SSM - Population Health 14 (2021) 100781

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: http://www.elsevier.com/locate/ssmph

Spatial distribution of various forms of malnutrition among reproductive age women in Nepal: A Bayesian geoadditive quantile regression approach

Umesh Ghimire [a,*,1], Richa Vatsa [b,1]

[a] New ERA, Rudramati Marga, Kalopul, Kathmandu, 44600, Nepal
[b] Central University of South Bihar, SH-7, Gaya Panchanpur Road, Village – Karhara, Post. Fatehpur, Gaya, 824236, Bihar, India

ARTICLE INFO

Keywords:
Malnutrition
Overweight/obesity
Undernutrition
Urbanization
Bayesian method
Quantile regression
Spatial analysis

ABSTRACT

Addressing both the under-and over-nutritional status of women is an eminent challenge for developing countries like Nepal. This paper examined a critical analysis of factors associated with various forms of malnutrition using Bayesian geoadditive quantile regression approach and assessed spatial variations of malnutrition among Nepalese women using Asian cut-off values. Data drawn from the 2016 Nepal Demographic and Health Survey was utilized to assess the spatial distributions of underweight, overweight and obesity at the provincial level. Spatial and nonlinear components were estimated using Markov random fields and Bayesian P-splines, respectively. The analysis of 4,338 women confirmed that women living in extremely urbanized areas and in Province 1, Province 3, and Province 4 were more likely to be overweight/obese. Similarly, the likelihood of being underweight was prominently high among women residing in rural municipality and women residing in Province 2 and Province 7. Women from the richest and richer quintiles, and with primary education were more likely to be obese. Furthermore, currently-working women and women having access to protected water source were less likely to be obese while improved toilet and access to electricity facility were associated with obesity. Women with access to newspaper and radio were less prone to obesity. Inconsistent distribution of under- and over-nutrition existed in Nepal, given that the high prevalence of overweight/obesity among women living in metropolitan and undernutrition among rural women. Specific intervention measures, addressing location-specific nutrition issues are urgent. Rigorous implementation of strategies incorporated in the national nutrition plan is called for to curb the burden of overweight/obesity. Involving mass media to promote healthier lifestyle and nutritious food could be advantageous at the population level, especially in rural municipalities.

Introduction

Nutrition is an essential requirement for the well-being of an individual. Due to physiological needs, nutritional requirements of children and women are unique and they suffer more from nutritional deficiencies (Arimond et al., 2010). In the long run malnutrition not only affect the health condition of women but also to their children's overall cognitive development (Nyaradi, Li, Hickling, Foster, & Oddy, 2013). The child born from a malnourished woman is probably undernourished, which continues to repeat over generations (Jehn & Brewis, 2009). The reproductive age group is the most critical phase and the nutritional status of women is more likely to be fluctuated throughout the reproductive age (Bessenoff & Del Priore, 2007).

Globally, nearly two billion people are affected by different forms of malnutrition, which accounts for 11% of the global burden of diseases (IFPRI, 2016). In 2018, 462 million adults were underweight, while 1.9 billion were either overweight or obese. The magnitude of malnutrition among women remained between 10% and 40% in most of the low-and middle-income counties (LMICs) (Young, Borrel, Holland, & Salama, 2004). A study conducted using Demographic and Health Survey datasets from North Africa, sub-Saharan Africa, Asia, and Latin America found that the urbanization, poverty, households with many children, low levels of education, and work in agricultural farms are significant risk factors of different forms of women malnutrition (Jehn & Brewis, 2009). Socio-demographic factors such as place of residence, literacy, religion, wealth index, sanitation, source of drinking water are also associated with the women's malnutrition (Besora-Moreno, Llauradó, Tarro, & Solà, 2020; Young et al., 2004). Since last few decades, countries in South Asia have been witnessing a rapid demographic and

* Corresponding author.
E-mail addresses: creationumesh@gmail.com (U. Ghimire), vatsa.richa@gmail.com (R. Vatsa).
[1] Umesh Ghimire and Richa Vatsa contributed equally to the manuscript.

https://doi.org/10.1016/j.ssmph.2021.100781
Received 5 November 2020; Received in revised form 21 February 2021; Accepted 23 March 2021
Available online 28 March 2021

List of abbreviations

BMI	Body Mass Index
CI	Credible Interval
LMICs	low- and middle-income countries
MCMC	Markov chain Monte Carlo
NCDs	Non-communicable diseases
NDHS	Nepal Demographic and Health Survey
USAID	United States Agency for International Development
WHO	World Health Organization

socio-economic transition where exponential upsurge of risk factors of non-communicable diseases (NCDs) are attributed due to the co-existence of both under-and over-nutrition (WHO, 2002). Exposure to sedentary lifestyle, along with eating junk food, and lack of physical exercise are some of the risk factors of overweight/obesity (De Onis, Blossner, & Organization, 1997; WHO, 2011) (Black et al., 2013; Tzioumis, Kay, Bentley, & Adair, 2016). Undernutrition, on the other hand, is common among women from rural, who consume low dietary intake and experience frequent illnesses (interference with ingestion, absorption, utilization, or excretion of nutrients) (Wang, Chen, Bruening, Raj, & Larsen, 2016). Despite continuous investment in women's health, the prevalence of undernutrition, and recently overweight/obesity in the LMICs remain disproportionately high (Mamun & Finlay, 2015; Mohindra & Nikiéma, 2010; Tzioumis et al., 2016). In Nepal, the prevalence of under- and over-nutrition among women are disproportionately distributed within the country which needs detailed study estimating various forms of malnutrition. Urbanization is one of the major determining factors in shaping nutritional status of overall country or region (Szabo, Padmadas, & Falkingham, 2018). The rapid pace of urbanization after decentralization of the country in 2015 could have potentially contributed in the prevalence of overweight/obesity, thus exacerbating in urban-rural variations in nutritional status in Nepal. However, a handful of studies have assessed the distribution of nutritional status due to urbanization. Thus, understanding their association is vital in recommending future prevention strategies focused on subgroups of population. The aim of this study is to present geographic mapping of under-and -over nutrition status among reproductive age women which would be of high importance in the implementation of nutritional intervention program at provincial and local levels.

Furthermore, studies published previously used conventional statistical methods, either by summary statistics or regression models to report women's nutritional status (Gupta et al., 2019; Rai, Gurung, Thapa, & Saville, 2019; Rawal et al., 2018). Another objective of our study is to address limitations noted in previous studies by applying regression of covariates on conditional quantiles. This method allows to precisely examine the extreme ends of response variables-distribution to vary according to changes in covariates. The fitting benefit of this method is that it is suitable to outline a broad effect of multiple outcomes and can be used to describe the effect of different types of covariates available (Waldmann, Kneib, Yue, Lang, & Flexeder, 2013). Hence, the method is considered more appropriate in modeling and analyzing malnutrition.

Moreover, this study analyzed the estimates of risk factors of underweight, overweight, and obesity among Nepalese women along with spatial dependence. This study further assessed the determining factors, including a spatial structure of three forms of malnutrition using Bayesian geoadditive quantile regression method (Belitz, Brezger, Kneib, Lang, & Umlauf, 2009; Fahrmeir, Kneib, & Lang, 2004). This semiparametric method considers the combined effect of various independent variables, spatial random effects, and nonlinear effects of metrical covariates simultaneously in a single modeling framework. The estimates from the spatial effects of malnutrition would be helpful at the central, provincial and local levels to develop policies, plans, and activities to implement nutrition programs particular to geographic region having high burden of malnutrition. For this reason, this study is helpful in planning and redesigning the nutrition action plans which will eventually help to curb burden of different forms of malnutrition in Nepal.

