The Nutrition Transition from 2013-2022 and its Association with Body Mass Index among Participants of the Dhulikhel Heart Study, Nepal

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A thesis
submitted in partial fulfillment of the
requirements for the degree of

Master of Public Health

University of Washington
2023

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Program Authorized to Offer Degree:

Department of Global Health

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Abstract

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Abstract:

Almost every country in the world has experienced dramatic shifts in diet quality marked by increased consumption of ultra-processed foods during a period of three to four decades. A nutrition transition is a change in population-level diet due to shifts in food availability, as well as other economic, social, demographic, and health factors. A study has reported that the average proportion of energy derived from total fat has grown considerably from 13% in 1970 to 17% in 2010 in Nepal. Obesity has also increased from 21% of women to 27% in the urban population. This study aims to measure the nutrition transition in terms of changes in dietary intake from 2013 to 2022 and to assess the associations between 9-year dietary change and body mass index (BMI) among the participants of the Dhulikhel Heart Study (DHS).

In this analysis, we utilized data from 307 participants of the DHS, a longitudinal observational cohort study (2013-2022) investigating heart health in Dhulikhel, Nepal. The study was comprised of two exams: wave 1 in 2013 and wave 2 in 2022. This retrospective study used the data from the specific sections "Food and Nutrition" and "Anthropometric Assessment" collected at each exam. DHS used a semiquantitative validated Food Frequency Questionnaire (FFQ) to assess participants' usual dietary intake. BMI was assessed using weight and height data collected at each home visit. Multivariate regression was used to evaluate the relationship between the nutrition transition score and BMI.

The mean age of the participants at wave 1 was 42.8 (±15.1) years and at wave 2 it was 50 (±15.1) years. We found that 19% and 30% of the participants were hypertensive in DHS waves 1 and 2, respectively. We observed changes in both healthy and unhealthy GDQS food group during the 9-year follow-up. The mean GDQS score was 28.6 for the DHS participants at wave 1 and 24.9 at wave 2, indicating poorer diet quality at the second wave. After adjusting for age, education, sex, ethnicity, and total caloric intake, BMI and GDQS score of DHS wave 1 participants were not significantly associated (Coefficient: -0.04, SE: 0.07, p= 0.51), whereas in wave 2, BMI and GDQS score were associated (Coefficient: 0.20, SE: 0.07, p= 0.005). In the model evaluating BMI at wave 2 and the nutritional transition score. for every one unit increase in diet quality, BMI was 0.009 kg/m2 higher (Coefficient: 0.09, SE: 0.05, p=0.06). This study suggests that diet quality has declined, and obesity has increased during a 9-year follow-up in the DHS. However, associations between the nutritional transition score and BMI were not found. Results may have been affected by small sample size, variables not included in the models, and residual confounding.

Background and Significance

A nutrition transition is a change in population-level diet due to shifts in food availability, as well as other economic, social, demographic, and health factors.[1] Increased daily consumption of energy-dense, nutrient poor foods, increasing frequency of snacks and meals consumed away from home, shifts from drinking water to sugar-sweetened beverages and increased portion sizes are among the most commonly reported dietary changes associated with the nutrition transition, consequently increasing rates of nutrition-related non-communicable disease (NCD).[2,3]

Almost every country in the world has experienced dramatic shifts of the nutrition transition marked by high consumption of ultra-processed foods during a period of three to four decades.[4] Rapid rises in the prevalence of overweight-obesity and other nutrition-related NCDs, such as diabetes, hypertension, and other elements of coronary heart disease, are associated with nutrition transitions.[5] Cardiovascular diseases (CVDs) are the topmost causes of death and disability in Nepal, with an increase in both absolute and relative number of deaths over the past 16 years.[6]

Obesity has increased worldwide, which is one of the most critical and serious consequences of dietary change.[7] Obesity and being overweight are significant risk factors for CVD. Overweight and obesity cause approximately 35.8 million disability-adjusted life years, and 2.8 million people die each year worldwide as a result of being overweight and obese.[8] In 2019, approximately one fourth of Nepalese adults had elevated blood pressure, 11% had elevated cholesterol, 20% were overweight or obese, 98% did not .consume sufficient fruits and vegetables.[9]

During the last decade in Nepal, traditional foods such as rice, lentils and green vegetables have been replaced by processed food such as instant noodles, sugar sweetened beverages, ready-made breads and other fast foods. In addition, the number of fast-food restaurants has grown and an “eating out” culture is developing.[10] Sedentary lifestyles and increased access to processed food, especially in urban areas, has resulted in a substantial increase in overweight status and obesity in Nepal.[11] A 2013 study conducted in Nepal shows that the average proportion of energy derived from total fat has grown considerably from 13% in 1970 to 17% in 2010.[11] Meat, fish, milk, and eggs are the biggest contributors to an increase in total calorie consumption trends during the last 40 years, followed by plant fat and sugar. The proportion of Nepalese women who are overweight or obese has climbed from 21% in the year 2013 to 27% in 2019.[14] A survey in 2019 showed geographical discrepancies in prevalence of overweight and/or obesity with higher prevalence among residents of urban areas and hills.[9]

These studies provide evidence that Nepal is presently undergoing an active nutritional transition with rapid increases in overweight and prevalence of comorbidities. No study to date has measured the level of the nutritional transition and its association with increases in body mass index (BMI) in Nepal. The Dhulikhel Heart Study (DHS), an observational cohort of adults living in and around Dhulikhel, Nepal, included a longitudinal assessment of food consumption and health status during two waves: November 2013 – February 2015 (wave 1) and May 2022-present (wave 2). During both waves, a food frequency questionnaire was administered along with measures of blood pressure, height and weight, and self-reported diseases. The DHS provides the opportunity to evaluate changes in nutrition over a 9-year period as well as its impact on cardiometabolic health.

Objectives:

1) To measure the nutrition transition in terms of changes in dietary intake (whole grains, fruits and vegetables, beverages, fast/junk foods) among Dhulikhel Heart Study participants from 2013 to 2022.

2) To assess the association between 9-year dietary change and obesity calculated from body mass index (BMI) among participants of the Dhulikhel Heart Study.

Methods

Study Design: This analysis utilized data from the DHS, a longitudinal study of heart health among Nepalese adults. The study was comprised of two exams over 9 years: wave 1 (2013-2015) and wave 2 (2022-present).

