much high.<sup>20, 32</sup> The findings from this study corroborate with these  
9 earlier findings.

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12 The odds of overweight and obesity increased by 0.25 and 0.18 among respondents who consumed  
13 red meat and took inadequate amount of fruits and vegetables, and decreased by 0.37 among those  
14 who consumed added salt. On the other hand, consumption of added salt and inactivity increased  
15 the odds of underweight by 0.32 and 0.20, respectively. A study on Malaysian adults showed that  
16 prevalence of obesity and overweight was more among those men who did vigorous physical  
17 activity. In contrast, females who did moderate physical activity were more obese and  
18 overweight.<sup>33</sup> Other studies also showed that underweight was more often associated with vigorous  
19 physical activity, while overweight and obesity were more related with sedentary lifestyle.  
20 Variable associations were also noted with gender, education level, marital status, working status,  
21 and wealth index.<sup>19, 34</sup> Most likely demographic features influence source, amount and variety of  
22 food intake, and type of physical activities undertaken based on knowledge and livelihood  
23 practices.

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26 The food habit of the rural population in Bangladesh is low in fat and protein, and high in  
27 carbohydrate.<sup>36, 37, 38</sup> This may be why people who perform vigorous physical activity can avoid  
28 getting overweight or obese. At the same time if balance is not maintained between intake and  
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3 output, there is increased likelihood of being obese or overweight, a phenomenon observed among  
4 a substantial number of subjects in this study. Rural women tend to regularly perform most  
5 household chores, some involving heavy activities, but these activities are not considered as such  
6 and overlooked by community members and health workers. Moreover, women tend to eat less  
7 food of poor quality while ensuring that other family members get more food of better quality.<sup>35</sup>

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15 <sup>39</sup> This may be why inactivity has been found to increase the likelihood of underweight in this  
16 study. Studies show that the prevalence of previously undiagnosed comorbidities such as  
17 hypertension and diabetes are on the rise in South-east Asian region.<sup>40</sup> In Bangladesh, about 50%  
18 - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher  
19 percentage among those from lower socioeconomic rural areas.<sup>27, 30</sup> People once diagnosed tend  
20 to visit health facilities more often than those who remain undiagnosed.  
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30 In its document on nutrition, World Health Organization has pointed at the double burden of  
31 malnutrition (characterized by coexisting undernutrition and overweight/obesity) and  
32 noncommunicable diseases within individuals, households, populations, and across life course of  
33 individuals. Epidemiological evidence support that undernutrition early in life, even when in-utero,  
34 may predispose to overweight and NCDs later in life. At the same time, underweight in later life  
35 is an expression of undernutrition. Again, overweight in mothers is often associated with  
36 overweight in their offspring. Biological mechanisms, along with environmental and social  
37 influences, are increasingly understood as essential drivers in the global burden of NCDs.<sup>35</sup>  
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## 49 **Strengths**

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53 The strength of this study was that this study attempted to assess the current burden of malnutrition  
54 and looked at the association of different modifiable risk factors with underweight, overweight,  
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3 and obesity among adults in a selected rural population of Bangladesh. The sampling technique  
4 was census and data was collected from all adults except those institutionalized in a hospital,  
5 prison, nursing home, or other similar institutes. Data from disabled or sick persons were collected  
6 from someone in the household who could provide the correct information. The number of such  
7 responses were very negligible, and most likely did not affect the overall result.  
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## 16 **Limitations**

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20 The limitations of this study was that household chores performed by women at home were not  
21 categorized into sedentary, moderate or vigorous activities, which may have affected the results.  
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23 The subjects included in the study were mostly on medication or received lifestyle modification  
24 counseling, which may have also affected the results. On the other hand, people who were already  
25 diagnosed with diabetes or hypertension tend to visit health facilities more often than those who  
26 remain undiagnosed for which reason, the data collected at the community clinic may have been  
27 more on those who were already diagnosed before.  
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## 38 **Conclusion**

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42 This cross-sectional study found that the prevalence of underweight was near equal to combined  
43 overweight and obesity among the adults in a selected rural area of Bangladesh. Factors such as  
44 age, sex, education, marital status, physical inactivity, and intake of added salt were strongly  
45 associated with underweight. While factors such as sex, education, marital status, and consumption  
46 of red meat, added salt and fruits and vegetables were associated with overweight and obesity.  
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48 Physical activity along with eating habits influence the nutritional status of adults. Sedentary  
49 lifestyle along with less food consumption lead to being underweight. Physically active persons  
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3 who eat more food, such as, red meat, tend to be overweight and obese. As such, considering the  
4 nutritional status, specific health messages to people on dietary habits and physical activity, can  
5 go a long way to reduce underweight, overweight, and obesity in the community. The effects of  
6 health messages can be further explored through qualitative studies so that policy makers and  
7 program managers can take informed decisions while developing policies and implementing  
8 programs.  
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30 **Author's contribution:**

31  
32 Conceptualization: SRM, AKMFR, MF, RAS, PCB, LB  
33

34 Data curation: SR, LB  
35

36 Formal analysis: SR, LB  
37

38 Methodology: AKMFR, SRM, MF, RAS, PCB, LB  
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40 Project administration: AKMFR, SRM, MF, RAS, PCB, LB  
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42 Supervision: SRM  
43

44 Writing original draft: SR  
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46 Writing: SR  
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48 Critic Review: AKMFR, SRM, MF, RAS, PCB, LB  
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5 with valid reasons.  
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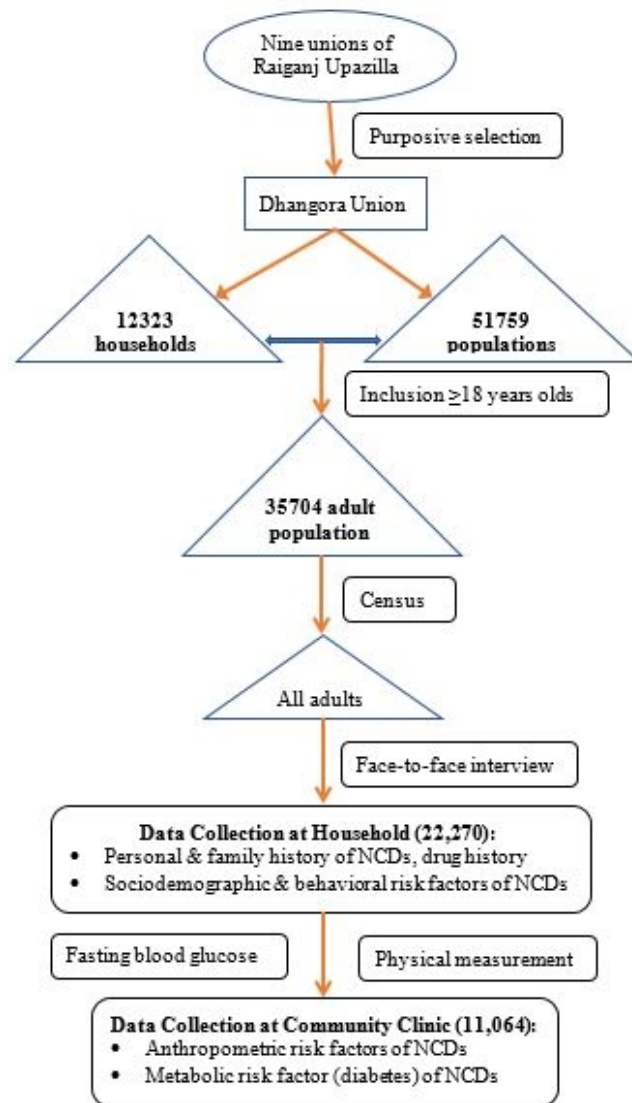
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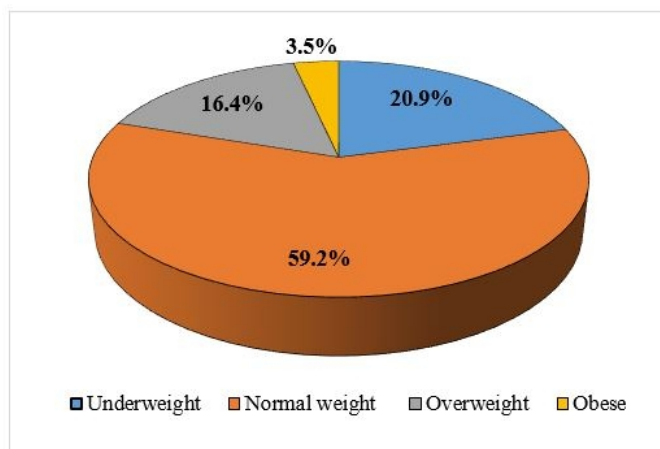




**Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh**

Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

120x163mm (96 x 96 DPI)



Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI is over 30.0 kg/m<sup>2</sup>

**Figure 2: Nutrition status of respondents (N = 11,064)**

Figure 2: Nutrition status of respondents (N = 11,064)

203x121mm (96 x 96 DPI)

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12-14
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	11

1			
2	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
3			14-17
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6			(b) Report category boundaries when continuous variables were categorized
7			14 & 16
8			
9			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
10			N/A
11	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
12			N/A
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14	<b>Discussion</b>		
15	Key results	18	Summarise key results with reference to study objectives
16			18-20
17	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
18			21
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20	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
21			18-22
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23			
24	Generalisability	21	Discuss the generalisability (external validity) of the study results
25			21-22
26	<b>Other information</b>		
27	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based
28			22
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\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

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## Malnutrition in all its forms and associated factors affecting the nutritional status of adult rural population in Bangladesh: results from a cross-sectional survey

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# Malnutrition in all its forms and associated factors affecting the nutritional status of adult rural population in Bangladesh: results from a cross-sectional survey

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## 22 Abstract

23 **Introduction:** The burden of malnutrition is widely evaluated in Bangladesh in different contexts.  
24 However, most of them determine the influence of sociodemographic factors, which have limited  
25 scope for modification and design intervention. This study attempted to determine the prevalence  
26 of underweight, overweight and obesity, and their modifiable lifestyle predictors in a rural  
27 population of Bangladesh.

28 **Method:** This study was part of a cross-sectional study that applied the WHO Package of Essential  
29 Noncommunicable Disease Interventions (WHO PEN) in a rural area of Bangladesh to assess the  
30 burden of diabetes, hypertension and their associated risk factors. The sampling technique was  
31 census. Anthropometric measurement, and data on sociodemographic characteristics and  
32 behavioral risk factors were collected following the standard protocol described in the WHO  
33 STEPS-wise approach. Analysis included means of continuous variables and multinomial logistic  
34 regression of factors.

35 **Result:** The mean BMI of the study population was 21.9 kg/m<sup>2</sup>. About 20.9% were underweight,  
36 16.4% were overweight, and 3.5% obese. Underweight was most predominant among people  
37 above 60 years, while overweight and obesity were predominant among people between 31-40  
38 years. Higher overweight and obesity were noted among females. Consumption of added salt and  
39 inactivity increased the odds of being underweight by 0.32 and 0.20, respectively. On the other  
40 hand, the odds of being overweight or obese increased by 0.96, 0.55, and 0.63 if a respondent was  
41 married, literate, and female; and by 0.25 and 0.18 if a respondent consumed red meat and took



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3 42 inadequate amounts of fruits and vegetables respectively. Consumption of added salt decreases the  
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5 43 odds of being overweight or obese by 0.37.  
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9 44 **Conclusion:** The study emphasized malnutrition to be a public health concern in spite of the  
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11 45 dynamic sociodemographic scenario. Specific health messages for targeted population may help  
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13 46 improve the nutritional status. Findings from further explorations may support policies and  
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16 47 programs in future.  
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19 48 **Keywords:** Obesity, overweight, underweight, physical activity, Bangladesh, body mass index  
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### 23 49 **Strengths and limitations of this study**

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- 27 50 • This study assessed the current status of malnutrition and look at its association with  
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29 51 different modifiable risk factors among adults in a selected rural population of Bangladesh  
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32 52 • The sampling technique was census and data were collected from all adults except those  
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34 53 institutionalized in a hospital, prison, nursing home, or other similar institutions  
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36 54 • The study could only investigate a third of the individuals since the community clinics  
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39 55 were not attended by everyone who were included in the household survey  
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## 1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.<sup>1, 2</sup> Near about one-third of people in any community have at least one form of malnutrition, which include disorders caused by excessive and/or imbalanced intake leading to obesity and overweight, and disorders caused by deficient intake of energy or nutrients leading to stunting, wasting, and micronutrient deficiencies. Both over- and under-nutrition are caused by intake of unhealthy and poor quality diets.<sup>1</sup> Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.<sup>2</sup> Studies show that prevalence of obesity and overweight are increasing over time.<sup>3</sup> Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.<sup>4</sup> At least 2.8 million people die each year due to causes related to obesity and overweight.<sup>5</sup> Data from a national survey show that in Bangladesh, about 30.4%, 18.9%, and 4.6% of adults were underweight, overweight, and obese respectively.<sup>6</sup>