Methods

Data source

Nationally representative Demographic and Health Survey (DHS) dataset of Nepal for the year 2016 was used in this study. The 2016 Nepal DHS was conducted after receiving ethical approval from the ethical committee of DHS program (http://www.dhsprogram.com) and the Nepal Health Research Council. The DHS program is a United States Agency for International Development (USAID) funded program authorized to collect data related to the demography, population health, and nutrition using standard DHS Program protocols and materials (Ties Boerma & Sommerfelt, 1993). Data of 2016 Nepal DHS was collected by interviewing ever-married women and men using a stratified sampling technique following two-stage and three-stage cluster design in rural and in urban areas, respectively. From 383 primary sampling units (wards), 30 households per cluster were selected with an equal selection probability from the household listing. After excluding non-response and missing data for anthropometric measurements, our analysis included a subsample of 4338 women of reproductive age group from a total of 12,862 women interviewed. The data also excluded the pregnant women ($n = 536$) and the women who had delivered within two months of the interview date ($n = 213$) were not involved in the analysis. Details of sampling procedure and methodology for the survey are available in the NDHS country report (Ministry of Health, 2017).

Study outcomes

The primary dependent variable of this study was Body Mass Index (BMI). BMI is a measure for quantifying nutritional status in adults which is calculated by using the formula weight in kg divided by height in meter square. This study utilized the Asia-specific cut-offs value to categorize BMI of the reproductive women. Underweight was defined as having BMI <18.5 kg/m^2, BMI between 23.0 to less than 27.5 kg/m^2 was defined as overweight and the value more than or equal to 27.5 kg/m^2 was categorized as obese. The Asian-specific cut-offs of BMI are recommended categorization of BMI and an appropriate measure for defining BMI in Asian populations (WHO Expert Consultation, 2004). In the 2016 NDHS, height and weight were measured by Shorr Board and SECA weight scale by the trained field surveyors following a standard protocol.

Explanatory variables

The standard DHS questionnaires were asked to the women on various socio-demographic variables. The demographic variables included in the study were the level of urbanization, wealth quintile, women's education and working status. For the analysis purpose, three levels of urbanization (metropolitan, urban municipality, and rural municipality) were categorized after grouping metropolitan and sub-metropolitan into one; considering it as the highest level of urbanization. Five-scaled household wealth quintiles (poorest/poorer/middle/richer/richest) was derived from the principal component analysis (Rutstein, S. O., 2004). Women's education status was categorized as no education, primary, secondary, and higher education. Household characteristics such as source of water (protected/unprotected), and toilet facility (improved/unimproved) were also categorized according to the WHO definitions (WHO& UNICEF, 2017). Women's working status and the availability of electricity in the household were included as dichotomous (yes/no) variables. Exposure to mass media (whether the woman read any newspapers/magazines, listened to the radio, or watched television) were dichotomized into yes (for at least once a week and almost every day) and no (for not at all and less than once a week). Furthermore, province of women was used for spatial analysis. Age of women was included (in years) as a continuous variable to plot the nonlinear effects of underweight, overweight and obesity.

Statistical method

We considered a Bayesian geoadditive quantile regression model to estimate the effects of explanatory variables on the categories of malnutrition through analyzing different quantiles of the BMI data. Corresponding to the i^{th} individual, let y_i be the BMI, x_i, the continuous covariates, age; z_i, the vector of categorical covariates, and u_{1i} and u_{2i} relate to the spatial covariates, province, respectively. The considered geoadditive quantile regression model based on these notations is defined for all $i = 1 : n$, as.$y_i = \eta_{i,q} + \varepsilon_{i,\,q}$, with $\eta_{i,q} = z_i^T\beta_q + f_q(x_i) + g_q(u_{1i}) + h_q(u_{2i})$, and. $\varepsilon_{i,\,q} \sim F(\varepsilon_{i,\,q}|\theta)$.

The notation $\eta_{i,q}$ stands for the quantile response function at quantile q of y_i defined at 0–1 scale. The term $f_q(.)$ denotes a smooth non-linear effect of x_i, whereas $g_q(.)$ and $h_q(.)$ stand for spatial effects of u_{1i} and u_{2i}, respectively, for a fixed quantile q. The notation β_q refers to the vector of regression coefficients of linear effects related to q^{th} quantile. The term $\varepsilon_{i,q}$ denotes the errors in the model with distribution $F_{\varepsilon_{i,q}}$, assumed as uncorrelated and defined such that $F^{-1}_{\varepsilon_{i,q}}(q|\theta) = 0$; θ stands for the unknown parameters in the error distribution. In words, the q-quantile of the error distribution is found at zero. Thus, in a quantile regression model, the response variable relates linearly or non-linearly to the covariates through a quantile response function. The response variable is assumed to follow asymmetric Laplace distribution with parameters-quantile response function as the location parameter, an unknown scale parameter, and quantile q as the known skewness parameter.

The non-linear smooth function $f_q(x_i)$ is approximated with penalized polynomial splines of degree d and equally spaced knots of x_i, $x_{i,min} = \zeta_{i,0} < \zeta_{i,1} < \ldots < \zeta_{i,m} = x_{i,max}$ over its space. The spline is found as a linear combination of $K = m + d$ B-spline basis functions $B_k(.)$ evaluated at the knots of x_i. Symbolically, $f_q(x_i) = \sum_{k=1}^{K} \gamma_k B_k(x_i),\ i = 1 : n$. The accuracy of spline approximation is ensured with sufficiently high number of knots.

We applied the Bayesian approach to inference with prior densities-second-order random walk for the non-linear smooth effect of continuous covariates[46], Gaussian Markov random field (Rue & Held, 2005) as prior for the spatial effects, and vague priors for the linear effects and other unknown parameters (or hyperparameters) of the model.

The Gaussian Markov random field (GMRF) assumes that the adjacent spatial locations share similar effects and are correlated. With $N(r)$ as the vector of neighbouring regions of a spatial location u_r, the conditional distribution of latent spatial effect $f(u_r)$ given spatial effects at location except r, $f(u_{-r})$, is Gaussian with mean equal to average of neighbouring regions and variance inversely proportional to. $N(r)$.

Symbolically, $f(u_r)\Big|f(u_{-r}) \sim N\left(\frac{1}{|N(r)|}\sum_{s\varepsilon N(r)} f(u_s),\ \frac{1}{|N(r)|\delta}\right)$.

For a note, the Bayesian framework enables one to have probabilistic statements over the unknowns (parameters) prior and posterior to observing data. It is appropriate with real-life scenarios which cannot be replicated in similar conditions to fulfil the theoretical conditions of frequentist approach of inference (Brezger & Lang, 2006; Gelman, 2019; Lakshminarayanan, 2013). The fitting of the considered Bayesian geoadditive quantile model was measured with WAIC (Widely Applicable Information Criterion). Less the WAIC value, the better is the model fit (Gelman, Hwang, & Vehtari, 2014; Spiegelhalter, Best, Carlin, & Van der Linde, 2014).

Data analysis

We employed the Bayesian estimation approach to perform geoadditive quantile regression analysis using software BayesX and implemented using the R-software BayesXsrc (Belitz et al., 2009). As a prerequisite for applying the method, quantiles of BMI were calculated for each type of malnutrition. We computed quantiles as the proportion of women with BMI below the threshold for each category of BMI relating to the forms of malnutrition. We found underweight at 13.67%, overweight at 60.44%, and obesity at 87.53% quantiles of BMI.

