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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^2 (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.

Conclusion: The study once again emphasized malnutrition to be of public health concern in spite of the dynamic sociodemographic scenario. Specific health messages for targeted population may help to improve the nutritional status. Findings from further explorations may support policies and programs in future.

Keywords: Obesity, overweight, underweight, physical activity, Bangladesh, body mass index

Strengths and limitations of this study

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

1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.[1, 2] 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.[1] Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.[2] Studies show that prevalence of obesity and overweight are increasing over time.[3] Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.[4] At least 2.8 million people die each year due to causes related to obesity and overweight.[5] 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.[6]

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.[7] 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.[8, 9, 10] Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.[1, 11] 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.[12] 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.[1, 13] In economically well-off countries, NCDs are noted disproportionately among vulnerable

and disadvantaged groups.[2] On the other hand, in less developed economies, childhood undernutrition affects health, survival, growth and development in rural population.[1] Globally, undernutrition contributes to around 45% of deaths among under-five children, the majority of which occur in low- and middle-income countries.[1]

Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical outcome of the dramatic shift in current food systems, which focus on increasing availability of inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets. Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts) has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat, sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely available.[1] Studies show that reduction in risk factors through lifestyle modifications help greatly in reducing the burden of most non-communicable diseases including hypertension, diabetes, malnutrition, and mental disorders.[14, 15] Studies in rural Bangladesh found that 55% of women ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly and monthly basis respectively.[16, 17]

Under these circumstances, developing countries like Bangladesh can benefit from interventions that help the primary health care facilities to be ready to tackle different noncommunicable diseases that are predisposed by overweight, obesity, and undernutrition. This study provides an opportunity to find the influencing factors and predictors of malnutrition in the current changing lifestyle among selected communities. This study was conducted to determine the prevalence of underweight, overweight and obesity, and their predictors in a rural population of Bangladesh. Previous studies in Bangladesh have looked at the risk factors of malnutrition in association with

different socio-demographic characteristics.[18-26] This study builds up on the previous studies by examining the association of various risk factors with underweight, overweight and obesity on a large dataset of adult population.

2. Methods

2.1 Study design, setting, and participants

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

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

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.[27]

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

scheduled for the screening as per convenience of the household members and data collector. All possible measures were taken to ensure full coverage of the population.

During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.) among the members was explored. Each participant was interviewed for approximately 25 to 30 minutes. Treatment and other medical documents were reviewed to confirm the disease conditions, and show-cards were used for food and physical activity to ensure quality data. In some cases, where a person was not able to respond to data collectors' queries (those who were ill or had some form of disability), an appropriate person from the household, for example- the caregiver was asked to answer on behalf provided he/she could give the exact information.

The household survey participants were advised to visit the nearby community clinic (CC) on the next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and biochemical parameters. In the community clinic, standard weight scale, height measurement scales, measuring tape, and automated digital BP machine were used to record their weight, height, waist circumference, and blood pressure respectively. Fasting capillary glucose was measured by a standard glucometer maintaining all necessary aseptic precautions. Blood pressure was measured twice – first, after 15 minutes' rest time, and second one 3 minutes after the first measurement. The mean of the two measurements was used to determine the actual BP. Physical measurements were carried out by well-trained male and female assistants maintaining adequate privacy. The data collected at the CC were synced with those collected at the household level. The Flow Chart of study methods applied to collect data is shown in Figure 1.

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

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.[28]

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 (≤ 600 MET-minutes per week), moderately active (between 600 and 3000 MET-minutes per week), and highly or vigorously active (≥ 3000 MET-minutes per week).[29]

Underweight: The respondents were considered as underweight when their body mass index (BMI) was less than 18.5 kg/m^2. [30]

Normal weight: The respondents were considered as normal weight when their BMI was between 18.5 and 25.0 kg/m^2. [30]

Overweight: The respondents were considered overweight when their BMI was between 25.0 and 29.9 kg/m^2. [30]

Obese: The respondents were considered obese when their BMI was over 30.0 kg/m^2. [30]

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^2, 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^2)	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^2. 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 ≥ 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 Behavorial 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%), took red meat (21.9%), ate fried food (21.3%), took sugary drinks (21.7%), took added salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand, overweight and obesity were noted as more among those who did moderate to vigorous exercise (16.7% & 3.3% - 3.9 % respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8% & 3.7%), did not consume processed food (16.5% & 3.4%), did not take sugary drinks (16.9% & 3.6%), did not take added salt (19.3% & 4.7%), and those who did not take inadequate (took adequate) fruits and vegetables (18.2% & 4.3%).

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^2; Normal weight = BMI is 18.5 – 25.0 kg/m^2; Overweight = BMI is 25.0 – 29.9 kg/m^2; Obese = BMI is over 30.0 kg/m^2

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^2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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	*Ref*					
	Sex						
	Female		– 0.239	< 0.001	0.787	0.684	0.906
	Male	*Ref*					
	Education						
	Literate		– 0.350	< 0.001	0.704	0.632	0.786
	Illiterate	*Ref*					
	Marital status						
	Married		– 0.568	< 0.001	0.566	0.468	0.685
	Unmarried	*Ref*					

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

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/m2; Overweight/obese, BMI is over 25.0 kg/m^2

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.[17] 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.[31] In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children was found to be less than ten percent.[18] 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. [6, 19, 20, 21] 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

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

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

The food habit of the rural population in Bangladesh is low in fat and protein, and high in carbohydrate.[36, 37, 38] This may be why people who perform vigorous physical activity can avoid getting overweight or obese. At the same time if balance is not maintained between intake and

output, there is increased likelihood of being obese or overweight, a phenomenon observed among a substantial number of subjects in this study. Rural women tend to regularly perform most household chores, some involving heavy activities, but these activities are not considered as such and overlooked by community members and health workers. Moreover, women tend to eat less food of poor quality while ensuring that other family members get more food of better quality.[35, 39] This may be why inactivity has been found to increase the likelihood of underweight in this study. Studies show that the prevalence of previously undiagnosed comorbidities such as hypertension and diabetes are on the rise in South-east Asian region.[40] In Bangladesh, about 50% - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher percentage among those from lower socioeconomic rural areas.[27, 30] People once diagnosed tend to visit health facilities more often than those who remain undiagnosed.

