Distribution of Body Mass Index of Indian Women: A Study Based on NFHS-2 and NFHS-3

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ABSTRACT

World Health Organization recommended Body Mass Index (BMI) as a measure of nutritional status of adults. This study investigates the distribution of BMI and its changes among Indian women in the age-group 15-49 years based on sampled data of 83,646 and 111,983 women from the National Family Health Survey-2 (NFHS-2) and NFHS-3 respectively. Background characteristics (BC) specific distributional changes in BMI are demonstrated by (i) fitting an appropriate probability distributions (ii) partial sum based on percentiles of distribution and (iii) test of equality of percentiles of distribution of BMI from NFHS-2 and NFHS-3. Relative measures R_1 and R_2 are defined to demonstrate burden of underweight and obesity. Changes in the prevalence of underweight, obesity and annual gain in mean BMI for synthetic cohort by age-groups are presented. Rapid increments are observed in mean and higher percentiles of BMI among married women, women in the higher age-groups, and women from south zone of India. High prevalence of underweight is observed among rural women (40.6%) and women from low standard of living (49.7%). Double burden of underweight and obesity is reported among older, rich and highly educated women and women from Christian and Sikh religions. Tests of equality of percentiles of BMI are rejected ($p < 0.001$) for many BC. Results may be useful for making health policy for Indian women. India need to address women health issues afflicting the underweight from poor class and obesity from the rich class.

KEYWORDS: *BMI*, *NFHS*, underweight, obesity, change in distribution, synthetic cohort.

1. Introduction

The Body Mass Index (*BMI*) or Quetelet Index is a statistical measure of the weight of a person scaled according to height. The *BMI* of a person is the ratio of person's weight in kilograms to the square of the height in meters (kg/m^2). Researchers have demonstrated the population based changes in *BMI* through the change in mean *BMI* or point estimates such as prevalence of obesity to summarize changes in overall distribution (Headley *et al.*, 2004; Flegal *et al.*, 2010; Ogden *et al.*, 2014). The implicit assumption in most of the studies was that the distribution of *BMI* or the dispersion in the population has remained constant, with the entire distribution moving typically to right, allowing summaries of population change by examining a single parameter. Previous research had showed greater increases in the upper deciles of the *BMI* distribution accompanied by increases in the variance across United states for birth cohorts from 1882 to 1986 (Komlos & Brabee, 2011). There has also been evidence of grater increases in *BMI* at higher quantiles within socioeconomic and demographic groups (Ljungvall & Zimmerman, 2012). The prevalence and distribution of malnutrition in a society have implications for public health outcomes and policy formulation. Underweight people die at much higher rates, perhaps because of diseases related to being malnourished, while overweight and obese people also have higher rates of death and disease, mostly from causes such as diabetes, heart disease and cancer (Razaket *al.*, 2013). This growing trend of body weight extremes is going to pose a major challenge for health care and policy leaders (Razaket *al.*, 2013). While exploring the prevalence of *BMI* categories and changes in mean *BMI* are important for understanding population health, they do not capture the whole distribution of *BMI*. Understanding the actual distribution of *BMI* is important since mean values may hide differences in patterns at both the upper and lower ends of the distribution.

Major objective of this study is to investigate the distributional changes in *BMI* of Indian women from *NFHS-2* to *NFHS-3*. For this study, we have used data from *NFHS-2* and *NFHS-3*. These nationwide surveys were conducted in India during 1998-99 and 2005-06 respectively. We have demonstrated the changes in the distribution of *BMI* of Indian women for some selected background characteristics (*BC*) using different approaches.

The paper is organized as follows. Methodology is described in Section 2, which include different approaches for studying change in distribution of *BMI* and derived output Tables of analysis. The results extracted from output Tables of

Section 2 are reported in Section 3. Discussion on results is also included in Section 3. In Section 4, we have given brief conclusion of the study.