Unhealthy dietary behavior, low physical activity, genetics, family history of certain diseases, community environment, and usage of some drugs can lead to obesity and overweight.<sup>7</sup> Obesity and overweight are two of the key risk factors for noncommunicable diseases such as cardiovascular diseases, and diabetes mellitus, which are known major public health concerns.<sup>8, 9,</sup><sup>10</sup> Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.<sup>1, 11</sup> Diabetes and hypertension have some common and important risk factors, such as unhealthy diet, inadequate physical inactivity, tobacco use, abnormal lipid profiles and overweight/obesity.<sup>12</sup> About 85.0% of premature deaths from NCDs now occur in low- and middle-income countries, where greater burden of undernutrition and infectious diseases also exist.<sup>1, 13</sup> In economically well-off countries, NCDs are noted disproportionately among vulnerable

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3 79 and disadvantaged groups.<sup>2</sup> On the other hand, in less developed economies, childhood  
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5 80 undernutrition affects health, survival, growth and development in rural population.<sup>1</sup> Globally,  
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7 81 undernutrition contributes to around 45% of deaths among under-five children, the majority of  
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9 82 which occur in low- and middle-income countries.<sup>1</sup>  
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13 83 Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical  
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15 84 outcome of the dramatic shift in current food systems, which focus on increasing availability of  
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17 85 inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets.  
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19 86 Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts)  
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21 87 has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat,  
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23 88 sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely  
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25 89 available.<sup>1</sup> Studies show that reduction in risk factors through lifestyle modifications help greatly  
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27 90 in reducing the burden of most non-communicable diseases including hypertension, diabetes,  
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29 91 malnutrition, and mental disorders.<sup>14, 15</sup> Studies in rural Bangladesh found that 55% of women  
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31 92 ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly  
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33 93 and monthly basis respectively.<sup>16, 17</sup>  
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40 94 Under these circumstances, developing countries like Bangladesh can benefit from interventions  
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42 95 that help the primary health care facilities to be ready to tackle different noncommunicable diseases  
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44 96 that are predisposed by overweight, obesity, and undernutrition. This study provides an  
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46 97 opportunity to find the influencing factors and predictors of malnutrition in the current changing  
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48 98 lifestyle among selected communities. This study was conducted to determine the prevalence of  
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50 99 underweight, overweight and obesity, and their predictors in a rural population of Bangladesh.  
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53 100 Previous studies in Bangladesh have looked at the risk factors of malnutrition in association with  
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3 101 different socio-demographic characteristics.<sup>18-26</sup> This study builds up on the previous studies by  
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5 102 examining the association of various risk factors with underweight, overweight and obesity on a  
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8 103 large dataset of adult population.  
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## 104 **2. Methods**

### 105 **2.1 Study design, setting, and participants**

106 This was a cross-sectional study that incorporated quantitative methods to fulfill the study  
107 objectives. It was a part of an implementation research in a randomly selected union (smallest rural  
108 administrative and local government units), Dhangora, among the three unions (Brammagachha,  
109 Chandaikona, and Dhangara) of Raiganj sub-district under Sirajganj district of Bangladesh. The  
110 three unions of Raiganj are under active health and demographic surveillance system of the  
111 implementing organization – Centre for Injury Prevention and Research Bangladesh (CIPRB),  
112 since 2006. Dhangara union has 12323 households with a population size of 51759, of whom  
113 35704 were adult population ( $\geq 18$  years old) during the data collection.

114 The sampling technique was a census that included all adults except those who were mentally  
115 challenged or institutionalized in a hospital, prison, nursing home, or other similar institutions. The  
116 duration of the study was six months from January to June 2019, while data was collected from  
117 March to June 2019.

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## 120 **2.2 Data collection instrument and procedure**

121 As a part of an implementation research, this study collected data by screening out the  
122 sociodemographic and cardio-metabolic risk factors of chronic diseases (hypertension, diabetes),  
123 and determine their prevalence. The study adapted the procedure as described in the WHO Package  
124 of Essential Noncommunicable Disease Interventions (WHO PEN) model.<sup>27</sup>

125 The data was collected electronically at the household level, using an Android-based mobile  
126 platform software. Interviewer administered face-to-face interview was used to collect data. The  
127 questionnaire was prepared based on the STEP-wise approach to Surveillance (STEPS) of NCD  
128 risk factors by the World Health Organization (WHO, Version 3.2). The STEPS questionnaire was  
129 modified and used to ask questions on sociodemographic characteristics, behavioral risk factors  
130 (such as tobacco and alcohol consumption, physical activity, dietary habits, added salt intake),  
131 occurrence of chronic disease, and to measure physical and biochemical parameters (height,  
132 weight, blood glucose, blood pressure). The English STEPS questionnaire was first translated to  
133 Bangla and then finalized after necessary modification following pre-testing on a suitable  
134 population. Data collectors having requisite background were recruited and intensively trained  
135 before the commencement of data collection.

136 Screening at community level posed specific challenges that were identified and addressed, such  
137 as, the time of a day or day of a week to reach a particular population like office goers, farmers,  
138 homemakers, especially for males. The use of active surveillance provided the advantage of having  
139 a full list of households and addresses, which ensured full coverage of the survey area. Data  
140 collectors were provided with the list and information required to track each household. If the  
141 respondent was unable to provide information when the data collector visited, a new time was

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3 142 scheduled for the screening as per convenience of the household members and data collector. All  
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5 143 possible measures were taken to ensure full coverage of the population.  
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9 144 During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.)  
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11 145 among the members was explored. Each participant was interviewed for approximately 25 to 30  
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13 146 minutes. Treatment and other medical documents were reviewed to confirm the disease  
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15 147 conditions, and show-cards were used for food and physical activity to ensure quality data. In some  
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17 148 cases, where a person was not able to respond to data collectors' queries (those who were ill or  
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19 149 had some form of disability), an appropriate person from the household, for example- the caregiver  
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22 150 was asked to answer on behalf provided he/she could give the exact information.  
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26 151 The household survey participants were advised to visit the nearby community clinic (CC) on the  
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28 152 next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and  
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30 153 biochemical parameters. In the community clinic, standard weight scale, height measurement  
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32 154 scales, measuring tape, and automated digital BP machine were used to record their weight, height,  
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34 155 waist circumference, hip circumference, and blood pressure respectively. Fasting capillary glucose  
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36 156 was measured by a standard glucometer maintaining all necessary aseptic precautions. Blood  
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38 157 pressure was measured twice – first, after 15 minutes' rest time, and second one 3 minutes after  
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40 158 the first measurement. The mean of the two measurements was used to determine the actual BP.  
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43 159 Physical measurements were carried out by well-trained male and female assistants maintaining  
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45 160 adequate privacy. The data collected at the CC were synced with those collected at the household  
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48 161 level. The Flow Chart of study methods applied to collect data is shown in Figure 1.  
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53 162 **Figure 1: Flow Chart of study methods applied to collect data from selected rural population of**  
54 163 **Bangladesh**  
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## 164 **2.3 Ascertainment of key variables**

165 **Age:** The respondents were asked what their age (in years) was at the time of data collection.

166 **Sex:** The respondents were asked which sex (male or female) did they identify themselves as at  
167 the time of data collection.

168 **Education:** The respondents were asked what was the highest level of education (no schooling,  
169 primary, and secondary and above) obtained by them at the time of data collection.

170 **Marital status:** The respondents were asked if they were ever married or never married.

171 **Occupation:** The respondents were asked about their occupation. Occupation was classified as  
172 unemployed, service holder, farmer, self-employed, and housewife.

173 **Red meat intake:** The respondents who said that they ate red meat on a weekly basis were  
174 categorized as consumers of red meat.

175 **Fried food intake:** The respondents who said that they ate fried food on a weekly basis were  
176 categorized as consumers of fried food.

177 **Processed food intake:** The respondents who said that they ate processed food on a weekly basis  
178 were categorized as consumers of processed food.

179 **Sugary drink intake:** The respondents who said that they ate sugary drinks on a weekly basis  
180 were categorized as consumers of sugary drinks.

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3 181 **Added salt intake:** The respondents who said they took extra dietary salt while eating any cooked  
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5 182 meal were categorized as consumers of added dietary salt.  
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9 183 **Adequate amount of fruit and vegetable (FAV):** Respondents whose dietary intake of FAV  
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11 184 corresponded to WHO recommended 5 servings were considered as taking adequate amount of  
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13 185 FAV.<sup>28</sup>  
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17 186 **Physical activity:** The respondents were asked about their work-related physical activities, the  
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19 187 number of days a week, and the amount of time (in minutes) per day that they spend on vigorous  
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21 188 and moderate activities. This was then converted to the metabolic equivalent of task-minutes  
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23 189 (MET-minutes) to find out the intensity of physical activity, which were then categorized. The  
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25 190 categories were: less active or sedentary ( $\leq 600$  MET-minutes per week), moderately active  
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27 191 (between 600 and 3000 MET-minutes per week), and highly or vigorously active ( $\geq 3000$  MET-  
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29 192 minutes per week).<sup>29</sup>  
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34 193 **Underweight:** The respondents were considered as underweight when their body mass index  
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36 194 (BMI) was less than  $18.5 \text{ kg/m}^2$ .<sup>30</sup>  
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40 195 **Normal weight:** The respondents were considered as normal weight when their BMI was  
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42 196 between  $18.5$  and  $25.0 \text{ kg/m}^2$ .<sup>30</sup>  
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46 197 **Overweight:** The respondents were considered overweight when their BMI was between  $25.0$   
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48 198 and  $29.9 \text{ kg/m}^2$ .<sup>30</sup>  
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51 199 **Obese:** The respondents were considered obese when their BMI was over  $30.0 \text{ kg/m}^2$ .<sup>30</sup>  
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## 201 **2.4 Data analysis**

202 The data were entered in the pre-designed Microsoft office excel format which was later imported  
203 into the statistical software SATA version 12. The raw data was initially checked for completeness,  
204 consistency and the absence of missing data, errors and outliers. Afterwards, it was carefully  
205 cleaned and edited for consistency and to preserve for longer time. Descriptive, and relevant  
206 statistical analysis were performed on this cleaned data set. The results were then presented in  
207 tables and illustrations. Of the 22270 respondents at the household level, a total of 11244  
208 respondents visited community clinic for the required physical measurements. After cleaning the  
209 data, the final analysis was done with a sample of 11,064 respondents.

210 To assess the distribution of anthropometric measurements among the respondents, the means of  
211 the continuous variables were calculated and presented in a tabulated form with range and standard  
212 deviation. A pie chart was used to show the overall nutrition status of the respondents. Descriptive  
213 analysis was done to show the distribution of nutritional status and presented as percentage. To  
214 identify the sociodemographic and behavioral risk factors affecting malnutrition, multinomial  
215 logistic regression analysis was used. In this regards, at first, the assumptions of regression analysis  
216 were checked and no violation of these assumptions were found. These assumptions included  
217 multicollinearity, outlier, normality, linearity, homoscedasticity, and the independence of  
218 observations. Univariate analysis was performed to determine the eligibility of the variables before  
219 including them in the multinomial logistic regression analysis. The dependent variable was  
220 categorized as underweight, normal weight, overweight and obese. As per literature review,  
221 overweight and obesity have similar predictors. As such, overweight and obese were merged  
222 together into one category, and normal weight was considered as reference. A *P*-value of < 0.05

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3 223 was considered as the cut-off. The regression table for each outcome variable included the  
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5 224 presentation of the factors with the corresponding odds ratios (OR) and OR > 1 was considered as  
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8 225 predictor. The estimates of precision were all presented at a 95% confidence interval (CI), as  
9  
10 226 appropriate.

## 11 12 13 14 227 **2.5 Patient and public involvement**

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18 228 Data was collected from all adults at household level. Further anthropometric data was collected  
19  
20 229 at the health facilities from those who visited the community clinics. However, the public were not  
21  
22 230 directly involved in the research. They did not play any role during the establishment of the  
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25 231 research questions, designing or implementing the study, measuring the study outcomes, or  
26  
27 232 interpretation of the results.

## 28 29 30 31 233 **Ethical consideration**

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35 234 Ethical approval was obtained from the Ethical Review Board of the Center for Injury Prevention  
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37 235 and Research, Bangladesh (ERC number: CIPRB/ERC/2019/003). Participants had the right to  
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39 236 withdraw at any point after starting the interview. Rigor, accuracy, and impartiality were ensured  
40  
41 237 during data collection through in-person and digital monitoring systems.

## 42 43 44 45 238 **3. Results**

### 46 47 48 49 50 239 **3.1 Anthropometric measurements**

240 The mean anthropometric measurements of the respondents and the standard deviations with the  
 241 minimum and maximum values are shown below in Table 1. The mean weight, height, and BMI  
 242 of the respondents were 51.4 kg, 153.4 cm., and 21.9 kg/m<sup>2</sup>, respectively. The mean waist  
 243 circumference, hip circumference, and waist-hip ratio were 79.9 cm, 87.2 cm, and 0.9,  
 244 respectively.