In its document on nutrition, World Health Organization has pointed at the double burden of malnutrition (characterized by coexisting undernutrition and overweight/obesity) and noncommunicable diseases within individuals, households, populations, and across life course of individuals. Epidemiological evidence support that undernutrition early in life, even when in-utero, may predispose to overweight and NCDs later in life. At the same time, underweight in later life is an expression of undernutrition. Again, overweight in mothers is often associated with overweight in their offspring. Biological mechanisms, along with environmental and social influences, are increasingly understood as essential drivers in the global burden of NCDs.[35]

Strengths

The strength of this study was that this study attempted to assess the current burden of malnutrition and looked at the association of different modifiable risk factors with underweight, overweight,

and obesity among adults in a selected rural population of Bangladesh. The sampling technique was census and data was collected from all adults except those institutionalized in a hospital, prison, nursing home, or other similar institutes. Data from disabled or sick persons were collected from someone in the household who could provide the correct information. The number of such responses were very negligible, and most likely did not affect the overall result.

Limitations

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

Conclusion

This cross-sectional study found that the prevalence of underweight was near equal to combined overweight and obesity among the adults in a selected rural area of Bangladesh. Factors such as age, sex, education, marital status, physical inactivity, and intake of added salt were strongly associated with underweight. While factors such as sex, education, marital status, and consumption of red meat, added salt and fruits and vegetables were associated with overweight and obesity. Physical activity along with eating habits influence the nutritional status of adults. Sedentary lifestyle along with less food consumption lead to being underweight. Physically active persons

who eat more food, such as, red meat, tend to be overweight and obese. As such, considering the nutritional status, specific health messages to people on dietary habits and physical activity, can go a long way to reduce underweight, overweight, and obesity in the community. The effects of health messages can be further explored through qualitative studies so that policy makers and program managers can take informed decisions while developing policies and implementing programs.

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Author's contribution:

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

Data curation: SR, LB

Formal analysis: SR, LB

Methodology: AKMFR, SRM, MF, RAS, PCB, LB

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

Supervision: SRM

Writing original draft: SR

Writing: SR

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

Data sharing statement: The corresponding author will make the data available when required, with valid reasons.

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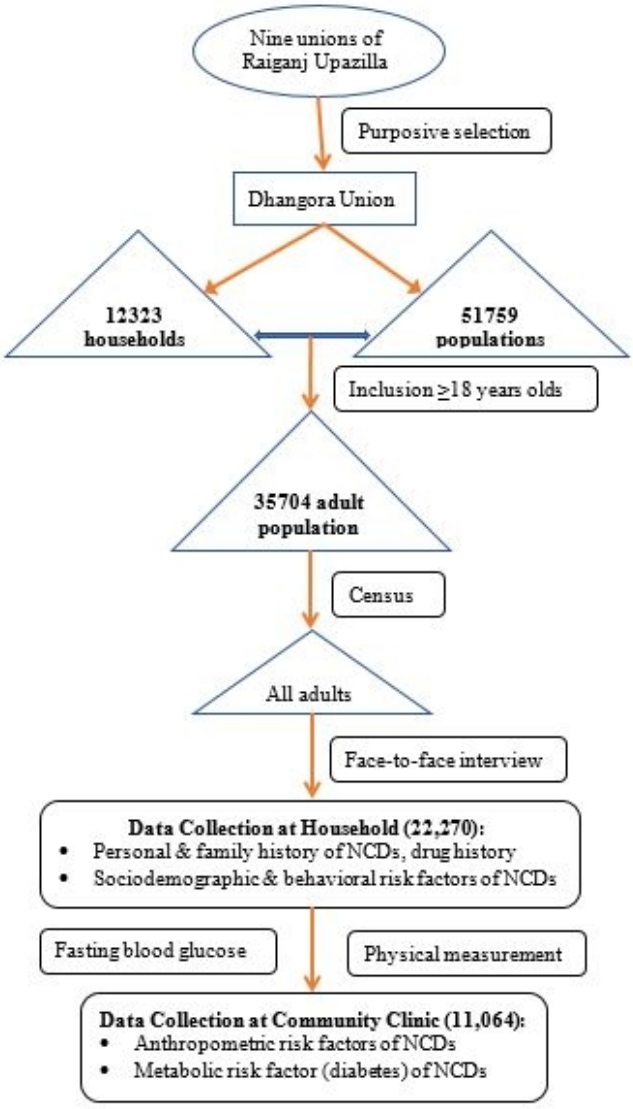

Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

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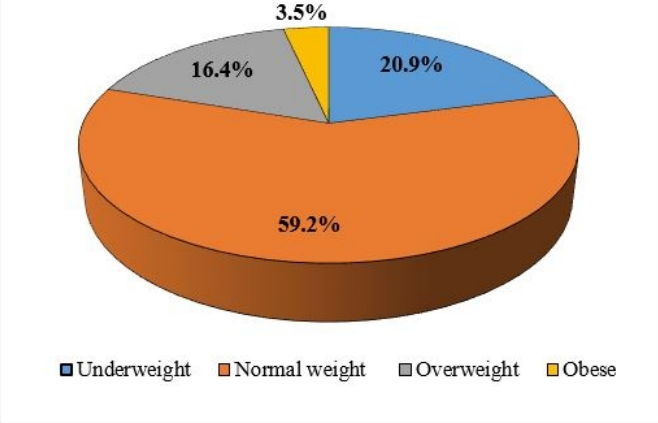
120x163mm (96 x 96 DPI)



Underweight, BMI less than 18.5 kg/m2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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

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	14-17
		(*b*) Report category boundaries when continuous variables were categorized	14 & 16
		(*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
Discussion			
Key results	18	Summarise key results with reference to study objectives	18-20
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	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-22
Generalisability	21	Discuss the generalisability (external validity) of the study results	21-22
Other information			
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	22

*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.

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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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Abstract

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

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. Anthropometric measurement, and data on sociodemographic characteristics and behavioral risk factors were collected following the standard protocol described in the WHO STEPS-wise approach. Analysis included means of continuous variables and multinomial logistic regression of factors.

Result: The mean BMI of the study population was 21.9 kg/m^2. About 20.9% were underweight, 16.4% were overweight, and 3.5% obese. Underweight was most predominant among people above 60 years, while overweight and obesity were predominant among people between 31-40 years. 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.

Conclusion: The study emphasized malnutrition to be a public health concern in spite of the dynamic sociodemographic scenario. Specific health messages for targeted population may help improve the nutritional status. Findings from further explorations may support policies and programs in future.

Keywords: Obesity, overweight, underweight, physical activity, Bangladesh, body mass index

Strengths and limitations of this study

- This study assessed the current status of malnutrition and look at its association with different modifiable risk factors among adults in a selected rural population of Bangladesh
- The sampling technique was census and data were collected from all adults except those institutionalized in a hospital, prison, nursing home, or other similar institutions
- The study could only investigate a third of the individuals since the community clinics were not attended by everyone who were included in the household survey

1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.[1, 2] 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.[1] Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.[2] Studies show that prevalence of obesity and overweight are increasing over time.[3] Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.[4] At least 2.8 million people die each year due to causes related to obesity and overweight.[5] 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.[6]

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.[7] 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.[8, 9, 10] Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.[1, 11] 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.[12] 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.[1, 13] In economically well-off countries, NCDs are noted disproportionately among vulnerable

and disadvantaged groups.[2] On the other hand, in less developed economies, childhood undernutrition affects health, survival, growth and development in rural population.[1] Globally, undernutrition contributes to around 45% of deaths among under-five children, the majority of which occur in low- and middle-income countries.[1]

Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical outcome of the dramatic shift in current food systems, which focus on increasing availability of inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets. Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts) has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat, sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely available.[1] Studies show that reduction in risk factors through lifestyle modifications help greatly in reducing the burden of most non-communicable diseases including hypertension, diabetes, malnutrition, and mental disorders.[14, 15] Studies in rural Bangladesh found that 55% of women ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly and monthly basis respectively.[16, 17]

Under these circumstances, developing countries like Bangladesh can benefit from interventions that help the primary health care facilities to be ready to tackle different noncommunicable diseases that are predisposed by overweight, obesity, and undernutrition. This study provides an opportunity to find the influencing factors and predictors of malnutrition in the current changing lifestyle among selected communities. This study was conducted to determine the prevalence of underweight, overweight and obesity, and their predictors in a rural population of Bangladesh. Previous studies in Bangladesh have looked at the risk factors of malnutrition in association with

different socio-demographic characteristics.[18-26] This study builds up on the previous studies by examining the association of various risk factors with underweight, overweight and obesity on a large dataset of adult population.

2. Methods

2.1 Study design, setting, and participants

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

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

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.[27]

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

scheduled for the screening as per convenience of the household members and data collector. All possible measures were taken to ensure full coverage of the population.

During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.) among the members was explored. Each participant was interviewed for approximately 25 to 30 minutes. Treatment and other medical documents were reviewed to confirm the disease conditions, and show-cards were used for food and physical activity to ensure quality data. In some cases, where a person was not able to respond to data collectors' queries (those who were ill or had some form of disability), an appropriate person from the household, for example- the caregiver was asked to answer on behalf provided he/she could give the exact information.

The household survey participants were advised to visit the nearby community clinic (CC) on the next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and biochemical parameters. In the community clinic, standard weight scale, height measurement scales, measuring tape, and automated digital BP machine were used to record their weight, height, waist circumference, hip circumference, and blood pressure respectively. Fasting capillary glucose was measured by a standard glucometer maintaining all necessary aseptic precautions. Blood pressure was measured twice – first, after 15 minutes' rest time, and second one 3 minutes after the first measurement. The mean of the two measurements was used to determine the actual BP. Physical measurements were carried out by well-trained male and female assistants maintaining adequate privacy. The data collected at the CC were synced with those collected at the household level. The Flow Chart of study methods applied to collect data is shown in Figure 1.