2. Methodology

2.1. Data from NFHS-2 and NFHS-3

In India, the National Family Health Survey (NFHS) program started in the early 1990s and it provides a nationally important source of representative data on population health for Indian states. NFHS program was initiated by the Ministry of Health and Family Welfare, Government of India. So far four rounds of NFHS are conducted namely NFHS-1 (1992-93), NFHS-2 (1998-99), NFHS-3 (2005-06) and NFHS-4 (2015-16). These are nationwide surveys conducted with a representative sample of households throughout the country. In NFHS-1 and NFHS-2 data were collected on women only. Data on height and weight of women were not collected in NFHS-1. In NFHS-2, information was collected from 91,196 households and interviewed 89,199 ever married women aged 15-49 years. Women who were pregnant at the time of survey, women who gave birth during the two months preceding the survey and women for whom there was no information on height and/or weight or for whom a BMI could not be estimated are excluded from the analysis. After omission cases of such women the total sample size from India during NFHS-2 became 83,646 ever married women. In NFHS-2, the response rate was 93.7% (IIPS, 2000).

In NFHS-3, for the participation 1,31,596 women aged 15-49 years were selected in the sample. Out of 1,31,596 selected women, 1,24,385 actually participated in the survey, yielding a response rate of 94.5%. After deleting the cases of not eligible women and women with missing observations on some BC, we have used data of 1,11,983 women (IIPS, 2007) from NFHS-3. We could not extend our study on NFHS-4 as data on NFHS-4 is not open in public domain till date.

For this study, BMI was considered as response variable. Categorical groups based on ranges of BMI are defined using the criteria established by World Health Organization and modified guidelines given by Health Ministry of India jointly with Indian Council of Medical Research (WHO, 2004). These four groups are as follows:

Underweight (UW): $BMI < 18.5$ Normal weight (NW): $18.5 \leq BMI < 23$

Overweight (OW): $23 \leq BMI < 25$ Obese (OB): $BMI \geq 25$

In this study, we considered some socio-economic and demographic variables as BC: age-group, formal educational level, religion, caste, type of residence, marital status, zone and standard of living index of the household of each

respondent. These variables were also considered and discussed in detail by Patil and Shinde (2014).

2.2 Methods for studying change in distribution of *BMI*

To demonstrate the changes in the distribution of *BMI* of Indian women based on the survey data of *NFHS-2* and *NFHS-3*, we have used following approaches: (i) prevalence rates and descriptive statistics of *BMI* (ii) longitudinal changes using synthetic cohorts based on age-groups (iii) fitting an appropriate probability distribution to *BMI* (iv) partial sums based on percentiles of distribution of *BMI* and (v) test of equality of percentiles of distribution of *BMI* from *NFHS-2* and *NFHS-3*. In the following subsections we have explained these approaches briefly and presented the tables derived from analysis.

2.2.1 Prevalence of underweight and obesity in Indian women

Using the categorical groups based on ranges of *BMI*, we define following two measures R_1 and R_2 to assess burden of malnutrition (UW/OW/OB) on population.

$$R_1 = \frac{\text{Prevalence percentage of women under (UW+OW+OB)}}{\text{Prevalence percentage of women under NW}} \quad (1)$$

$$R_2 = \frac{\text{Prevalence percentage of women under (OW+OB)}}{\text{Prevalence percentage of women under UW}} \quad (2)$$

Interpretations based on values of R_1 and R_2 are as follows.

- If $R_1 < 1$ then more than 50% of population belongs to NW. This case is rare under *BC* for Indian women (see Table 1).
- If $R_1 > 1$ then more than 50% of population is under malnutrition (UW/OW/OB) status. This case is commonly observed for many *BC*.
- If $R_1 > 1$ and $R_2 > 1$ then there is double burden of UW as well as obesity (OW/OB) and problem of obesity is of more concern than UW.
- If $R_1 > 1$ and $R_2 < 1$ then problem of UW is of more concern than obesity (OW/OB).

The weighted and un-weighted prevalence percentages based on ranges of *BMI* of Indian women according to *BC* are presented in Table 1 for *NFHS-2* and *NFHS-3*. The values of R_1 and R_2 based on weighted prevalence percentages are also presented in Table 1. Results are discussed in Section 3.