Results

Out of 4338 women, more than half (55.03%) lived in the urban municipality and one-third (33.31%) were from rural municipality. The highest percentage of women (21.74%) belonged to the poorest wealth quintile, and 16.55% of women were from the richest quintile. Nearly half of the women (45.93%) were illiterate, and less than ten percent had higher-level education. Approximately, two-thirds of women (64.08%) were currently working. Nine out of ten women had access to improved water source and 81.90% had access to improved sanitation facility. Out of total women, 43.22% and 25.20% watched television and listened to radio, respectively, while less than five percent read newspapers for at least once a week or almost everyday. The prevalence of overweight followed by obesity among women was 27.09% and 12.47%, respectively, and 13.67% women were underweight. (Table 1).

The posterior mean estimates and 95% credible intervals (CI) of linear effects of categorical covariates on the quantiles of BMI relating to the forms of malnutrition are shown in Table 2. It should be noted that positive effects of covariates on upper quantiles of BMI relates to overweight and obesity positively. On the other hand, the negative effects of explanatory variables on the lower quantiles of BMI reflects negative relationships, thus relate positively to underweight.

Estimates of the influence of level of urbanization on BMI showed that compared to rural municipality, women residing in metropolitan were more likely to be obese (mean: 0.293; 95%CI: 0.033, 0.291). Women from urban municipality were more likely to be underweight (mean: −0.132; 95%CI: −0.260, −0.001) and were less likely to be obese (mean −0.079; 95% CI: −0.252, −0.080). Poorer women were significantly more likely to be underweight (mean: −0.512; 95%CI: −0.689, −0.344) and less likely to be overweight and obese. Conversely, overweight (mean: 2.336; 95%CI: 2.019, 2.664) and obesity (mean: 2.466; 95%CI: 2.095, 2.464) were significantly higher among women from the richest households. Apparently, women with primary education were significantly more prone to being overweight (mean: 0.522; 95%CI: 0.277, 0.765) and obese (mean: 0.603; 95%CI: 0.345, 0.602). Contrarily, women having higher education were less likely to be obese (mean: −0.131; 95%CI: −0.442, −0.137).

Results show that, currently-working women were significantly less likely to be obese (mean: −0.142; 95%CI: −0.279, −0.141), however, the effects of employment on other categories of malnutrition were not significant. Similarly, women from households that used protected water source were significantly less likely overweight (mean: −0.266; 95%CI: −0.468, −0.049) and obese (mean: −0.298; 95%CI: −0.480, −0.297). A negative and significant association was found between access to improved toilet facilities and underweight (mean: 0.276; 95%CI: 0.158, 0.396), however, access to improved toilet facilities was positively associated to overweight (mean: 0.291; 95%CI: 0.129, 0.457) and obesity (mean: 0.452; 95%CI: 0.302, 0.452). In the same way, availability of electricity in the household was positively associated with overweight and obesity. However, women having access to electricity were less likely to be underweight (mean: 0.163; 95%CI: 0.014, 0.319). Findings suggest that, women who read newspapers at least once a week or almost every day were less likely to be obese (mean: −0.219; 95%CI:

Table 1
Frequency distribution of selected characteristics of reproductive age-group women.

Variable	N	%
Residence		
Metropolitan	506	11.66
Urban municipality	2387	55.03
Rural municipality	1445	33.31
Wealth quintile		
Poorest	943	21.74
Poorer	889	20.49
Middle	903	20.82
Richer	885	20.40
Richest	718	16.55
Educational level		
No Education	1992	45.93
Primary	791	18.23
Secondary	1144	26.37
Higher	411	9.47
Working Status		
No	1558	35.92
Yes	2780	64.08
Water Source		
Protected	3884	89.53
Unprotected	454	10.47
Toilet Facility		
Improved	3553	81.90
Unimproved	785	18.10
Electricity		
No	460	10.98
Yes	3729	89.02
Reads Newspaper		
No	4123	95.04
yes	215	4.96
Listens to Radio		
No	3245	74.80
yes	1093	25.20
Watches Television		
No	2463	56.78
yes	1875	43.22
Malnutrition		
Underweight	593	13.67
Normal	2029	46.77
Overweight	1175	27.09
Obese	541	12.47

−0.490, −0.219). Further, women who listened to radio (mean: 0.130; 95%CI: 0.029, 0.226) and watched television (mean: 0.311; 95%CI: 0.209, 0.412) were less likely to be underweight. While, women watching television were more prone to overweight (mean: 0.339; 95% CI: 0.193, 0.480) and obesity (mean: 0.349; 95%CI: 0.208, 0.347).

The maps shown in Fig. 1 represent the estimates of spatial effects for provinces on three forms of malnutrition. A set of maps in the left-hand side demonstrates the posterior mean estimates and the maps on the right-hand side represent the graphs of 95% credible intervals of posterior estimates reflecting the significance of their effects on the categories of malnutrition. The black shades in the 95%CI maps indicate significantly positive association with underweight (negative spatial effect on BMI is related to positive effect on underweight). On the other hand, the white shade implies significant positive association with overweight and obesity (positive spatial effect on BMI leads to positive effect on overweight and obesity), whereas the grey color indicates the non-significant results for the spatial effects. The spatial effects estimates shows that the likelihood of being underweight and overweight varies across geographical location in Nepal. Fig. 1 depicts that the women from Province 2 and Province 7 were more likely to be underweight, whereas women from Province 1, Province 3 and Province 4 were more prone to be overweight and obese. Similarly, women from Province 2 and Province 7 were less likely to be overweight and obese. Women from Province 6 were less likely to be obese whereas resuls for Province 5 were not significant.

Fig. 2 shows the median and interquartile range for BMI values of women by the level of urbanization (metropolitan, urban, and rural municipality) at province level in Nepal. Overall, the median BMI of women in metropolitan was high, particularly in Province 1, Province 3, and Province 4. The median of BMI was low in Province 2 and Province 7 for all three levels of urbanization. Typically, median BMI in rural municipality was low in all provinces except for Province 1 and Province 3.

The nonlinear effects of the woman's age for underweight, overweight, and obesity are presented in Fig. 3(a–c), respectively, along with posterior means (solid black lines) and 80% and 95% credible intervals (dashed lines). By using smooth functions, figures depict that the forms of malnutrition were non-linearly affected by the age covariate. There was a sharp decline in women being underweight up to age 35, as evident in Fig. 3(a). Women of ages below 27 were less likely to be overweight or obese, whereas, women above age 27 were more likely to be overweight or obese (Fig. 3(b) and (c)). However, obesity among women gradually declined after 40 years.

Discussion

This study aimed to examine the spatial distributions of underweight, overweight and obesity, among women of reproductive age in Nepal using the Asian BMI cut-offs criteria. This study explores a complete perusal of covariates' effects on different categories of malnutrition by the application of Bayesian geoadditive quantile regression method. Hence this method overcome the limitation of previous studies that used the conventional regression method. (Waldmann et al., 2013). Further, to better understand the variation of BMI status among women across the country, we fitted spatial effects of underweight, overweight and obesity. Our study results confirmed a high variability of prevalence of BMI and women in Nepal faced a double burden of malnutrition, as suggested by the spatial effects. Based on the analysis of nonlinear effects, a detectable nonlinear relationship was observed between the effects of women's age and under- and over-nutrition. The prevalence of overweight and obesity was apparently high in metropolitan and underweight was common in rural municipality.