245 **Table 1: Mean anthropometric measurements of respondents with standard deviation and**  
 246 **minimum and maximum values (N = 11,064)**

Mean measurements	Mean (SD)	Minimum	Maximum
Weight (kg)	51.4 (10.4)	30.0	139.0
Height (cm)	153.4 (8.9)	78.0	203.2
BMI (kg/m <sup>2</sup> )	21.9 (4.2)	10.1	78.9
Waist circumference (cm)	79.9 (10.8)	43.0	144.0
Hip circumference (cm)	87.2 (8.7)	60.0	160.0
Waist-hip ratio	0.9 (0.1)	0.6	1.6

247  
 248 Considering body mass index (BMI), 59.2% of the respondents were within normal range, that is,  
 249 between 18.5 – 25.0 kg/m<sup>2</sup>. Underweight was found in 20.9% respondents, while that of  
 250 overweight and obesity was found to be 16.4% and 3.5%, respectively (Figure 2).

251  
 252 **Figure 2: Nutrition status of respondents (N = 11,064)**

### 254 3.2 Sociodemographic characteristics

255 The socio-demographic characteristics of the respondents are stratified by nutritional status and  
 256 shown in Table 2 and Table 3, respectively. Irrespective of age, normal nutritional status was noted  
 257 in about 55-61% respondents as shown in Table 2. Underweight was reported to be highest at

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3 258 31.3% among  $\geq 60$  years, while overweight and obesity were highest at 21.0% and 5.1%  
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5 259 respectively among 31-40 years age group. About 62.5% male and 57.5% female were within the  
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7 260 normal range of weight. About 24.7% of men and 19.0% of females were underweight. Higher  
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9 261 overweight and obesity were noted among females with 18.8% and 4.6%, respectively.  
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11 262 Irrespective of years of schooling, normal weight was recorded in 59.2% of the respondents.  
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13 263 Underweight was more with 26.8% among those with no schooling, while overweight (20.3%)  
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15 264 and obesity (4.6%) was more among those with education up to or above secondary level. Normal  
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17 265 weight was seen in about 60.0%, irrespective of marital status. Underweight was more (20.3%) in  
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19 266 those never married, while overweight (17.0%) and obesity (3.7%) was more in those ever married.  
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21 267 Underweight was more among unemployed and farmers with 31.3% and 31.9% respectively,  
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23 268 overweight was 23.8% among service holders, and 4.8% obesity among homemakers. The socio-  
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25 269 demographic characteristics stratified by nutrition status was further stratified by sex  
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27 270 (Supplementary table).  
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### 271 **3.3 Behavioral risk factors**

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38 272 Nutritional status with respect to behavioral risk factors is shown in Table 3. Irrespective of the  
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40 273 risk factors considered, normal weight was noted in 57.3% to 60.5% respondents. Considering  
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42 274 each risk factor, underweight was noted to be more among those who led sedentary lifestyle  
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44 275 (25.1%), took red meat (21.9%), ate fried food (21.3%), took sugary drinks (21.7%), took added  
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46 276 salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand,  
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48 277 overweight and obesity were noted as more among those who did moderate to vigorous exercise  
49  
50 278 (16.7% & 3.3% - 3.9% respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8%  
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52 279 & 3.7%), did not consume processed food (16.5% & 3.4%), did not take sugary drinks (16.9% &  
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3 280 3.6%), did not take added salt (19.3% & 4.7%), and those who did not take inadequate (took  
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5 281 adequate) fruits and vegetables (18.2% & 4.3%).  
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282 **Table 2: Sociodemographic characteristics of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status % (95% CI)			
			Underweight	Normal weight	Overweight	Obese
Age (years)	≤30	2,184	23.7 (21.9–25.5)	61.2 (59.1–63.2)	12.9 (11.6–14.4)	2.2 (1.7 – 3.0)
	31 to 40	2,419	14.4 (13.0–15.8)	59.5 (57.5–61.4)	21.0 (19.5–22.7)	5.1 (4.3 – 6.0)
	41 to 50	2,482	16.3 (14.9–17.8)	59.3 (57.3–61.2)	20.1 (18.5–21.7)	4.4 (3.6 – 5.2)
	51 to 60	2,097	21.7 (20.0–23.5)	59.9 (57.8–62.0)	15.3 (13.8–16.9)	3.1 (2.4 – 3.9)
	> 60	1,882	31.3 (29.3–33.5)	55.5 (53.3–57.8)	10.6 (9.3 – 12.1)	2.5 (1.9 – 3.3)
Sex	Male	3,715	24.7 (23.3–26.1)	62.5 (60.9–64.0)	11.5 (10.5–12.6)	1.3 (1.0 – 1.8)
	Female	7,349	19.0 (18.2–20.0)	57.5 (56.4–58.6)	18.8 (17.9–19.7)	4.6 (4.2 – 5.1)
Education	No schooling	3,969	26.8 (25.5–28.2)	59.2 (57.6–60.7)	11.6 (10.7–12.7)	2.4 (1.9 – 2.9)
	Primary	3,171	19.8 (18.4–21.2)	59.2 (57.5–60.9)	17.4 (16.1–18.7)	3.7 (3.1 – 4.4)
	Secondary and above	3,924	15.9 (14.8–17.1)	59.2 (57.6–60.7)	20.3 (19.1–21.6)	4.6 (4.0 – 5.3)
Marital status	Never married	771	29.3 (26.2–32.6)	61.6 (58.1–65.0)	7.5 (5.9 – 9.6)	1.6 (0.9 – 2.7)
	Ever married	10,293	20.3 (19.5–21.1)	59.0 (58.0–60.0)	17.0 (16.3–17.8)	3.7 (3.3 – 4.1)
Occupation	Unemployed	1,057	31.2 (28.5–34.1)	57.6 (54.6–60.6)	8.7 (7.1 – 10.6)	2.5 (1.7 – 3.6)
	Service holder	307	11.1 (28.5–34.1)	62.2 (56.6–67.5)	23.8 (19.3–28.9)	2.9 (1.5 – 5.5)
	Farmer	1,353	31.9 (29.4–34.4)	61.6 (58.9–64.1)	5.9 (4.8 – 7.3)	0.7 (0.3 – 1.3)
	Self-employed	2,416	18.5 (17.0–20.1)	62.7 (60.7–64.6)	16.1 (14.7–17.7)	2.6 (2.1 – 3.4)
	Housewife	5,931	18.1 (17.1–19.1)	57.3 (56.1–58.6)	19.8 (18.8–20.8)	4.8 (4.3 – 5.3)

283 CI = confidence interval; Underweight = BMI less than 18.5 kg/m<sup>2</sup>; Normal weight = BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight = BMI is 25.0 – 29.9 kg/m<sup>2</sup>;  
 284 Obese = BMI is over 30.0 kg/m<sup>2</sup>

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287 **Table 3: Behavioral risk factors of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status % (95% CI)			
			Underweight	Normal weight	Overweight	Obese
Physical activity	Sedentary	1,995	25.1 (23.2–27.0)	57.3 (55.2–59.5)	14.7 (13.2–16.4)	2.9 (2.2 – 3.7)
	Moderate	3,134	22.0 (20.6–23.5)	58.0 (56.2–59.7)	16.7 (15.5–18.1)	3.3 (2.7 – 4.0)
	Vigorous	5,935	19.0 (18.0–20.0)	60.4 (59.2–61.7)	16.7 (15.8–17.7)	3.9 (3.4 – 4.4)
Red meat intake	Yes	2,687	17.9 (16.5–19.4)	58.2 (56.3–60.0)	19.9 (18.4–21.5)	4.0 (3.3 – 4.8)
	No	8,377	21.9 (21.0–22.8)	59.5 (58.5–60.6)	15.2 (14.5–16.0)	3.4 (3.0 – 3.8)
Fried food intake	Yes	2,949	21.3 (19.9–22.8)	60.5 (58.7–62.2)	15.2 (13.9–16.5)	3.1 (2.5 – 3.7)
	No	8,115	20.8 (19.9–21.7)	58.7 (57.6–59.8)	16.8 (16.0–17.6)	3.7 (3.3 – 4.1)
Processed food intake	Yes	2,278	20.9 (19.2–22.6)	59.3 (57.3–61.3)	15.6 (14.2–17.2)	4.2 (3.5 – 5.1)
	No	8,786	20.9 (20.1–21.8)	59.2 (58.1–60.2)	16.5 (15.8–17.3)	3.4 (3.0 – 3.8)
Sugary drinks intake	Yes	4,044	21.7 (20.4–23.0)	59.6 (58.0–61.1)	15.4 (14.3–16.5)	3.4 (2.9 – 4.0)
	No	7,020	20.5 (19.6–21.4)	59.0 (57.8–60.1)	16.9 (16.1–17.8)	3.6 (3.2 – 4.1)
Added salt intake	Yes	6,946	23.2 (22.2 –24.2)	59.3 (58.2–60.5)	14.6 (13.8–15.5)	2.9 (2.5 – 3.3)
	No	4,118	17.1 (16.0–18.3)	58.9 (57.4–60.4)	19.3 (18.1–20.5)	4.7 (4.1 – 5.4)
Inadequate intake of fruits and vegetables	Yes	8,331	21.4 (20.6–22.3)	59.5 (58.5–60.6)	15.7 (15.0–16.5)	3.3 (2.9 – 3.7)
	No	2,733	19.4 (17.9–20.9)	58.1 (56.3–60.0)	18.2 (16.8–19.7)	4.3 (3.6 – 5.1)

288 CI, confidence interval; Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI  
 289 is over 30.0 kg/m<sup>2</sup>

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### 3.4 Factors affecting the malnutrition

Table 4 shows the multinomial logistic regression analysis of the data. For this analysis, overweight and obese were merged into one variable as overweight/obese. It was found that the odds of being underweight will decrease by 0.27, 0.24, 0.35, and 0.57 if a respondent is less than 45 years of age, female, literate, and married respectively. Consumption of added salt and inactivity increases the odds of being underweight by 0.32 and 0.20, respectively.

On the other hand, the odds of being overweight/obese increased by 0.96, 0.55 and 0.63 if the respondent was married, literate, and female; and by 0.25 and 0.18 if the respondent consumed red meat and took inadequate amount of fruits and vegetables, respectively. Consumption of added salt decreased the odds of being overweight/obese by 0.37.

**Table 4: Factors affecting malnutrition in all its forms among the study population using multinomial logistic regression analysis considering normal body weight as reference (N = 11,064)**

Malnutrition	Factors	B	P-value*	AOR	95% CI for OR	
					Lower Bound	Upper Bound
Underweight	Age					
	< 45 years	- 0.268	< 0.001	0.765	0.685	0.855
	>= 45 years	<i>Ref</i>				
	Sex					
	Female	- 0.239	< 0.001	0.787	0.684	0.906
	Male	<i>Ref</i>				
	Education					
	Literate	- 0.350	< 0.001	0.704	0.632	0.786
	Illiterate	<i>Ref</i>				
	Marital status					
Married	- 0.568	< 0.001	0.566	0.468	0.685	
Unmarried	<i>Ref</i>					



	Added salt intake					
	Yes	0.319	< 0.001	1.376	1.239	1.527
	No	<i>Ref.</i>				
	Inadequate Physical activity					
	Yes	0.204	< 0.001	1.227	1.087	1.384
	No	<i>Ref.</i>				
Overweight/ obese	Sex					
	Female	0.630	< 0.001	1.878	0.600	2.204
	Male	<i>Ref.</i>				
	Education					
	Literate	0.552	< 0.001	1.738	1.541	1.959
	Illiterate	<i>Ref.</i>				
	Marital status					
	Married	0.961	< 0.001	2.615	1.997	3.425
	Unmarried	<i>Ref.</i>				
	Red meat intake					
	Yes	0.253	< 0.001	1.288	1.153	1.439
	No	<i>Ref.</i>				
	Added salt intake					
	Yes	- 0.373	< 0.001	0.689	0.623	0.762
No	<i>Ref.</i>					
Inadequate fruits and vegetables intake						
Yes	0.178	0.002	1.195	1.067	1.339	
No	<i>Ref.</i>					

304 Ref., reference; AOR, adjusted odd-ratio; CI, confidence interval

305 \*Significant at the threshold of  $p < 0.05$

306 Only OR > 1 and CI for OR didn't contain 1 was considered as predictors

307 Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Overweight/obese, BMI is over 25.0 kg/m<sup>2</sup>

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## 310 **4. Discussion**

311 This cross-sectional study was undertaken among adult population in a selected rural area. It was  
312 a part of an implementation research. The sampling strategy was census, but only a third of the  
313 population (those who attended the community clinics) was included in this study, for which  
314 reason the result do not represent a census. Several studies have explored the various preconditions  
315 and post-effects of malnutrition in all its forms mostly with regards to modifiable  
316 sociodemographic factors. However, this study attempts to explore the same, but with regards to  
317 the status of modifiable lifestyle factors. While adequate knowledge and practices can modify the  
318 quality of diet and adjust lifestyles, influence of a combination of economic, social and  
319 demographic factors also play a key role in modifying these.<sup>6</sup> Such complex phenomena may be  
320 assessed case by case to determine modification modalities so as to improve the overall health  
321 status of a population.