Study Setting: The study was conducted in the Dhulikhel Municipality, a semi-urban city in Nepal. Dhulikhel municipality is about 20 miles southeast of the capital city of Kathmandu. In 2021, Dhulikhel had a population of about 36,183.[13]

Study Population: The study comprised adults 18 years of age or older who participated in both the wave 1 and wave 2 exams. Inclusion criteria for the DHS were 1) being a permanent resident of Dhulikhel or residing in Dhulikhel for at least six months at time of the survey; and 2) participation in both wave 1 and wave 2 of the Dhulikhel Heart Study (DHS).[14]

Exclusion Criteria: Exclusion criteria included 1) individuals who were pregnant at time of data collection; 2) temporary residents who lived in hostels or motels; and 3) individuals who were unable to provide appropriate responses to survey questions due to health concerns or inability to communicate in Nepali or Newari language.[14]

Sample Size: There were 307 participants who completed both waves of DHS through March 2023. This number was affected by data enumerators not being able to locate DHS wave 1 participants. Many of these participants migrated to another place or were deceased.

Data Collection: During wave 1, the data collection team consisted of bachelor-educated graduates from Kathmandu University who were trained to conduct door-to-door surveys and measure variables. All of the 2225 households in the city were enumerated and about a third of the households (n=735) were randomly selected and stratified by ward (nine administrative divisions) in the first phase of DHS.[14] Wave 2 of DHS is using the same methodology as wave 1 targeting previous participants from wave 1 and randomly selected households who were not involved in the first phase of the study. Data were collected through a standardized personal and household questionnaire using electronic tablets, physical exams, and laboratory testing. Demographic information collected included age, sex, ethnicity, education, employment status, and other socioeconomic data. Physical, behavioral, and environmental risk factors were also assessed. This

longitudinal used the data from the specific sections "Food and Nutrition" and "Anthropometric assessment" of DHS cohort study.

Food and Nutrition Questionnaire: DHS used a semiquantitative Food Frequency Questionnaire (FFQ) for assessing participants' usual dietary intake. The FFQ was validated prior to its use in the DHS.[15] The FFQ contains questions on the average consumption frequency during the past year for 115 commonly consumed food items.[15] Subjects indicated their answers in times per day, per week, per month, per year, or as never. For the portions, DHS used FFQ pictures of all the food items indicating food servings in half servings, one serving, one and half servings and two servings. For this analysis in this study, we were most interested in intake of whole grains, fruits and vegetables, beverages, and fast/junk foods.

Anthropometric Assessment: Weight was measured on all participants without shoes and while wearing minimal clothing using an Omron Model HBF-400 Scale recorded to the nearest 0.1 pounds. Height was measured without shoes using a standard tape measure with participants standing against a wall and recorded to the nearest 0.1 cm. This study used weight and height to calculate BMI: weight in kilograms divided by height in meters squared. Overweight was defined as BMI $\geq$ 25 kg/m^2 and obesity was defined as BMI $\geq$ 30 kg/m^2 based on international cut points. [16]

Study Framework: The components of the DHS that were collected both in waves 1 and 2 were used to determine the extent of the nutrition transition. A framework depicting the relationships of the nutrition transition with BMI is shown below in Figure 1.

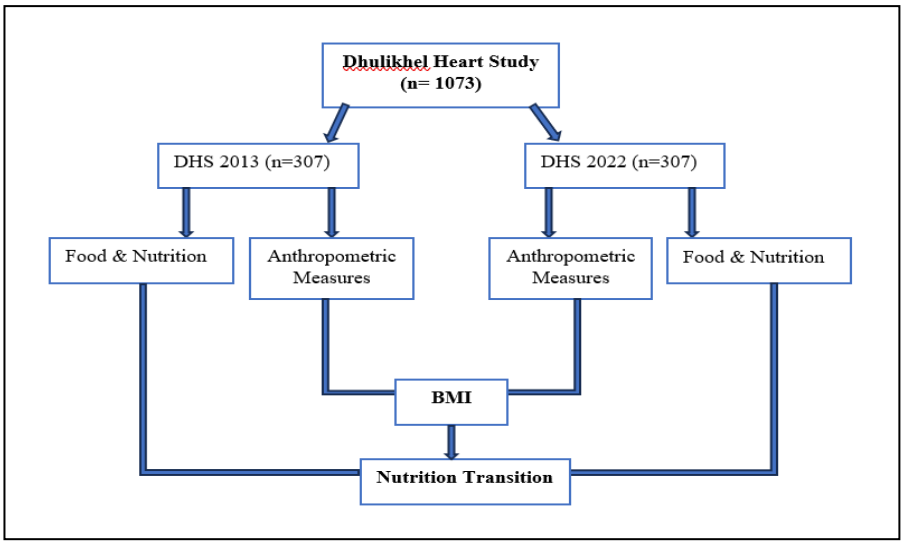

Figure 1. Study framework for evaluating the nutrition transition and body mass index in the Dhulikhel Heart Study

The GDQS (The Global Diet Quality Score) system was used to measure the nutritional transition by providing a quantitative measure of the 115 food items in the DHS food frequency questionnaire for each wave of the study. A higher GDQS score represents a healthier dietary intake based on consumption of fruits, vegetables, nuts and legumes, whole grains, dairy products, red and processed meats, beverages and fast/junk foods. The GDQS is a food-based metric, consisting of 25 food groups: 16 healthy food groups, 7 unhealthy food groups, and 2 food groups (red meat, high-fat dairy) that are unhealthy when consumed in excessive amounts (Appendix 1). For 24 of the GDQS food groups, three ranges are used in scoring the metric: low, medium, and high. For one food group (high-fat dairy), four ranges of consumption are used: low, medium, high, and very high.[17] In this study, each respondent received points for each GDQS food group, according to the quantity of consumption consumed for that food group during the one year reference period. The points of the healthy food groups increased for each higher quantity of consumption category. The points of the unhealthy food groups decreased for each higher quantity of consumption category. For the two food groups that are unhealthy in excessive consumption (high fat dairy and red meat), the points increased up to a certain threshold of quantity of consumption, after which the points decreased. The GDQS has a possible score of 0 to 49. Population-based cutoffs of 15 and 23 were be identified for the GDQS, as per the guideline, to allow for reporting the percent of the population at high risk for poor diet quality outcomes (GDQS <15) and the percent of the population at low risk for poor diet quality outcomes (GDQS $\geq$ 23).[17]

Appendix 1 provides the list of GDQS food groups, and the points assigned to each GDQS food group category of consumption, to tabulate the GDQS. The table is adopted from The Global Diet Quality Score: Data Collection Options and Tabulation Guidelines by Department of Nutrition, Harvard T.H. Chan.[16] The detail information on grouping of 115 food items based on the GDQS matrix is presented in the Appendix 2.