The prevalence of underweight among women in LMICs is well documented. Our study demonstrated that almost 15% of women were underweight. There are uniformities in the findings from Nepal (Rawal et al., 2018), and from other South Asian countries including Bangladesh (Biswas, Garnett, Pervin, & Rawal, 2017) and Pakistan (Janjua, Mahmood, Bhatti, & Khan, 2015) reporting a high prevalence of poor nutritional status among women than compared with males. Despite concerted programmatic interventions aiming at improving the nutritional status of women, overcoming women's undernutrition has always been a challenge in Nepal. We observed that the prevalence of underweight was high among women from rural municipality. Rural women were more prone to underweight due to several underlying factors such as poverty and inequities that influence dietary patterns, together with low dietary diversity and food insecurity (WHO, n.d.). Though, the undernutrition (BMI <18.5 kg/m^2) status of reproductive age group women declined slightly over the past decades, the rate of decline is not uniform across the country and ubiquitous inequalities exist across the country (Ghimire et al., 2019; Ministry of Health, 2017). On the other hand, overweight and obesity are developing gradually in an alarming rate among urban residents. In our study, we found that women from metropolitan were more likely to be obese. The residents from urban municipality were more prone to underweight but were less likely to be obese. The findings indicate that undernutrition is still prevalent among women from urban municipality. Urban populations especially urban poor and people living in the outskirts are more likely to consume unhealthy diets such as packaged/junk food lacking nutritional value which may lead to undernutrition. Women from metropolitan areas and women living in close proximity to haphazardly undergoing urbanized locations viz. from Province 1, Province 3, and Province 4, had a higher likelihood of being overweight and obese. Many districts in Nepal have been undergoing rapid urbanization after the country shifted to the

Table 2
Posterior mean estimates for the linear effects of underweight, overweight and obesity among women of reproductive age-group (15 to 49 years).

	Underweight		Overweight		Obese	
Variable	Mean	95% CI	Mean	95% CI	Mean	95% CI
Urbanization						
Metropolitan	0.152	−0.060, 0.353	0.265	−0.019, 0.528	0.293*	0.033, 0.291
Urban municipality	−0.132*	−0.260, −0.001	−0.167	−0.335, 0.007	−0.079*	−0.252, −0.080
Wealth Index						
Poorer	−0.512*	−0.689, −0.344	−0.777*	−1.019, −.546	−0.868*	−1.097, −0.868
Middle	−0.201*	−0.367, −0.040	−0.477*	−0.729, −0.221	−0.287*	−0.528, −0.286
Richer	−0.158	−0.335, 0.019	0.087	−0.142, 0.320	0.409*	0.162, 0.408
Richest	1.459*	1.224, 1.681	2.336*	2.019, 2.664	2.466*	2.095, 2.464
Education						
Primary	0.133	−0.063, 0.329	0.522*	0.277, 0.765	0.603*	0.345, 0.602
Secondary	0.288*	0.129, 0.445	0.165	−0.048, 0.376	0.002	−0.216, 0.002
Higher	−0.013	−0.280, 0.241	−0.312	−0.644, 0.021	−0.131*	−0.442, −0.137
Currently working						
Yes	0.024	−0.071, 0.115	0.004	−0.122, 0.130	−0.142*	−0.279, −0.141
Water sources						
Protected	−0.075	−0.214, 0.067	−0.266*	−0.468, −0.049	−0.298*	−0.480, −0.297
Toilet facilities						
Improved	0.276*	0.158, 0.396	0.291*	0.129, 0.457	0.452*	0.302, 0.452
Electricity						
Yes	0.163*	0.014, 0.319	0.317*	0.139, 0.514	0.328*	0.134, 0.328
Mass media newspaper						
Yes	0.208	−0.043, 0.441	−0.074	−0.386, 0.227	−0.219*	−0.490, −0.219
Radio						
Yes	0.130*	0.029, 0.226	0.105	−0.028, 0.241	−0.089*	−0.230, −0.089
Television						
Yes	0.311*	0.209, 0.412	0.339*	0.193, 0.480	0.349*	0.208, 0.347
Model Diagnostic WAIC	28650		23436.3		28428.9	

Mean linear-effect of categorical covariates is calculated by quantile regression method.
*significant at 0.05 level of significance.
CI: credible interval.
WAIC Watanabe: Akaike information criterion.

federal democratic state in 2015 and the power of central government decentralized to the local level. This move has an overarching effect on urbanization and the overall nutritional status of women, distinctively in urban areas. The distribution of urban population is skewed across the country with 33.5% of the population residing in 16 urban centers having more than 100,000 population. In fact, Province 3, followed by Province 1 are the most populous provinces having higher number of urban residents (Ministry of Urban Development, 2017). As indicated by our study, the prevalence of high BMI (above 23.0 kg/m^2) was prominent in these provinces. Previous studies have shown that residents of urban areas are less mobile, eat more high-calorie food, and therefore have high prevalence of overweight/obesity (Popkin, Adair, & Ng, 2012; Vaidya, Shakya, & Krettek, 2010). A study conducted in Nepal using STEPS data showed a rising number of BMI above 25 kg/m^2 among urban residents implying that the nation is amid the burden of under- and over-nutrition (Aryal et al., 2015). Furthermore, one-fourth of the population's BMI ranged above 25.0 kg/m^2 and the percentage of women having overweight or obese was higher than their counterparts (Ghimire, Shrestha, Gyawali, Pradhan, & Mishra, 2020). These are known facts that rapid urbanization, sedentary lifestyles, and over consumption of junk food and high-energy drinks are concurrently contributing to a surge in the prevalence of overweight/obesity in LMICs, and Nepal is not an exception to it. It was reported that poor cardiovascular health was found to be high among urban residents in Nepal (Ghimire, Shrestha, Gyawali, et al., 2020). Our estimates are comparable with previous studies from other South Asian nations which reported a higher prevalence of overweight and obesity in urban areas than in the rural (Biswas et al., 2017; Hong, Peltzer, Lwin, & Aung, 2018; Pradeepa et al., 2015). The escalation in the prevalence of overweight/obesity and chronic health conditions such as heart disease, hypertension, stroke, and diabetes, would be strenuous to the health systems in LMICs (WHO, 2013), including in Nepal where the health service readiness for non-communicable diseases is mediocre (Ghimire, Shrestha, Adhikari, et al., 2020). It is estimated that developing countries account for more than 60% of the burden of chronic diseases, globally (WHO, 2002). Adequate nutrition not only prevents malnutrition but also reduce the risk of chronic diseases (Vaidya et al., 2010). Dealing with both under- and over-nutrition requires political commitment, a practical integrated approach, and radical reform in policies and programs.

