BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (http://bmjopen.bmj.com).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

Urban-rural differences in overweight and obesity among 25-64 years old Myanmar residents: a cross-sectional, nationwide survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042561
Article Type:	Original research
Date Submitted by the Author:	08-Jul-2020
Complete List of Authors:	Thapa, Rupa; University of Oslo Faculty of Medicine, Department of Community Medicine and Global Health Dahl, Cecilie; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health Aung , Wai Phyo; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health; Ministry of Health and Sports, Department of Public Health, Occupational and Environmental Health Division Bjertness, Espen; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, PREVENTIVE MEDICINE

SCHOLARONE™
Manuscripts

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

For peer review only

Urban-rural differences in overweight and obesity among 25-64 years old Myanmar residents: a cross-sectional, nationwide survey

Rupa Thapa[1], Cecilie Dahl[1], Wai Phyo Aung[1,2], Espen Bjertness[1]

Author Affiliations

1. Department of Community Medicine and Global Health, Institute of Health and Society, Faculty of Medicine, University of Oslo, Oslo 0318, Norway; espen.bjertness@medisin.uio.no (EB); cecilie.dahl@medisin.uio.no (CD); rupathapa.rupa@gmail.com (RT)

2. Occupational and Environmental Health Division, Department of Public Health, Ministry of Health and Sports, Nay Pyi Taw 15011, Myanmar; w.p.aung@medisin.uio.no (WPA)

Correspondence to rupathapa.rupa@gmail.com

Word count: 4,362

Abstract

Objectives: To investigate whether urban-rural location and socioeconomic factors (income, education, and employment) are associated with body mass index (BMI) and waist-hip ratio (W/H-ratio), and to further explore whether the associations between urban-rural location and BMI or W/H-ratio could be mediated through variations in socioeconomic factors.

Design: Cross-sectional, WHO STEPS survey of non-communicable disease (NCD) risk factors

Setting: Urban and rural areas of Myanmar

Participants: A total of 8,390 men and women aged 25 to 64 years included during the study period from September to December 2014. Institutionalized people (Buddhist monks and nuns, hospitalized patients) and temporary residents were excluded.

Results: The prevalence of overweight and obesity was higher in the urban areas and increased with increasing SES score. Mean BMI was higher among urban residents (ß= 2.49 kg/m^2; 95% CI 2.28, 2.70; p<0.001), individuals living above poverty line, i.e. ≥ 1.9 USD/day (ß= 0.74 kg/m^2; 95% CI 0.43, 1.05; p<0.001), and those with high education attainment (ß= 1.48 kg/m^2; 95% CI 1.13, 1.82; p<0.001) when adjusting for potential confounders. Similarly, greater W/H-ratio was observed in participants living in an urban area, among those with earnings above poverty line, and among unemployed individuals. The association between

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

urban-rural location and BMI was found to be partially mediated by a composite SES score (9%), income (17%), education (16%), and employment (16%), while the association between urban-rural location and W/H-ratio was found to be partially mediated by income (12%), education (6%), and employment (6%).

Conclusion: Residents living in urban locations had higher BMI and greater W/H-ratio, partially explained by differences in socioeconomic indicators, indicating that socioeconomic factors should be emphasized in the management of overweight and obesity in the Myanmar population. Furthermore, new national or sub-national STEPS surveys should be conducted in Myanmar to observe the disparity in trends of the urban-rural differential.

Strengths and limitation of this study

- The study analyses a large nationally representative sample including both urban and rural areas.
- The internationally recommended WHO STEPS protocol was followed.
- The response rate was high (91%).
- The findings may be generalized to Myanmar's non-institutionalized population only.
- Due to cross-sectional nature of the study, causality cannot be determined.

INTRODUCTION

Overweight and obesity pose a major economic burden to society, and are important determinants for non-communicable diseases (NCDs), including cardiovascular diseases (CVDs), diabetes, musculoskeletal disorders, and certain types of cancers.[1] An even greater risk seems to be associated with excess abdominal obesity.[2,3] According to the World Health Organization (WHO), 39% of adults worldwide were overweight and 13% were obese in 2016.[1] In the South-east Asia region (SEAR), the estimated proportions of overweight and obese were 21.5% and 4.6%, respectively.[4,5]

Urbanization, a complex socioeconomic process that gradually transforms the society from rural into urban settlements, including migrations of people from rural to urban areas, is frequently cited as the most important factor contributing to increasing overweight and obesity, explained by increased access to unhealthy foods and a less physically active lifestyle in urban areas.[6-9] Moreover, among urban residents the socioeconomic status (SES) is likely to be higher, which in turn is associated with higher body mass index (BMI) in most low- and middle-income countries (LMICs).[10,11] However, a recent publication by the NCD risk Factor

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Collaboration comprising evidence from 2,009 population-based studies on trends in mean BMI (from 1985 to 2017), showed that increasing BMI in rural areas has been the main contributor to the global rise in mean BMI over the last 33 years, while the contribution from rural to urban migration was small.[12]

In Myanmar, two surveys were carried out in 2004 and 2014 in the most populated and developed part of Myanmar, the Yangon region.[13,14] Findings from these studies indicate increasing trends in overweight and obesity. The overall prevalence of combined overweight and obesity in urban areas of Yangon increased from 39.8% in 2004 to 40.9% in 2014, whereas in rural areas, there was an increase in overweight and obesity prevalence from 23.0% to 31.2%.[14-16] In 2009, a nationwide survey in Myanmar found an overall prevalence of overweight and obesity of 18.7% and 6.8% respectively.[17] The most recent nationwide study (2015-2016), the Myanmar Demographic and Health Survey,[18] included 12,160 women in reproductive age, and reported a high prevalence of overweight (28.1%) and obesity (13.1%), and a significantly higher proportion of overweight and obesity with urban residency, higher economic status, and having secondary education.

Myanmar has been lagging behind neighbouring countries in terms of sociodemographic development, which could partly be due to socio-political difficulties during more than 50 years of military rule, which was gradually replaced with a democratic development in 2011.[19] In order to contribute to a better understanding of socioeconomic determinants of overweight and obesity in Myanmar, we analysed a nationally representative sample of 25-64 year old men and women from 2014,[20] with the following objectives: 1) to investigate associations of urban-rural location with BMI and waist-hip ratio (W/H-ratio); 2) to explore the association of selected socioeconomic characteristics (income, education, and employment status) with BMI and W/H-ratio; and 3) to assess whether the potential associations between urban-rural location and BMI or W/H-ratio could be explained by (i.e. mediated through) variations in socioeconomic characteristics (income, education, and employment status).

METHODS

Study design, sampling, and participants

A national cross-sectional survey of NCD risk factors in Myanmar (WHO STEPS survey) was conducted between September and December 2014 in 52 different townships in Myanmar.[20] A detailed methodological description of the sampling and data collection has been published previously,[20] and is summarized below.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

The STEPS survey used a multistage cluster sampling method for the selection of townships, wards and villages, households, and eligible participants at each of the selected households. The first stage of the sampling method consisted of townships, which formed the Primary Sampling Units (PSUs). Overall, 52 PSUs were selected out of the total of 330 townships, using probability proportionate to size of population in each PSU (PPS). In the second stage, six Secondary Sampling Units (SSUs) i.e., wards (from urban townships) and villages (from rural townships) were selected from each chosen PSU giving a total of 312 SSUs for the whole country. The list of households with unique identification number developed from a recent listing of households was used as the sampling frame for the third stage. From each selected SSU, 30 households were chosen using a systematic random sampling method. In this sampling method, the elements to be included in the sample are selected based on a systematic rule, using a fixed sampling interval obtained by dividing population size by required sample size.[21] In the 4th stage, recruitment of one eligible participant aged between 25 and 64 years was done from the selected household. The Kish sampling method was used to rank the eligible participants in each household in order of decreasing age, starting with males then females, and randomly selected using the automated program for Kish selection in the handheld PDA (Personal Digital Assistant).[20]

The study population comprises 25 to 64 years old men and women residing in both urban and rural areas. The following exclusion criteria were used: individuals with a mental or physical illness deemed too ill to participate, institutionalized people (Buddhist monks and nuns, armed forces, hospitalized patients, prisoners), and temporary residents (living in a locality for less than 6 months).

Altogether, a total of 8,757 men and women aged 25-64 years, residing in both urban and rural areas, participated in the survey. The response rates were 94% for the questionnaire, 91% for physical measurements, and 90% for biochemical measurements. The final sample for the current study included 8,390 adults who participated in both STEP 1 and STEP 2, excluding 87 women who were currently pregnant, and 280 individuals with missing BMI.

Data collection and measurements

The STEPS Instrument covers the following three different levels of "STEPS" of risk factor assessment. STEP (1) questionnaire survey; STEP (2) physical measurement; STEP (3) biochemical measurements. In the present study, we included variables from STEP 1 and STEP 2.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Eighteen trained teams (containing six members in each) collected the data. The English WHO STEPS Instrument (core and expanded) questionnaire version 3.0 was translated into the Myanmar version for the survey. A five-day training was conducted at University of Medicine (2), Yangon. The data collection teams conducted a pilot survey of all steps of data collection in the wards of North Okkalapa Township, Yangon on the fifth day of the training. Data for STEP 1 and 2 were collected at the survey participant's household during the first visit. Face to face interviews were conducted to collect information on sociodemographic factors and behavioural risk factors.

A Seca 217 portable stadiometer was used to measure body height without footwear and any hat or hair ties. Findings were recorded in centimetre (cm) to the nearest 0.1 cm. Body weight was measured with a pre-calibrated portable Seca Digital Floor Scale with High Capacity (Model 813) to the nearest 0.1 kilogram (kg). During weighing, the participants were requested to wear light clothing without footwear.[20] Waist and hip circumference measurement were done in a private area using a Seca 201 measuring tape. The waist circumference was measured in centimetres over light clothing at the midpoint between the last palpable rib and the top of the iliac crest. The hip circumference measurement was taken by placing the tape horizontally at maximum circumference over the buttocks. Measures were taken to the nearest 0.1 cm.[20]

Variables

BMI and W/H-ratio

BMI is the most widely used measure of general overweight and obesity[22,23] whereas W/H-ratio measures abdominal or central obesity and is a better predictor of CVD risk.[24,25] Therefore, we have included both measures in our study.

BMI was calculated as weight in kilograms divided by the height in meters squared. Cut-off points for BMI were defined based on WHO recommendations: BMI of 25.0-29.9 kg/m^2 was considered overweight whereas having a BMI of 30 kg/m^2 or higher was considered obese.[26] For comparison, BMI was also classified according to Asian specific cut-off points: BMI of 23.0-27.5 kg/m^2 (overweight) and BMI of ≥27.5 kg/m^2 (obesity).[27] W/H-ratio was defined as the ratio of the circumference of the waist to that of the hip. Central obesity was defined as a W/H-ratio above 0.90 for men and above 0.85 for women.[28]

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Urban-rural location

According to the ward or village tract administration law 2012, a ward is defined as an urban unit and a village is defined as a rural unit.[29] Hence, the same definition was used to define urban and rural areas in the current study.

Sociodemographic factors

Age was defined as completed years of age. Education level was defined by both total number of years spent in school and by highest educational level obtained. It was categorized into seven categories: no formal schooling, less than primary school, primary school completed, secondary school completed, high school completed, college/university completed, and post graduate degree. In multivariable analyses, education level was collapsed into three groups: low level, medium level, and high level education. Low level was defined as education below primary school completion; Medium level: completion of primary and secondary school; High level: completion of high school, university, or post-graduate education.

Occupation was defined according to the main work status over the past 12 months and categorized as government employee, non-government employee, self-employed, nonpaid, student, homemaker, retired, unemployed (able to work), and unemployed (unable to work). In multivariable analyses, employment status was collapsed into two groups: employed and unemployed. Employed group included people who were government, non-government employee, self-employed, and homemakers. Nonpaid, student, retired, unemployed (both able and unable to work) were categorized in the unemployed group.

Daily personal income was calculated from the entire household income divided by the total number of household members excluding the household members under 18 years of age. Income was converted from Myanmar Kyats into United States Dollars (USD). Exchange rate of 1 USD was 970 Myanmar Kyats as of 1st September 2014.[30] Cut-off values for poverty line was used as defined by World Bank: 1.90 USD/day.[31]

Statistical methods

Statistical analysis was performed in the Statistical Package for Social Sciences (SPSS) version 26.0 (Armonk, NY: IBM Corp). The characteristics of the study participants were presented in the form of frequency (N) and percentages (%) for categorical variables, and mean with standard deviation (SD) for continuous variables. Differences in categorical variables were tested using the chi-square test of Fischer exact test, whereas differences in the

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

mean for continuous variables were tested using two tailed t-tests. Linear regression was used to estimate the association between the urban-rural location and socioeconomic factors variables (income, education, and employment status) with continuous outcomes (BMI and W/H-ratio), obtaining betas (β) with 95% confidence intervals (CIs). Potential multi-collinearity between variables was assessed with variance inflation factors (VIF). A VIF value greater than 10 was considered an indication of multi-collinearity; however, no significant multi-collinearity was observed. For all statistical analysis, the two-tailed significance level was set to 0.05.

Based on previous literature and construction of Directed Acyclic Graphs (DAGs),[32] we identified potential confounders and mediators (See Supplementary Figure 1). For objective 1, for associations of urban-rural location with BMI and W/H-ratio, age and gender were identified as confounders (See Supplementary Figure 1:A), and they were therefore included in multivariable models to obtain the total effect of urban-rural location on BMI (model 2, Table 2) and W/H-ratio (model 2, Table 3).

For the second objective, for the association of socioeconomic characteristics (income, education, and employment status) with BMI (Table 2) and W/H-ratio (Table 3), we constructed three different DAGs (See Supplementary Figure 1: B, C, and D) for confounder adjustments.

To study the statistical effect of the SES variables (income, education, and employment status) together, the variables were assigned SES values (0/1) and a composite SES score was calculated. Participants with earnings above poverty line, high education attainment (binary) and employment were assigned SES value=1 and the lower category was assigned SES value=0. Total SES score for each participant was obtained by summing up values and total SES score was further categorized into three SES groups: low (total SES score=0), medium (total SES score=1 and 2), and high (total SES score=3) (See Supplementary Table 1). We assessed the association between SES groups and BMI (Table 2) or W/H-ratio (Table 3) with adjustment for confounders (age, gender, and urban-rural location).

The third objective exploited whether the potential association between urban-rural location and BMI or W/H-ratio was mediated through socioeconomic characteristics (Table 4). We included the potential mediators income, education, employment, and the composite SES score variable one by one in order to obtain the direct effect of urban-rural location on BMI and W/H-ratio, and the proportion mediated through each of the socioeconomic factors.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Ethics

Informed consent was obtained from the study participants; all information was handled with strict confidentiality. The participants were informed about the purpose and procedures of the study. Ethical approvals were obtained from the Norwegian Regional Committees for Medical and Health Research Ethics (REK) (Reference no. REK 2016/379) and the Ethical Review Committee of Department of Medical Research (Myanmar).

Patient and Public Involvement

No patients or public were involved in setting the research question or the outcome measures, nor were they involved in the design and implementation of the study.

RESULTS

The mean age of the study participants was 44.9 years, with rural participants being slightly younger than urban participants (Table 1). Nearly three quarters of the participants (68.6%), were from rural areas (not shown in tables). The mean length of education was 7.7 years in urban areas and 4.8 years in rural areas. In urban areas, the majority had primary education only (31.9%), 6.6% had no formal schooling, and 42.7% were self-employed (Table 1). In the rural areas, 39.6% had primary education only, 18.8% had no formal schooling, and 68.6% were self-employed. The proportion living on <1.9 USD/day was 4.9% in urban areas and 17.5% in rural areas. The prevalence of overweight (WHO standard cut-off: BMI 25-29.9) and obesity (WHO standard cut-off: BMI ≥30) was 20.4% and 6.5% respectively (not shown in tables). The prevalence of overweight (Asian cut-off: BMI 23-27.4 kg/m²) was higher in women in urban areas (35.4%) in comparison to women in rural areas (28.4%) (Figure 1). Similarly, the prevalence of obesity (Asian cut-off: BMI ≥27.5 kg/m²) was higher in urban women (27.9%), compared to rural women (12.7%) (Figure 1).