Statistical Analysis: The data were analyzed with RStudio (*R version 4.2.3*). Descriptive statistics on participant demographics were presented as means/standard deviations for continuous variables and counts/percentages for categorical variables. The GDQS diet score system was used to compare the nutrition transition scores from wave 1 through wave 2 among the participants. The nutrition transition was defined by subtracting the GDQS scores of 2013-2015 from that calculated in 2022-23. Multivariate regression was used to evaluate the relationship between the nutrition transition score and BMI of the DHS participants. The following variables were used in the statistical models:

Primary Analysis: Nutrition transition from 2013 to 2022 (calculated as the difference between GDQS at the two waves of DHS) was the primary exposure of interest. The outcome was BMI from DHS wave 2. Models were adjusted for socio demographic variables as described below.

Secondary Analysis: Nutritional scores of all 115 food items were used as the exposure in a secondary analysis of this study.

Other Variables: We also used sociodemographic information collected by standardized tools adopted from the Nepal STEPS survey [9] as adjustment variables in the models. The variables included age (in years), sex (male/female/other), ethnicity (brahmin/ chhetri/ tharu/ newar/ tamang/ others), education (number of years of formal education), annual income (in Nepalese rupees) , marital status (never married/ unmarried/ separated or divorced/ widow), religion (hindu/ muslim/ buddhist/ christian/ others), and occupation (farmer/ house maker / service / business/ student/ others).

Ethical considerations: The DHS received approval from the Dhulikhel Hospital Institutional Review Board for implementation of the study. Consent forms in the Nepali languages were provided to the participants and consent was obtained before collecting data

Results

The total sample size for data collected during DHS wave 1 was 1073. Due to various reasons described in Appendix 3, enumerators were not able to reach 61% of these participants for wave 2. The total sample collected for this analysis was 307 (29%).

Table 1 describes the socio-demographic characteristics of the DHS participants included in this study at waves 1 and 2. The mean age of the participants at wave 1 was 42.8 (±15.1) years and at wave 2 it was 50 (±15.1) years. The majority of the participants were male (56%) and of Newar ethnicity (65%). Almost all (96%) followed Hindu religion and 30% were self-employed. During wave 1 about 36% of the participants reported being illiterate while this was slightly less at wave 2 (32%). Overall, 19% and 30% of the participants self-reported or were designated as hypertensive based on blood pressure in DHS waves 1 and 2, respectively. About 27% of the participants in wave 2 and only 12% of participants in wave 1 reported to go outside of their home for meals at a mean 5-7 times in a week. The mean BMI of the DHS wave 1 participants was 24.88(±4.53) kg/m^2, whereas it increased to 27.26(±4.95) kg/m^2 among DHS wave 2 participants.

Table 1. Background characteristics of the Dhulikhel Heart Study participants with nutritional data collected at waves 1 and 2

Characteristics (n=307)	**DHS wave 1 (2013)**		**DHS wave 2 (2022)**	
	Frequency	percentage	Frequency	percentage
Age				
18-30	74	24.6	25	8.1
31-49	124	41.2	112	36.5
50-65	78	26.0	115	37.5
66-80	24	8.0	46	15.0
>80	1	0.3	9	3.0
Mean(sd)	42.8(15.1)		50.0(15.1)	
Sex				
Male	173	56.4	173	56.4
Female	134	43.4	134	43.4
Ethnicity				
Bramhin	35	11.4	35	11.4
Chhetri/Thakuri/Sanyasi	37	12.1	37	12.1
Newar	198	64.5	198	64.5
Magar/Tamang/Rai/Limbu	31	10.1	31	10.1
Sherpa/Bhote	1	0.3	1	0.3
Dalit (Kami/damai/sarki/..)	5	1.6	5	1.6
Religion				
Hindu	286	93.2	295	96.1
Boudha	13	4.2	5	1.6
Kirat	2	0.7	2	0.7
Christians	5	1.6	5	1.6
Others	1	0.3	0	0.0
Education				
illiterate	97	31.6	111	36.2
Primary	32	10.4	23	7.5
lower Secondary	20	6.5	20	6.5
Secondary	74	24.1	75	24.4
Higher secondary and above	84	27.4	78	25.4
Marital status				
Never married	41	13.4	16	5.2
Currently married	251	81.8	260	84.7
Separated	1	0.3	2	0.7
Widowed	14	4.6	29	9.4
Occupation				
Governmental employee	7	2.3	18	5.9
Non-governmental employee	34	11.12	42	13.7
Self-employed	87	28.3	92	30.0
Non-paid works	2	0.7	3	1.0
Student	102	33.22	3	1.0
Home maker	6	2.0	13	4.2
Retired	27	8.8	4	1.3
Unemployed	19	6.2	18	5.9
Unable to work	23	7.5	45	14.7
Farming	0	0.0	69	22.5
Meals eaten Outside of the home	293	95.4	115	37.5
Eat outside frequency in a week				
Less than once in a week	172	58.7	4	3.5
1-2 times	51	17.4	59	51.3
3-4 times	34	11.6	21	18.3
5-7 times	36	12.3	31	27.0
Hypertension (ever)	57	18.6	93	30.4
BMI				
Mean (SD)	24.88 (4.53)		27.26 (4.95)	

Appendix 4 describes the number and percentage of participants by BMI category. In the first wave of DHS, 53% of the participants were of normal weight and only 13% were obese. Whereas only 32% of the participants from wave 2 were of normal weight and about 23% of them were obese. The overweight population also increased from 29% to 42% across the two waves of the studies. A graph showing the trends of the BMI categories transition from DHS wave 1 to wave 2 is presented in Figure 2.