2.2.2 Descriptive statistics of *BMI* of Indian women

The weighted descriptive statistics (Mean, Standard Deviation (SD), some

Table 1: Weighted and Un-weighted (in parenthesis) prevalence according to *BMI* ranges and *BC* of Indian women during *NFHS-2* and *NFHS-3*

BC	Survey	Sample size	Prevalence in %				R ₁	R ₂
			UW	NW	OW	OB		
Residence								
Rural	NFHS-2	57561	39.7(36.1)	48.3(50.6)	6.2(6.9)	5.8(6.4)	1.07	0.30
	NFHS-3	61293	40.6(35.6)	45.0(47.7)	7.0(8.1)	7.4(8.6)	1.22	0.35
Urban	NFHS-2	26085	22.4(20.4)	41.1(41.9)	13.4(13.7)	23.1(24.1)	1.43	1.63
	NFHS-3	50690	25.0(22.5)	39.5(41.5)	12.0(12.5)	23.5(23.5)	1.53	1.42
Age-group								
15-19	NFHS-2	6368	38.6(36.0)	55.8(57.5)	3.9(4.5)	1.7(2.0)	0.79	0.15
	NFHS-3	21650	46.8(42.1)	47.1(49.9)	3.7(4.8)	2.4(3.2)	1.12	0.13
20-24	NFHS-2	14725	39.5(35.9)	51.3(53.8)	5.5(6.2)	3.7(4.1)	0.95	0.23
	NFHS-3	18902	40.8(34.9)	47.0(50.5)	6.4(7.9)	5.8(6.7)	1.13	0.30
25-29	NFHS-2	16934	37.9(33.6)	47.4(49.8)	7.4(8.4)	7.3(8.2)	1.11	0.39
	NFHS-3	17921	35.3(29.4)	45.0(47.1)	9.1(10.5)	10.6(12.9)	1.22	0.56
30-34	NFHS-2	14745	34.3(30.1)	45.0(46.6)	8.9(10.0)	11.8(13.4)	1.22	0.60
	NFHS-3	16384	32.9(26.1)	41.6(43.3)	10.2(12.0)	15.3(18.6)	1.40	0.78
35-39	NFHS-2	12791	31.3(27.9)	43.3(44.4)	10.5(11.2)	14.9(17.1)	1.31	0.81
	NFHS-3	15233	28.9(22.8)	40.3(40.8)	11.2(12.6)	19.6(23.8)	1.48	1.07
40-44	NFHS-2	10187	31.4(27.6)	40.7(41.7)	10.6(11.1)	17.3(19.7)	1.46	0.89
	NFHS-3	12507	27.1(20.5)	38.2(38.3)	11.8(13.5)	23.0(27.8)	1.62	1.28
45-49	NFHS-2	7896	29.9(26.3)	40.1(40.9)	10.6(11.6)	19.4(21.2)	1.49	1.00
	NFHS-3	9386	25.6(20.1)	37.2(36.2)	12.5(14.1)	24.7(29.6)	1.69	1.45
Education								
No Education	NFHS-2	41048	42.0(38.5)	47.5(49.5)	5.8(6.3)	4.7(5.6)	1.11	0.25
	NFHS-3	35500	41.7(36.6)	44.4(45.7)	6.7(8.1)	7.3(9.6)	1.25	0.34
Primary	NFHS-2	14505	35.2(31.5)	46.2(48.3)	8.2(9.1)	10.5(11.2)	1.17	0.53
	NFHS-3	16157	34.9(29.9)	44.1(46.2)	8.8(10.0)	12.2(14.0)	1.27	0.60
Secondary	NFHS-2	20352	26.1(23.0)	45.9(47.2)	11.0(11.8)	17.0(18.1)	1.18	1.07
	NFHS-3	48932	32.4(27.5)	42.2(44.8)	9.5(10.5)	15.9(17.1)	1.37	0.78
Higher	NFHS-2	7720	15.5(13.3)	40.8(40.2)	15.3(16.2)	28.5(30.3)	1.45	2.83
	NFHS-3	11382	19.3(16.6)	40.0(41.1)	14.1(14.7)	26.7(27.6)	1.50	2.11

Table 1 continued...