322 This study found that underweight, overweight, and obesity are of similar concern among the adult  
323 rural population in Bangladesh. According to the WHO estimates, the age-standardized estimation  
324 of prevalence of overweight among adults in the South-east Asia was 21.9% in 2016, which was  
325 higher than that found in this study.<sup>17</sup> A study in South Africa found that the mean waist  
326 circumference for rural men and women was much higher, putting them at high risk of NCDs.<sup>31</sup>  
327 In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children  
328 was found to be less than ten percent.<sup>18</sup> Other studies among the rural and urban populations of  
329 Bangladesh found that prevalence of overweight and obesity were 15% – 18.9%, and 3% – 4.6%,  
330 respectively. <sup>6, 19, 20, 21</sup> The occurrence of overweight and obesity found in this study was near  
331 similar to the combined overweight and obesity as found in other studies in Bangladesh. However,

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3 332 the population of other studies included everyone in the study area, while this study included only  
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5 333 adult population. It was noted in this study that factors such as extreme age, varied occupation,  
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7 334 and other physio-demographic features influenced prevalence of obesity and overweight. Since  
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9 335 this study was conducted in a surveillance population, the community members may already have  
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12 336 been a little more aware of the importance of healthy lifestyles.

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16 337 In this study, respondents in the age group 31 – 40 years were the most overweight and obese,  
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18 338 while those 60 years and above were the most underweight. Females were found to be more  
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20 339 overweight and obese than males, while males were found to be more underweight than females.  
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22 340 The study also found that the likelihood of being overweight and obese increased among married  
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24 341 and literate females, in contrast to unmarried and illiterate males. On the other hand, literate and  
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26 342 married females less than 45 years were less likely to be underweight compared to illiterate and  
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28 343 married males more than 45 years of age. Age between 33 – 37 years was also found significantly  
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30 344 associated with obesity and overweight in other studies among rural women of Bangladesh (OR:  
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32 345 3.71; 95% CI: 2.84 – 4.86;  $p < 0.001$ ).<sup>19</sup> Other studies have shown that urban women aged 30 to 39  
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34 346 years were obese and/or overweight with a high association (OR: 3.9; 95% CI: 1.9 – 7.7;  
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36 347  $p < 0.001$ ).<sup>23</sup> There are studies that also showed that the prevalence of underweight among males of  
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38 348 more than 50 years of age was much high.<sup>20, 32</sup> The findings from this study corroborate with these  
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40 349 earlier findings.

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47 350 The odds of overweight and obesity increased by 0.25 and 0.18 among respondents who consumed  
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49 351 red meat and took inadequate amount of fruits and vegetables, and decreased by 0.37 among those  
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51 352 who consumed added salt. On the other hand, consumption of added salt and inactivity increased  
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53 353 the odds of underweight by 0.32 and 0.20, respectively. A study on Malaysian adults showed that

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3 354 prevalence of obesity and overweight was more among those men who did vigorous physical  
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5 355 activity. In contrast, females who did moderate physical activity were more obese and  
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7 356 overweight.<sup>33</sup> Other studies also showed that underweight was more often associated with vigorous  
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10 357 physical activity, while overweight and obesity were more related with sedentary lifestyle.  
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12 358 Variable associations were also noted with gender, education level, marital status, working status,  
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14 359 and wealth index.<sup>19, 34</sup> Most likely demographic features influence source, amount and variety of  
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16 360 food intake, and type of physical activities undertaken based on knowledge and livelihood  
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19 361 practices.

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23 362 The food habit of the rural population in Bangladesh is low in fat and protein, and high in  
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25 363 carbohydrate.<sup>35, 36, 37</sup> This may be why people who perform vigorous physical activity can avoid  
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27 364 getting overweight or obese. At the same time if balance is not maintained between intake and  
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29 365 output, there is increased likelihood of being obese or overweight, a phenomenon observed among  
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31 366 a substantial number of subjects in this study. Rural women tend to regularly perform most  
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33 367 household chores, some involving heavy activities, but these activities are not considered as such  
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35 368 and overlooked by community members and health workers. Moreover, women tend to eat less  
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37 369 food of poor quality while ensuring that other family members get more food of better quality.<sup>38,</sup>  
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39 370 <sup>39</sup> This may be why inactivity has been found to increase the likelihood of underweight in this  
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41 371 study. Studies show that the prevalence of previously undiagnosed comorbidities such as  
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43 372 hypertension and diabetes are on the rise in South-east Asian region.<sup>40</sup> In Bangladesh, about 50%  
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45 373 - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher  
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47 374 percentage among those from lower socioeconomic rural areas.<sup>27, 30</sup> People once diagnosed tend  
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51 375 to visit health facilities more often than those who remain undiagnosed.  
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3 376 In its document on nutrition, World Health Organization has pointed at malnutrition in all its forms  
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5 377 (characterized by coexisting undernutrition and overweight/obesity) and noncommunicable  
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7 378 diseases within individuals, households, populations, and across life course of individuals.  
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10 379 Epidemiological evidence support that undernutrition early in life, even when in-utero, may  
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12 380 predispose to overweight and NCDs later in life. At the same time, underweight in later life is an  
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14 381 expression of malnutrition. Again, overweight in mothers is often associated with overweight in  
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16 382 their offspring. Biological mechanisms, along with environmental and social influences, are  
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18 383 increasingly understood as essential drivers in the global burden of NCDs.<sup>38</sup>  
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23 384 In addition to increasing health literacy among rural population through training and awareness  
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25 385 programs, the Government may also take initiatives to encourage household backyard vegetable  
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27 386 and fruits gardening which would help to reduce the overall family. As an initial support, the  
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29 387 Government may distribute free (or at nominal price) saplings of fruits and vegetables among rural  
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31 388 population.  
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## 35 389 **Strengths**

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40 390 The strength of this study was that this study attempted to assess the current burden of malnutrition  
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42 391 in all its forms and looked at the association of different modifiable risk factors with underweight,  
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44 392 overweight, and obesity among adults in a selected rural population of Bangladesh. The sampling  
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46 393 technique was census and data was collected from all adults except those institutionalized in a  
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48 394 hospital, prison, nursing home, or other similar institutes. Data from disabled or sick persons were  
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50 395 collected from someone in the household who could provide the correct information. The number  
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52 396 of such responses were very negligible, and most likely did not affect the overall result.  
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## 397 **Limitations**

398 Although the sampling strategy was census, but the study could only investigate a third of the  
399 individuals (those who attended the community clinic). As such, the result do not represent a  
400 census. The limitations of this study was that household chores performed by women at home were  
401 not categorized into sedentary, moderate or vigorous activities, which may have affected the  
402 results. Some of the subjects included in the study may have been on medication or may have  
403 received lifestyle modification counseling, and this may have also affected the results. On the other  
404 hand, people who were already diagnosed with diabetes or hypertension tend to visit health  
405 facilities more often than those who remain undiagnosed for which reason, the data collected at  
406 the community clinic may have been more on those who were already diagnosed before.

## 407 **Conclusion**

408 This cross-sectional study found that the prevalence of underweight was near equal to combined  
409 overweight and obesity among the adults in a selected rural area of Bangladesh. Factors such as  
410 age, sex, education, marital status, physical inactivity, and intake of added salt were strongly  
411 associated with underweight. While factors such as sex, education, marital status, and consumption  
412 of red meat, added salt and fruits and vegetables were associated with overweight and obesity.  
413 Physical activity along with eating habits influence the nutritional status of adults. Sedentary  
414 lifestyle along with less food consumption lead to being underweight. Physically active persons  
415 who eat more food, such as, red meat, tend to be overweight and obese. As such, considering the  
416 nutritional status, specific health messages to people on dietary habits and physical activity, can  
417 go a long way to reduce underweight, overweight, and obesity in the community. The effects of

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3 418 health messages can be further explored through qualitative studies so that policy makers and  
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5 419 program managers can take informed decisions while developing policies and implementing  
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8 420 programs.

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22  
23 425 **Author's contribution:**

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25 426 Conceptualization: SRM, AKMFR, MF, RAS, PCB, LB

26  
27 427 Data curation: SR, LB

28  
29 428 Formal analysis: SR, LB

30  
31 429 Methodology: AKMFR, SRM, MF, RAS, PCB, LB

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33 430 Project administration: AKMFR, SRM, MF, RAS, PCB, LB

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35 431 Supervision: SRM

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37 432 Writing original draft: SR

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39 433 Writing: SR

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41 434 Critic Review: AKMFR, SRM, MF, RAS, PCB, LB

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47 435 **Data sharing statement:** The corresponding author will make the data available when required,  
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49 436 with valid reasons.  
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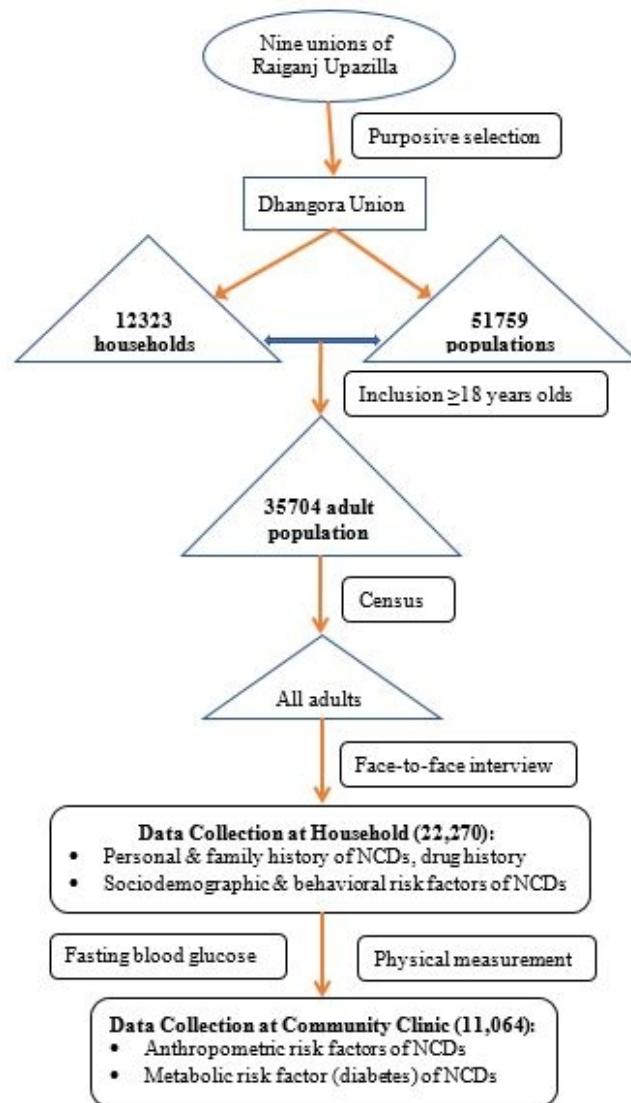
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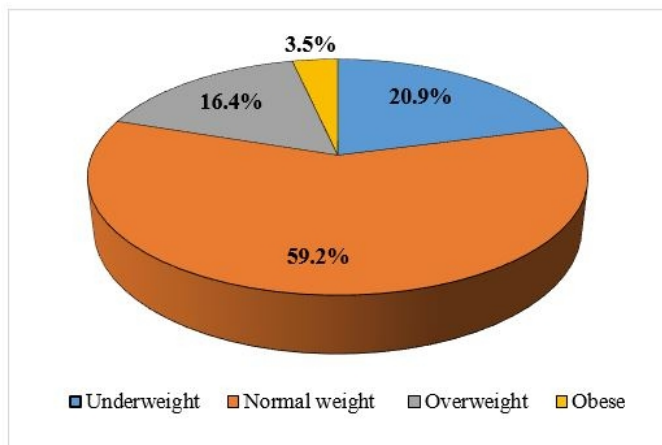


**Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh**

Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

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Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI is over 30.0 kg/m<sup>2</sup>

**Figure 2: Nutrition status of respondents (N = 11,064)**

Figure 2: Nutrition status of respondents (N = 11,064)

203x121mm (96 x 96 DPI)



Supplementary table: Sociodemographic characteristics of respondents, stratified by nutrition status and sex (N = 11,064)