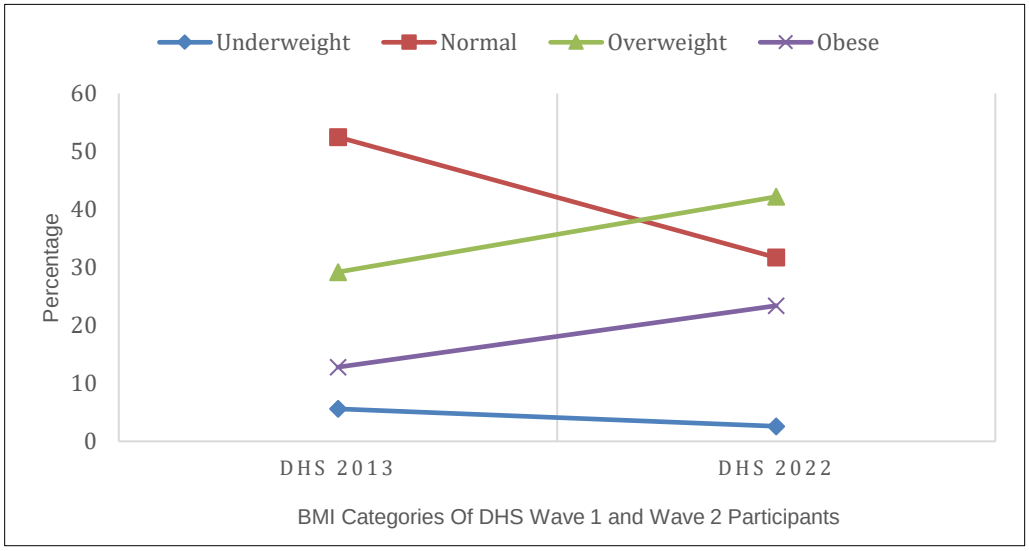

Figure 2: Trends of BMI categorization among DHS participants from wave 1 to wave 2

We saw changes in the percentage of food intake from wave 1 to wave 2 in both healthy and unhealthy GDQS food groups (Table 2). High intake of dark green leafy vegetables and cruciferous vegetables was reduced by almost half from 61% to 30% among DHS participants from wave 1 to wave 2, respectively. The participants with low intake of deep orange fruits increased more than two-fold from 10% in wave 1 to 24% in wave 2. Similarly, percentages of participants with low intake of legumes increased from 0% to 19% and of deep orange tubers from 35% to 95% between the years of the study. Likewise, participants with high intake of legumes decreased from 99% to 31% and of other vegetables from 99% to 79% across the years. There was also a great difference in the intake of nuts and seeds among the participants from the first to second waves of the study.

Among unhealthy food groups, all (100%) of the participants at wave 1 consumed high fat dairy foods at the low level of intake. This decreased to 85% at wave 2 as the remaining participants increased high fat foods at the middle (4.9%) and high level (9.8%) of intake. Low intake of sugar sweetened beverages and juice was calculated for 100% of the DHS participants at wave 1. Whereas, at wave 2, low intake of these same food groups decreased to 38% and 87% respectively (Table 2).

Table 2. Frequency and percentage of food intake categories and GDQS food groups of the DHS participants based on food intakes in gram per day

Food group	DHS wave 1 (2013), n (%)			DHS wave 2 (2022), n (%)		
	Low	Middle	High	Low	Middle	High
GDQS + (Healthy foods)						
Citrus fruits	28 (9.1)	54 (17.6)	225 (73.2)	33 (10.7)	37 (12.1)	237 (77.2)
Deep orange fruits	31 (10.1)	112 (36.5)	164 (53.4)	74 (24.1)	160 (52.1)	73 (23.8)
Other fruits	3 (1.0)	19 (6.2)	285 (92.8)	18 (5.9)	5 (1.6)	284 (92.5)
Dark green leafy vegetables	107 (34.9)	12 (3.9)	188 (61.2)	106 (34.5)	109 (35.5)	92 (30.0)
Cruciferous vegetables	107 (34.9)	12 (3.9)	188 (61.2)	106 (34.5)	109 (35.5)	92 (30.0)
Deep orange vegetables	8 (2.6)	49 (16.0)	250 (81.4)	66 (21.5)	76 (24.8)	165 (53.7)
Other vegetables	0 (0.0)	2 (0.7)	305 (99.3)	21 (6.8)	44 (14.3)	242 (78.8)
Legumes	0 (0.0)	5 (1.6)	302 (98.4)	57 (18.6)	154 (50.2)	96 (31.3)
Deep orange tubers	106 (34.5)	179 (58.3)	22 (7.2)	291 (94.8)	8 (2.6)	8 (2.6)
Nuts and seeds	15 (4.9)	22 (7.2)	270 (87.9)	71 (23.1)	27 (8.8)	209 (68.1)
Whole grains	20 (6.5)	10 (3.3)	277 (90.2)	37 (12.1)	21 (6.8)	249 (81.1)
Liquid oils	196 (63.8)	24 (7.8)	87 (28.3)	230 (74.9)	18 (5.9)	59 (19.2)
Fish and shellfish	138 (45.0)	137 (44.6)	32 (10.4)	177 (57.7)	110 (35.8)	20 (6.5)
Poultry and game meat	112 (36.5)	60 (19.5)	135 (44.0)	75 (24.4)	41 (13.4)	191 (62.2)
Low-fat dairy	240 (78.2)	59 (19.2)	8 (2.6)	69 (22.4)	88 (28.7)	150 (48.9)
Eggs	70 (22.8)	90 (29.3)	147 (47.9)	100 (32.6)	31 (10.1)	176 (57.3)
GDQS – (Unhealthy foods)						
High-fat dairy*	307 (100.0)	0 (0.0)	0 (0.0)	261 (85.0)	15 (4.9)	30 (9.8)
Red meat	55 (17.9)	62 (20.2)	190 (61.9)	58 (18.9)	53 (17.3)	196 (63.8)
Processed meat	118 (38.4)	70 (22.8)	119 (38.8)	137 (44.6)	34 (11.1)	136 (44.3)
Refined grains / baked goods	0 (0.0)	3 (1.0)	304 (99.0)	16 (5.2)	1 (0.3)	290 (94.5)
Sweets and ice cream	14 (4.6)	36 (11.7)	257 (83.7)	92 (30.0)	81 (26.4)	134 (43.6)
Sugar-sweetened beverages	307 (100.0)	0 (0.0)	0 (0.0)	115 (37.5)	78 (25.4)	114 (37.1)
Juice	307 (100.0)	0 (0.0)	0 (0.0)	268 (87.3)	30 (9.8)	9 (2.9)
White roots and tubers	282 (91.6)	5 (1.6)	20 (6.5)	49 (16.0)	71 (23.1)	187 (60.9)
Purchased deep fried foods	9 (2.9)	24 (7.8)	274 (89.3)	48 (15.6)	51 (16.6)	208 (67.8)

*GDQS has a score for very high intake for high-fat dairy; Only 1 (0.3 %) in wave 2 received this score.

#Higher the intake in GDQS healthy groups and lower the intake in unhealthy food groups indicate healthier eating patterns.