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 1: Characteristics of 25-64 years old residents in Myanmar, by gender and urban-rural location

Variables	Total (n=8390) N (%)	Urban			Rural		
		Male (n=830) N (%)	Female (n=1798) N (%)	Total (n=2628) N (%)	Male (n=2117) N (%)	Female (n=3645) N (%)	Total (n=5762) N (%)
Age (Mean years ± SD)	44.9 ±10.7	47.0 ± 10.8	46.0 ± 10.3	46.4 ± 10.4	44.1 ± 10.9	44.4 ± 10.7	44.2 ± 10.8
Age group (years)							
25-34	1689 (20.1)	139 (16.7)	272 (15.1)	411 (15.6)	488 (23.1)	790 (21.7)	1278 (22.2)
35-44	2315 (27.6)	178 (21.4)	511 (28.4)	689 (26.2)	577 (27.3)	1049 (28.8)	1626 (28.2)
45-54	2412 (28.7)	269 (32.4)	558 (31.0)	827 (31.5)	580 (27.4)	1005 (27.6)	1585 (27.5)
55-64	1974 (23.5)	244 (29.4)	457 (25.4)	701 (26.7)	472 (22.3)	801 (22.0)	1273 (22.1)
Education (Mean Years ± SD)	5.7 ± 4.1	8.4 ± 3.9	7.5 ± 4.2	7.7 ± 4.1	5.3 ± 3.4	4.5 ± 3.8	4.8 ± 3.7
Education level							
No formal School	1256 (15.0)	51 (6.1)	122 (6.8)	173 (6.6)	370 (17.5)	713 (19.6)	1083 (18.8)
Less than Primary School	1912 (22.8)	66 (8.0)	293 (16.3)	359 (13.7)	434 (20.5)	1119 (30.7)	1553 (27.0)
Primary School completed	3121 (37.2)	265 (31.9)	574 (31.9)	839 (31.9)	933 (44.1)	1349 (37.0)	2282 (39.6)
Secondary School completed	1044 (12.4)	214 (25.8)	349 (19.4)	563 (21.4)	239 (11.3)	242 (6.6)	481 (8.3)
High School completed	524 (6.2)	117 (14.1)	203 (11.3)	320 (12.2)	86 (4.1)	118 (3.2)	204 (3.5)
College/university completed	499 (5.9)	110 (13.3)	241 (13.4)	351 (13.4)	53 (2.5)	95 (2.6)	148 (2.6)
Post graduate degree	34 (0.4)	7 (0.8)	16 (0.9)	23 (0.9)	2 (0.1)	9 (0.2)	11 (0.2)
Employment Status							
Government Employee	359 (4.3)	81 (9.8)	120 (6.7)	201 (7.6)	59 (2.8)	99 (2.7)	158 (2.7)
Non-Government Employee	560 (6.7)	88 (10.6)	78 (4.3)	166 (6.3)	182 (8.6)	212 (5.8)	394 (6.8)
Self-employed	5074 (60.5)	495 (59.6)	628 (34.9)	1123 (42.7)	1667 (78.7)	2284 (62.7)	3951 (68.6)
Nonpaid	210 (2.5)	36 (4.3)	28 (1.6)	64 (2.4)	59 (2.8)	87 (2.4)	146 (2.5)
Student	8 (0.1)	3 (0.4)	0 (0.0)	3 (0.1)	2 (0.1)	3 (0.1)	5 (0.1)
Homemaker	1559 (18.6)	6 (0.7)	811 (45.1)	817 (31.1)	7 (0.3)	735 (20.2)	742 (12.9)
Retired	174 (2.1)	61 (7.3)	38 (2.1)	99 (3.8)	44 (2.1)	31 (0.9)	75 (1.3)
Unemployed (able to work)	298 (3.6)	47 (5.7)	70 (3.9)	117 (4.5)	59 (2.8)	122 (3.3)	181 (3.1)
Unemployed (unable to work)	144 (1.7)	13 (1.6)	24 (1.3)	37 (1.4)	38 (1.8)	69 (1.9)	107 (1.9)
Refused to answer	4 (0.0)	0 (0.0)	1 (0.1)	1 (0.0)	0 (0.0)	3 (0.1)	3 (0.1)
Daily Income USD/day (n=7408)							
< 1.9	992 (13.4)	38 (5.0)	79 (4.8)	117 (4.9)	316 (17.0)	559 (17.8)	875 (17.5)
≥ 1.9	6416 (86.6)	727 (95.0)	1559 (95.2)	2286 (95.1)	1540 (83.0)	2590 (82.2)	4130 (82.5)

SD, Standard deviation; USD, United States Dollar

Objective 1: Association between urban-rural location and BMI or W/H-ratio

The mean BMI was higher among urban than rural residents (β=2.49 kg/m^2; 95% CI 2.28, 2.70; p<0.001) when adjusting for age and gender (model 2, Table 2). Similarly, a greater W/H-ratio was observed in participants living in an urban area (β=0.015; 95% CI 0.011, 0.020; p<0.001) compared to rural, when adjusting for age and gender (model 2, Table 3).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 2: Mean Body mass index (BMI) and associations between urban-rural location (objective 1) and socioeconomic factors (objective 2) with BMI (kg/m^2) among 25-64 years old Myanmar residents, Crude (Model 1) and adjusted for confounders (Model 2). Confounders are specified in footnotes.

Variables	Category	Mean BMI ± SD	Model 1 β (95% CI)	Model 2 β (95% CI)
Location	Rural	21.9 ± 4.1	Ref.	Ref.
	Urban	24.5 ± 5.5	2.62** (2.40-2.83)	2.49[a]** (2.28-2.70)
Income[1]	< 1.9 USD/day	21.5 ± 4.1	Ref	Ref.
	≥ 1.9 USD/day	22.9 ± 4.8	1.44** (1.12-1.76)	0.74[b]** (0.43-1.05)
Education	Low	21.9 ± 4.2	Ref.	Ref.
	Medium	22.9 ± 4.8	0.98** (0.76-1.21)	0.88[c]**(0.66-1.10)
	High	24.2 ± 5.7	2.28** (1.95-2.61)	1.48[c]**(1.13-1.82)
Employment[2]	Employed	22.7 ± 4.7	Ref.	Ref.
	Unemployed	22.7 ± 5.1	0.04 (-0.30-0.38)	-0.06[d] (-0.39-0.26)
SES	Low	21.4 ± 4.0	Ref.	Ref.
	Medium	22.9 ± 4.8	1.42** (1.09-1.76)	0.81[c]** (0.49-1.14)
	High	24.1 ± 4.8	2.65** (1.54-3.77)	1.28[c]* (0.21-2.36)

**p<0.001, *p<0.05, [1]982 participants with missing value for income excluded in all models; [2]4 participants with missing employment status excluded in all models; BMI, Body mass index; CI, Confidence interval; Ref., reference category; SD, Standard Deviation; SES, Socioeconomic Status

a) adjusted for age and gender
b) adjusted for age, gender, urban-rural location, education, and employment
c) adjusted for age, gender, and urban-rural location
d) adjusted for age, gender, urban-rural location, and education

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 3: Mean Waist-hip ratio (W/H-ratio) and associations between urban-rural location (objective 1) and socioeconomic factors (objective 2) with W/H-ratio among 25-64 years old Myanmar residents, crude (Model 1) and adjusted for confounders (Model 2). Confounders are specified in footnotes.

Variables	Category	Mean W/H-ratio ± SD	Model 1 β (95% CI)	Model 2 β (95% CI)
Location	Rural	0.84 ± 0.09	Ref.	Ref.
	Urban	0.86 ± 0.11	0.016*** (0.012-0.021)	0.015[a]*** (0.011-0.020)
Income[1]	< 1.9 USD/day	0.84 ± 0.07	Ref.	Ref.
	≥ 1.9 USD/day	0.85 ± 0.09	0.010* (0.004-0.016)	0.007*[b] (0.001-0.013)
Education	Low	0.84 ±0.08	Ref.	Ref.
	Medium	0.85 ± 0.10	0.005* (0.00-0.009)	0.002[c] (-0.003-0.006)
	High	0.85 ± 0.11	0.006 (-0.001-0.013)	0.002[c] (-0.006-0.009)
Employment[2]	Employed	0.85 ± 0.09	Ref.	Ref.
	Unemployed	0.86 ± 0.10	0.018*** (0.011-0.025)	0.006[d] (-0.001-0.014)
SES	Low	0.84 ± 0.07	Ref.	Ref.
	Medium	0.85 ± 0.09	0.012** (0.005-0.018)	0.008[c]* (0.001-0.014)
	High	0.88 ± 0.19	0.044*** (0.022-0.066)	0.019[c] (-0.002-0.040)

***p<0.001, **p<0.01, *p<0.05; 7 participants with missing W/H-ratio excluded in all models; [1]982 participants with missing value for income excluded in all models; [2]4 participants with missing employment status excluded in all models; CI, Confidence interval; Ref., Reference category; SD, Standard Deviation; SES, Socioeconomic Status; W/H-ratio, Waist-hip ratio

a) adjusted for age and gender
b) adjusted for age, gender, urban-rural location, education, and employment
c) adjusted for age, gender, and urban-rural location
d) adjusted for age, gender, urban-rural location, and education

Objective 2: Association between socioeconomic factors (income, education, and employment status) and BMI or W/H-ratio

The socioeconomic factors income and education but not employment, were associated with BMI (model 2, Table 2). Mean BMI was higher among individuals living above poverty line (β=0.74 kg/m^2; 95% CI 0.43, 1.05; p<0.001), versus below, when adjusting for age, gender, urban-rural location, education, and employment. BMI was higher among individuals with medium and high education, versus low (Medium education: β=0.88 kg/m^2; 95% CI 0.66, 1.10; p<0.001 and High education: β=1.48 kg/m^2; 95% CI 1.13, 1.82; p<0.001). Moreover, BMI was higher in medium and high SES group, versus low (Medium SES: β=0.81 kg/m^2; 95% CI 0.49, 1.14; p<0.001 and High SES: β=1.28 kg/m^2; 95% CI 0.21, 2.36; p<0.05) (Table 2).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

There was an association between the socioeconomic indicators income and employment but not education, with W/H-ratio (model 2, Table 3). Among those with earnings ≥ 1.9 USD/day, the W/H-ratio was greater (β=0.007; 95% CI 0.001, 0.013; p<0.05) than those earning <1.9 USD/day. Unemployed participants had greater W/H-ratio than employed participants in the crude model, but the association was attenuated in the adjusted model (model 1, Table 3). In addition, medium and high SES groups had greater W/H-ratios than the low SES group in the crude model (model 1, Table 3).

When combining income, education, and employment status into a composite SES score, the prevalence of overweight (BMI 25-29.9) and obesity (BMI ≥30) increased with increasing SES score for both genders (Figure 2). Similarly, the prevalence of central obesity (W/H-ratio >0.9 for men and W/H-ratio >0.85 for women) increased with increasing SES score in men, whereas in women the prevalence was almost similar in medium and high SES group (Figure 2).

Objective 3: Association between urban-rural location and BMI or W/H-ratio mediated by socioeconomic factors (income, education, and employment status)

Table 4 shows the adjusted total- and direct effects of urban-rural location on BMI and W/H-ratio. There was change in the estimates for BMI after adjusting for income (Table 4), which gave an indirect effect of urban-rural location through income: 2.50-2.08=0.42 kg/m^2, and a mediated proportion of 17% (0.42/2.50= 0.17). Similarly, adjusting for education gave an indirect effect of urban-rural location through education of 0.40 kg/m^2, and a mediated proportion of 16%. When adjusting for employment, corresponding figures were 0.40 kg/m^2 and mediated proportion of 16%. Adjustment for the composite SES score gave an indirect effect of urban-rural location through composite SES score of 0.22 kg/m^2, and a mediated proportion of 9%. There was change in the estimates for W/H-ratio after adjusting for income, which gave an indirect effect of urban-rural location through income of 0.002, and a mediated proportion of 12%. Similarly, adjusting for education gave an indirect effect of urban-rural location through education of 0.001, and a mediated proportion of 6%, and when adjusting for employment: 0.001 (mediated proportion of 6%) (Table 4). Furthermore, adjusting for composite SES score gave an indirect effect of urban-rural location through composite SES score of 0.002, and a mediated proportion of 12%.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 4: Total- versus direct effect of urban-rural location on BMI and W/H-ratio (objective 3), among 25-64 years old Myanmar residents

Location	BMI					W/H-ratio[1]				
	Total effect (a)	Direct effect through composite SES score (b)	Direct effect through income (c)	Direct effect through education (d)	Direct effect through employment (e)	Total effect (a)	Direct effect through composite SES score (b)	Direct effect through income (c)	Direct effect through education (d)	Direct effect through employment (e)
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Rural	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Urban	2.50* (2.27-2.72)	2.28* (2.05-2.51)	2.08* (1.85-2.32)	2.10* (1.86-2.33)	2.10* (1.86-2.34)	0.017* (0.012-0.021)	0.015* 0.010-0.019)	0.015* (0.010-0.020)	0.016* (0.011-0.021)	0.016* (0.011-0.021)

*p<0.001; 982 participants with missing value for income and 4 participants with missing employment status excluded in all models for comparison; [1]7 participants with missing W/H-ratio excluded. Exclusion of missing values gives slightly different total estimates from Table 1; BMI, Body mass index; CI, Confidence interval; Ref., Reference category; W/H-ratio, Waist-hip ratio.

(a) adjusted for age and gender (confounders)
(b) adjusted for age, gender, and composite SES score
(c) adjusted for age, gender, education, employment, and income
(d) adjusted for age, gender, and education
(e) adjusted for age, gender, education, and employment

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

DISCUSSION

We found the prevalence of overweight and obesity, including central obesity to be higher in urban areas in Myanmar compared to rural areas. There was a consistent positive adjusted association between SES and BMI, while the association between SES and W/H-ratio was less consistent. Out of the socioeconomic factors, education was found to have the strongest association with BMI (general overweight and obesity), whereas income had the strongest association with W/H-ratio (central obesity). The association between urban-rural location and BMI was found to be partially mediated by the SES indicators with income, education, and employment status contributing almost equally. In the association between urban-rural location and W/H-ratio, the highest proportion was mediated by income.

A previous study from Myanmar report an 28% overall prevalence of overweight and 13% prevalence of obesity, which is higher than in the current study.[18] The higher prevalence could be due to the inclusion of adult women only and the use of Asian specific BMI cut-offs. However, our findings of a higher BMI and greater W/H-ratio in urban compared to rural areas corroborates previous studies conducted in Myanmar.[14-16] Further, it is also consistent with findings of studies carried out in other countries of the SEAR,[33-37] and of a global study conducted in 2010, which reported that the overall prevalence of overweight and obesity was higher in urban areas compared to their rural counterpart.[38] In contrast to our findings, a recent study composed of data from 2,009 population-based studies showed that BMI is rising at the same proportion or faster in rural areas compared to urban in LMICs except women in sub-Saharan Africa.[12] Similar study reported that mean BMI was generally higher in rural compared to urban men in South Asia while BMI increased at a similar rate in rural and urban men in East and Southeast Asia. The study also reported that changes in rural areas are driving the increase in mean BMI globally.[12] The authors suggested that improved road infrastructure and transportation has led to an increased access to high calorie foods, mechanized farming equipment, in addition to shifts from manual labour to more sedentary work,[12] i.e. an *urbanization* of the rural areas.