Sex	Variable	Category	N	Nutritional status % (95% CI)			
				Underweight	Normal weight	Overweight	Obese
Male	Age (years)	<=30	670	27.2 (23.9–30.7)	63.1 (59.4–66.7)	9.0 (7.0–11.4)	0.7 (0.3–1.8)
		31 to 40	712	18.1 (15.5–21.1)	66.7 (63.2–70.1)	13.8 (11.4–16.5)	1.4 (0.8–2.6)
		41 to 50	788	18.7 (16.1–21.5)	65.9 (62.5–69.1)	14.1 (11.8–16.7)	1.4 (0.8–2.5)
		51 to 60	792	24.6 (21.7–27.7)	62.4 (58.9–65.7)	11.6 (9.6–14.0)	1.4 (0.8–2.5)
		> 60	753	34.9 (31.6–38.4)	54.6 (51.0–58.1)	8.8 (6.9–11.0)	1.7 (1.0–3.0)
	Education	No schooling	1137	31.9 (29.3–34.7)	59.5 (56.6–62.3)	7.7 (6.2–9.3)	1.0 (0.5–1.7)
		Primary	1052	26.9 (24.3–29.7)	63.7 (60.7–66.5)	8.4 (6.8–10.2)	1.0 (0.6–1.9)
		Secondary and above	1526	17.7 (15.9–19.7)	64.0 (61.5–66.3)	16.5 (14.7–18.5)	1.8 (1.3–2.6)
	Marital status	Never married	463	28.9 (25.0–33.2)	62.6 (58.1–66.9)	7.6 (5.5–10.4)	0.9 (0.3–2.3)
		Ever married	3252	24.0 (22.6–25.5)	62.5 (60.8–64.1)	12.1 (11.0–13.2)	1.4 (1.1–1.9)
	Occupation	Unemployed	550	31.6 (27.9–35.6)	58.5 (54.4–62.6)	8.4 (6.3–11.0)	1.5 (0.7–2.9)
		Service holder	223	9.4 (6.2–14.0)	63.7 (57.1–69.7)	24.7 (19.4–30.8)	2.2 (0.9–5.3)
		Farmer	1303	32.0 (29.5–34.6)	61.3 (58.6–63.9)	6.1 (4.9–7.5)	0.6 (0.3–1.2)
		Self-employed	1549	17.9 (16.1–19.9)	65.3 (62.9–67.6)	15.2 (13.5–17.0)	1.7 (1.1–2.5)
		Housewife	90	30.0 (21.4–40.3)	53.3 (43.0–63.4)	13.3 (7.7–22.1)	3.3 (1.1–9.9)
Female	Age (years)	<=30	1514	22.1 (20.1–24.3)	60.3 (57.8–62.7)	14.7 (13.0–16.5)	2.9 (2.2–3.9)
		31 to 40	1707	12.8 (11.3–14.5)	56.5 (54.1–58.8)	24.1 (22.1–26.2)	6.6 (5.5–7.9)
		41 to 50	1694	15.2 (13.6–17.0)	56.2 (53.8–58.5)	22.8 (20.9–24.9)	5.7 (4.7–6.9)
		51 to 60	1305	19.9 (17.8–22.2)	58.5 (55.8–61.1)	17.5 (15.6–19.7)	4.1 (3.1–5.3)
		> 60	1129	29.0 (26.4–31.7)	56.2 (53.2–59.0)	11.9 (10.1–13.9)	3.0 (2.2–4.2)
	Education	No schooling	2832	24.8 (23.2–26.4)	59.1 (57.3–60.9)	13.2 (12.0–14.5)	2.9 (2.4–3.6)
		Primary	2119	16.2 (14.7–17.9)	57.0 (54.8–59.1)	21.8 (20.1–23.7)	5.0 (4.1–6.0)
		Secondary and above	2398	14.8 (13.4–16.2)	56.1 (54.1–58.1)	22.7 (21.1–24.4)	6.4 (5.5–7.4)
	Marital status	Never married	308	29.9 (25.0–35.2)	60.1 (54.5–65.4)	7.5 (5.0–11.0)	2.6 (1.3–5.1)
		Ever married	7041	18.6 (17.7–19.5)	57.4 (56.2–58.5)	19.3 (18.4–20.3)	4.7 (4.3–5.3)
Occupation	Unemployed	507	30.8 (26.9–34.9)	56.6 (52.2–60.9)	9.1 (6.9–11.9)	3.6 (2.2–5.6)	

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Service holder	84	15.5 (9.2–24.9)	58.3 (47.5–68.4)	21.4 (13.9–31.5)	4.8 (1.8–12.1)
Farmer	50	28.0 (17.2–42.0)	68.0 (53.8–79.5)	2.0 (0.3–13.1)	2.0 (0.3–13.1)
Self-employed	867	19.7 (17.2–22.5)	58.0 (54.7–61.3)	17.9 (15.5–20.6)	4.4 (3.2–6.0)
Housewife	5841	17.9 (16.9–18.9)	57.4 (56.1–58.7)	19.9 (18.9–21.0)	4.8 (4.3–5.4)

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For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-12
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11-12
		(b) Describe any methods used to examine subgroups and interactions	11-12
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13-17
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	13

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Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	16-19
		(b) Report category boundaries when continuous variables were categorized	16 & 18
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	20-23
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	24
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	23-25
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	25

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

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## Malnutrition in all its forms and associated factors affecting the nutritional status of adult rural population in Bangladesh: results from a cross-sectional survey

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# Malnutrition in all its forms and associated factors affecting the nutritional status of adult rural population in Bangladesh: results from a cross-sectional survey

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## 22 Abstract

23 **Introduction:** The burden of malnutrition is widely evaluated in Bangladesh in different contexts.  
24 However, most of them determine the influence of sociodemographic factors, which have limited  
25 scope for modification and design intervention. This study attempted to determine the prevalence  
26 of underweight, overweight and obesity, and their modifiable lifestyle predictors in a rural  
27 population of Bangladesh.

28 **Method:** This study was part of a cross-sectional study that applied the WHO Package of Essential  
29 Noncommunicable Disease Interventions (WHO PEN) in a rural area of Bangladesh to assess the  
30 burden of diabetes, hypertension and their associated risk factors. The sampling technique was  
31 census. Anthropometric measurement, and data on sociodemographic characteristics and  
32 behavioral risk factors were collected following the standard protocol described in the WHO  
33 STEPS-wise approach. Analysis included means of continuous variables and multinomial logistic  
34 regression of factors.

35 **Result:** The mean BMI of the study population was 21.9 kg/m<sup>2</sup>. About 20.9% were underweight,  
36 16.4% were overweight, and 3.5% obese. Underweight was most predominant among people  
37 above 60 years, while overweight and obesity were predominant among people between 31-40  
38 years. Higher overweight and obesity were noted among females. Employment, consumption of  
39 added salt, and inactivity increased the odds of being underweight by 0.32, 0.33, and 0.14,  
40 respectively. On the other hand, the odds of being overweight or obese increased by 0.58, 0.55,  
41 0.78, 0.21, and 0.25 if a respondent was female, literate, married, housewife, and consumed red  
42 meat; and decreased by 0.38 and 0.18 if a respondent consumed added salt and inadequate amounts



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3 43 of fruits and vegetables respectively. Consumption of added salt decreases the odds of being  
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5 44 overweight or obese by 0.37.  
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9 **Conclusion:** The study emphasized malnutrition to be a public health concern in spite of the  
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11 46 dynamic sociodemographic scenario. Specific health messages for targeted population may help  
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13 47 improve the nutritional status. Findings from further explorations may support policies and  
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16 48 programs in future.  
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19 **Keywords:** Obesity, overweight, underweight, physical activity, Bangladesh, body mass index  
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### 23 **Strengths and limitations of this study** 24 25 26

- 27 51 • This study assessed the current status of malnutrition and look at its association with  
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29 52 different modifiable risk factors among adults in a selected rural population of Bangladesh  
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32 53 • The sampling technique was census and data were collected from all adults except those  
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34 54 institutionalized in a hospital, prison, nursing home, or other similar institutions  
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36 55 • The study could only investigate a third of the individuals since the community clinics  
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39 56 were not attended by everyone who were included in the household survey  
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## 1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.<sup>1, 2</sup> Near about one-third of people in any community have at least one form of malnutrition, which include disorders caused by excessive and/or imbalanced intake leading to obesity and overweight, and disorders caused by deficient intake of energy or nutrients leading to stunting, wasting, and micronutrient deficiencies. Both over- and under-nutrition are caused by intake of unhealthy and poor quality diets.<sup>1</sup> Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.<sup>2</sup> Studies show that prevalence of obesity and overweight are increasing over time.<sup>3</sup> Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.<sup>4</sup> At least 2.8 million people die each year due to causes related to obesity and overweight.<sup>5</sup> Data from a national survey show that in Bangladesh, about 30.4%, 18.9%, and 4.6% of adults were underweight, overweight, and obese respectively.<sup>6</sup>

Unhealthy dietary behavior, low physical activity, genetics, family history of certain diseases, community environment, and usage of some drugs can lead to obesity and overweight.<sup>7</sup> Obesity and overweight are two of the key risk factors for noncommunicable diseases such as cardiovascular diseases, and diabetes mellitus, which are known major public health concerns.<sup>8, 9,</sup><sup>10</sup> Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.<sup>1, 11</sup> Diabetes and hypertension have some common and important risk factors, such as unhealthy diet, inadequate physical inactivity, tobacco use, abnormal lipid profiles and overweight/obesity.<sup>12</sup> About 85.0% of premature deaths from NCDs now occur in low- and middle-income countries, where greater burden of undernutrition and infectious diseases also exist.<sup>1, 13</sup> In economically well-off countries, NCDs are noted disproportionately among vulnerable

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3 80 and disadvantaged groups.<sup>2</sup> On the other hand, in less developed economies, childhood  
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5 81 undernutrition affects health, survival, growth and development in rural population.<sup>1</sup> Globally,  
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7 82 undernutrition contributes to around 45% of deaths among under-five children, the majority of  
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9 83 which occur in low- and middle-income countries.<sup>1</sup>  
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13 84 Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical  
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15 85 outcome of the dramatic shift in current food systems, which focus on increasing availability of  
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17 86 inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets.  
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19 87 Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts)  
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21 88 has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat,  
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23 89 sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely  
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25 90 available.<sup>1</sup> Studies show that reduction in risk factors through lifestyle modifications help greatly  
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27 91 in reducing the burden of most non-communicable diseases including hypertension, diabetes,  
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29 92 malnutrition, and mental disorders.<sup>14, 15</sup> Studies in rural Bangladesh found that 55% of women  
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31 93 ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly  
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33 94 and monthly basis respectively.<sup>16, 17</sup>  
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40 95 Under these circumstances, developing countries like Bangladesh can benefit from interventions  
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42 96 that help the primary health care facilities to be ready to tackle different noncommunicable diseases  
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44 97 that are predisposed by overweight, obesity, and undernutrition. This study provides an  
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46 98 opportunity to find the influencing factors and predictors of malnutrition in the current changing  
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48 99 lifestyle among selected communities. This study was conducted to determine the prevalence of  
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50 100 underweight, overweight and obesity, and their predictors in a rural population of Bangladesh.  
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53 101 Previous studies in Bangladesh have looked at the risk factors of malnutrition in association with  
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3 102 different socio-demographic characteristics.<sup>18-26</sup> This study builds up on the previous studies by  
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5 103 examining the association of various risk factors with underweight, overweight and obesity on a  
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8 104 large dataset of adult population.  
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## 105 **2. Methods**

### 106 **2.1 Study design, setting, and participants**

107 This was a cross-sectional study that incorporated quantitative methods to fulfill the study  
108 objectives. It was a part of an implementation research in a randomly selected union (smallest rural  
109 administrative and local government units), Dhangora, among the three unions (Brammagachha,  
110 Chandaikona, and Dhangara) of Raiganj sub-district under Sirajganj district of Bangladesh. The  
111 three unions of Raiganj are under active health and demographic surveillance system of the  
112 implementing organization – Centre for Injury Prevention and Research Bangladesh (CIPRB),  
113 since 2006. Dhangara union has 12323 households with a population size of 51759, of whom  
114 35704 were adult population ( $\geq 18$  years old) during the data collection.

115 The sampling technique was a census that included all adults except those who were mentally  
116 challenged or institutionalized in a hospital, prison, nursing home, or other similar institutions. The  
117 duration of the study was six months from January to June 2019, while data was collected from  
118 March to June 2019.

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## 121 **2.2 Data collection instrument and procedure**

122 As a part of an implementation research, this study collected data by screening out the  
123 sociodemographic and cardio-metabolic risk factors of chronic diseases (hypertension, diabetes),  
124 and determine their prevalence. The study adapted the procedure as described in the WHO Package  
125 of Essential Noncommunicable Disease Interventions (WHO PEN) model.<sup>27</sup>

126 The data was collected electronically at the household level, using an Android-based mobile  
127 platform software. Interviewer administered face-to-face interview was used to collect data. The  
128 questionnaire was prepared based on the STEP-wise approach to Surveillance (STEPS) of NCD  
129 risk factors by the World Health Organization (WHO, Version 3.2). The STEPS questionnaire was  
130 modified and used to ask questions on sociodemographic characteristics, behavioral risk factors  
131 (such as tobacco and alcohol consumption, physical activity, dietary habits, added salt intake),  
132 occurrence of chronic disease, and to measure physical and biochemical parameters (height,  
133 weight, blood glucose, blood pressure). The English STEPS questionnaire was first translated to  
134 Bangla and then finalized after necessary modification following pre-testing on a suitable  
135 population. Data collectors having requisite background were recruited and intensively trained  
136 before the commencement of data collection.