BC	Survey	Sample size	Prevalence in %				R ₁	R ₂
			UW	NW	OW	OB		
Standard of living								
Low	NFHS-2	23118	46.9(44.0)	46.3(48.7)	4.3(4.7)	2.6(2.7)	1.16	0.15
	NFHS-3	18051	49.7(45.5)	42.8(46.0)	4.4(5.2)	3.0(3.4)	1.33	0.15
Medium	NFHS-2	39722	34.8(31.7)	48.5(50.5)	8.1(8.7)	8.5(9.1)	1.06	0.48
	NFHS-3	32272	40.2(35.1)	45.7(48.6)	6.9(8.0)	7.2(8.4)	1.19	0.35
High	NFHS-2	19812	17.2(15.5)	41.5(41.5)	14.3(14.7)	27.0(28.2)	1.41	2.40
	NFHS-3	54740	24.3(21.1)	41.0(42.2)	12.1(12.9)	22.5(23.8)	1.44	1.42
Religion								
Hindu	NFHS-2	65069	36.3(33.2)	46.6(47.3)	7.7(8.5)	9.3(10.9)	1.14	0.47
	NFHS-3	81342	36.4(31.9)	43.5(43.7)	8.3(9.6)	11.8(14.8)	1.30	0.55
Muslim	NFHS-2	9734	32.9(29.5)	45.7(47.2)	9.1(9.8)	12.3(13.6)	1.19	0.65
	NFHS-3	14452	35.1(30.1)	42.1(42.0)	8.6(10.3)	14.1(17.6)	1.37	0.65
Christian	NFHS-2	4709	24.4(19.3)	47.1(56.4)	11.4(11.4)	17.1(13.0)	1.12	1.17
	NFHS-3	10024	23.2(16.8)	45.8(58.5)	12.8(12.1)	18.2(12.5)	1.18	1.34
Sikh	NFHS-2	1998	16.3(16.4)	40.7(39.9)	13.8(13.6)	29.2(30.1)	1.46	2.64

	NFHS-3	2591	17.8(17.9)	36.7(36.6)	13.9(13.7)	31.6(31.8)	1.72	2.56
Other	NFHS-2	2136	23.6(17.6)	43.2(56.1)	9.3(11.8)	14.8(14.5)	1.10	1.02
	NFHS-3	3574	36.8(21.7)	42.4(51.1)	8.8(12.7)	11.9(14.5)	1.36	0.56
Caste								
SC	NFHS-2	14225	41.2(38.7)	46.9(47.5)	6.1(6.8)	5.7(7.0)	1.13	0.29
	NFHS-3	18343	41.1(36.4)	42.9(43.3)	7.1(8.5)	8.9(11.7)	1.33	0.39
ST	NFHS-2	10234	44.9(32.7)	47.3(55.7)	4.6(7.0)	3.1(4.6)	1.11	0.17
	NFHS-3	14985	46.6(28.3)	45.2(56.3)	4.7(9.1)	3.5(6.3)	1.21	0.18
OBC	NFHS-2	24409	35.0(33.2)	47.8(48.3)	7.9(8.5)	9.3(9.9)	1.09	0.49
	NFHS-3	35172	35.7(32.3)	44.2(44.2)	8.4(9.5)	11.6(14.0)	1.26	0.56
Gen and Other	NFHS-2	34302	30.0(26.0)	44.7(45.4)	10.1(11.0)	15.2(17.6)	1.24	0.84
	NFHS-3	43483	29.7(25.1)	41.7(42.2)	10.5(11.6)	18.1(21.1)	1.40	0.96
Marital status								
Married	NFHS-2	78638	34.9(31.0)	46.6(48.0)	8.2(9.1)	10.3(11.9)	1.15	0.53
	NFHS-3	77524	33.0(26.9)	42.6(43.0)	9.5(11.2)	14.9(18.9)	1.35	0.74
Unmarried and Other	NFHS-2	5008	39.2(34.7)	42.9(45.6)	7.7(8.4)	10.2(11.2)	1.33	0.46
	NFHS-3	34459	42.8(35.9)	44.9(49.1)	6.0(7.6)	6.3(7.4)	1.23	0.29
Zone								
North	NFHS-2	20750	26.9(24.5)	47.6(44.6)	9.8(9.8)	15.7(21.1)	1.10	0.95
	NFHS-3	20671	29.3(26.6)	44.3(44.4)	10.0(10.7)	16.5(18.3)	1.26	0.90
Central	NFHS-2	16233	35.9(28.3)	50.4(40.9)	7.0(5.5)	6.7(25.3)	0.98	0.38
	NFHS-3	19850	38.3(35.5)	46.3(44.6)	7.0(7.8)	8.4(12.1)	1.16	0.40
East	NFHS-2	15857	41.8(38.5)	47.1(45.0)	5.6(5.8)	5.5(10.7)	1.12	0.27
	NFHS-3	16441	41.9(37.2)	43.5(43.2)	7.0(8.5)	7.6(11.1)	1.30	0.35
North-East	NFHS-2	11015	25.9(19.9)	60.7(57.1)	8.1(9.5)	5.2(13.4)	0.65	0.51
	NFHS-3	19855	31.9(20.2)	51.3(57.5)	8.8(11.7)	8.0(10.6)	0.95	0.53
West	NFHS-2	10482	38.2(32.0)	40.4(37.8)	8.8(9.8)	12.7(20.4)	1.48	0.56
	NFHS-3	14481	36.2(32.9)	39.1(38.9)	9.4(10.6)	15.3(17.6)	1.56	0.68
South	NFHS-2	15966	32.2(29.8)	43.7(42.3)	10.0(10.3)	14.1(17.6)	1.29	0.75
	NFHS-3	20685	30.6(27.8)	40.4(39.1)	10.4(11.0)	18.6(22.0)	1.48	0.95
Total	NFHS-2	83646	35.2(28.9)	46.4(44.3)	8.1(8.4)	10.3(18.4)	1.16	0.52
	NFHS-3	111983	35.6(29.6)	43.2(44.9)	8.6(10.1)	12.6(15.4)	1.31	0.60