There is a paucity of studies investigating the association of all three socioeconomic factors (income, education, and employment status) with BMI and W/H-ratio in both male and female populations in Myanmar, hence the current study is the first to report these novel findings. In our study, higher income and higher education was associated with increased BMI, which is in accordance with a systematic review of studies investigating the association between SES and obesity in LMICs.[6] Additionally, a wide scale and much larger study

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

focusing on the association between socioeconomic factors and weight status across 53 countries in 2010 found that the prevalence of obesity was highest in the richest quintile of the participants.[38] Another study from 70 low- middle- and high-income countries found a strong, positive association between individual income and obesity.[39] Furthermore, our result correspond with evidence from a systematic review of studies[40] and a study involving non-pregnant women from 37 developing countries,[41] which observed positive associations between education and obesity in low income countries. Several studies from Bangladesh, Nepal, India, and Sri Lanka also supports this.[34-37 ,42] Based on the Myanmar Demographic and Health Survey 2015-2016, 28% of Myanmar's population is living in urban areas.[43] However, Myanmar is still considered to be in the early phase of the demographic transition. Much of the current development is happening in the cities,[44] which indicates that many of the rural areas in Myanmar are not yet influenced by the ongoing urbanization of the country. The economic growth in Myanmar, has reduced the proportion of people living below the poverty line (a reduction in poverty from 48% to 25% between 2005 and 2017).[45] Because of the continuing economic development of the country, there may be an increase in sedentary lifestyle, higher income and more availability of processed food in urban areas, culminating to an increased burden of overweight and obesity as diet and physical activity are its major risk factors.[46] As rice is the main staple food of Myanmar, people generally consume high amounts of carbohydrates, which in turn is associated with high BMI.[47 ,48] In urban Myanmar residents, high intakes of fat and protein have been reported.[49] Moreover, the consumption of fast food and high caloric soft drinks and alcohol is higher in urban inhabitants compared to rural dwellers.[48] Additionally, in a study conducted in the Yangon region of Myanmar, the prevalence of physical inactivity was low, and no difference was observed between urban and rural residents.[14] However, most of the physical activity was linked to work, and high energy expenditure in the workplace was higher among rural- than among urban residents.[14] There may also be cultural determinants of BMI, as a larger body size often symbolizes high status and good health in Myanmar, which means that people with a high SES may even prefer a larger body size.[48] In LMICs, in general, high SES individuals have been found to have a higher energy intake, reflecting a greater access to both inexpensive energy dense foods and expensive higher-quality food items.[50]

We found that the association between urban-rural location and BMI was only partially mediated by socioeconomic factors such as income, education, and employment status. Our finding is in line with a study conducted in women in reproductive age in 38 LMICs,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

reporting that much, but not all of the urban-rural differences in BMI is driven by the socioeconomic composition (measured by household wealth).[10] This indicates that other important factors could explain the urban-rural BMI difference in Myanmar, including differences in non-leisure physical activity opportunities, less energy intensive occupation in urban areas, differences in neighbourhood environment, better transportation facilities, and better access to high ultra-processed and packaged food in urban areas.[51-53] Future prospective studies may be able to provide information that can explain this association. Road infrastructure and transportation facility is not well developed in the rural part of Myanmar.[54] As many as 40% of villages are without road access and additional 30% villages have access only part of the season, requiring the rural population to travel long distances to access markets and basic services leading to high energy expenditure.[54]

Strengths and limitations

The findings of this study add to the current research related to large population analyses of overweight and obesity. One of the major strengths of this study is the analyses of a large nationally representative sample of 8,390 participants that constitutes both urban and rural populations in Myanmar. In addition, the internationally recommended WHO STEPS protocol was diligently followed, and the outcome measures were assessed using standardised procedures. The response rate was high, at 91%. Moreover, we used W/H-ratio as the measure of central obesity in addition to BMI. There are, however, some limitations. The study was cross-sectional which means that causality cannot be determined, e.g. the temporal relationships between socioeconomic factors and obesity cannot be inferred; evidence suggests the relationship is likely to be bidirectional.[55,56] Furthermore, 982 participants refused to provide information on their income were excluded. These have a higher likelihood of belonging to lower income groups as most of them were unemployed, which may have given underestimation of socioeconomic differences in BMI. At the analysis stage, 280 participants were excluded from the study due to missing BMI values. As association measures are robust, it is unlikely that this exclusion has substantially contributed to selection bias.[57] Institutionalized people like monks, nuns and soldiers were excluded from the sampling frame as their lifestyle may differ from most of the general population, which means that the findings can only be generalized to Myanmar's non-institutionalized population.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

CONCLUSION

The current study examines the relation between urban-rural location and socioeconomic factors with general- and central overweight and obesity in adult residents in Myanmar. Taken together, we found an independent and positive association between urban-rural location and BMI, partially, but not fully explained by socioeconomic factors. Mean BMI was higher among urban dwellers, individuals living above poverty line and in those with higher attained education level.

Knowledge about the significant roles played by location of living (urban and rural) and socioeconomic factors in relation to overweight and obesity can contribute to the development of well-targeted policies. Currently, mainly behavioural factors have been emphasised in prevention strategies for the management of overweight and obesity in Myanmar. Our findings imply that there should also be a focus on socioeconomic factors in order to reduce the burden of overweight and obesity. Moreover, updated national or sub-national STEPS surveys should be conducted to continue monitoring the trends and urban-rural differences in overweight and obesity.

For peer review only

Footnotes

Contributors: RT contributed to the design of the article, statistical analysis, interpreted the data and drafted the manuscript. EB, CD, and WPA contributed to the conception and design of the study and the article, interpretation of the data and the content of the article. All authors contributed revising the manuscript for important intellectual content and approved the final version to be published.

Funding: The 2014 STEPS study was funded by the World Health Organization, the World Diabetes Foundation, and the report was printed with the financial assistance of the European Union and HelpAge International.

Acknowledgments: The authors acknowledge Professor, Tint Swe Latt, the principle investigator for the 2014 STEPS study. The authors are grateful to the World Health Organization, the University of Oslo and the Norwegian agency for Development Cooperation (Norad) for the project “Health and Sustainable development in Myanmar–Competence Building in Public Health and Medical Research and Education (MY-NORTH) Project: MMY-13/0049, NORHED, UiO:211782. We would like to thank all the participants, medical doctors from the Myanmar Medical Association, township medical officers, basic health staffs and local administrative authorities from all the surveyed areas.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Competing interests: No competing interests

Patient consent: Obtained

Data availability statement: No additional data are available

REFERENCES

1. World Health Organization. Obesity and Overweight WHO; 2020 [Available from: https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight (accessed 18th May 2020).

2. Klein S, Allison DB, Heymsfield SB, et al. Waist Circumference and Cardiometabolic Risk: a Consensus Statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Obesity (Silver Spring, Md)* 2007;15(5):1061-7. doi: 10.1038/oby.2007.632 [published Online First: 2007/05/15].

3. Amato MC, Guarnotta V, Giordano C. Body composition assessment for the definition of cardiometabolic risk. *J Endocrinol Invest* 2013;36(7):537-43. doi: 10.3275/8943 [published Online First: 2013/04/25].

4. World Health Organization. Global Health Observatory Data Repository (South-East Asia Region): Prevalence of overweight among adults, BMI ≥ 25, crude Estimates by WHO Region 2016 [updated September 27, 2017]. Available from: http://apps.who.int/gho/data/view.main-searo.BMI25CREGv?lang=en (accessed 18th May 2020).

5. World Health Organization. Global Health Observatory Data Repository (South-East Asia Region): Prevalence of obesity among adults, BMI ≥ 30, crude Estimates by WHO region 2016 [updated September 22, 2017]. Available from: http://apps.who.int/gho/data/view.main-searo.BMI30CREGv?lang=en (accessed 18th May 2020).

6. Dinsa GD, Goryakin Y, Fumagalli E, et al. Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev* 2012;13(11):1067-79. doi: 10.1111/j.1467-789X.2012.01017.x [published Online First: 2012/07/07].

7. Ford ND, Patel SA, Narayan KM. Obesity in Low- and Middle-Income Countries: Burden, Drivers, and Emerging Challenges. *Annu Rev Public Health* 2017;38:145-64. doi: 10.1146/annurev-publhealth-031816-044604 [published Online First: 2017/01/10].

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

8. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev* 2012;70(1):3-21. doi: 10.1111/j.1753-4887.2011.00456.x [published Online First: 2012/01/10].

9. United Nations. 2018 revision of world urbanization prospects: United Nations Department of Economic and Social Affairs, 2018.

10. Neuman M, Kawachi I, Gortmaker S, et al. Urban-rural differences in BMI in low- and middle-income countries: the role of socioeconomic status. *Am J Clin Nutr* 2013;97(2):428-36. doi: 10.3945/ajcn.112.045997 [published Online First: 2013/01/02].

11. McLaren L. Socioeconomic status and obesity. *Epidemiol Rev* 2007;29(1):29-48. doi: 10.1093/epirev/mxm001 [published Online First: 2007/05/05].

12. Bixby H, Bentham J, Zhou B, et al. Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature* 2019;569(7755):260-64. doi: 10.1038/s41586-019-1171-x [published Online First: 2019/05/10].

13. World Health Organization. Myanmar (Yangon Division) STEPS Survey 2004 Fact Sheet 2004 [Available from: https://www.who.int/ncds/surveillance/steps/Myanmar_2004_FactSheet.pdf (accessed 23rd April 2019).

14. Htet AS, Bjertness MB, Sherpa LY, et al. Urban-rural differences in the prevalence of non-communicable diseases risk factors among 25-74 years old citizens in Yangon Region, Myanmar: a cross sectional study. *BMC Public Health* 2016;16(1):1225. doi: 10.1186/s12889-016-3882-3 [published Online First: 2016/12/07].

15. World Health Organization. WHO STEPwise approach to NCD surveillance 2004, Myanmar Disagregation of Urban annd rural data (urban). Available from: https://www.who.int/ncds/surveillance/steps/MyanmarSTEPSReport2004URBAN.pdf (accessed 23rd April 2019).

16. World Health Organization. WHO STEPwise approach to NCD surveillance 2004, Myanmar Disagregation of Urban annd rural data (rural). Available from: https://www.who.int/ncds/surveillance/steps/MyanmarSTEPSReport2004RURAL.pdf (accessed 23rd April 2019).

17. World Health Organization. Noncommunicable Disease Risk Factor Survey Myanmar 2009. 2011. [Available from:

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

https://www.who.int/ncds/surveillance/steps/2009_STEPS_Survey_Myanmar.pdf (accessed 23rd April 2019).

18. Hong SA, Peltzer K, Lwin KT, et al. The prevalence of underweight, overweight and obesity and their related socio-demographic and lifestyle factors among adult women in Myanmar, 2015-16. *PLoS One* 2018;13(3):e0194454. doi: 10.1371/journal.pone.0194454 [published Online First: 2018/03/17].

19. Stokke K, Vakulchuk R, Øverland I. Myanmar: A political economy analysis. 2018.

20. World Health Organization. Report on National Survey of Diabetes Mellitus and Risk Factors for Non-Communicable Diseases in Myanmar (2014). 2018. Available from: www.who.int/ncds/surveillance/steps/Myanmar_2014_STEPS_Report.pdf (accessed 23rd April 2019).

21. Elfil M, Negida A. Sampling methods in Clinical Research; an Educational Review. *Emerg (Tehran)* 2017;5(1):e52-e52. [published Online First: 2017/01/14].

22. Colditz GA, Willett WC, Rotnitzky A, et al. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med* 1995;122(7):481-6. doi: 10.7326/0003-4819-122-7-199504010-00001 [published Online First: 1995/04/01].

23. Pajak A, Kuulasmaa K, Tuomilehto J, et al. Geographical variation in the major risk factors of coronary heart disease in men and women aged 35-64 years : the WHO MONICA Project / prepared by Andrzej Pajak ... [et al.]. *World health statistics quarterly* 1988;41(3/4):115-140. https://apps.who.int/iris/handle/10665/51270

24. Bigaard J, Frederiksen K, Tjonneland A, et al. Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes (Lond)* 2005;29(7):778-84. doi: 10.1038/sj.ijo.0802976 [published Online First: 2005/05/27].

25. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. *Am J Clin Nutr* 2004;79(3):379-84. doi: 10.1093/ajcn/79.3.379 [published Online First: 2004/02/27].

26. Lim JU, Lee JH, Kim JS, et al. Comparison of World Health Organization and Asia-Pacific body mass index classifications in COPD patients. *Int J Chron Obstruct Pulmon Dis* 2017;12:2465-75. doi: 10.2147/COPD.S141295

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

27. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet (London, England)* 2004;363(9403):157.

28. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008. 2011.

29. The Republic of Union of Myanmar MoHA. The ward or village tract administration law 2012 [Available from: http://www.myanmar-law-library.org/law-library/laws-and-regulations/laws/myanmar-laws-1988-until-now/union-solidarity-and-development-party-laws-2012-2016/myanmar-laws-2012/pyidaungsu-hluttaw-law-no-1-2012-ward-or-village-administration-law-burmese.html (accessed 20th October 2019).

30. Central Bank of Myanmar. Reference exchange rate [Available from: https://forex.cbm.gov.mm/index.php/fxrate (accessed 20th August 2019).

31. Ferreira FH, Chen S, Dabalen A, et al. A global count of the extreme poor in 2012: data issues, methodology and initial results: The World Bank 2015.

32. Textor J, van der Zander B, Gilthorpe MS, et al. Robust causal inference using directed acyclic graphs: the R package 'dagitty'. *Int J Epidemiol* 2016;45(6):1887-94. doi: 10.1093/ije/dyw341 [published Online First: 2017/01/17].

33. Angkurawaranon C, Jiraporncharoen W, Chenthanakij B, et al. Urban environments and obesity in southeast Asia: a systematic review, meta-analysis and meta-regression. *PLoS One* 2014;9(11):e113547. doi: 10.1371/journal.pone.0113547 [published Online First: 2014/11/27].

34. Biswas T, Garnett SP, Pervin S, et al. The prevalence of underweight, overweight and obesity in Bangladeshi adults: Data from a national survey. *PLoS One* 2017;12(5):e0177395. doi: 10.1371/journal.pone.0177395

35. Siddiqui ST, Kandala N-B, Stranges S. Urbanisation and geographic variation of overweight and obesity in India: a cross-sectional analysis of the Indian Demographic Health Survey 2005–2006. *Int J Public Health* 2015;60(6):717-26.

36. Biswas T, Townsend N, Islam MS, et al. Association between socioeconomic status and prevalence of non-communicable diseases risk factors and comorbidities in Bangladesh: findings from a nationwide cross-sectional survey. *BMJ Open* 2019;9(3):e025538. doi: 10.1136/bmjopen-2018-025538

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

37. De Silva AP, De Silva SH, Haniffa R, et al. A cross sectional survey on social, cultural and economic determinants of obesity in a low middle income setting. *Int J Equity Health* 2015;14(1):6. doi: 10.1186/s12939-015-0140-8 [published Online First: 2015/01/18].

38. Moore S, Hall JN, Harper S, et al. Global and national socioeconomic disparities in obesity, overweight, and underweight status. *J Obes* 2010;2010 doi: 10.1155/2010/514674 [published Online First: 2010/08/20].

39. Masood M, Reidpath DD. Effect of national wealth on BMI: An analysis of 206,266 individuals in 70 low-, middle- and high-income countries. *PLoS One* 2017;12(6):e0178928. doi: 10.1371/journal.pone.0178928 [published Online First: 2017/07/01].

40. Cohen AK, Rai M, Rehkopf DH, et al. Educational attainment and obesity: a systematic review. *Obes Rev* 2013;14(12):989-1005. doi: 10.1111/obr.12062 [published Online First: 2013/07/25].

41. Monteiro CA, Conde WL, Lu B, et al. Obesity and inequities in health in the developing world. *Int J Obes Relat Metab Disord* 2004;28(9):1181-86. doi: 10.1038/sj.ijo.0802716 [published Online First: 2004/06/24].

42. Al Kibria GM. Prevalence and factors affecting underweight, overweight and obesity using Asian and World Health Organization cutoffs among adults in Nepal: Analysis of the Demographic and Health Survey 2016. *Obes Res Clin Pract* 2019;13(2):129-36. doi: https://doi.org/10.1016/j.orcp.2019.01.006 [published Online First: 2019/02/06].