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

2.3 Ascertainment of key variables

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

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

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

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

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

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

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

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

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

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.[28]

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 (≤ 600 MET-minutes per week), moderately active (between 600 and 3000 MET-minutes per week), and highly or vigorously active (≥ 3000 MET-minutes per week).[29]

Underweight: The respondents were considered as underweight when their body mass index (BMI) was less than 18.5 kg/m^2. [30]

Normal weight: The respondents were considered as normal weight when their BMI was between 18.5 and 25.0 kg/m^2. [30]

Overweight: The respondents were considered overweight when their BMI was between 25.0 and 29.9 kg/m^2. [30]

Obese: The respondents were considered obese when their BMI was over 30.0 kg/m^2. [30]

2.4 Data analysis

The data were entered in the pre-designed Microsoft office excel format which was later imported into the statistical software SATA version 12. The raw data was initially checked for completeness, consistency and the absence of missing data, errors and outliers. Afterwards, it was carefully cleaned and edited for consistency and to preserve for longer time. Descriptive, and relevant statistical analysis were performed on this cleaned data set. 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.

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

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

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 the minimum and maximum values 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^2, 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 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^2)	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

Considering body mass index (BMI), 59.2% of the respondents were within normal range, that is, between 18.5 – 25.0 kg/m^2. 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 ≥ 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. The socio-demographic characteristics stratified by nutrition status was further stratified by sex (Supplementary table).

3.3 Behavorial 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%), took red meat (21.9%), ate fried food (21.3%), took sugary drinks (21.7%), took added salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand, overweight and obesity were noted as more among those who did moderate to vigorous exercise (16.7% & 3.3% - 3.9 % respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8% & 3.7%), did not consume processed food (16.5% & 3.4%), did not take sugary drinks (16.9% &

3.6%), did not take added salt (19.3% & 4.7%), and those who did not take inadequate (took adequate) fruits and vegetables (18.2% & 4.3%).

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^2; Normal weight = BMI is 18.5 – 25.0 kg/m^2; Overweight = BMI is 25.0 – 29.9 kg/m^2; Obese = BMI is over 30.0 kg/m^2

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^2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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	*Ref*					
	Sex						
	Female		– 0.239	< 0.001	0.787	0.684	0.906
	Male	*Ref*					
	Education						
	Literate		– 0.350	< 0.001	0.704	0.632	0.786
	Illiterate	*Ref*					
	Marital status						
	Married		– 0.568	< 0.001	0.566	0.468	0.685
	Unmarried	*Ref*					

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

Ref., reference; AOR, adjusted 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 as predictors

Underweight, BMI less than 18.5 kg/m2; Overweight/obese, BMI is over 25.0 kg/m^2

4. Discussion

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

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.[17] 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.[31] In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children was found to be less than ten percent.[18] 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. [6, 19, 20, 21] 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 married males more than 45 years of age. Age between 33 – 37 years was also found significantly associated with obesity and overweight in other studies among rural women of Bangladesh (OR: 3.71; 95% CI: 2.84 – 4.86; p<0.001).[19] Other studies have shown that urban women aged 30 to 39 years were obese and/or overweight with a high association (OR: 3.9; 95% CI: 1.9 – 7.7; p<0.001).[23] There are studies that also showed that the prevalence of underweight among males of more than 50 years of age was much high.[20, 32] The findings from this study corroborate with these earlier findings.

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

prevalence of obesity and overweight was more among those men who did vigorous physical activity. In contrast, females who did moderate physical activity were more obese and overweight.[33] Other studies also showed that underweight was more often associated with vigorous physical activity, while overweight and obesity were more related with sedentary lifestyle. Variable associations were also noted with gender, education level, marital status, working status, and wealth index.[19, 34] Most likely demographic features influence source, amount and variety of food intake, and type of physical activities undertaken based on knowledge and livelihood practices.

The food habit of the rural population in Bangladesh is low in fat and protein, and high in carbohydrate.[35, 36, 37] This may be why people who perform vigorous physical activity can avoid getting overweight or obese. At the same time if balance is not maintained between intake and output, there is increased likelihood of being obese or overweight, a phenomenon observed among a substantial number of subjects in this study. Rural women tend to regularly perform most household chores, some involving heavy activities, but these activities are not considered as such and overlooked by community members and health workers. Moreover, women tend to eat less food of poor quality while ensuring that other family members get more food of better quality.[38, 39] This may be why inactivity has been found to increase the likelihood of underweight in this study. Studies show that the prevalence of previously undiagnosed comorbidities such as hypertension and diabetes are on the rise in South-east Asian region.[40] In Bangladesh, about 50% - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher percentage among those from lower socioeconomic rural areas.[27, 30] People once diagnosed tend to visit health facilities more often than those who remain undiagnosed.

In its document on nutrition, World Health Organization has pointed at malnutrition in all its forms (characterized by coexisting undernutrition and overweight/obesity) and noncommunicable diseases within individuals, households, populations, and across life course of individuals. Epidemiological evidence support that undernutrition early in life, even when in-utero, may predispose to overweight and NCDs later in life. At the same time, underweight in later life is an expression of malnutrition. Again, overweight in mothers is often associated with overweight in their offspring. Biological mechanisms, along with environmental and social influences, are increasingly understood as essential drivers in the global burden of NCDs.[38]

In addition to increasing health literacy among rural population through training and awareness programs, the Government may also take initiatives to encourage household backyard vegetable and fruits gardening which would help to reduce the overall family. As an initial support, the Government may distribute free (or at nominal price) saplings of fruits and vegetables among rural population.

Strengths

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

Limitations

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

Conclusion

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

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

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Author's contribution:

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

Data curation: SR, LB

Formal analysis: SR, LB

Methodology: AKMFR, SRM, MF, RAS, PCB, LB

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

Supervision: SRM

Writing original draft: SR

Writing: SR

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

Data sharing statement: The corresponding author will make the data available when required, with valid reasons.