137 Screening at community level posed specific challenges that were identified and addressed, such  
138 as, the time of a day or day of a week to reach a particular population like office goers, farmers,  
139 homemakers, especially for males. The use of active surveillance provided the advantage of having  
140 a full list of households and addresses, which ensured full coverage of the survey area. Data  
141 collectors were provided with the list and information required to track each household. If the  
142 respondent was unable to provide information when the data collector visited, a new time was

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3 143 scheduled for the screening as per convenience of the household members and data collector. All  
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5 144 possible measures were taken to ensure full coverage of the population.  
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9 145 During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.)  
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11 146 among the members was explored. Each participant was interviewed for approximately 25 to 30  
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13 147 minutes. Treatment and other medical documents were reviewed to confirm the disease  
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15 148 conditions, and show-cards were used for food and physical activity to ensure quality data. In some  
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17 149 cases, where a person was not able to respond to data collectors' queries (those who were ill or  
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19 150 had some form of disability), an appropriate person from the household, for example- the caregiver  
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21 151 was asked to answer on behalf provided he/she could give the exact information.  
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26 152 The household survey participants were advised to visit the nearby community clinic (CC) on the  
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28 153 next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and  
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30 154 biochemical parameters. In the community clinic, standard weight scale, height measurement  
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32 155 scales, measuring tape, and automated digital BP machine were used to record their weight, height,  
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34 156 waist circumference, hip circumference, and blood pressure respectively. Fasting capillary glucose  
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36 157 was measured by a standard glucometer maintaining all necessary aseptic precautions. Blood  
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38 158 pressure was measured twice – first, after 15 minutes' rest time, and second one 3 minutes after  
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40 159 the first measurement. The mean of the two measurements was used to determine the actual BP.  
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43 160 Physical measurements were carried out by well-trained male and female assistants maintaining  
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45 161 adequate privacy. The data collected at the CC were synced with those collected at the household  
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47 162 level. The Flow Chart of study methods applied to collect data is shown in Figure 1.  
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53 163 **Figure 1: Flow Chart of study methods applied to collect data from selected rural population of**  
54 164 **Bangladesh**  
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## 165 2.3 Ascertainment of key variables

166 **Age:** The respondents were asked what their age (in years) was at the time of data collection.

167 **Sex:** The respondents were asked which sex (male or female) did they identify themselves as at  
168 the time of data collection.

169 **Education:** The respondents were asked what was the highest level of education (no schooling,  
170 primary, and secondary and above) obtained by them at the time of data collection.

171 **Marital status:** The respondents were asked if they were ever married or never married.

172 **Occupation:** The respondents were asked about their occupation. Occupation was classified as  
173 unemployed, service holder, farmer, self-employed, and housewife.

174 **Red meat intake:** The respondents who said that they ate red meat on a weekly basis were  
175 categorized as consumers of red meat.

176 **Fried food intake:** The respondents who said that they ate fried food on a weekly basis were  
177 categorized as consumers of fried food.

178 **Processed food intake:** The respondents who said that they ate processed food on a weekly basis  
179 were categorized as consumers of processed food.

180 **Sugary drink intake:** The respondents who said that they ate sugary drinks on a weekly basis  
181 were categorized as consumers of sugary drinks.

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3 182 **Added salt intake:** The respondents who said they took extra dietary salt while eating any cooked  
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5 183 meal were categorized as consumers of added dietary salt.  
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9 184 **Adequate amount of fruit and vegetable (FAV):** Respondents whose dietary intake of FAV  
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11 185 corresponded to WHO recommended 5 servings were considered as taking adequate amount of  
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13 186 FAV.<sup>28</sup>  
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17 187 **Physical activity:** The respondents were asked about their work-related physical activities, the  
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19 188 number of days a week, and the amount of time (in minutes) per day that they spend on vigorous  
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21 189 and moderate activities. This was then converted to the metabolic equivalent of task-minutes  
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23 190 (MET-minutes) to find out the intensity of physical activity, which were then categorized. The  
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25 191 categories were: less active or sedentary ( $\leq 600$  MET-minutes per week), moderately active  
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27 192 (between 600 and 3000 MET-minutes per week), and highly or vigorously active ( $\geq 3000$  MET-  
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29 193 minutes per week).<sup>29</sup>  
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34 194 **Underweight:** The respondents were considered as underweight when their body mass index  
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36 195 (BMI) was less than  $18.5 \text{ kg/m}^2$ .<sup>30</sup>  
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40 196 **Normal weight:** The respondents were considered as normal weight when their BMI was  
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42 197 between  $18.5$  and  $25.0 \text{ kg/m}^2$ .<sup>30</sup>  
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46 198 **Overweight:** The respondents were considered overweight when their BMI was between  $25.0$   
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48 199 and  $29.9 \text{ kg/m}^2$ .<sup>30</sup>  
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51 200 **Obese:** The respondents were considered obese when their BMI was over  $30.0 \text{ kg/m}^2$ .<sup>30</sup>  
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## 202 **2.4 Data analysis**

203 The data were entered in the pre-designed Microsoft office excel format which was later imported  
204 into the statistical software STATA version 12. The raw data was initially checked for  
205 completeness, consistency and the absence of missing data, errors and outliers. Afterwards, it was  
206 carefully cleaned and edited for consistency and to preserve for longer time. Descriptive, and  
207 relevant statistical analysis were performed on this cleaned data set. The results were then  
208 presented in tables and illustrations. Of the 22270 respondents at the household level, a total of  
209 11244 respondents visited community clinic for the required physical measurements. After  
210 cleaning the data, the final analysis was done with a sample of 11,064 respondents.

211 To assess the distribution of anthropometric measurements among the respondents, the means of  
212 the continuous variables were calculated and presented in a tabulated form with range and standard  
213 deviation. A pie chart was used to show the overall nutrition status of the respondents. Descriptive  
214 analysis was done to show the distribution of nutritional status and presented as percentage. To  
215 identify the sociodemographic and behavioral risk factors affecting malnutrition, multinomial  
216 logistic regression analysis was used. In this regards, at first, the assumptions of regression analysis  
217 were checked and no violation of these assumptions were found. These assumptions included  
218 multicollinearity, outlier, normality, linearity, homoscedasticity, and the independence of  
219 observations. Univariate analysis was performed to determine the eligibility of the variables before  
220 including them in the multinomial logistic regression analysis. The variables included were age,  
221 sex, education, marital status, occupation, physical activity, red meat intake, fried food intake,  
222 processed food intake, sugary drink intake, added salt intake, and inadequate intake of fruits and  
223 vegetables. During the univariate analysis, only the variables which showed  $p < 0.05$

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3 224 (Supplementary table 1) were considered as eligible to be included in the multinomial logistic  
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5 225 regression analysis. The dependent variable was categorized as underweight, normal weight,  
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7 226 overweight and obesity. As per literature review, overweight and obesity have similar predictors.  
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10 227 As such, overweight and obesity were merged together into one category, and normal weight was  
11  
12 228 considered as reference. The regression table for each outcome variable included the presentation  
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14 229 of the factors with the corresponding odds ratios (OR) and OR > 1 was considered as predictor.  
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17 230 The estimates of precision were all presented at a 95% confidence interval (CI), as appropriate.  
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19 231 The significant threshold of *P* value for all tables included in the analysis was less than 0.05.  
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## 23 232 **2.5 Patient and public involvement**

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27 233 Data was collected from all adults at household level. Further anthropometric data was collected  
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29 234 at the health facilities from those who visited the community clinics. However, the public were not  
30  
31 235 directly involved in the research. They did not play any role during the establishment of the  
32  
33 236 research questions, designing or implementing the study, measuring the study outcomes, or  
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36 237 interpretation of the results.  
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## 40 238 **Ethical consideration**

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44 239 Ethical approval was obtained from the Ethical Review Board of the Center for Injury Prevention  
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46 240 and Research, Bangladesh (ERC number: CIPRB/ERC/2019/003). Participants had the right to  
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48 241 withdraw at any point after starting the interview. Rigor, accuracy, and impartiality were ensured  
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50 242 during data collection through in-person and digital monitoring systems.  
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## 244 3. Results

### 245 3.1 Anthropometric measurements

246 The mean anthropometric measurements of the respondents and the standard deviations with the  
 247 minimum and maximum values are shown below in Table 1. The mean weight, height, and BMI  
 248 of the respondents were 51.4 kg, 153.4 cm., and 21.9 kg/m<sup>2</sup>, respectively. The mean waist  
 249 circumference, hip circumference, and waist-hip ratio were 79.9 cm, 87.2 cm, and 0.9,  
 250 respectively.

251 **Table 1: Mean anthropometric measurements of respondents with standard deviation and**  
 252 **minimum and maximum values (N = 11,064)**

Mean measurements	Mean (SD)	Minimum	Maximum
Weight (kg)	51.4 (10.4)	30.0	139.0
Height (cm)	153.4 (8.9)	78.0	203.2
BMI (kg/m <sup>2</sup> )	21.9 (4.2)	10.1	78.9
Waist circumference (cm)	79.9 (10.8)	43.0	144.0
Hip circumference (cm)	87.2 (8.7)	60.0	160.0
Waist-hip ratio	0.9 (0.1)	0.6	1.6

253  
 254 Considering body mass index (BMI), 59.2% of the respondents were within normal range, that is,  
 255 between 18.5 – 25.0 kg/m<sup>2</sup>. Underweight was found in 20.9% respondents, while that of  
 256 overweight and obesity was found to be 16.4% and 3.5%, respectively (Figure 2).

257  
 258 **Figure 2: Nutrition status of respondents (N = 11,064)**

259

## 3.2 Sociodemographic characteristics

The socio-demographic characteristics of the respondents are stratified by nutritional status and shown in Table 2. Irrespective of age, normal nutritional status was noted in about 55.5-61.2% respondents as shown in Table 2. Underweight was reported to be highest at 31.3% among  $\geq 60$  years, while overweight and obesity were highest at 21.0% and 5.1% respectively among 31-40 years age group. About 62.5% male and 57.5% female were within the normal range of weight. About 24.7% of males and 19.0% of females were underweight. Higher overweight and obesity were noted among females with 18.8% and 4.6%, respectively. Irrespective of years of schooling, normal weight was recorded in 59.2% of the respondents. Underweight (26.8%) was more among those with no schooling, while overweight (20.3%) and obesity (4.6%) was more among those with education up to or above secondary level. Normal weight was seen in about 60.0%, irrespective of marital status. Underweight was more (29.3%) in those never married, while overweight (17.0%) and obesity (3.7%) was more in those ever married. Underweight was more among unemployed and farmers with 31.2% and 31.9% respectively, overweight was 23.8% among service holders, and 4.8% obesity among homemakers. The socio-demographic characteristics stratified by nutrition status was further stratified by sex (Supplementary table 2).

## 3.3 Behavioral risk factors

Nutritional status with respect to behavioral risk factors is shown in Table 3. Irrespective of the risk factors considered, normal weight was noted in 57.3% to 60.5% respondents. Considering each risk factor, underweight was noted to be more among those who led sedentary lifestyle (25.1%), did not take red meat (21.9%), ate fried food (21.3%), took sugary drinks (21.7%), took

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3 281 added salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand,  
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5 282 overweight and obesity were noted as more among those who did moderate to vigorous exercise  
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7 283 (16.7% & 3.3% - 3.9 % respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8%  
8  
9 284 & 3.7%), did not take sugary drinks (16.9% & 3.6%), did not take added salt (19.3% & 4.7%), and  
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11 285 those who did not take inadequate (took adequate) fruits and vegetables (18.2% & 4.3%). Those  
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13 286 who did not consume processed food was more overweight (16.5%) while those who consumed  
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15 287 processed food was more obese (4.2%).  
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288 **Table 2: Sociodemographic characteristics of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status n (%)			
			Underweight	Normal weight	Overweight	Obese
Age (years)	<=30	2,184	517 (23.7)	1336 (61.2)	282 (12.9)	49 (2.2)
	31 to 40	2,419	348 (14.4)	1439 (59.5)	509 (21.0)	123 (5.1)
	41 to 50	2,482	405 (16.3)	1471 (59.3)	498 (20.1)	108 (4.4)
	51 to 60	2,097	455 (21.7)	1257 (59.9)	321 (15.3)	64 (3.1)
	> 60	1,882	590 (31.3)	1045 (55.5)	200 (10.6)	47 (2.5)
Sex	Male	3,715	916 (24.7)	2322 (62.5)	427 (11.5)	50 (1.3)
	Female	7,349	1399 (19.0)	4226 (57.5)	1383 (18.8)	341 (4.6)
Education	No schooling	3,969	1064 (26.8)	2349 (59.2)	462 (11.6)	94 (2.4)
	Primary	3,171	627 (19.8)	1877 (59.2)	551 (17.4)	116 (3.7)
	Secondary and above	3,924	624 (15.9)	2322 (59.2)	797 (20.3)	181 (4.6)
Marital status	Never married	771	226 (29.3)	475 (61.6)	58 (7.5)	12 (1.6)
	Ever married	10,293	2089 (20.3)	6073 (59.0)	1752 (17.0)	379 (3.7)
Occupation	Unemployed	1,057	330 (31.2)	609 (57.6)	92 (8.7)	26 (2.5)
	Service holder	307	34 (11.1)	191 (62.2)	73 (23.8)	9 (2.9)
	Farmer	1,353	431 (31.9)	833 (61.6)	80 (5.9)	9 (0.7)
	Self-employed	2,416	448 (18.5)	1514 (62.7)	390 (16.1)	64 (2.6)
	Housewife	5,931	1072 (18.1)	3401 (57.3)	1175 (19.8)	283 (4.8)

289 CI = confidence interval; Underweight = BMI less than 18.5 kg/m<sup>2</sup>; Normal weight = BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight = BMI is 25.0 – 29.9 kg/m<sup>2</sup>;  
 290 Obese = BMI is over 30.0 kg/m<sup>2</sup>

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292

293 **Table 3: Behavioral risk factors of respondents, stratified by nutrition status (N = 11,064)**