43. Health Mo, Sports - MoHS/Myanmar, ICF. Myanmar Demographic and Health Survey 2015-16. Nay Pyi Taw, Myanmar: MoHS and ICF; 2017. Available from: http://dhsprogram.com/pubs/pdf/FR324/FR324.pdf

44. The World Bank. Myanmar's Urbanization: Creating Opportunities for All 2019. Available from: https://www.worldbank.org/en/country/myanmar/publication/myanmars-urbanization-creating-opportunities-for-all (accessed 28th August 2019).

45. The World Bank in Myanmar. Overview 2020. Available from: https://www.worldbank.org/en/country/myanmar/overview (accessed 11th June 2020).

46. International Food Policy Research Institute. Global food policy report 2017. Washington, DC: International Food Policy Research Institute (IFPRI) 2017. doi: https://doi.org/10.2499/9780896292529

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

47. Unwin D, Unwin J. Low carbohydrate diet to achieve weight loss and improve HbA1cin type 2 diabetes and pre-diabetes: experience from one general practice. *Practical Diabetes* 2014;31(2):76-79. doi: 10.1002/pdi.1835

48. Aye T, Aung M, Oo E. Diabetes mellitus in Myanmar: Socio-cultural challenges and strength. *Journal of Social Health and Diabetes* 2018;02(01):009-13. doi: 10.4103/2321-0656.120255

49. Hlaing HH, Liabsuetrakul T. Dietary intake, food pattern, and abnormal blood glucose status of middle-aged adults: a cross-sectional community-based study in Myanmar. *Food Nutr Res* 2016;60(1):28898. doi: 10.3402/fnr.v60.28898 [published Online First: 2016/05/07].

50. Mayen AL, Marques-Vidal P, Paccaud F, et al. Socioeconomic determinants of dietary patterns in low- and middle-income countries: a systematic review. *Am J Clin Nutr* 2014;100(6):1520-31. doi: 10.3945/ajcn.114.089029 [published Online First: 2014/11/21].

51. Popkin BM. Technology, transport, globalization and the nutrition transition food policy. *Food Policy* 2006;31(6):554-69. doi: 10.1016/j.foodpol.2006.02.008

52. Solomons NW, Gross R. Urban nutrition in developing countries. *Nutr Rev* 1995;53(4 Pt 1):90-5. doi: 10.1111/j.1753-4887.1995.tb01526.x [published Online First: 1995/04/01].

53. Mohammed SH, Habtewold TD, Birhanu MM, et al. Neighbourhood socioeconomic status and overweight/obesity: a systematic review and meta-analysis of epidemiological studies. *BMJ Open* 2019;9(11):e028238. doi: 10.1136/bmjopen-2018-028238 [published Online First: 2019/11/16].

54. Asian Development Bank. Myanmar Transport Sector Policy Note: Rural Roads and Access. 2016. Available from: https://www.adb.org/sites/default/files/publication/189079/mya-rural-roads.pdf (accessed 22nd April, 2020).

55. Kim TJ, von dem Knesebeck O. Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis. *BMJ Open* 2018;8(1):e019862. doi: 10.1136/bmjopen-2017-019862 [published Online First: 2018/01/08].

56. Kim TJ, Roesler NM, von dem Knesebeck O. Causation or selection - examining the relation between education and overweight/obesity in prospective observational studies: a meta-analysis. *Obes Rev* 2017;18(6):660-72. doi: 10.1111/obr.12537 [published Online First: 2017/04/13].

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

57. Søgaard AJ, Selmer R, Bjertness E, et al. The Oslo Health Study: The impact of self-selection in a large, population-based survey. *Int J Equity Health* 2004;3(1):3. doi: 10.1186/1475-9276-3-3 [published Online First: 2004/05/07].

Figures

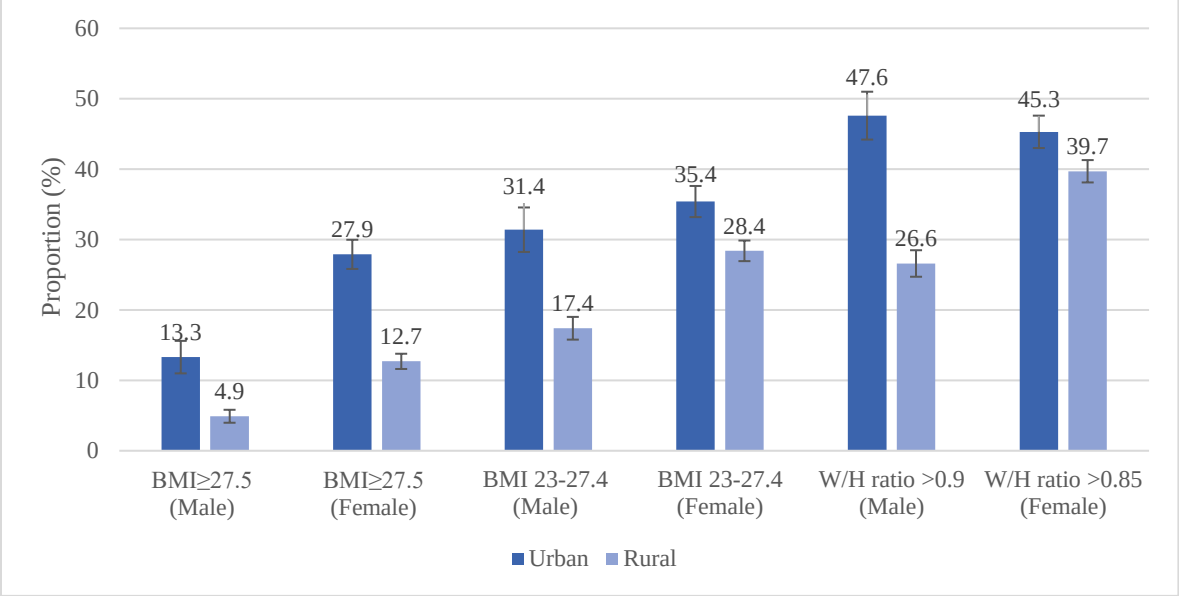
Figure 1: Proportion of participants with high Body mass index (BMI) (above Asian overweight and obesity cut-off) and Waist-hip ratio (W/H-ratio), with 95% confidence interval, of 25-64 years old Myanmar residents by urban-rural location and gender

Figure 2: Prevalence of overweight (BMI 25-29.9), obesity (BMI ≥30) and central obesity (W/H-ratio >0.9 for males and W/H-ratio >0.85 for females) across three levels of SES (calculated composite SES score) among 25-64 years old Myanmar residents, by gender

For peer review only

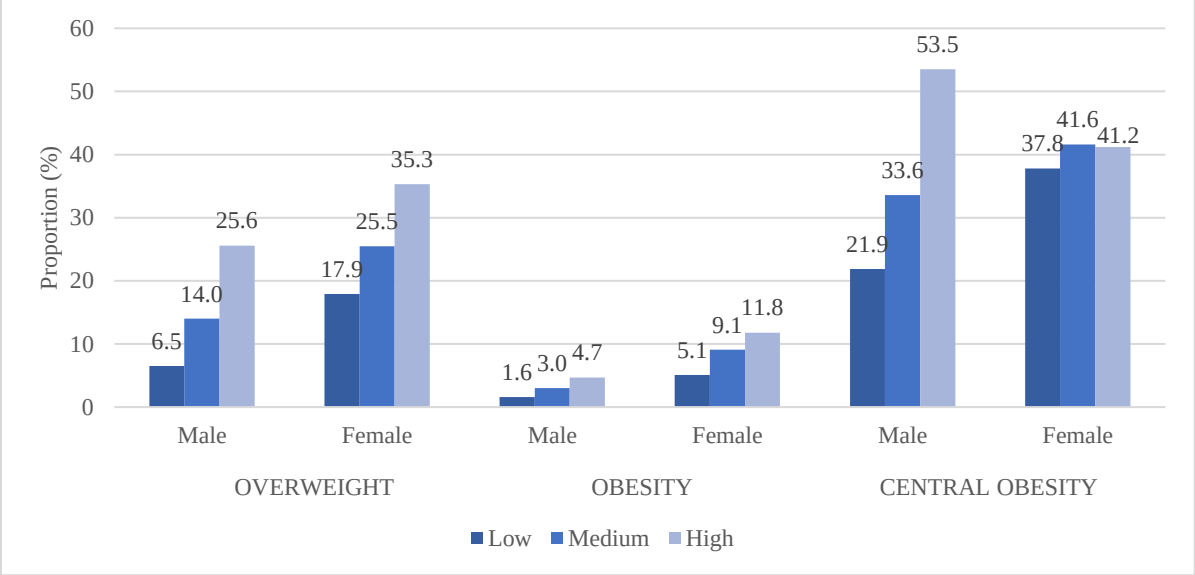
For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Figure 1: Proportion of participants with high Body mass index (BMI) (above Asian overweight and obesity cut-off) and Waist-hip ratio (W/H-ratio), with 95% confidence interval, of 25-64 years old Myanmar residents by urban-rural location and gender



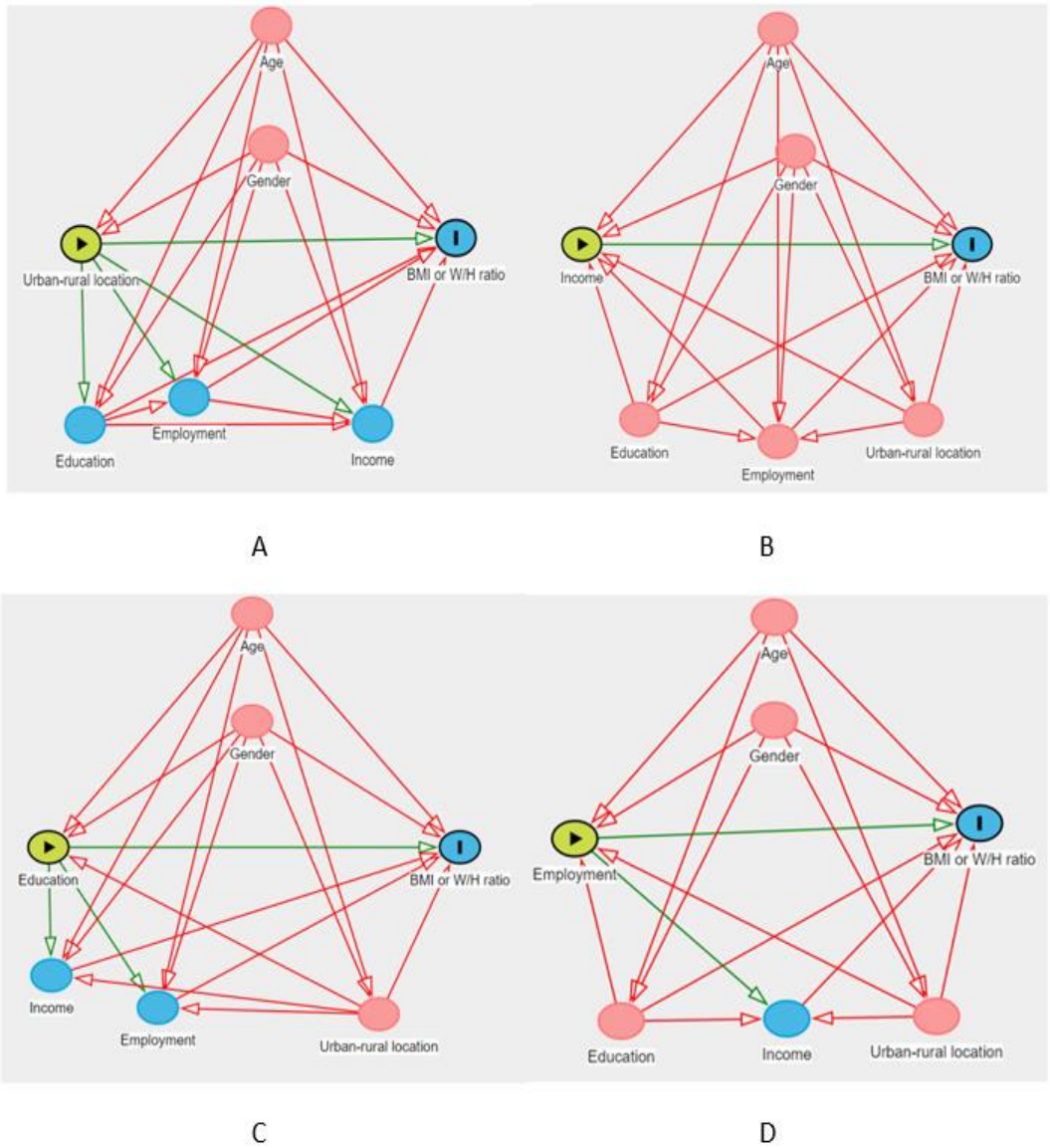
For peer review only

Figure 2: Prevalence of overweight (BMI 25-29.9), obesity (BMI ≥30) and central obesity (W/H-ratio >0.9 for males and W/H-ratio >0.85 for females) across three levels of SES (calculated composite SES score) among 25-64 years old Myanmar residents, by gender



For peer review only

Supplementary Figure 1: DAGs for the casual relationship between exposure and outcome



A: showing hypothesized causal relationships between urban-rural location and BMI or W/H-ratio, adjusted for age and gender

B: showing hypothesized causal relationships between income and BMI or W/H-ratio, adjusted for age, gender, urban-rural location, education, and employment

C: showing hypothesized causal relationships between education and BMI or W/H-ratio, adjusted for age, gender and urban-rural location

D: showing hypothesized causal relationships between employment and BMI or W/H-ratio, adjusted for age, gender, urban-rural location and education

Supplementary Table 1: Socioeconomic status (SES) score: description of the variable, calculation procedure, score range and SES groups

	Variables combined	Variables value	Score range	SES groups
SES score	Education	Low education= 0 (below high school completion)	0-3	Low (Total SES score 0)
		High education= 1 (high school completion and above)		Medium (Total SES score 1 and 2)
	Income	Below poverty line= 0		
		Above poverty line= 1		
	Employment	Unemployed= 0		High (Total SES score 3)
		Employed= 1		

For peer review only

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	3-4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
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	5
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	10, 11, 13
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			

For peer review only

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	4
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	5
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	10-13
		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
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	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
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	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

For peer review only

BMJ Open

Urban-rural differences in overweight and obesity among 25-64 years old Myanmar residents: a cross-sectional, nationwide survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042561.R1
Article Type:	Original research
Date Submitted by the Author:	04-Nov-2020
Complete List of Authors:	Thapa, Rupa; University of Oslo Faculty of Medicine, Department of Community Medicine and Global Health Dahl, Cecilie; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health Aung , Wai Phyo; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health; Ministry of Health and Sports, Department of Public Health, Occupational and Environmental Health Division Bjertness, Espen; University of Oslo Faculty of Medicine, Department of Community Medicine and Global health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Global health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, PREVENTIVE MEDICINE

SCHOLARONE™
Manuscripts

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

For peer review only

Urban-rural differences in overweight and obesity among 25-64 years old Myanmar residents: a cross-sectional, nationwide survey

Rupa Thapa[1], Cecilie Dahl[1], Wai Phyo Aung[1,2], Espen Bjertness[1]

Author Affiliations

1. Department of Community Medicine and Global Health, Institute of Health and Society, Faculty of Medicine, University of Oslo, Oslo 0318, Norway; espen.bjertness@medisin.uio.no (EB); cecilie.dahl@medisin.uio.no (CD); rupathapa.rupa@gmail.com (RT)

2. Occupational and Environmental Health Division, Department of Public Health, Ministry of Health and Sports, Nay Pyi Taw 15011, Myanmar; w.p.aung@medisin.uio.no (WPA)

Correspondence to rupathapa.rupa@gmail.com

Word count: 4,525

Abstract

Objectives: To investigate whether urban-rural location and socioeconomic factors (income, education, and employment) are associated with body mass index (BMI) and waist-hip ratio (W/H-ratio), and to further explore whether the associations between urban-rural location and BMI or W/H-ratio could be mediated through variations in socioeconomic factors.

Design: Cross-sectional, WHO STEPS survey of non-communicable disease (NCD) risk factors

Setting: Urban and rural areas of Myanmar

Participants: A total of 8,390 men and women aged 25 to 64 years included during the study period from September to December 2014. Institutionalized people (Buddhist monks and nuns, hospitalized patients) and temporary residents were excluded.