Similarly, our findings from spatial effects demonstrated that women from districts of Province 2 and Province 7 were more likely to be underweight. Studies found that, districts from Province 2, Province 6 and Province 7 lag behind in achieving targets of health indicators due to poverty, low education attainment, inequalities in health service utilization, socio-cultural norms and practices affecting healthcare-seeking behaviors (Ghimire et al., 2019; UNDP & GoN, 2014). Hilly and mountain districts from Province 6 and Province 7 are amongst the highest food insecure districts in Nepal (Pandey & Fusaro, 2020). Evidence suggests that low diet diversity and food insecurity limits household's ability to consume nutritious food and diet rich in protein, subsequently contributing to nutritional deficiencies (Chandrasekhar, Aguayo, Krishna, & Nair, 2017). Contrarily, overweight/obesity are gradually rising in an alarming rate among urban residents. Women from Province 1, Province 3, and Province 4 had a higher likelihood of being overweight and obese. Notably, districts from the above-mentioned provinces, including from Province 5 are high-ranking in terms of the Human Development Index and constitute many affluent cities. The uneven distributions of under- and over-nutrition across the country is suggestive that the country is dealing with double burden of malnutrition. This findings is supported by a study that included geospatial analysis revealing a higher likelihood of women to be overweight and obese in Province 3 and Province 4 (Shrestha et al., 2020). The provincial and urban and rural variations in women's over- and

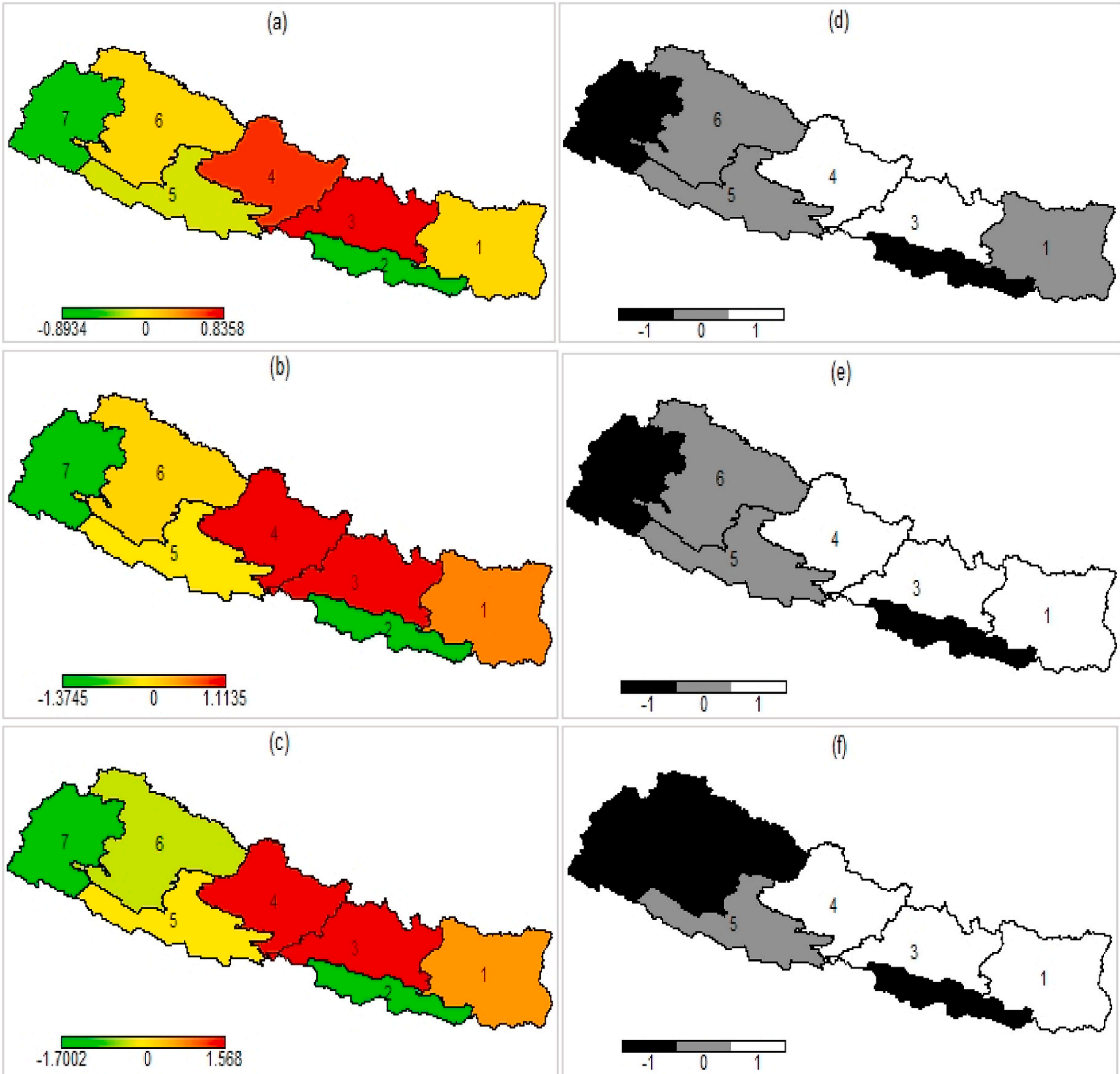

Fig. 1. Province maps of Nepal showing the spatial effects of: a) underweight and d) its 95% CI; b) overweight and e) its 95% CI; c) obesity and f) its 95% CI.

under-nutrition are nothing but a systemic limitation due to lack of prudent planning and program implementation. These findings call for particular nutritional support programs targeting specific geographic territory to intervene the aggravating situation of undernutrition and intervention to curtail the burden of overweight and obesity.

Our study findings further confirmed that women from wealthier households and women with primary education were more likely to be obese and women having higher education were less likely to be obese. Education status and eating behaviors go hand in hand. Better education can be taken as a proxy indicator of having knowledge of nutritious food, which can eventually lead to optimal health. Highly educated women have adequate knowledge on impact of eating commercialized food rich in caloric. Education also enables person to eat healthy and nutritious food and adopt optimum level of exercise to be healthy. Likewise, women from the richest wealth quintile were more likely to be overweight and obese compared to the poorest wealth quintile. Our finding is comparable with the study reporting a positive association between wealth and obesity and between higher-level education and low body mass index (Al Kibria, 2019). Women in wealthier households can afford to purchase varieties of food and have access to buy widely available sugary and energy-rich commercialized foods resulting in over-nutrition (Vaidya et al., 2010). Relatively, women with poor economic status have a low opportunity of affording varieties of nutritious diet and poor access to health services leading to undernutrition. Similarly, currently-working women were less likely to be obese. Women in rural parts of the country predominantly work in agriculture sector which adds up to more than 60 percent of agricultural workforce in Nepal (Komatsu, Malapit, & Theis, 2018). Working women have added advantage that they do perform high physical activity, a predictor of having low BMI (Bowen et al., 2015).

Our study included variables of mass media access to women. Our study findings showed that women who listened to the radio and watched television had a lower likelihood of being underweight. However, access to newspaper and listening to radio at least for once a week were found to be protective against obesity. Accessibility of newspaper and other print media are not common in rural areas, while other media sources such as radio and television are widely available nationwide. Mass media are the readily available source of information to impart information on adequate nutrition and healthy behaviors and lifestyle. These findings are in agreement with the study done in Botswana (Letamo & Navaneetham, 2014), which reported that women were less likely to be thin or underweight who had access to mass media. While, watching television, a sedentary activity, was more likely to be associated with obesity among women. A study from Bangladesh showed that,

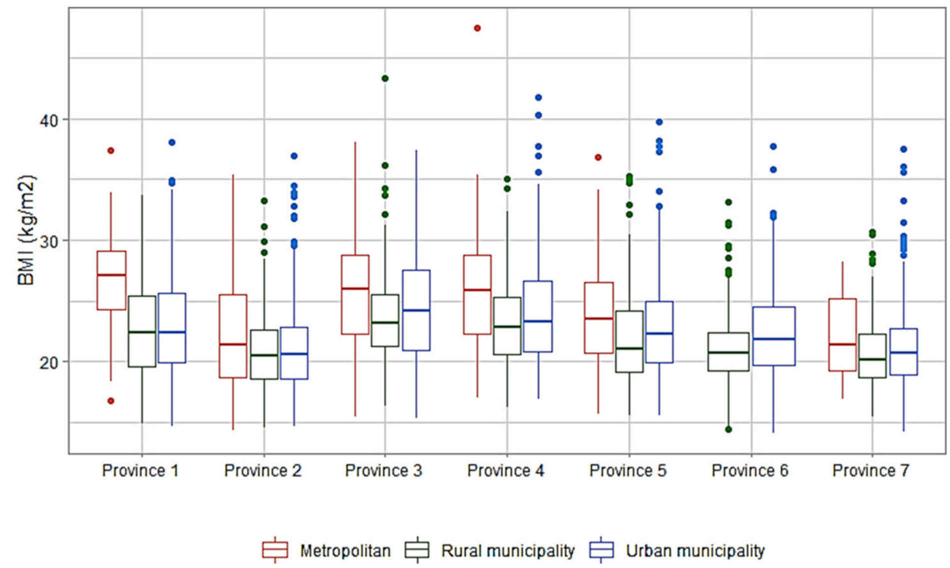

Fig. 2. Distribution of Body Mass Index among reproductive age women across seven provinces in Nepal.