The mean GDQS score was 28.6 for the DHS participants at wave 1 and 24.9 at wave 2 (Table 3). There was a difference of 3.7 of mean score between the two time periods indicating that healthy eating had declined. Table 6 shows the mean GDQS score assigned for healthy and unhealthy food groups. Higher scores for GDQS healthy and unhealthy food groups indicate healthier eating patterns. We can see a nutrition transition from DHS wave 1 and 2 among the participants with differences of 2.4 mean score among healthy food groups and differences of 1.3 mean score in unhealthy food groups.

Table 3. GDQS score of the DHS wave 1 and 2 participants and the estimated percentages of people at risk of poor diet based on their food intake scores.

	Mean GDQS Healthy score	**Mean GDQS Unhealthy score**	**Mean GDQS total score**	**% of people at low risk of poor diet**	**% of people at high risk of poor diet**
DHS wave 1 (2013)	21.4	7.2	28.6	283 (92.2)	0 (0.0)
DHS wave 2 (2022)	19.0	5.9	24.9	214 (69.7)	17 (5.5)
Difference in score	-2.4	-1.3	-3.7		

#Higher scores for GDQS healthy and unhealthy food groups indicate healthier eating patterns.
#Higher difference in scores between DHS waves one and two indicate poor nutrition in wave two than one

In Figure 3 we provide a graphical representation of DHS participants at low and high risk of poor diet based on the GDQS score. About 92 % of the DHS wave 1 participants were at low risk of poor diet and none of them were at high risk. Whereas, among the DHS wave 2 participants, about 6% of them were at high risk of poor diet.

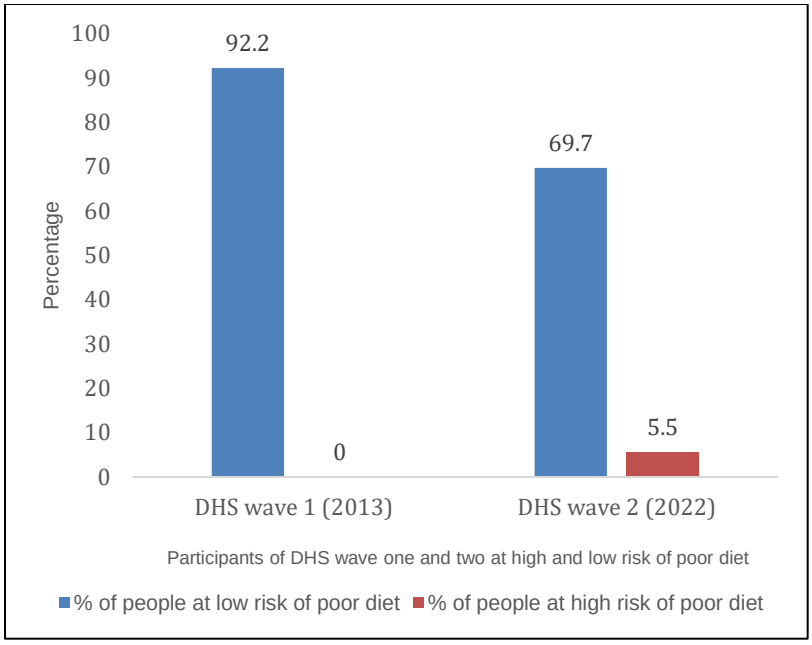

Figure 3. Percentage of DHS participants at risk of poor diet based on GDQS score from wave 1 and wave 2.

Table 4 represents the results of the adjusted multiple regression model between the BMI and GDQS score after adjusting for age, education, sex, ethnicity, and food consumption at wave 1. After adjustment, for each additional point a participant scored for food intakes, their BMI was lowered by 0.04 kg/m^2 of BMI. The p-value of 0.51 indicates that BMI and GDQS score of DHS wave one participants were not significantly associated after adjustments for the covariates.

Similarly for DHS wave 2, for each additional point scored for food intakes by the participants, their BMI higher by 0.20 kg/m^2. The p-value indicates that BMI and GDQS score after adjusting for age, education, sex, ethnicity and total food consumption were associated (p-value = 0.005).

Table 4. Multiple regression model for BMI and GDQS score (adjusted for age, sex, ethnicity and education and caloric intake) of the DHS participants.

coefficients	**DHS wave 1 (2013)**				**DHS wave 2 (2022)**			
	Estimate	St. error	t-value	P-value	Estimate	St. error	t-value	P-value
GDQS score	-0.04	0.07	-0.66	0.51	0.20	0.07	2.80	0.005*
Age	0.04	0.02	1.80	0.07	-0.04	0.02	-1.64	0.10
Education	0.05	0.06	0.72	0.47	0.04	0.07	0.53	0.60
Sex_male	0.94	0.56	1.66	0.08	-0.64	0.63	0.53	0.60
Ethnicity_chhetri	0.94	1.03	0.91	0.36	-2.61	1.14	-2.28	0.02*
Ethnicity_Newar	3.46	0.81	4.29	0.001*	-0.09	0.89	-0.10	0.92
Ethnicity_magar/Tamang	1.21	1.09	1.12	0.26	-1.14	1.22	-0.93	0.35
Ethnicity_sherpa	-1.08	4.41	-0.25	0.81	-6.71	4.90	-1.37	0.17
Ethnicity_Dalit	1.46	2.08	0.70	0.48	0.79	2.31	0.34	0.73
Total caloric intake	-0.03	0.06	-0.52	0.61	-0.001	0.001	-0.74	0.46

(*p-value < 0.05, statistically significant)

Table 5 represents the output of the adjusted multiple regression model between the outcome (BMI) and nine-year changes in nutritional score after adjusting for age, education, sex, ethnicity and food consumption. After adjustment, for each additional point increase in nutrition score difference, participants have an increase of 0.09 kg/m^2 in BMI. The p-value of 0.06 indicates that the BMI of DHS wave 2 participants and change in nutrition score from wave 1 to wave 2 were not significantly associated. The XY-plot of the correlation between the nutrition transition and BMI is presented in Figure 4.

Table 5. Adjusted multiple regression model of BMI and 9-year nutrition transition score (adjusted for age, sex, ethnicity, education and caloric intake) of the DHS participants.