Results: The prevalence of overweight and obesity was higher in the urban areas and increased with increasing SES score. Mean BMI was higher among urban residents (ß= 2.49 kg/m^2; 95% CI 2.28, 2.70; p<0.001), individuals living above poverty line, i.e. ≥ 1.9 USD/day (ß= 0.74 kg/m^2; 95% CI 0.43, 1.05; p<0.001), and those with high education attainment (ß= 1.48 kg/m^2; 95% CI 1.13, 1.82; p<0.001) when adjusting for potential confounders. Similarly, greater W/H-ratio was observed in participants living in an urban area, among those with earnings above poverty line, and among unemployed individuals. The association between

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

urban-rural location and BMI was found to be partially mediated by a composite SES score (9%), income (17%), education (16%), and employment (16%), while the association between urban-rural location and W/H-ratio was found to be partially mediated by income (12%), education (6%), and employment (6%).

Conclusion: Residents living in urban locations had higher BMI and greater W/H-ratio, partially explained by differences in socioeconomic indicators, indicating that socioeconomic factors should be emphasized in the management of overweight and obesity in the Myanmar population. Furthermore, new national or sub-national STEPS surveys should be conducted in Myanmar to observe the disparity in trends of the urban-rural differential.

Strengths and limitation of this study

- The study is novel in reporting associations between income, education, employment with BMI or W/H-ratio in Myanmar.
- The study analyses a large nationally representative sample including both urban and rural populations.
- The internationally recommended WHO STEPS protocol was followed.
- The findings may be generalized to Myanmar's non-institutionalized population only.
- Due to cross-sectional nature of the study, causality cannot be inferred.

INTRODUCTION

Overweight and obesity pose a major economic burden to society, and are important determinants for non-communicable diseases (NCDs), including cardiovascular diseases (CVDs), diabetes, musculoskeletal disorders, and certain types of cancers.[1] An even greater risk seems to be associated with excess abdominal obesity.[2,3] According to the World Health Organization (WHO), 39% of adults worldwide were overweight and 13% were obese in 2016.[1] In the South-east Asia region (SEAR), the estimated proportions of overweight and obese were 21.5% and 4.6%, respectively.[4,5]

Urbanization, a complex socioeconomic process that gradually transforms the society from rural into urban settlements, including migrations of people from rural to urban areas, is frequently cited as the most important factor contributing to increasing overweight and obesity, explained by increased access to unhealthy foods and a less physically active lifestyle in urban areas.[6-9] Moreover, among urban residents the socioeconomic status (SES) is likely to be higher, which in turn is associated with higher body mass index (BMI) in most low- and

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

middle-income countries (LMICs).[10,11] However, a recent publication by the NCD risk Factor Collaboration comprising evidence from 2,009 population-based studies on trends in mean BMI (from 1985 to 2017), showed that increasing BMI in rural areas has been the main contributor to the global rise in mean BMI over the last 33 years, while the contribution from rural to urban migration was small.[12]

In Myanmar, two surveys were carried out in 2004 and 2014 in the most populated and developed part of Myanmar, the Yangon region.[13,14] Findings from these studies indicate increasing trends in overweight and obesity. The overall prevalence of combined overweight and obesity in urban areas of Yangon increased from 39.8% in 2004 to 40.9% in 2014, whereas in rural areas, there was an increase in overweight and obesity prevalence from 23.0% to 31.2%.[14-16] In 2009, a nationwide survey in Myanmar found an overall prevalence of overweight and obesity of 18.7% and 6.8% respectively.[17] The most recent nationwide study (2015-2016), the Myanmar Demographic and Health Survey,[18] included 12,160 women in reproductive age, and reported a high prevalence of overweight (28.1%) and obesity (13.1%), and a significantly higher proportion of overweight and obesity with urban residency, higher economic status, and having secondary education.

Myanmar has been lagging behind neighbouring countries in terms of sociodemographic development, which could partly be due to socio-political difficulties during more than 50 years of military rule, which was gradually replaced with a democratic development in 2011.[19] In order to contribute to a better understanding of socioeconomic determinants of overweight and obesity in Myanmar, we analysed a nationally representative sample of 25-64 year old men and women from 2014,[20] with the following objectives: 1) to investigate associations of urban-rural location with BMI and waist-hip ratio (W/H-ratio); 2) to explore the association of selected socioeconomic characteristics (income, education, and employment status) with BMI and W/H-ratio; and 3) to assess whether the potential associations between urban-rural location and BMI or W/H-ratio could be explained by (i.e. mediated through) variations in socioeconomic characteristics (income, education, and employment status).

METHODS

Study design, sampling, and participants

A national cross-sectional survey of NCD risk factors in Myanmar (WHO STEPS survey) was conducted between September and December 2014 in 52 different townships in Myanmar.[20]

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

A detailed methodological description of the sampling and data collection has been published previously,[20] and is summarized below.

The STEPS survey used a multistage cluster sampling method for the selection of townships, wards and villages, households, and eligible participants at each of the selected households. The first stage of the sampling method consisted of townships, which formed the Primary Sampling Units (PSUs). Overall, 52 PSUs were selected out of the total of 330 townships, using probability proportionate to size of population in each PSU (PPS). In the second stage, six Secondary Sampling Units (SSUs) i.e., wards (from urban townships) and villages (from rural townships) were selected from each chosen PSU giving a total of 312 SSUs for the whole country. The list of households with unique identification number developed from a recent listing of households was used as the sampling frame for the third stage. From each selected SSU, 30 households were chosen using a systematic random sampling method. In this sampling method, the elements to be included in the sample are selected based on a systematic rule, using a fixed sampling interval obtained by dividing population size by required sample size.[21] In the 4th stage, recruitment of one eligible participant aged between 25 and 64 years was done from the selected household. The Kish sampling method was used to rank the eligible participants in each household in order of decreasing age, starting with males then females, and randomly selected using the automated program for Kish selection in the handheld PDA (Personal Digital Assistant).[20]

The study population comprises 25 to 64 years old men and women residing in both urban and rural areas. The following exclusion criteria were used: individuals with a mental or physical illness deemed too ill to participate, institutionalized people (Buddhist monks and nuns, armed forces, hospitalized patients, prisoners), and temporary residents (living in a locality for less than 6 months).

Altogether, a total of 8,757 men and women aged 25-64 years, residing in both urban and rural areas, participated in the survey. The response rates were 94% for the questionnaire, 91% for physical measurements, and 90% for biochemical measurements. The final sample for the current study included 8,390 adults who participated in both STEP 1 and STEP 2, excluding 87 women who were currently pregnant, and 280 individuals with missing BMI.

Data collection and measurements

The STEPS Instrument covers the following three different levels of "STEPS" of risk factor assessment. STEP (1) questionnaire survey; STEP (2) physical measurement; STEP (3)

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

biochemical measurements. In the present study, we included variables from STEP 1 and STEP 2.

Eighteen trained teams (containing six members in each) collected the data. The English WHO STEPS Instrument (core and expanded) questionnaire version 3.0 was translated into the Myanmar version for the survey. A five-day training was conducted at University of Medicine (2), Yangon. The data collection teams conducted a pilot survey of all steps of data collection in the wards of North Okkalapa Township, Yangon on the fifth day of the training. Data for STEP 1 and 2 were collected at the survey participant's household during the first visit. Face to face interviews were conducted to collect information on sociodemographic factors and behavioural risk factors.

A Seca 217 portable stadiometer was used to measure body height without footwear and any hat or hair ties. Findings were recorded in centimetre (cm) to the nearest 0.1 cm. Body weight was measured with a pre-calibrated portable Seca Digital Floor Scale with High Capacity (Model 813) to the nearest 0.1 kilogram (kg). During weighing, the participants were requested to wear light clothing without footwear.[20] Waist and hip circumference measurement were done in a private area using a Seca 201 measuring tape. The waist circumference was measured in centimetres over light clothing at the midpoint between the last palpable rib and the top of the iliac crest. The hip circumference measurement was taken by placing the tape horizontally at maximum circumference over the buttocks. Measures were taken to the nearest 0.1 cm.[20]

Variables

BMI and W/H-ratio

BMI is the most widely used measure of general overweight and obesity[22,23] whereas W/H-ratio measures abdominal or central obesity and is a better predictor of CVD risk.[24,25] Therefore, we have included both measures in our study.

BMI was calculated as weight in kilograms divided by the height in meters squared. Cut-off points for BMI were defined based on WHO recommendations: BMI of 25.0-29.9 kg/m^2 was considered overweight whereas having a BMI of 30 kg/m^2 or higher was considered obese.[26] For comparison, BMI was also classified according to Asian specific cut-off points: BMI of 23.0-27.4 kg/m^2 (overweight) and BMI of ≥27.5 kg/m^2 (obesity).[27] W/H-ratio was defined as

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

the ratio of the circumference of the waist to that of the hip. Central obesity was defined as a W/H-ratio above 0.90 for men and above 0.85 for women.[28]

Urban-rural location

According to the ward or village tract administration law 2012, a ward is defined as an urban unit and a village is defined as a rural unit.[29] Hence, the same definition was used to define urban and rural areas in the current study.

Sociodemographic factors

Age was defined as completed years of age. Education level was defined by both total number of years spent in school and by highest educational level obtained. It was categorized into seven categories: no formal schooling, less than primary school, primary school completed, secondary school completed, high school completed, college/university completed, and post graduate degree. In multivariable analyses, education level was collapsed into three groups: low level, medium level, and high level education. Low level was defined as education below primary school completion; Medium level: completion of primary and secondary school; High level: completion of high school, university, or post-graduate education.

Occupation was defined according to the main work status over the past 12 months and categorized as government employee, non-government employee, self-employed, nonpaid, student, homemaker, retired, unemployed (able to work), and unemployed (unable to work). In multivariable analyses, employment status was collapsed into two groups: employed and unemployed. Employed group included people who were government, non-government employee, self-employed, and homemakers. Nonpaid, student, retired, unemployed (both able and unable to work) were categorized in the unemployed group.

Daily personal income was calculated from the entire household income divided by the total number of household members excluding the household members under 18 years of age. Income was converted from Myanmar Kyats into United States Dollars (USD). Exchange rate of 1 USD was 970 Myanmar Kyats as of 1st September 2014.[30] Cut-off values for poverty line was used as defined by World Bank: 1.90 USD/day.[31]

Statistical methods

Statistical analysis was performed in the Statistical Package for Social Sciences (SPSS) version 26.0 (Armonk, NY: IBM Corp). The characteristics of the study participants were presented in the form of frequency (N) and percentages (%) for categorical variables, and

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

mean with standard deviation (SD) for continuous variables. Differences in categorical variables were tested using the chi-square test or Fischer's exact test, whereas differences in the mean for continuous variables were tested using two tailed t-tests. Linear regression was used to estimate the association between the urban-rural location and socioeconomic factors variables (income, education, and employment status) with continuous outcomes (BMI and W/H-ratio), obtaining betas (β) with 95% confidence intervals (CIs). Potential multi-collinearity between variables was assessed with variance inflation factors (VIF). A VIF value greater than 10 was considered an indication of multi-collinearity; however, no significant multi-collinearity was observed. We tested for heteroscedasticity by using robust estimator and there were only minor changes in the estimates, which indicates there was no problem of heteroscedasticity. For all statistical analysis, the two-tailed significance level was set to 0.05.

Based on previous literature and construction of Directed Acyclic Graphs (DAGs),[32] we identified potential confounders and mediators (See Supplementary Figure 1). For objective 1, for associations of urban-rural location with BMI and W/H-ratio, age and gender were identified as confounders (See Supplementary Figure 1:A), and they were therefore included in multivariable models to obtain the total effect of urban-rural location on BMI and W/H-ratio.

For the second objective, for the association of socioeconomic characteristics (income, education, and employment status) with BMI and W/H-ratio, we constructed three different DAGs (See Supplementary Figure 1: B, C, and D) for confounder adjustments.

To study the statistical effect of the SES variables (income, education, and employment status) together, the variables were assigned SES values (0/1) and a composite SES score was calculated. For this, education level was collapsed into two groups: high education (defined as high school completion and above) and low education (defined as education below high school completion). Participants with earnings above poverty line, high education attainment (binary) and employment were assigned SES value=1 and the lower category was assigned SES value=0. Total SES score for each participant was obtained by summing up values and total SES score was further categorized into three SES groups: low (total SES score=0), medium (total SES score=1 and 2), and high (total SES score=3) (See Supplementary Table 1). We assessed the association between SES groups and BMI or W/H-ratio with adjustment for confounders (age, gender, and urban-rural location).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

The third objective exploited whether the potential association between urban-rural location and BMI or W/H-ratio was mediated through socioeconomic characteristics. We included the potential mediators income, education, employment, and the composite SES score variable one by one in order to obtain the direct effect of urban-rural location on BMI and W/H-ratio, and the proportion mediated through each of the socioeconomic factors.

Ethics

Informed consent was obtained from the study participants; all information was handled with strict confidentiality. The participants were informed about the purpose and procedures of the study. Ethical approvals were obtained from the Norwegian Regional Committees for Medical and Health Research Ethics (REK) (Reference no. REK 2016/379) and the Ethical Review Committee of Department of Medical Research (Myanmar).

Patient and Public Involvement

No patients or public were involved in setting the research question or the outcome measures, nor were they involved in the design and implementation of the study.

RESULTS

The mean age of the study participants was 44.9 years, with rural participants being slightly younger than urban participants (Table 1). Nearly three quarters of the participants (68.6%), were from rural areas (not shown in tables). The mean length of education was 7.7 years in urban areas and 4.8 years in rural areas. In urban areas, the majority had primary education only (31.9%), 6.6% had no formal schooling, and 42.7% were self-employed (Table 1). In the rural areas, 39.6% had primary education only, 18.8% had no formal schooling, and 68.6% were self-employed. The proportion living on <1.9 USD/day was 4.9% in urban areas and 17.5% in rural areas. The prevalence of overweight (WHO standard cut-off: BMI 25-29.9) and obesity (WHO standard cut-off: BMI ≥30) was 20.4% and 6.5% respectively (not shown in tables). The prevalence of overweight (Asian cut-off: BMI 23-27.4 kg/m²) was higher in women in urban areas (35.4%) in comparison to women in rural areas (28.4%) (Figure 1). Similarly, the prevalence of obesity (Asian cut-off: BMI ≥27.5 kg/m²) was higher in urban women (27.9%), compared to rural women (12.7%) (Figure 1).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 1: Characteristics of 25-64 years old residents in Myanmar, by gender and urban-rural location