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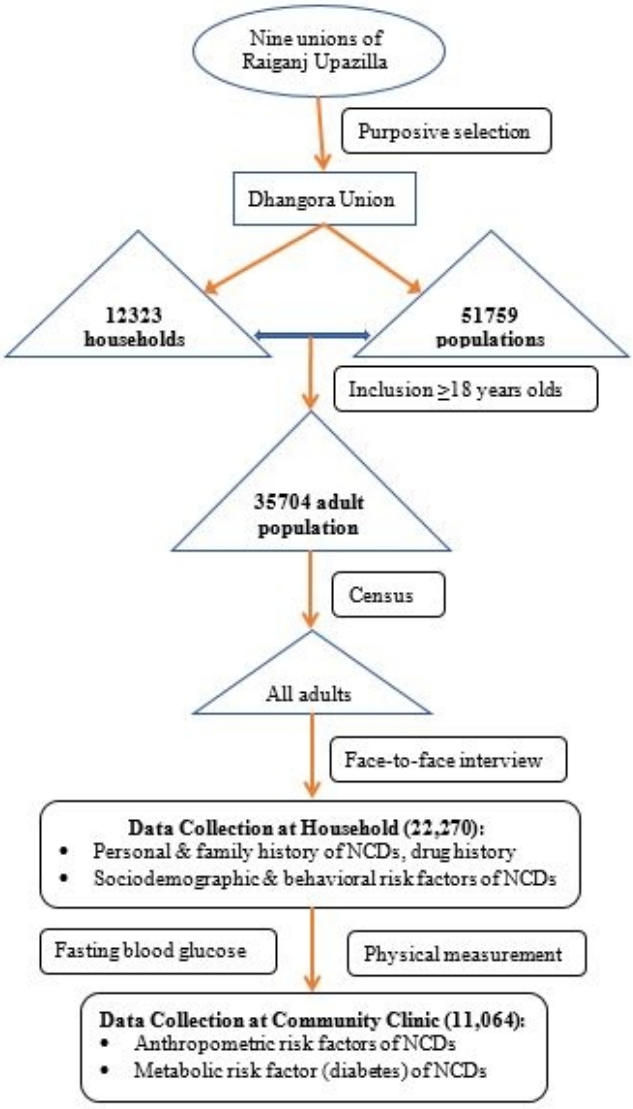

Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

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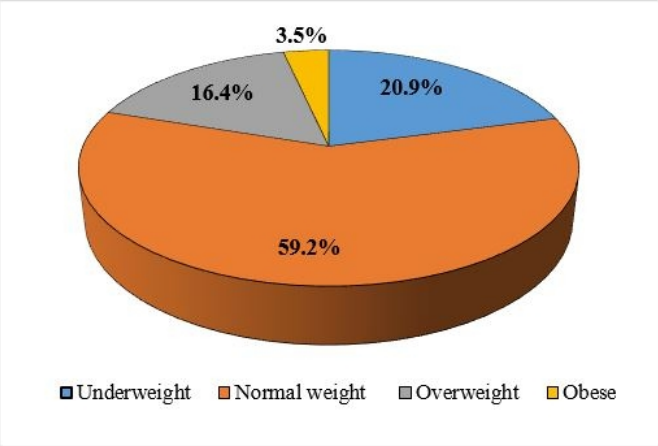

Underweight, BMI less than 18.5 kg/m2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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

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

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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)

	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)

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

	Item No	Recommendation	Page No
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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

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
Discussion			
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
Other information			
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.

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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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Abstract

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

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. Anthropometric measurement, and data on sociodemographic characteristics and behavioral risk factors were collected following the standard protocol described in the WHO STEPS-wise approach. Analysis included means of continuous variables and multinomial logistic regression of factors.

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

of fruits and vegetables respectively. Consumption of added salt decreases the odds of being overweight or obese by 0.37.

Conclusion: The study emphasized malnutrition to be a public health concern in spite of the dynamic sociodemographic scenario. Specific health messages for targeted population may help improve the nutritional status. Findings from further explorations may support policies and programs in future.

Keywords: Obesity, overweight, underweight, physical activity, Bangladesh, body mass index

Strengths and limitations of this study

- This study assessed the current status of malnutrition and look at its association with different modifiable risk factors among adults in a selected rural population of Bangladesh
- The sampling technique was census and data were collected from all adults except those institutionalized in a hospital, prison, nursing home, or other similar institutions
- The study could only investigate a third of the individuals since the community clinics were not attended by everyone who were included in the household survey

1. Introduction

As studies show, malnutrition is one of the risk factors responsible for noncommunicable diseases (NCDs) globally.[1, 2] 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.[1] Body mass index (BMI) is an indicator of healthy weight, underweight, overweight, and obesity.[2] Studies show that prevalence of obesity and overweight are increasing over time.[3] Globally, about 39% of adult population were overweight, and 13% were obese as of 2016.[4] At least 2.8 million people die each year due to causes related to obesity and overweight.[5] 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.[6]

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.[7] 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.[8, 9, 10] Cardiovascular and respiratory diseases, cancer, and diabetes are responsible for about 41 million deaths each year.[1, 11] 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.[12] 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.[1, 13] In economically well-off countries, NCDs are noted disproportionately among vulnerable

and disadvantaged groups.[2] On the other hand, in less developed economies, childhood undernutrition affects health, survival, growth and development in rural population.[1] Globally, undernutrition contributes to around 45% of deaths among under-five children, the majority of which occur in low- and middle-income countries.[1]