Coefficients	Estimate	St. error	t-value	P-value
9-year nutritional score difference	0.09	0.05	1.86	0.06
Age	-0.04	0.02	-1.63	0.10
Education	0.04	0.07	0.59	0.56
Sex_male	-0.50	0.65	-0.76	0.45
Ethnicity_chhetri	-2.46	1.15	-2.13	0.06
Ethnicity_Newar	-0.04	0.90	-0.20	0.10
Ethnicity_magar/Tamang	-1.21	1.22	-1.11	0.33
Ethnicity_sherpa	-6.22	4.93	-1.31	0.21
Ethnicity_Dalit	0.77	2.33	0.25	0.74
Total calorie consumption	0.005	0.001	-0.06	0.95

(*p-value < 0.05, statistically significant)

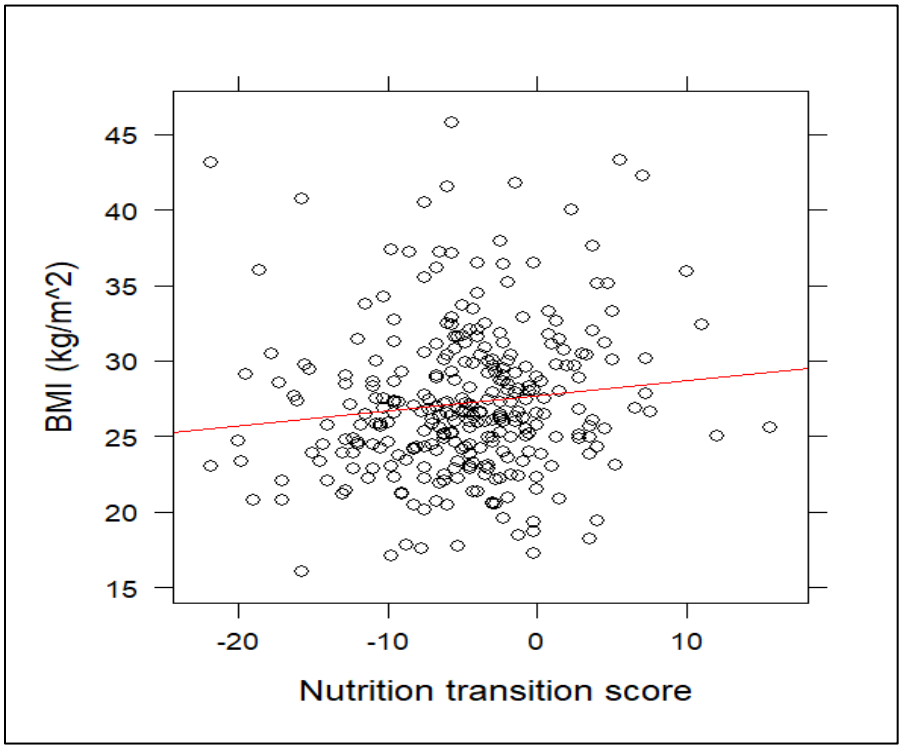

Figure 4: Scatterplot between 9-year difference in nutritional score and BMI of DHS participants

Discussion

The total sample size for this study was 307 Nepalese participants with a mean age of 50.0 years (SD 15.1) and 56% were male. Most of the participants were of Newar ethnicity (65%). About 19% of the participants from DHS wave 1 and 30% of the participants from DHS wave 2 were hypertensive. The mean BMI of the DHS wave 1 and wave 2 participants were 24.88(±4.53) kg/m^2 and 27.26(±4.95) kg/m^2, respectively. We found that an increase in overweight and obesity occurred between the two waves of the study. In the first wave of DHS, 13% of the participants were obese. Whereas in wave 2, 23% of them were obese. The overweight population also increased from 29% to 42% over the nine years. There was a change in the quality of food intake among participants from wave 1 to wave 2. High intake of dark green leafy vegetables and cruciferous vegetables was reduced by almost half from 61% to 30%, low intake of deep orange fruits increased more than two-fold from 10% in to 24%, high intake of legumes decreased from 99% to 31% and other vegetables from 99% to 79% among DHS participants from wave 1 to wave 2, respectively, across the years. In terms of unhealthy foods, low consumption of high fat dairy decreased from 100% to 85%. The low intake of sugar sweetened beverages and juice was calculated for both at 100% in wave 1, whereas, at wave 2, low intake of these same food groups decreased to 38% and 87% respectively.

The nutrition transition from DHS wave 1 and 2 was calculated as a mean difference of 2.4 points for healthy food groups and a mean difference of 1.3 points in unhealthy food groups, both differences indicating a reduction in nutritious foods. About 6% of the DHS wave 2 participants were at high risk of poor diet from 0% at DHS wave 1. After adjustment, for each additional point a participant scored for food intake, the BMI was reduced by 0.04 kg/m^2 (p-value = 0.51) among DHS wave 1 participants and increased by 0.20 kg/m^2 (p-value = 0.005) among DHS wave 2 participants. Combining the transitions for both healthy and unhealthy foods, each additional point increase in the nutrition transition (indicating a healthy change) was associated with an increase of 0.09 kg/m^2 in BMI (p-value of 0.06). While the associations shown between the GDQS score and BMI at wave 1 were in the expected direction (healthier food choices resulting in lower BMI), in wave 2 the direction was the opposite with an increase in healthier foods showing an increase in BMI. The final transition score between the two waves resulted in a non-significant association of an increase in healthier foods with an increase in BMI, also an unexpected result.

A study conducted in 2017, "Where is Nepal in the nutrition transition?", reported the changes in Nepalese dietary patterns over the past 40 years.[18] In that study, energy consumption as a proportion of total energy grew from 12.4% in 1970 to 17.3% in 2010, increasing at a pace of 0.8% per year. Caloric intake was also reported to increase from 1795 kcal/day in 1970 to 2450 kcal/day in 2010. This study also revealed that

while fat intake in Nepal has been steadily increasing over the past 40 years, per capita supplies of protein and carbohydrates have decreased.[18] Our study has also shown changes in food intake consumption over time in grams/day. We found that the high consumption of both dark green leafy vegetable and deep orange fruits decreased by approximately half, and high consumption of legumes and white roots and tubers has decreased by close to 70% over 9 years. Our data confirmed the trends in unhealthy foods as consumption of high fat dairy, sugar sweetened beverages and juices increased.