Variables	Total (n=8390) N (%)	Urban			Rural		
		Male (n=830) N (%)	Female (n=1798) N (%)	Total (n=2628) N (%)	Male (n=2117) N (%)	Female (n=3645) N (%)	Total (n=5762) N (%)
Age (Mean years ± SD)	44.9 ±10.7	47.0 ± 10.8	46.0 ± 10.3	46.4 ± 10.4	44.1 ± 10.9	44.4 ± 10.7	44.2 ± 10.8
Age group (years)							
25-34	1689 (20.1)	139 (16.7)	272 (15.1)	411 (15.6)	488 (23.1)	790 (21.7)	1278 (22.2)
35-44	2315 (27.6)	178 (21.4)	511 (28.4)	689 (26.2)	577 (27.3)	1049 (28.8)	1626 (28.2)
45-54	2412 (28.7)	269 (32.4)	558 (31.0)	827 (31.5)	580 (27.4)	1005 (27.6)	1585 (27.5)
55-64	1974 (23.5)	244 (29.4)	457 (25.4)	701 (26.7)	472 (22.3)	801 (22.0)	1273 (22.1)
Education (Mean Years ± SD)	5.7 ± 4.1	8.4 ± 3.9	7.5 ± 4.2	7.7 ± 4.1	5.3 ± 3.4	4.5 ± 3.8	4.8 ± 3.7
Education level							
No formal School	1256 (15.0)	51 (6.1)	122 (6.8)	173 (6.6)	370 (17.5)	713 (19.6)	1083 (18.8)
Less than Primary School	1912 (22.8)	66 (8.0)	293 (16.3)	359 (13.7)	434 (20.5)	1119 (30.7)	1553 (27.0)
Primary School completed	3121 (37.2)	265 (31.9)	574 (31.9)	839 (31.9)	933 (44.1)	1349 (37.0)	2282 (39.6)
Secondary School completed	1044 (12.4)	214 (25.8)	349 (19.4)	563 (21.4)	239 (11.3)	242 (6.6)	481 (8.3)
High School completed	524 (6.2)	117 (14.1)	203 (11.3)	320 (12.2)	86 (4.1)	118 (3.2)	204 (3.5)
College/university completed	499 (5.9)	110 (13.3)	241 (13.4)	351 (13.4)	53 (2.5)	95 (2.6)	148 (2.6)
Post graduate degree	34 (0.4)	7 (0.8)	16 (0.9)	23 (0.9)	2 (0.1)	9 (0.2)	11 (0.2)
Employment Status							
Government Employee	359 (4.3)	81 (9.8)	120 (6.7)	201 (7.6)	59 (2.8)	99 (2.7)	158 (2.7)
Non-Government Employee	560 (6.7)	88 (10.6)	78 (4.3)	166 (6.3)	182 (8.6)	212 (5.8)	394 (6.8)
Self-employed	5074 (60.5)	495 (59.6)	628 (34.9)	1123 (42.7)	1667 (78.7)	2284 (62.7)	3951 (68.6)
Nonpaid	210 (2.5)	36 (4.3)	28 (1.6)	64 (2.4)	59 (2.8)	87 (2.4)	146 (2.5)
Student	8 (0.1)	3 (0.4)	0 (0.0)	3 (0.1)	2 (0.1)	3 (0.1)	5 (0.1)
Homemaker	1559 (18.6)	6 (0.7)	811 (45.1)	817 (31.1)	7 (0.3)	735 (20.2)	742 (12.9)
Retired	174 (2.1)	61 (7.3)	38 (2.1)	99 (3.8)	44 (2.1)	31 (0.9)	75 (1.3)
Unemployed (able to work)	298 (3.6)	47 (5.7)	70 (3.9)	117 (4.5)	59 (2.8)	122 (3.3)	181 (3.1)
Unemployed (unable to work)	144 (1.7)	13 (1.6)	24 (1.3)	37 (1.4)	38 (1.8)	69 (1.9)	107 (1.9)
Refused to answer	4 (0.0)	0 (0.0)	1 (0.1)	1 (0.0)	0 (0.0)	3 (0.1)	3 (0.1)
Daily Income USD/day (n=7408)							
< 1.9	992 (13.4)	38 (5.0)	79 (4.8)	117 (4.9)	316 (17.0)	559 (17.8)	875 (17.5)
≥ 1.9	6416 (86.6)	727 (95.0)	1559 (95.2)	2286 (95.1)	1540 (83.0)	2590 (82.2)	4130 (82.5)

SD, Standard deviation; USD, United States Dollar

Objective 1: Association between urban-rural location and BMI or W/H-ratio

The mean BMI was higher among urban than rural residents by 2.49 kg/m^2 (β=2.49 kg/m^2; 95% CI 2.28, 2.70; p<0.001) when adjusting for age and gender (Table 2). Similarly, W/H-ratio was 0.015 greater in participants living in an urban area (β=0.015; 95% CI 0.011, 0.020; p<0.001) compared to rural, when adjusting for age and gender (Table 3).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 2: Level of associations between urban-rural location and socioeconomic factors with BMI (kg/m^2) among 25-64 years old Myanmar residents

Variables	Category	Mean BMI ± SD	Crude estimates β (95% CI)	Adjusted estimates β (95% CI)
Location	Rural	21.9 ± 4.1	Ref.	Ref.
	Urban	24.5 ± 5.5	2.62** (2.40-2.83)	2.49[a]** (2.28-2.70)
Income[1]	< 1.9 USD/day	21.5 ± 4.1	Ref	Ref.
	≥ 1.9 USD/day	22.9 ± 4.8	1.44** (1.12-1.76)	0.74[b]** (0.43-1.05)
Education	Low	21.9 ± 4.2	Ref.	Ref.
	Medium	22.9 ± 4.8	0.98** (0.76-1.21)	0.88[c]**(0.66-1.10)
	High	24.2 ± 5.7	2.28** (1.95-2.61)	1.48[c]**(1.13-1.82)
Employment[2]	Employed	22.7 ± 4.7	Ref.	Ref.
	Unemployed	22.7 ± 5.1	0.04 (-0.30-0.38)	-0.06[d] (-0.39-0.26)
SES	Low	21.4 ± 4.0	Ref.	Ref.
	Medium	22.9 ± 4.8	1.42** (1.09-1.76)	0.81[c]** (0.49-1.14)
	High	24.1 ± 4.8	2.65** (1.54-3.77)	1.28[c]* (0.21-2.36)

**p<0.001, *p<0.05, [1]982 participants with missing value for income excluded in crude and adjusted estimates; [2]4 participants with missing employment status excluded in crude and adjusted estimates; BMI, Body mass index; CI, Confidence interval; Ref., reference category; SD, Standard Deviation; SES, Socioeconomic Status; USD, United States Dollar

a) adjusted for age and gender
b) adjusted for age, gender, urban-rural location, education, and employment
c) adjusted for age, gender, and urban-rural location
d) adjusted for age, gender, urban-rural location, and education

For Peer Review Only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 3: Level of associations between urban-rural location and socioeconomic factors with W/H-ratio among 25-64 years old Myanmar residents

Variables	Category	Mean W/H-ratio ± SD	Crude estimates β (95% CI)	Adjusted estimates β (95% CI)
Location	Rural	0.84 ± 0.09	Ref.	Ref.
	Urban	0.86 ± 0.11	0.016*** (0.012-0.021)	0.015[a]*** (0.011-0.020)
Income[1]	< 1.9 USD/day	0.84 ± 0.07	Ref.	Ref.
	≥ 1.9 USD/day	0.85 ± 0.09	0.010* (0.004-0.016)	0.007*[b] (0.001-0.013)
Education	Low	0.84 ±0.08	Ref.	Ref.
	Medium	0.85 ± 0.10	0.005* (0.00-0.009)	0.002[c] (-0.003-0.006)
	High	0.85 ± 0.11	0.006 (-0.001-0.013)	0.002[c] (-0.006-0.009)
Employment[2]	Employed	0.85 ± 0.09	Ref.	Ref.
	Unemployed	0.86 ± 0.10	0.018*** (0.011-0.025)	0.006[d] (-0.001-0.014)
SES	Low	0.84 ± 0.07	Ref.	Ref.
	Medium	0.85 ± 0.09	0.012** (0.005-0.018)	0.008[c]* (0.001-0.014)
	High	0.88 ± 0.19	0.044*** (0.022-0.066)	0.019[c] (-0.002-0.040)

***p<0.001, **p<0.01, *p<0.05; 7 participants with missing W/H-ratio excluded in crude and adjusted estimates; [1]982 participants with missing value for income excluded in crude and adjusted estimates; [2]4 participants with missing employment status excluded in all models; CI, Confidence interval; Ref., Reference category; SD, Standard Deviation; SES, Socioeconomic Status; USD, United States Dollar; W/H-ratio, Waist-hip ratio

a) adjusted for age and gender
b) adjusted for age, gender, urban-rural location, education, and employment
c) adjusted for age, gender, and urban-rural location
d) adjusted for age, gender, urban-rural location, and education

Objective 2: Association between socioeconomic factors (income, education, and employment status) and BMI or W/H-ratio

The socioeconomic factors income and education but not employment, were associated with BMI (Table 2). Mean BMI was 0.74 kg/m^2 higher among individuals living above compared to those living below poverty line (β=0.74 kg/m^2; 95% CI 0.43, 1.05; p<0.001), when adjusting for age, gender, urban-rural location, education, and employment. BMI was 0.88 kg/m^2 higher among individuals with medium education and 1.48 kg/m^2 higher among individuals with high education (Medium education vs. low: β=0.88 kg/m^2; 95% CI 0.66, 1.10; p<0.001 and High education vs. low: β=1.48 kg/m^2; 95% CI 1.13, 1.82; p<0.001). Moreover, BMI was higher in medium and high SES groups (Medium SES vs. low: β=0.81 kg/m^2; 95% CI 0.49, 1.14; p<0.001 and High SES vs. low: β=1.28 kg/m^2; 95% CI 0.21, 2.36; p<0.05) (Table 2).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

There was an association between the socioeconomic indicators income and employment but not education, with W/H-ratio (Table 3). Among those with earnings ≥ 1.9 USD/day, the W/H-ratio was 0.007 greater (β=0.007; 95% CI 0.001, 0.013; p<0.05) than those earning <1.9 USD/day. Unemployed participants had greater W/H-ratio than employed participants in the crude estimates, but the association was attenuated in the adjusted estimates (Table 3). In addition, medium and high SES groups had greater W/H-ratios than the low SES group in the crude estimates (Table 3).

When combining income, education, and employment status into a composite SES score, the prevalence of overweight (BMI 25-29.9) and obesity (BMI ≥30) increased with increasing SES score for both genders (Figure 2). Similarly, the prevalence of central obesity (W/H-ratio >0.9 for men and W/H-ratio >0.85 for women) increased with increasing SES score in men, whereas in women the prevalence was almost similar in medium and high SES group (Figure 2).

Objective 3: Association between urban-rural location and BMI or W/H-ratio mediated by socioeconomic factors (income, education, and employment status)

Table 4 shows the adjusted total- and direct effects of urban-rural location on BMI and W/H-ratio. There was change in the estimates for BMI after adjusting for income (Table 4), which gave an indirect effect of urban-rural location through income: 2.50-2.08=0.42 kg/m^2, and a mediated proportion of 17% (0.42/2.50= 0.17). Similarly, adjusting for education gave an indirect effect of urban-rural location through education of 0.40 kg/m^2, and a mediated proportion of 16%. When adjusting for employment, corresponding figures were 0.40 kg/m^2 and mediated proportion of 16%. Adjustment for the composite SES score gave an indirect effect of urban-rural location through composite SES score of 0.22 kg/m^2, and a mediated proportion of 9%. There was change in the estimates for W/H-ratio after adjusting for income, which gave an indirect effect of urban-rural location through income of 0.002, and a mediated proportion of 12%. Similarly, adjusting for education gave an indirect effect of urban-rural location through education of 0.001, and a mediated proportion of 6%, and when adjusting for employment: 0.001 (mediated proportion of 6%) (Table 4). Furthermore, adjusting for composite SES score gave an indirect effect of urban-rural location through composite SES score of 0.002, and a mediated proportion of 12%.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 4: Total- versus direct effect of urban-rural location on BMI and W/H-ratio (objective 3), among 25-64 years old Myanmar residents

Location	BMI					W/H-ratio[1]				
	Total effect (a)	Direct effect through composite SES score (b)	Direct effect through income (c)	Direct effect through education (d)	Direct effect through employment (e)	Total effect (a)	Direct effect through composite SES score (b)	Direct effect through income (c)	Direct effect through education (d)	Direct effect through employment (e)
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Rural	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Urban	2.50* (2.27-2.72)	2.28* (2.05-2.51)	2.08* (1.85-2.32)	2.10* (1.86-2.33)	2.10* (1.86-2.34)	0.017* (0.012-0.021)	0.015* 0.010-0.019)	0.015* (0.010-0.020)	0.016* (0.011-0.021)	0.016* (0.011-0.021)

*p<0.001; 982 participants with missing value for income and 4 participants with missing employment status excluded in all models for comparison; [1]7 participants with missing W/H-ratio excluded. Exclusion of missing values gives slightly different total estimates from Table 1; BMI, Body mass index; CI, Confidence interval; Ref., Reference category; W/H-ratio, Waist-hip ratio.

(a) adjusted for age and gender (confounders)
(b) adjusted for age, gender, and composite SES score
(c) adjusted for age, gender, education, employment, and income
(d) adjusted for age, gender, and education
(e) adjusted for age, gender, education, and employment

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

DISCUSSION

We found the prevalence of overweight and obesity, including central obesity to be higher in urban areas in Myanmar compared to rural areas. There was a consistent positive adjusted association between SES and BMI, while the association between SES and W/H-ratio was less consistent. Out of the socioeconomic factors, education was found to have the strongest association with BMI (general overweight and obesity), whereas income had the strongest association with W/H-ratio (central obesity). The association between urban-rural location and BMI was found to be partially mediated by the SES indicators with income, education, and employment status contributing almost equally. In the association between urban-rural location and W/H-ratio, the highest proportion was mediated by income.

A previous study from Myanmar report an 28% overall prevalence of overweight and 13% prevalence of obesity, which is higher than in the current study.[18] The higher prevalence could be due to the inclusion of adult women only and the use of Asian specific BMI cut-offs. However, our findings of a higher BMI and greater W/H-ratio in urban compared to rural areas corroborates previous studies conducted in Myanmar.[14-16] Further, it is also consistent with findings of studies carried out in other countries of the SEAR,[33-37] and of a global study conducted in 2010, which reported that the overall prevalence of overweight and obesity was higher in urban areas compared to their rural counterpart.[38] In contrast to our findings, a recent study composed of data from 2,009 population-based studies showed that BMI is rising at the same proportion or faster in rural areas compared to urban in LMICs except women in sub-Saharan Africa.[12] Similar study reported that mean BMI was generally higher in rural compared to urban men in South Asia while BMI increased at a similar rate in rural and urban men in East and Southeast Asia. The study also reported that changes in rural areas are driving the increase in mean BMI globally.[12] The authors suggested that improved road infrastructure and transportation has led to an increased access to high calorie foods, mechanized farming equipment, in addition to shifts from manual labour to more sedentary work,[12] i.e. an *urbanization* of the rural areas.