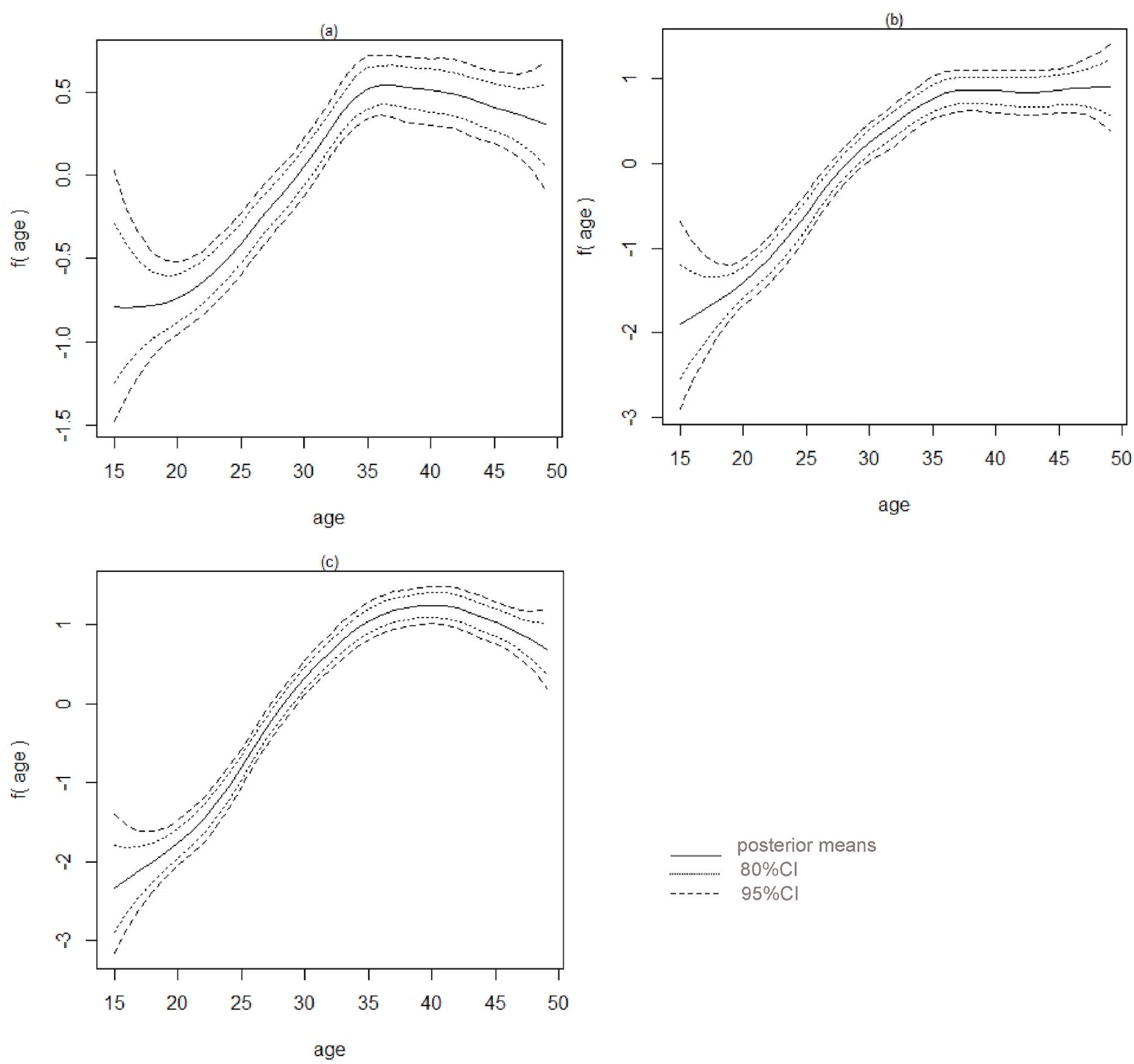

Fig. 3. Nonlinear effects of respondent's age for **a)** underweight, **b)** overweight and **c)** obesity.

urban women were 67% and rural women were 63% more likely to be obese (Ghose, 2017).

As expected, our study showed that improved toilet facility was negatively associated with undernutrition. It implies that women without improved toilet facilities were more at risk of being underweight. A study from Nigeria involving spatial analysis of malnutrition found similar results which indicated that women without access to improved toilet facilities suffer from undernutrition (Akeresola & Gayawan, 2018). Unimproved toilet facility and unprotective sources of drinking water, mainly in low-income countries, are the primary causes of infectious diseases which contribute to seven percent of the total disease burden (Prüss-Üstün, Bos, Gore, & Bartram, 2008). A vicious interaction between malnutrition and infection was reported in a study stating that malnutrition aggravates the pathway of infectious disease, which further conduce malnutrition (Tomkins & Watson, 1989).

The output of nonlinear models showed that women's likelihood of being overweight and obese increased with a gradual increment in age after 27 years. Whereas, the tendency of being underweight was high in the younger age-group. Although studies from Ethiopia (Tebekaw, Teller, & Colón-Ramos, 2014), Pakistan (Janjua et al., 2015) and Bangladesh (Biswas et al., 2017) showed similar observations, our study purports unbiased estimation showing more likelihood of being overweight and obesity in older women. Younger age-group women are more involved in physical activity and have low BMI in developing countries than compared to developed countries (Tamura, Bell, Masaki, & Amella, 2013). As age increases, people tend to have a sedentary lifestyle contributing to an increase in body mass composition in the long run (Ng & Popkin, 2012). A study conducted among black and white women reported that BMI increased significantly with the increase in age indicating a linear correlation between body fat percentage (Gallagher et al., 1996).

The strengths of this study include its use of a large sample size obtained by highly trained field researchers using standardized tools. The nationally representative data provides an opportunity to represent the true picture of malnutrition of the whole nation. It is worthwhile to note that this study is the first of its kind to explore different forms of nutritional status of women in Nepal using Bayesian geoadditive quantile regression method. The method allows for estimating linear, nonlinear, and spatial effects in a unified platform. Moreover, the Bayesian approach offers a flexible framework to work with complex modeling. Furthermore, the spatial approach used in the study is advantageous as spatial dependencies may play a major role in nutritional pattern. This study has some limitations that need to be acknowledged. The 2016 NDHS data lack the information on food availability, consumption, and other dietary habits of women which could partly influence the BMI of women. Similar to other cross-sectional data, causal relationship cannot be established with the NDHS data. These limitations, however, would not undermine the study conclusions.