Trends in food intake have been studied in other low- and middle-income countries (LMICs). Nepal's neighbor country, India, appears to be at an earlier stage of the nutrition transition shift and that it is occurring only in the metropolitan regions according to research posted online by Cambridge University Press. India's food has a very high dairy and sugar intake, and both in the cities and the countryside, there are noticeable increases in the diet's energy density.[19] The consumption of cereal grains increased, indicative of a progressive improvement in calorie intake per person, but the consumption of the majority of other food products, such as milk, oil, sugar, etc., remained relatively stable.[20] Another research study by Kosulwat found that, as part of a noticeable shift in the structure of the diet towards one dominated by animal products in Thailand, consumption of animal products and energy from fat has grown noticeably while carbohydrate intake has decreased. Additionally, there has been a rise in the consumption of fruits and vegetables.[21] According to the Harvard T.H. Chan, Obesity Prevention Website of the School of Public Health explaining thenutrition transition, the majority of LMICs are presently transitioning quickly from pattern 3 (the end of famine) to pattern 4 (eating more calorie-dense foods). In these low-resource nations, the obesity pandemic has been further exacerbated by this switch from traditional diets to Western-style diets.[22] Our prospective study, conducted among DHS participants, also showed a negative nutrition transition score from 2013 to 2022 based on a reduction in the GDQS score over time. At the same time, the percentage of obese participants increased from 13% to 23% over 9 years. In contrast to this increase in obesity, the regression model between the nutrition transition score and BMI showed that a higher difference in nutritional score was associated with an increase in BMI, which was the opposite of our research hypothesis.

Reasons for these unexpected results can only be speculated. One reason may be that the small sample size of participants from wave 1 agreeing to complete wave 2 was biased or not representative of the Nepalese population. We acknowledge that this was not a random sample and participants self-selected to be involved. It is also possible that errors in measurement during data collection occurred. While the study enumerators for both waves were rigorously trained, mistakes may still have occured resulting in our findings. Although not probable, the manner in which the FFQ data were collected may not be compatible

with the scoring system developed in the GDQS scoring system. However, the most likely explanation for our findings may be the exclusion of several important variables into the models. The potential for confounding by factors not included in these analyses, or residual confounding by covariates that were included, is a real possibility. Since data from the DHS is ongoing, some important variables, such as physical activity and amount of alcohol consumed, had not yet been made available to researchers. Similarly, there were some participants with BMI higher than 50kg/m^2, which can also be affecting the results. Hence, inclusion of these and other factors relevant to weight gain and removal of participants with higher BMI may modify results and conclusions of this study. We plan to rerun these analyses when the DHS has completed data collection to learn if a larger sample size or inclusion of other important variables may result in different findings.

Although the data for these analyses were extracted from the pioneer Dhulikhel Heart Study, there were various limitations associated with this study. In addition to those mentioned above, this study used secondary data from one municipality in Nepal; conclusions about the nutrition transition and related BMI may not be representative of the larger country of Nepal. Second, due to many variables being self-reported responses, there is a potential for inaccurate reporting or biased responses. Therefore, any inferences drawn from this study may not be applicable to other regions of Nepal. And third, since data were collected by others, we did not have control over any aspects of how the data were collected or how well it was done. Regardless, this is the first study to attempt to understand how the nutrition transition may impact BMI in Nepal. Further work on this topic may prove to provide important information that can be used to address public health concerns.

Conclusion

Although the relationship between the nutrition transition score and BMI was not significant in this study, and unexpected results were found, we documented a pattern of nutrition degrading and more unhealthy food intake increasing over time. The higher nutrition score among DHS wave 1 (2013) participants than DHS wave 2 (2022) shows the negative trend of food consumption among the DHS participants over 9 years. This study needs further analysis with other variables including physical activity that might impact the BMI and nutrition associations of the DHS participants. Hence, further and more studies related to nutrition transitions and BMI are needed in the future.

Acknowledgement

I would like to acknowledge (a) the University of Washington, Department of Global Health for this opportunity to conduct a thesis for the partial fulfillment of the degree, (b) Cardio-Metabolic Research Training Program, NIH for funding my degree and (c) Prof. Annette L. Fitzpatrick, Dr. Mandy Fretts and Dr. Archana Shrestha for regular guidance and support throughout this study.

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Appendix 1. GDQS food groups and scoring

Inclusion in metrics	Scoring classification	Food group	Categories of consumed amounts (g/day)				Point assigned			
			Low (1)	Middle (2)	High (3)	Very high (4)	Low	Middle	High	Very high
GDQS +	Healthy	Citrus fruits	<24	24-69	>69		0	1	2	
		Deep orange fruits	<25	25-123	>123		0	1	2	
		Other fruits	<27	27-107	>107		0	1	2	
		Dark green leafy vegetables	<13	13-37	>37		0	2	4	
		Cruciferous vegetables	<13	13-36	>36		0	0.25	0.5	
		Deep orange vegetables	<9	9-45	>45		0	0.25	0.5	
		Other vegetables	<23	23-114	>114		0	0.25	0.5	
		Legumes	<9	9-42	>42		0	2	4	
		Deep orange tubers	<12	12-63	>63		0	0.25	0.5	
		Nuts and seeds	<7	7-13	>13		0	2	4	
		Whole grains	<8	8-13	>13		0	1	2	
		Liquid oils	<2	2-7.5	>7.5		0	1	2	
		Fish and shellfish	<14	14-71	>71		0	1	2	
		Poultry and game meat	<16	16-44	>44		0	1	2	
		Low-fat dairy	<33	33-132	>132		0	1	2	
		Eggs	<6	6-32	>32		0	1	2	
GDQS -	Unhealthy in excessive amount	High-fat dairy*	<35	35-142	>142-734	>734	0	1	2	0
		Red meat	<9	9-46	>46		0	1	0	
	Unhealthy	Processed meat	<9	9-30	>30		2	1	0	
		Refined grains and baked goods	<7	7-33	>33		2	1	0	
		Sweets and ice cream	<13	13-37	>37		2	1	0	
		Sugar-sweetened beverages	<57	57-180	>180		2	1	0	
		Juice	<36	36-144	>144		2	1	0	
		White roots and tubers	<27	27-107	>107		2	1	0	
		Purchased deep fried foods	<9	9-45	>45		2	1	0	

Appendix 2: Food items categorization based on GDQS matrix and Operational Definitions of GDQS Food Groups