There is a paucity of studies investigating the association of all three socioeconomic factors (income, education, and employment status) with BMI and W/H-ratio in both male and female populations in Myanmar, hence the current study is the first to report these novel findings. In our study, higher income and higher education was associated with increased BMI, which is in accordance with a systematic review of studies investigating the association between SES and obesity in LMICs.[6] Additionally, a wide scale and much larger study

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

focusing on the association between socioeconomic factors and weight status across 53 countries in 2010 found that the prevalence of obesity was highest in the richest quintile of the participants.[38] Another study from 70 low- middle- and high-income countries found a strong, positive association between individual income and obesity.[39] Furthermore, our result correspond with evidence from a systematic review of studies[40] and a study involving non-pregnant women from 37 developing countries,[41] which observed positive associations between education and obesity in low income countries. Several studies from Bangladesh, Nepal, India, and Sri Lanka also supports this.[34-37 ,42] Based on the Myanmar Demographic and Health Survey 2015-2016, 28% of Myanmar's population is living in urban areas.[43] However, Myanmar is still considered to be in the early phase of the demographic transition. Much of the current development is happening in the cities,[44] which indicates that many of the rural areas in Myanmar are not yet influenced by the ongoing urbanization of the country. The economic growth in Myanmar, has reduced the proportion of people living below the poverty line (a reduction in poverty from 48% to 25% between 2005 and 2017).[45] Because of the continuing economic development of the country, there may be an increase in sedentary lifestyle, higher income and more availability of processed food in urban areas, culminating to an increased burden of overweight and obesity as diet and physical activity are its major risk factors.[46] As rice is the main staple food of Myanmar, people generally consume high amounts of carbohydrates, which in turn is associated with high BMI.[47 ,48] In urban Myanmar residents, high intakes of fat and protein have been reported.[49] Moreover, the consumption of fast food and high caloric soft drinks and alcohol is higher in urban inhabitants compared to rural dwellers.[48] Additionally, in a study conducted in the Yangon region of Myanmar, the prevalence of physical inactivity was low, and no difference was observed between urban and rural residents.[14] However, most of the physical activity was linked to work, and high energy expenditure in the workplace was higher among rural- than among urban residents.[14] There may also be cultural determinants of BMI, as a larger body size often symbolizes high status and good health in Myanmar, which means that people with a high SES may even prefer a larger body size.[48] In LMICs, in general, high SES individuals have been found to have a higher energy intake, reflecting a greater access to both inexpensive energy dense foods and expensive higher-quality food items.[50] Rural populations in high income countries have excess BMI compared to urban populations.[12 ,51-54] As compared with urban populations in high income countries, rural populations often have lower income and education, limited access to healthy and fresh food choices, and they have less sports facilities and recreational activities, possibly explaining the higher rural BMI.[55 ,56] In high-income countries, the obesity

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

risk is often higher for individuals in low SES groups compared to high SES groups,[57-60] as those in the high SES groups are more likely to consume healthy foods, such as whole grains, lean meats, fish, low-fat dairy products, and fruit and vegetables.[61,62] They also more often have several physical activity opportunities and more knowledge about healthy choices.[63]

We found that the association between urban-rural location and BMI was only partially mediated by socioeconomic factors such as income, education, and employment status. Our finding is in line with a study conducted in women in reproductive age in 38 LMICs, reporting that much, but not all of the urban-rural differences in BMI is driven by the socioeconomic composition (measured by household wealth).[10] This indicates that other important factors could explain the urban-rural BMI difference in Myanmar, including differences in non-leisure physical activity opportunities, less energy intensive occupation in urban areas, differences in neighbourhood environment, better transportation facilities, and better access to high ultra-processed and packaged food in urban areas.[64-66] Future prospective studies may be able to provide information that can explain this association. Road infrastructure and transportation facility is not well developed in the rural part of Myanmar.[67] As many as 40% of villages are without road access and additional 30% villages have access only part of the season, requiring the rural population to travel long distances to access markets and basic services leading to high energy expenditure.[67]

Strengths and limitations

The findings of this study add to the current research related to large population analyses of overweight and obesity. One of the major strengths of this study is the analyses of a large nationally representative sample of 8,390 participants that constitutes both urban and rural populations in Myanmar. In addition, the internationally recommended WHO STEPS protocol was diligently followed, and the outcome measures were assessed using standardised procedures. The response rate was high, at 91%. Moreover, we used W/H-ratio as the measure of central obesity in addition to BMI. There are, however, some limitations. The study was cross-sectional which means that causality cannot be determined, e.g. the temporal relationships between socioeconomic factors and obesity cannot be inferred; evidence suggests the association is likely to be bidirectional.[68,69] Furthermore, 982 participants refused to provide information on their income were excluded. These have a higher likelihood of belonging to lower income groups as most of them were unemployed, which may have given an underestimation of socioeconomic differences in BMI. At the analysis stage, 280 participants were excluded from the study due to missing BMI values. As association

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

measures are robust, it is unlikely that this exclusion has substantially contributed to selection bias.[70] Institutionalized people like monks, nuns and soldiers were excluded from the sampling frame as their lifestyle may differ from most of the general population, which means that the findings can only be generalized to Myanmar's non-institutionalized population.

CONCLUSION

The current study examines the relation between urban-rural location and socioeconomic factors with general- and central overweight and obesity in adult residents in Myanmar. Taken together, we found an independent and positive association between urban-rural location and BMI, partially, but not fully explained by socioeconomic factors. Mean BMI was higher among urban dwellers, individuals living above poverty line and in those with higher attained education level.

Knowledge about the significant roles played by location of living (urban and rural) and socioeconomic factors in relation to overweight and obesity can contribute to the development of well-targeted policies. Currently, mainly behavioural factors have been emphasised in prevention strategies for the management of overweight and obesity in Myanmar. Our findings imply that there should also be a focus on socioeconomic factors in order to reduce the burden of overweight and obesity. Moreover, updated national or sub-national STEPS surveys should be conducted to continue monitoring the trends and urban-rural differences in overweight and obesity.

Footnotes

Contributors: RT contributed to the design of the article, statistical analysis, interpreted the data and drafted the manuscript. EB, CD, and WPA contributed to the conception and design of the study and the article, interpretation of the data and the content of the article. All authors contributed revising the manuscript for important intellectual content and approved the final version to be published.

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Acknowledgments: The authors acknowledge Professor, Tint Swe Latt, the principle investigator for the 2014 STEPS study. The authors are grateful to the World Health Organization, the University of Oslo and the Norwegian agency for Development Cooperation (Norad) for the project "Health and Sustainable development in Myanmar–

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Competence Building in Public Health and Medical Research and Education (MY-NORTH) Project: MMY-13/0049, NORHED, UiO:211782. We would like to thank all the participants, medical doctors from the Myanmar Medical Association, township medical officers, basic health staffs and local administrative authorities from all the surveyed areas.

Competing interests: None declared

Patient consent: Obtained

Data availability statement: No additional data are available

REFERENCES

1. World Health Organization. Obesity and Overweight WHO; 2020 [Available from: https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight (accessed 18th May 2020).

2. Klein S, Allison DB, Heymsfield SB, et al. Waist Circumference and Cardiometabolic Risk: a Consensus Statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Obesity (Silver Spring, Md)* 2007;15(5):1061-7. doi: 10.1038/oby.2007.632 [published Online First: 2007/05/15].

3. Amato MC, Guarnotta V, Giordano C. Body composition assessment for the definition of cardiometabolic risk. *J Endocrinol Invest* 2013;36(7):537-43. doi: 10.3275/8943 [published Online First: 2013/04/25].

4. World Health Organization. Global Health Observatory Data Repository (South-East Asia Region): Prevalence of overweight among adults, BMI ≥ 25, crude Estimates by WHO Region 2016 [updated September 27, 2017]. Available from: http://apps.who.int/gho/data/view.main-searo.BMI25CREGv?lang=en (accessed 18th May 2020).

5. World Health Organization. Global Health Observatory Data Repository (South-East Asia Region): Prevalence of obesity among adults, BMI ≥ 30, crude Estimates by WHO region 2016 [updated September 22, 2017]. Available from: http://apps.who.int/gho/data/view.main-searo.BMI30CREGv?lang=en (accessed 18th May 2020).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

6. Dinsa GD, Goryakin Y, Fumagalli E, et al. Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev* 2012;13(11):1067-79. doi: 10.1111/j.1467-789X.2012.01017.x [published Online First: 2012/07/07].

7. Ford ND, Patel SA, Narayan KM. Obesity in Low- and Middle-Income Countries: Burden, Drivers, and Emerging Challenges. *Annu Rev Public Health* 2017;38:145-64. doi: 10.1146/annurev-publhealth-031816-044604 [published Online First: 2017/01/10].

8. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev* 2012;70(1):3-21. doi: 10.1111/j.1753-4887.2011.00456.x [published Online First: 2012/01/10].

9. United Nations. 2018 revision of world urbanization prospects: United Nations Department of Economic and Social Affairs, 2018.

10. Neuman M, Kawachi I, Gortmaker S, et al. Urban-rural differences in BMI in low- and middle-income countries: the role of socioeconomic status. *Am J Clin Nutr* 2013;97(2):428-36. doi: 10.3945/ajcn.112.045997 [published Online First: 2013/01/02].

11. McLaren L. Socioeconomic status and obesity. *Epidemiol Rev* 2007;29(1):29-48. doi: 10.1093/epirev/mxm001 [published Online First: 2007/05/05].

12. Bixby H, Bentham J, Zhou B, et al. Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature* 2019;569(7755):260-64. doi: 10.1038/s41586-019-1171-x [published Online First: 2019/05/10].

13. World Health Organization. Myanmar (Yangon Division) STEPS Survey 2004 Fact Sheet 2004 [Available from: https://www.who.int/ncds/surveillance/steps/Myanmar_2004_FactSheet.pdf (accessed 23rd April 2019).

14. Htet AS, Bjertness MB, Sherpa LY, et al. Urban-rural differences in the prevalence of non-communicable diseases risk factors among 25-74 years old citizens in Yangon Region, Myanmar: a cross sectional study. *BMC Public Health* 2016;16(1):1225. doi: 10.1186/s12889-016-3882-3 [published Online First: 2016/12/07].

15. World Health Organization. WHO STEPwise approach to NCD surveillance 2004, Myanmar Disagregation of Urban annd rural data (urban). Available from: https://www.who.int/ncds/surveillance/steps/MyanmarSTEPSReport2004URBAN.pdf (accessed 23rd April 2019).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

16. World Health Organization. WHO STEPwise approach to NCD surveillance 2004, Myanmar Disagregation of Urban annd rural data (rural). Available from: https://www.who.int/ncds/surveillance/steps/MyanmarSTEPSReport2004RURAL.pdf (accessed 23rd April 2019).

17. World Health Organization. Noncommunicable Disease Risk Factor Survey Myanmar 2009. 2011. [Available from: https://www.who.int/ncds/surveillance/steps/2009_STEPS_Survey_Myanmar.pdf (accessed 23rd April 2019).

18. Hong SA, Peltzer K, Lwin KT, et al. The prevalence of underweight, overweight and obesity and their related socio-demographic and lifestyle factors among adult women in Myanmar, 2015-16. *PLoS One* 2018;13(3):e0194454. doi: 10.1371/journal.pone.0194454 [published Online First: 2018/03/17].

19. Stokke K, Vakulchuk R, Øverland I. Myanmar: A political economy analysis. 2018.

20. World Health Organization. Report on National Survey of Diabetes Mellitus and Risk Factors for Non-Communicable Diseases in Myanmar (2014). 2018. Available from: www.who.int/ncds/surveillance/steps/Myanmar_2014_STEPS_Report.pdf (accessed 23rd April 2019).

21. Elfil M, Negida A. Sampling methods in Clinical Research; an Educational Review. *Emerg (Tehran)* 2017;5(1):e52-e52. [published Online First: 2017/01/14].

22. Colditz GA, Willett WC, Rotnitzky A, et al. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med* 1995;122(7):481-6. doi: 10.7326/0003-4819-122-7-199504010-00001 [published Online First: 1995/04/01].

23. Pajak A, Kuulasmaa K, Tuomilehto J, et al. Geographical variation in the major risk factors of coronary heart disease in men and women aged 35-64 years : the WHO MONICA Project / prepared by Andrzej Pajak ... [et al.]. *World health statistics quarterly* 1988;41(3/4):115-140. https://apps.who.int/iris/handle/10665/51270

24. Bigaard J, Frederiksen K, Tjonneland A, et al. Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes (Lond)* 2005;29(7):778-84. doi: 10.1038/sj.ijo.0802976 [published Online First: 2005/05/27].

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

25. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. *Am J Clin Nutr* 2004;79(3):379-84. doi: 10.1093/ajcn/79.3.379 [published Online First: 2004/02/27].

26. Lim JU, Lee JH, Kim JS, et al. Comparison of World Health Organization and Asia-Pacific body mass index classifications in COPD patients. *Int J Chron Obstruct Pulmon Dis* 2017;12:2465-75. doi: 10.2147/COPD.S141295

27. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet (London, England)* 2004;363(9403):157.

28. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008. 2011.

29. The Republic of Union of Myanmar MoHA. The ward or village tract administration law 2012 [Available from: http://www.myanmar-law-library.org/law-library/laws-and-regulations/laws/myanmar-laws-1988-until-now/union-solidarity-and-development-party-laws-2012-2016/myanmar-laws-2012/pyidaungsu-hluttaw-law-no-1-2012-ward-or-village-administration-law-burmese.html (accessed 20th October 2019).

30. Central Bank of Myanmar. Reference exchange rate [Available from: https://forex.cbm.gov.mm/index.php/fxrate (accessed 20th August 2019).

31. Ferreira FH, Chen S, Dabalen A, et al. A global count of the extreme poor in 2012: data issues, methodology and initial results: The World Bank 2015.

32. Textor J, van der Zander B, Gilthorpe MS, et al. Robust causal inference using directed acyclic graphs: the R package 'dagitty'. *Int J Epidemiol* 2016;45(6):1887-94. doi: 10.1093/ije/dyw341 [published Online First: 2017/01/17].

33. Angkurawaranon C, Jiraporncharoen W, Chenthanakij B, et al. Urban environments and obesity in southeast Asia: a systematic review, meta-analysis and meta-regression. *PLoS One* 2014;9(11):e113547. doi: 10.1371/journal.pone.0113547 [published Online First: 2014/11/27].

34. Biswas T, Garnett SP, Pervin S, et al. The prevalence of underweight, overweight and obesity in Bangladeshi adults: Data from a national survey. *PLoS One* 2017;12(5):e0177395. doi: 10.1371/journal.pone.0177395

For peer review only

35. Siddiqui ST, Kandala N-B, Stranges S. Urbanisation and geographic variation of overweight and obesity in India: a cross-sectional analysis of the Indian Demographic Health Survey 2005–2006. *Int J Public Health* 2015;60(6):717-26.

36. Biswas T, Townsend N, Islam MS, et al. Association between socioeconomic status and prevalence of non-communicable diseases risk factors and comorbidities in Bangladesh: findings from a nationwide cross-sectional survey. *BMJ Open* 2019;9(3):e025538. doi: 10.1136/bmjopen-2018-025538

37. De Silva AP, De Silva SH, Haniffa R, et al. A cross sectional survey on social, cultural and economic determinants of obesity in a low middle income setting. *Int J Equity Health* 2015;14(1):6. doi: 10.1186/s12939-015-0140-8 [published Online First: 2015/01/18].

38. Moore S, Hall JN, Harper S, et al. Global and national socioeconomic disparities in obesity, overweight, and underweight status. *J Obes* 2010;2010 doi: 10.1155/2010/514674 [published Online First: 2010/08/20].

39. Masood M, Reidpath DD. Effect of national wealth on BMI: An analysis of 206,266 individuals in 70 low-, middle- and high-income countries. *PLoS One* 2017;12(6):e0178928. doi: 10.1371/journal.pone.0178928 [published Online First: 2017/07/01].

40. Cohen AK, Rai M, Rehkopf DH, et al. Educational attainment and obesity: a systematic review. *Obes Rev* 2013;14(12):989-1005. doi: 10.1111/obr.12062 [published Online First: 2013/07/25].

41. Monteiro CA, Conde WL, Lu B, et al. Obesity and inequities in health in the developing world. *Int J Obes Relat Metab Disord* 2004;28(9):1181-86. doi: 10.1038/sj.ijo.0802716 [published Online First: 2004/06/24].

42. Al Kibria GM. Prevalence and factors affecting underweight, overweight and obesity using Asian and World Health Organization cutoffs among adults in Nepal: Analysis of the Demographic and Health Survey 2016. *Obes Res Clin Pract* 2019;13(2):129-36. doi: https://doi.org/10.1016/j.orcp.2019.01.006 [published Online First: 2019/02/06].

43. Health Mo, Sports - MoHS/Myanmar, ICF. Myanmar Demographic and Health Survey 2015-16. Nay Pyi Taw, Myanmar: MoHS and ICF; 2017. Available from: http://dhsprogram.com/pubs/pdf/FR324/FR324.pdf

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

44. The World Bank. Myanmar's Urbanization: Creating Opportunities for All 2019. Available from: https://www.worldbank.org/en/country/myanmar/publication/myanmars-urbanization-creating-opportunities-for-all (accessed 28th August 2019).

45. The World Bank in Myanmar. Overview 2020. Available from: https://www.worldbank.org/en/country/myanmar/overview (accessed 11th June 2020).

46. International Food Policy Research Institute. Global food policy report 2017. Washington, DC: International Food Policy Research Institute (IFPRI) 2017. doi: https://doi.org/10.2499/9780896292529

47. Unwin D, Unwin J. Low carbohydrate diet to achieve weight loss and improve HbA1cin type 2 diabetes and pre-diabetes: experience from one general practice. *Practical Diabetes* 2014;31(2):76-79. doi: 10.1002/pdi.1835

48. Aye T, Aung M, Oo E. Diabetes mellitus in Myanmar: Socio-cultural challenges and strength. *Journal of Social Health and Diabetes* 2018;02(01):009-13. doi: 10.4103/2321-0656.120255

49. Hlaing HH, Liabsuetrakul T. Dietary intake, food pattern, and abnormal blood glucose status of middle-aged adults: a cross-sectional community-based study in Myanmar. *Food Nutr Res* 2016;60(1):28898. doi: 10.3402/fnr.v60.28898 [published Online First: 2016/05/07].