In conclusion, inconsistent distribution of various forms of malnutrition existed in Nepal, revealing heterogeneous influence of sociodemographic factors in nutritional outcomes. The spatial analysis showed that there is an urgent need for location-specific intervention of supplementary nutritional programs in Province 2, Province 7 and rural municipalities where the prevalence of underweight is high. The government is focusing on addressing already existing poor health indicators while not giving enough attention and resources for overweight and obesity prevention programs. The high prevalence of overweight and obesity was observed in highly urbanized areas and in Province 1, Province 3 and Province 4. Thus, proactive nutrition action plan is eminent in addressing the rising number of overweight and obesity, mostly in metropolitan areas.

Ethical statement

The Nepal Health Research Council, Kathmandu, Nepal, has granted ethical approval to conduct the 2016 Nepal Demographic and Health Survey. We acknowledge the DHS program-USAID for providing access to download the 2016 Nepal Demographic and Health Survey dataset. The data is publicly available and can be downloaded with due permission at https://dhsprogram.com/data/available-datasets.cfm.

CRediT authorship contribution statement

Umesh Ghimire: Conceptualization, Data curation, Validation, Writing – original draft, preparation, Supervision, Writing – review & editing. **Richa Vatsa:** Conceptualization, Data curation, Methodology, Software, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgements

We appreciate Measure DHS for granting access to the data and boundary file used for the analysis and useful comments from Elisabeth Waldmann on Bayesian quantile regression and from Ezra Gayawan on the use of BayesX.

References

Akeresola, R. A., & Gayawan, E. (2018). Analysis of the spatial patterns of malnutrition among women in Nigeria with a Bayesian structured additive model. *Geojournal*, 1–12. https://doi.org/10.1007/s10708-018-9958-0

Al Kibria, G. M. (2019). 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. *Obesity Research & Clinical Practice, 13*(2), 129–136. https://doi.org/10.1016/j.orcp.2019.01.006

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M. C., Deitchler, M., et al. (2010). Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings1-7. *Journal of Nutrition*. https://doi.org/10.3945/jn.110.123414

Aryal, K. K., Thapa, P., Mehata, S., Vaidya, A., Pandey, A. R., Bista, B., et al. (2015). Alcohol use by Nepalese women: Evidence from non communicable disease risk factors STEPS survey Nepal 2013. *Journal of Nepal Health Research Council, 13*(29), 1–6.

Belitz, C., Brezger, A., Kneib, T., Lang, S., & Umlauf, N. (2009). *BayesX-Software for Bayesian inference in structured additive regression models*. Version.

Besora-Moreno, M., Llauradó, E., Tarro, L., & Solà, R. (2020). Social and economic factors and malnutrition or the risk of malnutrition in the elderly: A systematic review and meta-analysis of observational studies. *Nutrients, 12*(3), 737. https://doi.org/10.3390/nu12030737

Bessenoff, G. R., & Del Priore, R. E. (2007). Women, weight, and age: Social comparison to magazine images across the lifespan. *Sex Roles*. https://doi.org/10.1007/s11199-006-9164-2

Biswas, T., Garnett, S. P., Pervin, S., & Rawal, L. B. (2017). The prevalence of underweight, overweight and obesity in Bangladeshi adults: Data from a national survey. *PloS One, 12*(5), Article e0177395. https://doi.org/10.1371/journal.pone.0177395

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet, 382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Bowen, L., Taylor, A. E., Sullivan, R., Ebrahim, S., Kinra, S., Krishna, K. R., et al. (2015). Associations between diet, physical activity and body fat distribution: A cross sectional study in an Indian population. *BMC Public Health*. https://doi.org/10.1186/s12889-015-1550-7

Brezger, A., & Lang, S. (2006). Generalized structured additive regression based on Bayesian P-splines. *Computational Statistics and Data Analysis*. https://doi.org/10.1016/j.csda.2004.10.011

Chandrasekhar, S., Aguayo, V. M., Krishna, V., & Nair, R. (2017). Household food insecurity and children's dietary diversity and nutrition in India. Evidence from the comprehensive nutrition survey in Maharashtra. *Maternal and Child Nutrition*. https://doi.org/10.1111/mcn.12447

De Onis, M., Blossner, M., & Organization, W. H. (1997). *WHO global database on child growth and malnutrition*. Geneva: World Health Organization.

Fahrmeir, L., Kneib, T., & Lang, S. (2004). Penalized structured additive regression for space-time data: A bayesian perspective. *Statistica Sinica*, 731–761.

Gallagher, D., Visser, M., Sepulveda, D., Pierson, R. N., Harris, T., & Heymsfield, S. B. (1996). How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? *American Journal of Epidemiology, 143*(3), 228–239. https://doi.org/10.1093/oxfordjournals.aje.a008733

Gelman, A. (2019). Bayesian data analysis(3rd edition). In *Journal of chemical information and modeling*.

Gelman, A., Hwang, J., & Vehtari, A. (2014). Understanding predictive information criteria for Bayesian models. In *Statistics and computing*. https://doi.org/10.1007/s11222-013-9416-2

Ghimire, U., Manandhar, J., Gautam, A., Tuladhar, S., Prasai, Y., & Gebreselassie, T. (2019). Inequalities in health outcomes and access to services by caste/ethnicity, province, and wealth quintile in Nepal. In *DHS further analysis reports No. 117*. ICF. http://dhsprogram.com/pubs/pdf/FA117/FA117.pdf.

Ghimire, U., Shrestha, N., Adhikari, B., Meheta, S., Pokharel, Y., & Mishra, S. R. (2020). Health system's readiness to provide cardiovascular, diabetes and chronic respiratory disease related services in Nepal: Analysis using 2015 health facility survey. *BMC Public Health*. https://doi.org/10.1186/s12889-020-09279-z

Ghimire, U., Shrestha, N., Gyawali, B., Pradhan, P. M. S., & Mishra, S. R. (2020). Prevalence of American heart association defined ideal cardiovascular health metrics in Nepal: Findings from a nationally representative cross-sectional study. *International Health*. https://doi.org/10.1093/inthealth/ihz088

Ghose, B. (2017). Frequency of TV viewing and prevalence of overweight and obesity among adult women in Bangladesh: A cross-sectional study. *BMJ Open*. https://doi.org/10.1136/bmjopen-2016-014399

Gupta, R. D., Haider, S. S., Sutradhar, I., Hashan, M. R., Sajal, I. H., Hasan, M., et al. (2019). Association of frequency of television watching with overweight and obesity among women of reproductive age in India: Evidence from a nationally representative study. *PloS One*. https://doi.org/10.1371/journal.pone.0221758

Hong, S. A., Peltzer, K., Lwin, K. T., & Aung, L. S. (2018). The prevalence of underweight, overweight and obesity and their related socio-demographic and lifestyle factors among adult women in Myanmar, 2015-16. *PloS One, 13*(3). https://doi.org/10.1371/journal.pone.0194454

IFPRI. (2016). Global nutrition report: From promise to impact. In *Global nutrition report - from promise to impact*. ending malnutrition by 2030.

Janjua, N. Z., Mahmood, B., Bhatti, J. A., & Khan, M. I. (2015). Association of household and community socioeconomic position and urbanicity with underweight and overweight among women in Pakistan. *PloS One, 10*(4), Article e0122314. https://doi.org/10.1371/journal.pone.0122314

Jehn, M., & Brewis, A. (2009). Paradoxical malnutrition in mother–child pairs: Untangling the phenomenon of over-and under-nutrition in underdeveloped economies. *Economics and Human Biology, 7*(1), 28–35.