Food group	Operational definition	Food types
Citrus fruits	Whole fruits in the genus Citrus	Lemon, Orange, Grapefruit
Deep orange fruits	Whole fruits (not including juice or spreads) containing ≥120 retinol equivalents per 100g.	Peach, Papaya, Mango
Other fruits	Whole fruits not belonging in the other fruit categories (not including coconuts)	Pineapple, Plum, Apple, Guava, Litchi, Grapes, Banana, Pomegranate, Watermelon, Cucumber
Dark green leafy vegetables	Leafy vegetables containing ≥120 retinol equivalents per 100g.	Green vegetables
Cruciferous vegetables	Vegetables in the family Brassicaceae.	Broccoli_Cauliflower Cabbage, Radish_Turnip, Egg-plant
Deep orange vegetables	Non-tuberous vegetables containing ≥120 retinol equivalents per 100g.	Pumpkin, Carrot
Other vegetables	Vegetables do not belong in the other vegetable categories.	Pointed gourd, Bitter gourd, Tomato, Bottle gourd, Chayote, Lady's-finger, Luffa gourd, Jackfruit, Sprout, Bamboo shoot, dried veggies, Mushroom, Garlic, Onion
Legumes	Legumes and foods derived from legumes, such as tofu and soymilk. Does not include bean sprouts (classified in "Other vegetables") or groundnuts (classified in "Nuts and seeds").	Dry beans, Soyabean, green peas
Deep orange tubers	Tuberous vegetables containing ≥120 retinol equivalents per 100g (includes variants biofortified with vitamin A)	Sweet potato, Yam
Nuts and seeds	Nuts, seeds, and products derived from nuts and seeds, such as nut-based butters (but not oils). Also includes groundnuts. Seeds that are used as spices are included when used in their whole (not powdered) form.	Peanut, Cashew, Almonds, Walnut, Pistachio, Dry fruits
Whole grains	Whole grains and whole grain products. Does not include products with significant amounts of added sugar (classified as "Sweets and ice cream").	Whole flour bread, Wheat, Brown_bread, Millet flour, whole pulse, Roasted maize
Liquid oils	All types of oils that are liquid at room temperature, regardless of fatty acid profile (this includes palm olein, liquid palm kernel oil, and liquid coconut oil). Does not include oil used to deep fry foods that are purchased. But it does include oil used to deep fry foods prepared at home.	mustard_oil, sunflower_oil, soyabean_oil
Fish and shellfish	Fish (whether processed or unprocessed) based on phylogenetic classifications (including sharks, eels, and rays), and other seafood high in n3 fatty acids (including shellfish, jellyfish, cetaceans, and pinnipeds, but not echinoderms). Includes organs.	nonfried fish
Poultry and game meat	Unprocessed poultry and game, including a range of undomesticated animals and bush meat, for example: primates, rodents, canines, felines, marsupials, leporids (rabbits and hares), wild boar, bats, bears, semiaquatic mammals (including otters and beavers), undomesticated ungulates, reptiles (aquatic and terrestrial), and amphibians. Includes organs.	chicken_without skin, chicken_with skin
Low-fat dairy	Reduced or naturally low-fat dairy products (≤2% milk fat). Includes flavored milk, and milk or cream added to coffee or tea.	Butter, ghee, Yogurt, low_fat_milk, paneer, cheese

Eggs	All types of eggs. Does not include mayonnaise.	Egg
High-fat dairy*	High-fat milk and dairy products (>2% milk fat). Includes flavored milk, and milk or cream added to coffee or tea. Does not include butter or clarified butter. This category also does not include ice cream and whipped cream.	whole_milk
Red meat	Unprocessed red meat belonging to domesticated animals (i.e., not game), including organs. "Red" classification is not based on color but on nutritional characteristics, and thus includes pork and lamb.	Mutton, buff meat, pork meat
Processed meat	Processed red meat, poultry, or game, including organs, and excluding fish or seafood. Processing is defined as per International Agency for Research on Cancer: "salting, curing, fermentation, smoking or other processes to enhance flavor or improve preservation."	chicken_momo, chicken sausage, buff_mo_mo, buff_sausage, pork_mo_mo
Refined grains and baked goods	Refined grains and refined grain products. Does not include products with significant amounts of added sugar, which should instead be classified as "Sweets and ice cream".	Rice, beaten_rice, choumin, pasta, sooji, white_bread, noodles, biscuit, pizza, canned_food, veg_burger, chicken_burger, pickles
Sweets and ice cream	Sugar-sweetened foods that are not beverages. This category includes sugar and other caloric sweeteners added to other foods and drinks. Whipped cream is also classified in this category.	ice_cream, chocolate, sweets, malpa, sugar, jaggary, jam
Sugar-sweetened beverages	Sweetened drinks that do not contain any fruit juice at all. Includes, for example: sodas, energy drinks, and sports drinks, and beverages made using low-calorie sweeteners, such as diet sodas. Sweetened tea and coffee, and dairy or cereal-based drinks are not included.	coke_pepsi_dew, fanta_sprite, canned_juice, milk_tea, black_tea,, milk_coffee, black coffee
Juice	Unsweetened or sweetened drinks that are at least partly composed of fruit juice. This category also includes fruit smoothies made from whole fruit.	fruit_juice
White roots and tubers	Tuberous vegetables with <120 retinol equivalents per 100g. Includes flours such as potato or cassava flour.	Potato
Purchased deep fried foods	Deep fried foods are foods that are fried in an amount of fat or oil sufficient to cover the food completely. Only deep fried foods that are purchased (i.e., not prepared at home) are classified in this category. Foods that are classified in this category are "double classified." The food should be classified as belonging to the purchased deep fried food category and should also be classified in the food group to which the food normally belongs if not purchased and deep fried (e.g., deep fried white potatoes that are purchased should be classified in both the purchased deep fried foods category and in the white roots and tubers category).	fried_fish, swaari, pakauda, french_fries, bhujiya, , potato_chips, donought

Appendix 3: Results of attempts to contact participants from DHS wave 1 to participate in wave 2

Total participants in DHS wave 1 (2013)	**1073**
Unsuccessful call	687
Successful calls	386
Results of successful contacts	**418**
Shifted to another place than Dhulikhel	31
Went abroad	21
Patient expired	47
Denied	5
Disabled	2
Data collected	312
Final data set after matching of IDs	**307**

Appendix 4. Frequency and percentage of DHS wave 1 and 2 participants based on their BMI categories.

	DHS wave 1 (2013)		**DHS wave 2 (2022)**	
	Frequency	Percentage	Frequency	Percentage
Underweight (less than 18.5 kg/$m^{2)}$	17	5.6	8	2.6
Normal (18.5 kg/m^2– 24.9 kg/$m^{2)}$	160	52.5	96	31.7
Overweight (25 kg/m^2 – 29.9 kg/m^2)	89	29.2	128	42.2
Obese (30 kg/m^2 and above)	39	12.8	71	23.4

#missing data: 2 in wave one and 4 in wave two