Attempting to look closely at the link between unhealthy diets and NCDs, it is seen to be the logical outcome of the dramatic shift in current food systems, which focus on increasing availability of inexpensive, high-calorie foods at the expense of diversity replacing local, often healthier, diets. Availability of micronutrient-rich foods (e.g., fresh fruits, vegetables, legumes, pulses, and nuts) has not improved equally for everyone. Unhealthy foods with salt, sugars, saturated-fat/trans-fat, sweetened drinks, and processed and ultra-processed foods have become cheaper and more widely available.[1] Studies show that reduction in risk factors through lifestyle modifications help greatly in reducing the burden of most non-communicable diseases including hypertension, diabetes, malnutrition, and mental disorders.[14, 15] Studies in rural Bangladesh found that 55% of women ate rice twice a day as the staple food, while about 80 % and 18% women ate chicken on weekly and monthly basis respectively.[16, 17]

Under these circumstances, developing countries like Bangladesh can benefit from interventions that help the primary health care facilities to be ready to tackle different noncommunicable diseases that are predisposed by overweight, obesity, and undernutrition. This study provides an opportunity to find the influencing factors and predictors of malnutrition in the current changing lifestyle among selected communities. This study was conducted to determine the prevalence of underweight, overweight and obesity, and their predictors in a rural population of Bangladesh. Previous studies in Bangladesh have looked at the risk factors of malnutrition in association with

different socio-demographic characteristics.[18-26] This study builds up on the previous studies by examining the association of various risk factors with underweight, overweight and obesity on a large dataset of adult population.

2. Methods

2.1 Study design, setting, and participants

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

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

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.[27]

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

scheduled for the screening as per convenience of the household members and data collector. All possible measures were taken to ensure full coverage of the population.

During household data collection, existing chronic diseases (hypertension, diabetes, CVD etc.) among the members was explored. Each participant was interviewed for approximately 25 to 30 minutes. Treatment and other medical documents were reviewed to confirm the disease conditions, and show-cards were used for food and physical activity to ensure quality data. In some cases, where a person was not able to respond to data collectors' queries (those who were ill or had some form of disability), an appropriate person from the household, for example- the caregiver was asked to answer on behalf provided he/she could give the exact information.

The household survey participants were advised to visit the nearby community clinic (CC) on the next day in a fasting state (not taking food and water for 8 to 12 hours) to assess their physical and biochemical parameters. In the community clinic, standard weight scale, height measurement scales, measuring tape, and automated digital BP machine were used to record their weight, height, waist circumference, hip circumference, and blood pressure respectively. Fasting capillary glucose was measured by a standard glucometer maintaining all necessary aseptic precautions. Blood pressure was measured twice – first, after 15 minutes' rest time, and second one 3 minutes after the first measurement. The mean of the two measurements was used to determine the actual BP. Physical measurements were carried out by well-trained male and female assistants maintaining adequate privacy. The data collected at the CC were synced with those collected at the household level. The Flow Chart of study methods applied to collect data is shown in Figure 1.

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

2.3 Ascertainment of key variables

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

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

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

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

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

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

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

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

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

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.[28]

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 (≤ 600 MET-minutes per week), moderately active (between 600 and 3000 MET-minutes per week), and highly or vigorously active (≥ 3000 MET-minutes per week).[29]

Underweight: The respondents were considered as underweight when their body mass index (BMI) was less than 18.5 kg/m^2. [30]

Normal weight: The respondents were considered as normal weight when their BMI was between 18.5 and 25.0 kg/m^2. [30]

Overweight: The respondents were considered overweight when their BMI was between 25.0 and 29.9 kg/m^2. [30]

Obese: The respondents were considered obese when their BMI was over 30.0 kg/m^2. [30]

2.4 Data analysis

The data were entered in the pre-designed Microsoft office excel format which was later imported into the statistical software STATA version 12. The raw data was initially checked for completeness, consistency and the absence of missing data, errors and outliers. Afterwards, it was carefully cleaned and edited for consistency and to preserve for longer time. Descriptive, and relevant statistical analysis were performed on this cleaned data set. 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.

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

(Supplementary table 1) were considered as eligible to be included in the multinomial logistic regression analysis. The dependent variable was categorized as underweight, normal weight, overweight and obesity. As per literature review, overweight and obesity have similar predictors. As such, overweight and obesity were merged together into one category, and normal weight was considered as reference. The regression table for each outcome variable included the presentation of the factors with the corresponding odds ratios (OR) and OR > 1 was considered as predictor. The estimates of precision were all presented at a 95% confidence interval (CI), as appropriate. The significant threshold of *P* value for all tables included in the analysis was less than 0.05.

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 the minimum and maximum values 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^2, 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 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^2)	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

Considering body mass index (BMI), 59.2% of the respondents were within normal range, that is, between 18.5 – 25.0 kg/m^2. 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. 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 ≥ 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 Behavorial 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

added salt (23.2%), and had inadequate intake of fruits and vegetables (21.4%). On the other hand, overweight and obesity were noted as more among those who did moderate to vigorous exercise (16.7% & 3.3% - 3.9 % respectively), took red meat (19.9% & 4.0%), did not eat fried food (16.8% & 3.7%), did not take sugary drinks (16.9% & 3.6%), did not take added salt (19.3% & 4.7%), and those who did not take inadequate (took adequate) fruits and vegetables (18.2% & 4.3%). Those who did not consume processed food was more overweight (16.5%) while those who consumed processed food was more obese (4.2%).

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)

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

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^2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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 0.25, 0.35, 0.40, and 0.14 if a respondent is less than 45 years of age, literate, married, and consumed red meat respectively. Employment, consumption of added salt, and inactivity increases the odds of being underweight by 0.32, 0.33, and 0.14, respectively.