Variable	Category	N	Nutritional status % (95% CI)			
			Underweight	Normal weight	Overweight	Obese
Physical activity	Sedentary	1,995	25.1 (23.2–27.0)	57.3 (55.2–59.5)	14.7 (13.2–16.4)	2.9 (2.2 – 3.7)
	Moderate	3,134	22.0 (20.6–23.5)	58.0 (56.2–59.7)	16.7 (15.5–18.1)	3.3 (2.7 – 4.0)
	Vigorous	5,935	19.0 (18.0–20.0)	60.4 (59.2–61.7)	16.7 (15.8–17.7)	3.9 (3.4 – 4.4)
Red meat intake	Yes	2,687	17.9 (16.5–19.4)	58.2 (56.3–60.0)	19.9 (18.4–21.5)	4.0 (3.3 – 4.8)
	No	8,377	21.9 (21.0–22.8)	59.5 (58.5–60.6)	15.2 (14.5–16.0)	3.4 (3.0 – 3.8)
Fried food intake	Yes	2,949	21.3 (19.9–22.8)	60.5 (58.7–62.2)	15.2 (13.9–16.5)	3.1 (2.5 – 3.7)
	No	8,115	20.8 (19.9–21.7)	58.7 (57.6–59.8)	16.8 (16.0–17.6)	3.7 (3.3 – 4.1)
Processed food intake	Yes	2,278	20.9 (19.2–22.6)	59.3 (57.3–61.3)	15.6 (14.2–17.2)	4.2 (3.5 – 5.1)
	No	8,786	20.9 (20.1–21.8)	59.2 (58.1–60.2)	16.5 (15.8–17.3)	3.4 (3.0 – 3.8)
Sugary drinks intake	Yes	4,044	21.7 (20.4–23.0)	59.6 (58.0–61.1)	15.4 (14.3–16.5)	3.4 (2.9 – 4.0)
	No	7,020	20.5 (19.6–21.4)	59.0 (57.8–60.1)	16.9 (16.1–17.8)	3.6 (3.2 – 4.1)
Added salt intake	Yes	6,946	23.2 (22.2 –24.2)	59.3 (58.2–60.5)	14.6 (13.8–15.5)	2.9 (2.5 – 3.3)
	No	4,118	17.1 (16.0–18.3)	58.9 (57.4–60.4)	19.3 (18.1–20.5)	4.7 (4.1 – 5.4)
Inadequate intake of fruits and vegetables	Yes	8,331	21.4 (20.6–22.3)	59.5 (58.5–60.6)	15.7 (15.0–16.5)	3.3 (2.9 – 3.7)
	No	2,733	19.4 (17.9–20.9)	58.1 (56.3–60.0)	18.2 (16.8–19.7)	4.3 (3.6 – 5.1)

294 CI, confidence interval; Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI  
 295 is over 30.0 kg/m<sup>2</sup>

296

### 297 **3.4 Factors affecting the malnutrition**

298 Table 4 shows the multinomial logistic regression analysis of the data. For this analysis,  
299 overweight and obese were merged into one variable as overweight/obese. It was found that the  
300 odds of being underweight will decrease by 0.25, 0.35, 0.40, and 0.14 if a respondent is less than  
301 45 years of age, literate, married, and consumed red meat respectively. Employment, consumption  
302 of added salt, and inactivity increases the odds of being underweight by 0.32, 0.33, and 0.14,  
303 respectively.

304 On the other hand, the odds of being overweight/obese increased by 0.58, 0.55, 0.78, 0.21, and  
305 0.25 if the respondent was female, literate, married, housewife, and consumed red meat; and  
306 decreased by 0.38 and 0.18 if the respondent consumed added salt and inadequate amount of fruits  
307 and vegetables, respectively. Consumption of added salt decreased the odds of being  
308 overweight/obese by 0.37.

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310

311 **Table 4: Factors affecting malnutrition in all its forms among the study population using**  
 312 **multinomial logistic regression analysis considering normal body weight as reference (N =**  
 313 **11,064)**

Malnutrition	Factors	B	P-value	AOR	95% CI for OR	
					Lower Bound	Upper Bound
Underweight (BMI <18.5 kg/m <sup>2</sup> )	Age (years)					
	< 45	- 0.252	<0.001*	0.777	0.696	0.869
	≥ 45	<i>Reference</i>				
	Sex					
	Female	-0.147	0.050	0.863	0.745	1.000
	Male	<i>Reference</i>				
	Education					
	Literate	-0.346	<0.001*	0.707	0.634	0.789
	Illiterate	<i>Reference</i>				
	Marital status					
	Married	-0.396	<0.001*	0.673	0.542	0.835
	Unmarried	<i>Reference</i>				
	Occupation					
	Housewife	-0.037	0.634	0.964	0.828	1.122
	Employed	0.316	0.001*	1.371	1.133	1.659
	Unemployed	<i>Reference</i>				
	Red meat intake					
	Yes	-0.141	0.019*	0.869	0.772	0.977
	No	<i>Reference</i>				
	Added salt intake					
	Yes	0.327	<0.001*	1.387	1.249	1.540
	No	<i>Reference</i>				
	Physical inactivity					
Yes	0.142	0.028*	1.152	1.016	1.308	
No	<i>Reference</i>					
Inadequate fruit/vegetable intake						
Yes	0.030	0.614	1.030	0.917	1.157	
No	<i>Reference</i>					

	Age (years)					
	< 45	-0.039	0.477	0.961	0.862	1.072
	≥ 45	<i>Reference</i>				
	Sex					
	Female	0.581	<0.001*	1.788	1.511	2.115
	Male	<i>Reference</i>				
	Education					
	Literate	0.547	<0.001*	1.727	1.532	1.948
	Illiterate	<i>Reference</i>				
	Marital status					
	Married	0.775	<0.001*	2.170	1.601	2.942
	Unmarried	<i>Reference</i>				
	Occupation					
	Housewife	0.205	0.011*	1.228	1.049	1.438
	Employed	-0.108	0.407	0.897	0.695	1.159
	Unemployed	<i>Reference</i>				
	Red meat intake					
	Yes	0.252	<0.001*	1.287	1.152	1.438
	No	<i>Reference</i>				
	Added salt intake					
	Yes	-0.378	<0.001*	.685	.619	.758
	No	<i>Reference</i>				
	Physical inactivity					
	Yes	0.017	0.813	1.017	0.886	1.167
	No	<i>Reference</i>				
	Inadequate fruit/vegetable intake					
	Yes	-0.181	0.002*	0.835	0.745	0.935
	No	<i>Reference</i>				

314 Ref., reference; AOR, adjusted odd-ratio; CI, confidence interval

315 \*Significant at the threshold of  $p < 0.05$

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## 317 4. Discussion

318 This cross-sectional study was undertaken among adult population in a selected rural area. It was  
319 a part of an implementation research. The sampling strategy was census, but only a third of the  
320 population (those who attended the community clinics) was included in this study, for which  
321 reason the result do not represent a census. Several studies have explored the various preconditions  
322 and post-effects of malnutrition in all its forms mostly with regards to modifiable  
323 sociodemographic factors. However, this study attempts to explore the same, but with regards to  
324 the status of modifiable lifestyle factors. While adequate knowledge and practices can modify the  
325 quality of diet and adjust lifestyles, influence of a combination of economic, social and  
326 demographic factors also play a key role in modifying these.<sup>6</sup> Such complex phenomena may be  
327 assessed case by case to determine modification modalities so as to improve the overall health  
328 status of a population.

329 This study found that underweight, overweight, and obesity are of similar concern among the adult  
330 rural population in Bangladesh. According to the WHO estimates, the age-standardized estimation  
331 of prevalence of overweight among adults in the South-east Asia was 21.9% in 2016, which was  
332 higher than that found in this study.<sup>17</sup> A study in South Africa found that the mean waist  
333 circumference for rural men and women was much higher, putting them at high risk of NCDs.<sup>31</sup>  
334 In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children  
335 was found to be less than ten percent.<sup>18</sup> Other studies among the rural and urban populations of  
336 Bangladesh found that prevalence of overweight and obesity were 15% – 18.9%, and 3% – 4.6%,  
337 respectively. <sup>6, 19, 20, 21</sup> The occurrence of overweight and obesity found in this study was near  
338 similar to the combined overweight and obesity as found in other studies in Bangladesh. However,

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3 339 the population of other studies included everyone in the study area, while this study included only  
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5 340 adult population. It was noted in this study that factors such as extreme age, varied occupation,  
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7 341 and other physio-demographic features influenced prevalence of obesity and overweight. Since  
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9 342 this study was conducted in a surveillance population, the community members may already have  
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11 343 been a little more aware of the importance of healthy lifestyles.  
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16 344 In this study, respondents in the age group 31 – 40 years were the most overweight and obese,  
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18 345 while those 60 years and above were the most underweight. Females were found to be more  
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20 346 overweight and obese than males, while males were found to be more underweight than females.  
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22 347 The study also found that the likelihood of being overweight and obese increased among married  
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24 348 and literate females, in contrast to unmarried and illiterate males. On the other hand, literate and  
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26 349 married females less than 45 years were less likely to be underweight compared to illiterate and  
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28 350 married males more than 45 years of age. Age between 33 – 37 years was also found significantly  
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30 351 associated with obesity and overweight in other studies among rural women of Bangladesh (OR:  
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32 352 3.71; 95% CI: 2.84 – 4.86;  $p < 0.001$ ).<sup>19</sup> Other studies have shown that urban women aged 30 to 39  
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34 353 years were obese and/or overweight with a high association (OR: 3.9; 95% CI: 1.9 – 7.7;  
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36 354  $p < 0.001$ ).<sup>23</sup> There are studies that also showed that the prevalence of underweight among males of  
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38 355 more than 50 years of age was much high.<sup>20, 32</sup> The findings from this study corroborate with these  
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40 356 earlier findings.  
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47 357 The odds of overweight and obesity increased by 0.25 among respondents who consumed red  
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49 358 meat, and decreased by 0.38 and 0.18 among those who consumed added salt and inadequate  
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51 359 amount of fruits and vegetables. On the other hand, consumption of added salt and inactivity  
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53 360 increased the odds of underweight by 0.33 and 0.14, respectively. A study on Malaysian adults  
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3 361 showed that prevalence of obesity and overweight was more among those men who did vigorous  
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5 362 physical activity. In contrast, females who did moderate physical activity were more obese and  
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7 363 overweight.<sup>33</sup> Other studies also showed that underweight was more often associated with vigorous  
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9 364 physical activity, while overweight and obesity were more related with sedentary lifestyle.  
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11 365 Variable associations were also noted with gender, education level, marital status, working status,  
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13 366 and wealth index.<sup>19, 34</sup> Most likely demographic features influence source, amount and variety of  
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15 367 food intake, and type of physical activities undertaken based on knowledge and livelihood  
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17 368 practices.

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22 369 The food habit of the rural population in Bangladesh is low in fat and protein, and high in  
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24 370 carbohydrate.<sup>35, 36, 37</sup> This may be why people who perform vigorous physical activity can avoid  
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26 371 getting overweight or obese. At the same time if balance is not maintained between intake and  
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28 372 output, there is increased likelihood of being obese or overweight, a phenomenon observed among  
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30 373 a substantial number of subjects in this study. Rural women tend to regularly perform most  
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32 374 household chores, some involving heavy activities, but these activities are not considered as such  
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34 375 and overlooked by community members and health workers. Moreover, women tend to eat less  
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36 376 food of poor quality while ensuring that other family members get more food of better quality.<sup>38,</sup>  
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38 377 <sup>39</sup> This may be why inactivity has been found to increase the likelihood of underweight in this  
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40 378 study. Studies show that the prevalence of previously undiagnosed comorbidities such as  
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42 379 hypertension and diabetes are on the rise in South-east Asian region.<sup>40</sup> In Bangladesh, about 50%  
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44 380 - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher  
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46 381 percentage among those from lower socioeconomic rural areas.<sup>27, 30</sup> People once diagnosed tend  
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48 382 to visit health facilities more often than those who remain undiagnosed.  
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3 383 In its document on nutrition, World Health Organization has pointed at malnutrition in all its forms  
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5 384 (characterized by coexisting undernutrition and overweight/obesity) and noncommunicable  
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7 385 diseases within individuals, households, populations, and across life course of individuals.  
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10 386 Epidemiological evidence support that undernutrition early in life, even when in-utero, may  
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12 387 predispose to overweight and NCDs later in life. At the same time, underweight in later life is an  
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14 388 expression of malnutrition. Again, overweight in mothers is often associated with overweight in  
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16 389 their offspring. Biological mechanisms, along with environmental and social influences, are  
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18 390 increasingly understood as essential drivers in the global burden of NCDs.<sup>38</sup>  
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23 391 In addition to increasing health literacy among rural population through training and awareness  
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25 392 programs, the Government may also take initiatives to encourage household backyard vegetable  
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27 393 and fruits gardening which would help to reduce the overall family. As an initial support, the  
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29 394 Government may distribute free (or at nominal price) saplings of fruits and vegetables among rural  
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31 395 population.  
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## 35 396 **Strengths**

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40 397 The strength of this study was that this study attempted to assess the current burden of malnutrition  
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42 398 in all its forms and looked at the association of different modifiable risk factors with underweight,  
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44 399 overweight, and obesity among adults in a selected rural population of Bangladesh. The sampling  
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46 400 technique was census and data was collected from all adults except those institutionalized in a  
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48 401 hospital, prison, nursing home, or other similar institutes. Data from disabled or sick persons were  
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50 402 collected from someone in the household who could provide the correct information. The number  
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52 403 of such responses were very negligible, and most likely did not affect the overall result.  
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## 404 **Limitations**

405 Although the sampling strategy was census, but the study could only investigate a third of the  
406 individuals (those who attended the community clinic). As such, the result do not represent a  
407 census. The limitations of this study was that household chores performed by women at home were  
408 not categorized into sedentary, moderate or vigorous activities, which may have affected the  
409 results. Some of the subjects included in the study may have been on medication or may have  
410 received lifestyle modification counseling, and this may have also affected the results. On the other  
411 hand, people who were already diagnosed with diabetes or hypertension tend to visit health  
412 facilities more often than those who remain undiagnosed for which reason, the data collected at  
413 the community clinic may have been more on those who were already diagnosed before.