Komatsu, H., Malapit, H. J. L., & Theis, S. (2018). Does women's time in domestic work and agriculture affect women's and children's dietary diversity? Evidence from Bangladesh, Nepal, Cambodia, Ghana, and Mozambique. *Food Policy*. https://doi.org/10.1016/j.foodpol.2018.07.002

Lakshminarayanan, M. (2013). Bayesian biostatistics , by emmanuel lesaffre and andrew B. Lawson, john wiley & sons. *2012 . Journal of Biopharmaceutical Statistics*. https://doi.org/10.1080/10543406.2013.789819

Letamo, G., & Navaneetham, K. (2014). Prevalence and determinants of adult under-nutrition in Botswana. *PloS One, 9*(7). https://doi.org/10.1371/journal.pone.0102675

Mamun, A. A., & Finlay, J. E. (2015). Shifting of undernutrition to overnutrition and its determinants among women of reproductive ages in the 36 low to medium income countries. *Obesity Research & Clinical Practice, 9*(1), 75–86. https://doi.org/10.1016/j.orcp.2014.03.001

Ministry of Health, N. N. E. and I. (2017). *Nepal demographic and health survey 2016. Kathmandu Nepal*. Nepal: Ministry of Health. https://doi.org/10.1007/b138909

Ministry of Urban Development. (2017). National urban development strategy 2017 Part B. In *Government of Nepal*.

Mohindra, K. S., & Nikiéma, B. (2010). Women's health in developing countries: Beyond an investment? *International Journal of Health Services, 40*(3), 543–567. https://doi.org/10.2190/hs.40.3.i

Ng, S. W., & Popkin, B. M. (2012). Time use and physical activity: A shift away from movement across the globe. *Obesity Reviews*. https://doi.org/10.1111/j.1467-789X.2011.00982.x

Nyaradi, A., Li, J., Hickling, S., Foster, J., & Oddy, W. H. (2013). The role of nutrition in children's neurocognitive development, from pregnancy through childhood. In *Frontiers in human neuroscience*. https://doi.org/10.3389/fnhum.2013.00097

Pandey, S., & Fusaro, V. (2020). Food insecurity among women of reproductive age in Nepal: Prevalence and correlates. *BMC Public Health*. https://doi.org/10.1186/s12889-020-8298-4

Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews*. https://doi.org/10.1111/j.1753-4887.2011.00456.x

Pradeepa, R., Anjana, R. M., Joshi, S. R., Bhansali, A., Deepa, M., Joshi, P. P., et al. (2015). Prevalence of generalized & abdominal obesity in urban & rural India–the ICMR-INDIAB Study (Phase-I) [ICMR- NDIAB-3]. *Indian Journal of Medical Research, 142*(2), 139–150. https://doi.org/10.4103/0971-5916.164234

Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008). In *Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health*. https://apps.who.int/iris/bitstream/handle/10665/43840/9789241596435_eng.pdf?sequence=1.

Rai, A., Gurung, S., Thapa, S., & Saville, N. M. (2019). Correlates and inequality of underweight and overweight among women of reproductive age: Evidence from the 2016 Nepal Demographic Health Survey. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0216644

Rawal, L. B., Kanda, K., Mahumud, R. A., Joshi, D., Mehata, S., Shrestha, N., et al. (2018). Prevalence of underweight, overweight and obesity and their associated risk factors in Nepalese adults: Data from a nationwide survey, 2016. In *PLoS ONE*. https://doi.org/10.1371/journal.pone.0205912

Rue, H., & Held, L. (2005). *Gaussian Markov random fields: Theory and applications*. CRC press.

Rutstein, S. O., & Johnson, K. (2004). The DHS wealth index. *DHS Comparative Reports No. 6*. https://dhsprogram.com/pubs/pdf/cr6/cr6.pdf.

Shrestha, N., Mishra, S. R., Ghimire, S., Gyawali, B., Pradhan, P. M. S., & Schwarz, D. (2020). Application of single-level and multi-level modeling approach to examine geographic and socioeconomic variation in underweight, overweight and obesity in Nepal: Findings from NDHS 2016. *Scientific Reports, 10*(1), 1–14. https://doi.org/10.1038/s41598-019-56318-w

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., & Van der Linde, A. (2014). The deviance information criterion: 12 years on. *Journal of the Royal Statistical Society - Series B: Statistical Methodology*. https://doi.org/10.1111/rssb.12062

Szabo, S., Padmadas, S., & Falkingham, J. (2018). Is rapid urbanisation exacerbating wealth-related urban inequalities in child nutritional status? Evidence from least developed countries. *European Journal of Development Research*. https://doi.org/10.1057/s41287-017-0089-0

Tamura, B. K., Bell, C. L., Masaki, K. H., & Amella, E. J. (2013). Factors associated with weight loss, low BMI, and malnutrition among nursing home patients: A systematic review of the literature. In *Journal of the American medical directors association*. https://doi.org/10.1016/j.jamda.2013.02.022

Tebekaw, Y., Teller, C., & Colón-Ramos, U. (2014). The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health, 14*(1), 1126. https://doi.org/10.1186/1471-2458-14-1126

Ties Boerma, J., & Sommerfelt, A. E. (1993). *Demographic and health surveys (DHS: Contributions and limitations*.

Tomkins, A., & Watson, F. (1989). Malnutrition and infection-A review-nutrition policy discussion paper No. 5. In *United nations-administrative commitee on coordination-subcommitee on nutrition [google scholar]*.

Tzioumis, E., Kay, M. C., Bentley, M. E., & Adair, L. S. (2016). Prevalence and trends in the childhood dual burden of malnutrition in low-and middle-income countries, 1990–2012. *Public Health Nutrition, 19*(8), 1375–1388. https://doi.org/10.1017/s1368980016000276

UNDP, & GoN. (2014). *Nepal human development report 2014. Beyond geography unlocking human potential*. Nepal.

Vaidya, A., Shakya, S., & Krettek, A. (2010). Obesity prevalence in Nepal: Public health challenges in a low-income nation during an alarming worldwide trend. *International Journal of Environmental Research and Public Health, 7*(6), 2726–2744. https://doi.org/10.3390/ijerph7062726

Waldmann, E., Kneib, T., Yue, Y. R., Lang, S., & Flexeder, C. (2013). Bayesian semiparametric additive quantile regression. *Statistical Modelling, 13*(3), 223–252.

Wang, F., Chen, W., Bruening, K. S., Raj, S., & Larsen, D. A. (2016). Nutrition screening tools and the prediction of clinical outcomes among Chinese hospitalized gastrointestinal disease patients. *PloS One, 11*(8). https://doi.org/10.1371/journal.pone.0159436. e0159436–e0159436.

WHO. Background: The global burden of chronic diseases (n.d.). https://www.who.int/nutrition/topics/2_background/en/. World Health Organization

WHO. (2002). Diet, physical activity and health. In *World health organization*. World Health Organization (documents A55/16 and A55/16 Corr. 1).

WHO. (2011). *Global database on body mass index*. Wold Health Organization. http://apps.who.int/bmi/index.jsp.

WHO. (2013). *Implementation tools: Package of essential noncommunicable (PEN) disease interventions for primary health care in low-resource settings*. World Health Organization.

WHO Expert Consultation. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet, 363*(9403), 157–163.

WHO, & UNICEF. (2017). *Progress on drinking water, sanitation and hygiene: 2017 update and SDG baseline*. World Health Organization.

Young, H., Borrel, A., Holland, D., & Salama, P. (2004). Public nutrition in complex emergencies. *The Lancet, 364*(9448), 1899–1909. https://doi.org/10.1016/S0140-6736(04)17447-3