On the other hand, the odds of being overweight/obese increased by 0.58, 0.55, 0.78, 0.21, and 0.25 if the respondent was female, literate, married, housewife, and consumed red meat; and decreased by 0.38 and 0.18 if the respondent consumed added salt and 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 (BMI <18.5 kg/m^2)	Age (years)					
	< 45	- 0.252	<0.001*	0.777	0.696	0.869
	≥ 45	*Reference*				
	Sex					
	Female	-0.147	0.050	0.863	0.745	1.000
	Male	*Reference*				
	Education					
	Literate	-0.346	<0.001*	0.707	0.634	0.789
	Illiterate	*Reference*				
	Marital status					
	Married	-0.396	<0.001*	0.673	0.542	0.835
	Unmarried	*Reference*				
	Occupation					
	Housewife	-0.037	0.634	0.964	0.828	1.122
	Employed	0.316	0.001*	1.371	1.133	1.659
	Unemployed	*Reference*				
	Red meat intake					
	Yes	-0.141	0.019*	0.869	0.772	0.977
	No	*Reference*				
	Added salt intake					
	Yes	0.327	<0.001*	1.387	1.249	1.540
	No	*Reference*				
	Physical inactivity					
	Yes	0.142	0.028*	1.152	1.016	1.308
	No	*Reference*				
	Inadequate fruit/vegetable intake					
	Yes	0.030	0.614	1.030	0.917	1.157
	No	*Reference*				

Overweight / Obesity (BMI ≥ 25.0 kg/m^2)	Age (years)					
	< 45	-0.039	0.477	0.961	0.862	1.072
	≥ 45	*Reference*				
	Sex					
	Female	0.581	<0.001*	1.788	1.511	2.115
	Male	*Reference*				
	Education					
	Literate	0.547	<0.001*	1.727	1.532	1.948
	Illiterate	*Reference*				
	Marital status					
	Married	0.775	<0.001*	2.170	1.601	2.942
	Unmarried	*Reference*				
	Occupation					
	Housewife	0.205	0.011*	1.228	1.049	1.438
	Employed	-0.108	0.407	0.897	0.695	1.159
	Unemployed	*Reference*				
	Red meat intake					
	Yes	0.252	<0.001*	1.287	1.152	1.438
	No	*Reference*				
	Added salt intake					
	Yes	-0.378	<0.001*	.685	.619	.758
	No	*Reference*				
	Physical inactivity					
	Yes	0.017	0.813	1.017	0.886	1.167
	No	*Reference*				
	Inadequate fruit/vegetable intake					
	Yes	-0.181	0.002*	0.835	0.745	0.935
	No	*Reference*				

Ref., reference; AOR, adjusted odd-ratio; CI, confidence interval
*Significant at the threshold of $p < 0.05$

4. Discussion

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

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.[17] 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.[31] In a nationwide study in Bangladesh, the prevalence of overweight and obesity among children was found to be less than ten percent.[18] 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. [6, 19, 20, 21] 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 married males more than 45 years of age. Age between 33 – 37 years was also found significantly associated with obesity and overweight in other studies among rural women of Bangladesh (OR: 3.71; 95% CI: 2.84 – 4.86; p<0.001).[19] Other studies have shown that urban women aged 30 to 39 years were obese and/or overweight with a high association (OR: 3.9; 95% CI: 1.9 – 7.7; p<0.001).[23] There are studies that also showed that the prevalence of underweight among males of more than 50 years of age was much high.[20, 32] The findings from this study corroborate with these earlier findings.

The odds of overweight and obesity increased by 0.25 among respondents who consumed red meat, and decreased by 0.38 and 0.18 among those who consumed added salt and inadequate amount of fruits and vegetables. On the other hand, consumption of added salt and inactivity increased the odds of underweight by 0.33 and 0.14, respectively. A study on Malaysian adults

showed that prevalence of obesity and overweight was more among those men who did vigorous physical activity. In contrast, females who did moderate physical activity were more obese and overweight.[33] Other studies also showed that underweight was more often associated with vigorous physical activity, while overweight and obesity were more related with sedentary lifestyle. Variable associations were also noted with gender, education level, marital status, working status, and wealth index.[19, 34] Most likely demographic features influence source, amount and variety of food intake, and type of physical activities undertaken based on knowledge and livelihood practices.

The food habit of the rural population in Bangladesh is low in fat and protein, and high in carbohydrate.[35, 36, 37] This may be why people who perform vigorous physical activity can avoid getting overweight or obese. At the same time if balance is not maintained between intake and output, there is increased likelihood of being obese or overweight, a phenomenon observed among a substantial number of subjects in this study. Rural women tend to regularly perform most household chores, some involving heavy activities, but these activities are not considered as such and overlooked by community members and health workers. Moreover, women tend to eat less food of poor quality while ensuring that other family members get more food of better quality.[38, 39] This may be why inactivity has been found to increase the likelihood of underweight in this study. Studies show that the prevalence of previously undiagnosed comorbidities such as hypertension and diabetes are on the rise in South-east Asian region.[40] In Bangladesh, about 50% - 80% of patients with diabetes and hypertension remain undiagnosed, with a significantly higher percentage among those from lower socioeconomic rural areas.[27, 30] People once diagnosed tend to visit health facilities more often than those who remain undiagnosed.