50. Mayen AL, Marques-Vidal P, Paccaud F, et al. Socioeconomic determinants of dietary patterns in low- and middle-income countries: a systematic review. *Am J Clin Nutr* 2014;100(6):1520-31. doi: 10.3945/ajcn.114.089029 [published Online First: 2014/11/21].

51. Fogelholm M, Valve R, Absetz P, et al. Rural-urban differences in health and health behaviour: a baseline description of a community health-promotion programme for the elderly. *Scand J Public Health* 2006;34(6):632-40. doi: 10.1080/14034940600616039 [published Online First: 2006/11/30].

52. Jackson JE, Doescher MP, Jerant AF, et al. A national study of obesity prevalence and trends by type of rural county. *J Rural Health* 2005;21(2):140-8. doi: 10.1111/j.1748-0361.2005.tb00074.x [published Online First: 2005/04/30].

53. Befort CA, Nazir N, Perri MG. Prevalence of obesity among adults from rural and urban areas of the United States: findings from NHANES (2005-2008). *J Rural Health* 2012;28(4):392-7. doi: 10.1111/j.1748-0361.2012.00411.x [published Online First: 2012/10/23].

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

54. Marques A, Peralta M, Naia A, et al. Prevalence of adult overweight and obesity in 20 European countries, 2014. *Eur J Public Health* 2018;28(2):295-300. doi: 10.1093/eurpub/ckx143 [published Online First: 2017/10/17].

55. Seguin R, Connor L, Nelson M, et al. Understanding barriers and facilitators to healthy eating and active living in rural communities. *J Nutr Metab* 2014;2014:146502. doi: 10.1155/2014/146502 [published Online First: 2015/01/13].

56. Liese AD, Weis KE, Pluto D, et al. Food store types, availability, and cost of foods in a rural environment. *J Am Diet Assoc* 2007;107(11):1916-23. doi: 10.1016/j.jada.2007.08.012 [published Online First: 2007/10/30].

57. Pigeyre M, Rousseaux J, Trouiller P, et al. How obesity relates to socio-economic status: identification of eating behavior mediators. *Int J Obes (Lond)* 2016;40(11):1794-801. doi: 10.1038/ijo.2016.109 [published Online First: 2016/07/06].

58. Wang Y, Beydoun MA. The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev* 2007;29(1):6-28. doi: 10.1093/epirev/mxm007 [published Online First: 2007/05/19].

59. Sobal J, Stunkard AJ. Socioeconomic status and obesity: a review of the literature. *Psychol Bull* 1989;105(2):260-75. doi: 10.1037/0033-2909.105.2.260 [published Online First: 1989/03/01].

60. Ameye H, Swinnen J. Obesity, income and gender: The changing global relationship. *Global Food Security* 2019;23:267-81. doi: 10.1016/j.gfs.2019.09.003

61. Giskes K, Avendano M, Brug J, et al. A systematic review of studies on socioeconomic inequalities in dietary intakes associated with weight gain and overweight/obesity conducted among European adults. *Obes Rev* 2010;11(6):413-29. doi: 10.1111/j.1467-789X.2009.00658.x [published Online First: 2009/11/06].

62. Darmon N, Drewnowski A. Does social class predict diet quality? *Am J Clin Nutr* 2008;87(5):1107-17. doi: 10.1093/ajcn/87.5.1107 [published Online First: 2008/05/13].

63. Miech R, Pampel F, Kim J, et al. The Enduring Association between Education and Mortality: The Role of Widening and Narrowing Disparities. *Am Sociol Rev* 2011;76(6):913-34. doi: 10.1177/0003122411411276 [published Online First: 2011/12/01].

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

64. Popkin BM. Technology, transport, globalization and the nutrition transition food policy. *Food Policy* 2006;31(6):554-69. doi: 10.1016/j.foodpol.2006.02.008

65. Solomons NW, Gross R. Urban nutrition in developing countries. *Nutr Rev* 1995;53(4 Pt 1):90-5. doi: 10.1111/j.1753-4887.1995.tb01526.x [published Online First: 1995/04/01].

66. Mohammed SH, Habtewold TD, Birhanu MM, et al. Neighbourhood socioeconomic status and overweight/obesity: a systematic review and meta-analysis of epidemiological studies. *BMJ Open* 2019;9(11):e028238. doi: 10.1136/bmjopen-2018-028238 [published Online First: 2019/11/16].

67. Asian Development Bank. Myanmar Transport Sector Policy Note: Rural Roads and Access. 2016. Available from: https://www.adb.org/sites/default/files/publication/189079/mya-rural-roads.pdf (accessed 22nd April, 2020).

68. Kim TJ, von dem Knesebeck O. Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis. *BMJ Open* 2018;8(1):e019862. doi: 10.1136/bmjopen-2017-019862 [published Online First: 2018/01/08].

69. Kim TJ, Roesler NM, von dem Knesebeck O. Causation or selection - examining the relation between education and overweight/obesity in prospective observational studies: a meta-analysis. *Obes Rev* 2017;18(6):660-72. doi: 10.1111/obr.12537 [published Online First: 2017/04/13].

70. Søgaard AJ, Selmer R, Bjertness E, et al. The Oslo Health Study: The impact of self-selection in a large, population-based survey. *Int J Equity Health* 2004;3(1):3. doi: 10.1186/1475-9276-3-3 [published Online First: 2004/05/07].

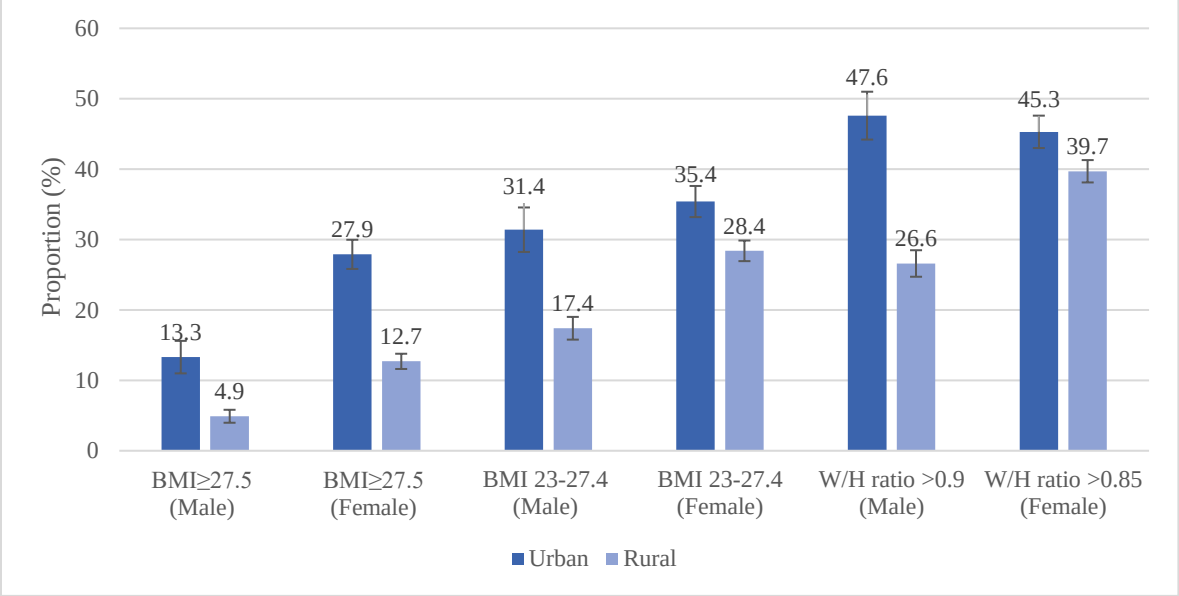
Figures

Figure 1: Proportion of participants with high Body mass index (BMI) (above Asian overweight and obesity cut-off) and Waist-hip ratio (W/H-ratio), with 95% confidence interval, of 25-64 years old Myanmar residents by urban-rural location and gender

Figure 2: Prevalence of overweight (BMI 25-29.9), obesity (BMI ≥30) and central obesity (W/H-ratio >0.9 for males and W/H-ratio >0.85 for females) across three levels of SES (calculated composite SES score) among 25-64 years old Myanmar residents, by gender

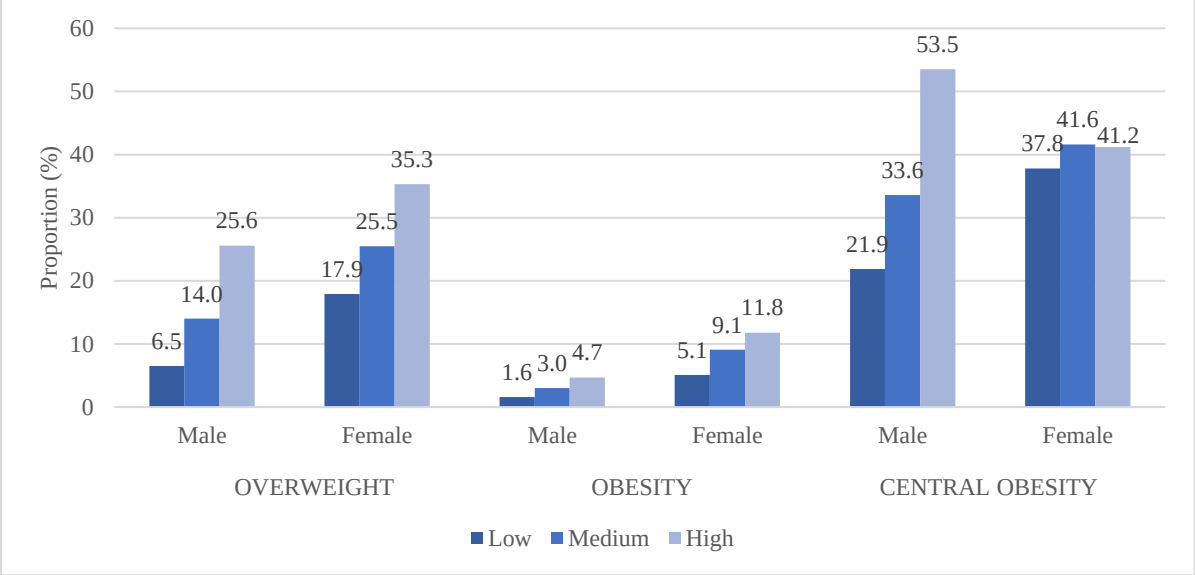
For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Figure 1: Proportion of participants with high Body mass index (BMI) (above Asian overweight and obesity cut-off) and Waist-hip ratio (W/H-ratio), with 95% confidence interval, of 25-64 years old Myanmar residents by urban-rural location and gender



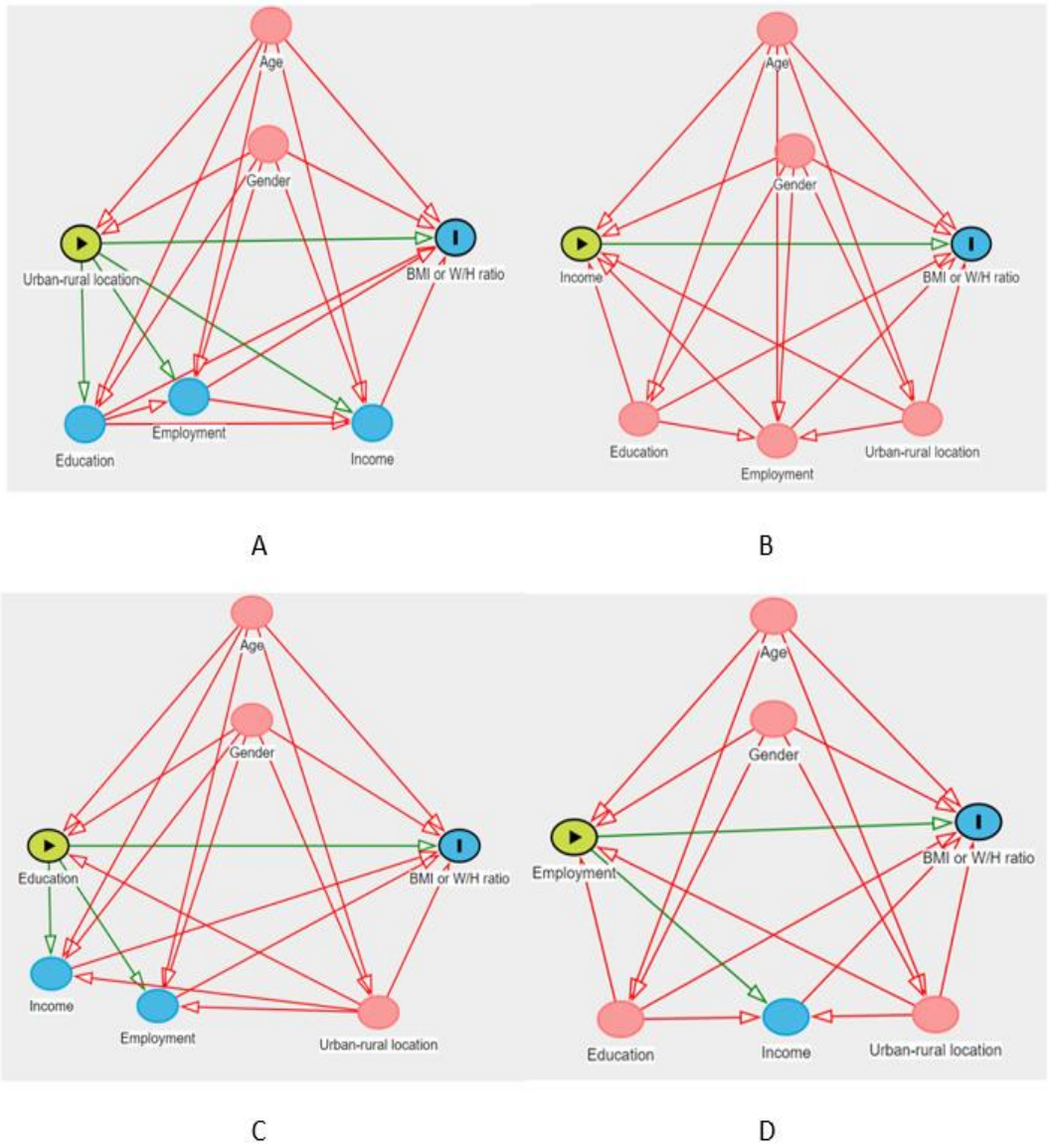
For peer review only

Figure 2: Prevalence of overweight (BMI 25-29.9), obesity (BMI ≥30) and central obesity (W/H-ratio >0.9 for males and W/H-ratio >0.85 for females) across three levels of SES (calculated composite SES score) among 25-64 years old Myanmar residents, by gender



For peer review only

Supplementary Figure 1: DAGs for the casual relationship between exposure and outcome



A: showing hypothesized causal relationships between urban-rural location and BMI or W/H-ratio, adjusted for age and gender

B: showing hypothesized causal relationships between income and BMI or W/H-ratio, adjusted for age, gender, urban-rural location, education, and employment

C: showing hypothesized causal relationships between education and BMI or W/H-ratio, adjusted for age, gender and urban-rural location

D: showing hypothesized causal relationships between employment and BMI or W/H-ratio, adjusted for age, gender, urban-rural location and education

Supplementary Table 1: Socioeconomic status (SES) score: description of the variable, calculation procedure, score range and SES groups

	Variables combined	Variables value	Score range	SES groups
SES score	Education	Low education= 0 (below high school completion)	0-3	Low (Total SES score 0) Medium (Total SES score 1 and 2) High (Total SES score 3)
		High education= 1 (high school completion and above)		
	Income	Below poverty line= 0		
		Above poverty line= 1		
	Employment	Unemployed= 0		
		Employed= 1		

For peer review only

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	3-4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
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	5-6
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	10, 11, 13
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			

For peer review only

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	4
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	5
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	10-13
		(*b*) Report category boundaries when continuous variables were categorized	6-7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
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	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
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	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

For peer review only