## 414 **Conclusion**

415 This cross-sectional study found that the prevalence of underweight was near equal to combined  
416 overweight and obesity among the adults in a selected rural area of Bangladesh. Factors such as  
417 age, sex, education, marital status, physical inactivity, and intake of added salt were strongly  
418 associated with underweight. While factors such as sex, education, marital status, and consumption  
419 of red meat, added salt and fruits and vegetables were associated with overweight and obesity.  
420 Physical activity along with eating habits influence the nutritional status of adults. Sedentary  
421 lifestyle along with less food consumption lead to being underweight. Physically active persons  
422 who eat more food, such as, red meat, tend to be overweight and obese. As such, considering the  
423 nutritional status, specific health messages to people on dietary habits and physical activity, can  
424 go a long way to reduce underweight, overweight, and obesity in the community. The effects of

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3 425 health messages can be further explored through qualitative studies so that policy makers and  
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5 426 program managers can take informed decisions while developing policies and implementing  
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8 427 programs.  
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26

27 434 Data curation: SR, LB  
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29 435 Formal analysis: SR, LB  
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31 436 Methodology: AKMFR, SRM, MF, RAS, PCB, LB  
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34 437 Project administration: AKMFR, SRM, MF, RAS, PCB, LB  
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36 438 Supervision: SRM  
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38 439 Writing original draft: SR  
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47 442 **Data sharing statement:** The corresponding author will make the data available when required,  
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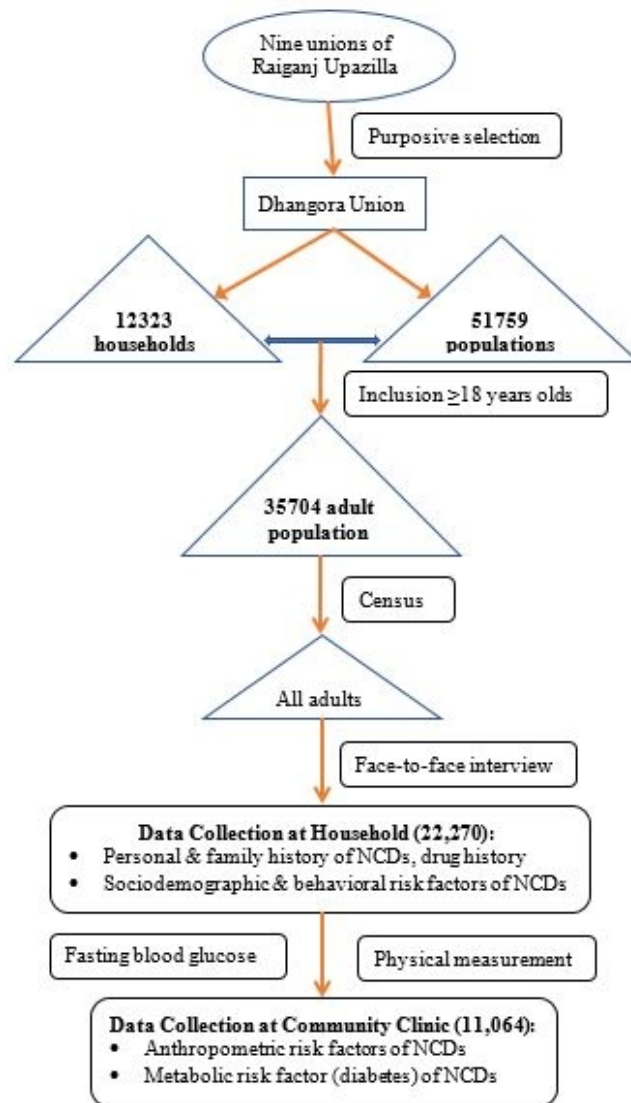
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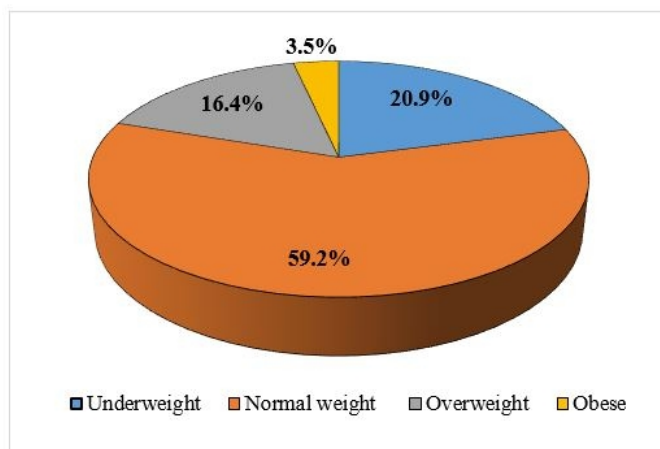


**Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh**

Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

120x163mm (96 x 96 DPI)





Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI is over 30.0 kg/m<sup>2</sup>

**Figure 2: Nutrition status of respondents (N = 11,064)**

Figure 2: Nutrition status of respondents (N = 11,064)

203x121mm (96 x 96 DPI)

**Supplementary table 1: Univariate analysis ( $\chi^2$ -test) between the nutritional status (underweight, normal weight, overweight/obese) and the sociodemographic characteristics and behavioral risk factors of respondents (N = 11,064)**

Variables	Categories	Nutritional status (%)			$\chi^2$ -value	P-value
		Underweight	Normal weight	Overweight/ obese		
Age	< 45 years	17.9	60.4	21.7	72.4	<0.001*
	$\geq$ 45 years	24.0	57.9	18.0		
Sex	Male	24.7	62.5	12.8	187.5	<0.001*
	Female	19.0	57.5	23.5		
Education	Illiterate	26.8	59.2	14.0	210.2	<0.001*
	Literate	17.6	59.2	23.2		
Marital status	Never married	29.3	61.6	9.1	77.4	<0.001*
	Ever married	20.3	59.0	20.7		
Occupation	Housewife	18.1	57.3	24.6	239.8	<0.001*
	Unemployed	31.2	57.6	11.2		
Physical activity	Income group	22.4	62.3	15.3	27.8	<0.001*
	Inactive	25.1	57.3	17.6		
Red meat intake	Active	20.0	59.6	20.4	45.2	<0.001*
	Yes	17.9	58.2	23.9		
Added salt intake	No	21.9	59.5	18.6	100.7	<0.001*
	Yes	23.2	59.3	17.5		
Inadequate intake of fruits and vegetables	No	17.1	58.9	24.0	17.4	<0.001*
	Yes	21.4	59.5	19.0		
	No	19.4	58.1	22.5		

Underweight, BMI less than 18.5 kg/m<sup>2</sup>; Normal weight, BMI is 18.5 – 25.0 kg/m<sup>2</sup>; Overweight, BMI is 25.0 – 29.9 kg/m<sup>2</sup>; Obese, BMI is over 30.0 kg/m<sup>2</sup>

\*Significant at the threshold of P-value < 0.05

**Supplementary table 2: Sociodemographic characteristics of respondents, stratified by nutrition status and sex (N = 11,064)**

Sex	Variable	Category	N	Nutritional status % (95% CI)			
				Underweight	Normal weight	Overweight	Obese
Male	Age (years)	<=30	670	27.2 (23.9–30.7)	63.1 (59.4–66.7)	9.0 (7.0–11.4)	0.7 (0.3–1.8)
		31 to 40	712	18.1 (15.5–21.1)	66.7 (63.2–70.1)	13.8 (11.4–16.5)	1.4 (0.8–2.6)
		41 to 50	788	18.7 (16.1–21.5)	65.9 (62.5–69.1)	14.1 (11.8–16.7)	1.4 (0.8–2.5)
		51 to 60	792	24.6 (21.7–27.7)	62.4 (58.9–65.7)	11.6 (9.6–14.0)	1.4 (0.8–2.5)
		> 60	753	34.9 (31.6–38.4)	54.6 (51.0–58.1)	8.8 (6.9–11.0)	1.7 (1.0–3.0)
	Education	No schooling	1137	31.9 (29.3–34.7)	59.5 (56.6–62.3)	7.7 (6.2–9.3)	1.0 (0.5–1.7)
		Primary	1052	26.9 (24.3–29.7)	63.7 (60.7–66.5)	8.4 (6.8–10.2)	1.0 (0.6–1.9)
		Secondary and above	1526	17.7 (15.9–19.7)	64.0 (61.5–66.3)	16.5 (14.7–18.5)	1.8 (1.3–2.6)
	Marital status	Never married	463	28.9 (25.0–33.2)	62.6 (58.1–66.9)	7.6 (5.5–10.4)	0.9 (0.3–2.3)
		Ever married	3252	24.0 (22.6–25.5)	62.5 (60.8–64.1)	12.1 (11.0–13.2)	1.4 (1.1–1.9)
	Occupation	Unemployed	550	31.6 (27.9–35.6)	58.5 (54.4–62.6)	8.4 (6.3–11.0)	1.5 (0.7–2.9)
		Service holder	223	9.4 (6.2–14.0)	63.7 (57.1–69.7)	24.7 (19.4–30.8)	2.2 (0.9–5.3)
		Farmer	1303	32.0 (29.5–34.6)	61.3 (58.6–63.9)	6.1 (4.9–7.5)	0.6 (0.3–1.2)
		Self-employed	1549	17.9 (16.1–19.9)	65.3 (62.9–67.6)	15.2 (13.5–17.0)	1.7 (1.1–2.5)
		Housewife	90	30.0 (21.4–40.3)	53.3 (43.0–63.4)	13.3 (7.7–22.1)	3.3 (1.1–9.9)
Female	Age (years)	<=30	1514	22.1 (20.1–24.3)	60.3 (57.8–62.7)	14.7 (13.0–16.5)	2.9 (2.2–3.9)
		31 to 40	1707	12.8 (11.3–14.5)	56.5 (54.1–58.8)	24.1 (22.1–26.2)	6.6 (5.5–7.9)
		41 to 50	1694	15.2 (13.6–17.0)	56.2 (53.8–58.5)	22.8 (20.9–24.9)	5.7 (4.7–6.9)
		51 to 60	1305	19.9 (17.8–22.2)	58.5 (55.8–61.1)	17.5 (15.6–19.7)	4.1 (3.1–5.3)
		> 60	1129	29.0 (26.4–31.7)	56.2 (53.2–59.0)	11.9 (10.1–13.9)	3.0 (2.2–4.2)
	Education	No schooling	2832	24.8 (23.2–26.4)	59.1 (57.3–60.9)	13.2 (12.0–14.5)	2.9 (2.4–3.6)
		Primary	2119	16.2 (14.7–17.9)	57.0 (54.8–59.1)	21.8 (20.1–23.7)	5.0 (4.1–6.0)
		Secondary and above	2398	14.8 (13.4–16.2)	56.1 (54.1–58.1)	22.7 (21.1–24.4)	6.4 (5.5–7.4)
	Marital status	Never married	308	29.9 (25.0–35.2)	60.1 (54.5–65.4)	7.5 (5.0–11.0)	2.6 (1.3–5.1)
		Ever married	7041	18.6 (17.7–19.5)	57.4 (56.2–58.5)	19.3 (18.4–20.3)	4.7 (4.3–5.3)
Occupation	Unemployed	507	30.8 (26.9–34.9)	56.6 (52.2–60.9)	9.1 (6.9–11.9)	3.6 (2.2–5.6)	

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Service holder	84	15.5 (9.2–24.9)	58.3 (47.5–68.4)	21.4 (13.9–31.5)	4.8 (1.8–12.1)
Farmer	50	28.0 (17.2–42.0)	68.0 (53.8–79.5)	2.0 (0.3–13.1)	2.0 (0.3–13.1)
Self-employed	867	19.7 (17.2–22.5)	58.0 (54.7–61.3)	17.9 (15.5–20.6)	4.4 (3.2–6.0)
Housewife	5841	17.9 (16.9–18.9)	57.4 (56.1–58.7)	19.9 (18.9–21.0)	4.8 (4.3–5.4)

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For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-12
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11-12
		(b) Describe any methods used to examine subgroups and interactions	11-12
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13-17
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	13

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Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	16-20
		(b) Report category boundaries when continuous variables were categorized	16-20
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	21-24
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	25
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	21-26
Generalisability	21	Discuss the generalisability (external validity) of the study results	24-26
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	26-27

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).