In its document on nutrition, World Health Organization has pointed at malnutrition in all its forms (characterized by coexisting undernutrition and overweight/obesity) and noncommunicable diseases within individuals, households, populations, and across life course of individuals. Epidemiological evidence support that undernutrition early in life, even when in-utero, may predispose to overweight and NCDs later in life. At the same time, underweight in later life is an expression of malnutrition. Again, overweight in mothers is often associated with overweight in their offspring. Biological mechanisms, along with environmental and social influences, are increasingly understood as essential drivers in the global burden of NCDs.[38]

In addition to increasing health literacy among rural population through training and awareness programs, the Government may also take initiatives to encourage household backyard vegetable and fruits gardening which would help to reduce the overall family. As an initial support, the Government may distribute free (or at nominal price) saplings of fruits and vegetables among rural population.

Strengths

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

Limitations

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

Conclusion

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

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

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Author's contribution:

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Data curation: SR, LB

Formal analysis: SR, LB

Methodology: AKMFR, SRM, MF, RAS, PCB, LB

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Supervision: SRM

Writing original draft: SR

Writing: SR

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

Data sharing statement: The corresponding author will make the data available when required, with valid reasons.

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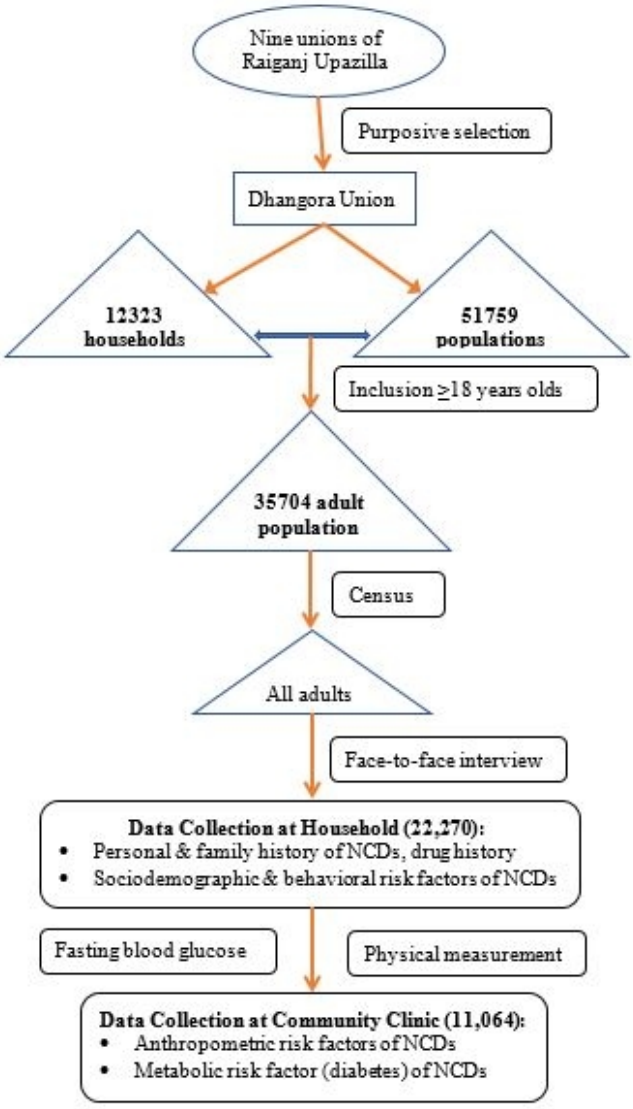
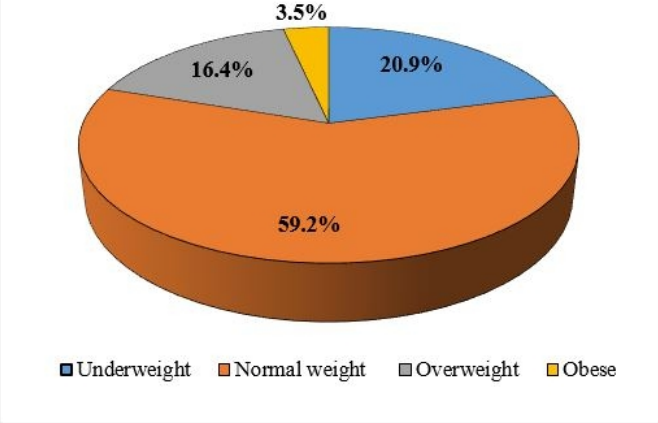


Figure 1: Flow Chart of study methods applied to collect data from selected rural population of Bangladesh

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/m2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2

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 (χ^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 (%)			χ^2-value	*P*-value
		Underweight	Normal weight	Overweight/ obese		
Age	< 45 years	17.9	60.4	21.7	72.4	<0.001*
	≥ 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		
	Income group	22.4	62.3	15.3		
Physical activity	Inactive	25.1	57.3	17.6	27.8	<0.001*
	Active	20.0	59.6	20.4		
Red meat intake	Yes	17.9	58.2	23.9	45.2	<0.001*
	No	21.9	59.5	18.6		
Added salt intake	Yes	23.2	59.3	17.5	100.7	<0.001*
	No	17.1	58.9	24.0		
Inadequate intake of fruits and vegetables	Yes	21.4	59.5	19.0	17.4	<0.001*
	No	19.4	58.1	22.5		

Underweight, BMI less than 18.5 kg/m^2; Normal weight, BMI is 18.5 – 25.0 kg/m^2; Overweight, BMI is 25.0 – 29.9 kg/m^2; Obese, BMI is over 30.0 kg/m^2
*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)

	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)

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

	Item No	Recommendation	Page No
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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

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
Discussion			
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
Other information			
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.