SC: Scheduled Caste, ST: Scheduled Tribe, OBC: Other Backward Class percentiles, Coefficient of Skewness (β_1) and Kurtosis(β_2) of *BMI* for women according to various *BC* are presented in Table 2 for both surveys. Estimated annual percent gain in mean *BMI* during the period of *NFHS-2* and *NFHS-3* (in 7 years span) is calculated by using following formula.

$$\text{Annual percent gain} = \left\{ \left(\frac{\text{Mean } BMI \text{ in } NFHS3}{\text{Mean } BMI \text{ in } NFHS2} \right)^{1/7} - 1 \right\} \times 100 \quad (3)$$

Table 2: Weighted descriptive Statistics of BMI

<i>BC</i>	Survey	Mean	SD	Percentiles					β_1	β_2	Annual % gain in Mean <i>BMI</i>
				5th	25th	50th	75th	95th			
Residence											
Urban	NFHS-2	22.07	4.48	16.13	18.78	21.34	24.69	30.36	0.90	1.18	-0.07
	NFHS-3	21.96	4.63	15.92	18.49	21.13	24.70	30.60	0.89	0.91	
Rural	NFHS-2	19.63	3.11	15.63	17.56	19.14	21.12	25.39	1.44	5.04	0.09

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	NFHS-3	19.75	3.32	15.61	17.51	19.12	21.31	26.17	1.38	3.82	
Age-group											
15-19	NFHS-2	19.29	2.31	15.99	17.70	19.10	20.65	23.18	0.96	4.09	-0.25
	NFHS-3	18.96	2.54	15.48	17.28	18.67	20.27	23.38	1.35	8.15	
20-24	NFHS-2	19.46	2.75	15.80	17.64	19.11	20.86	24.31	1.53	8.99	0.12
	NFHS-3	19.62	3.09	15.72	17.54	19.08	21.06	25.45	1.43	4.28	
25-29	NFHS-2	19.88	3.28	15.72	17.67	19.28	21.47	26.09	1.33	3.44	0.31
	NFHS-3	20.32	3.66	15.76	17.76	19.56	22.17	27.43	1.21	2.24	
30-34	NFHS-2	20.47	3.82	15.76	17.84	19.73	22.32	27.80	1.30	2.83	0.27
	NFHS-3	20.86	4.06	15.80	17.91	20.02	23.06	28.65	1.11	1.99	
35-39	NFHS-2	20.89	4.13	15.67	17.97	20.04	23.05	28.81	1.19	2.29	0.34
	NFHS-3	21.39	4.38	15.81	18.14	20.51	23.95	29.75	0.94	1.02	
40-44	NFHS-2	21.09	4.33	15.61	17.94	20.26	23.51	29.15	1.09	1.82	0.49
	NFHS-3	21.83	4.67	15.86	18.28	20.97	24.59	30.69	0.90	0.90	
45-49	NFHS-2	21.31	4.51	15.48	18.02	20.50	23.83	29.96	0.94	1.08	0.50
	NFHS-3	22.07	4.78	15.81	18.42	21.24	24.95	30.88	0.89	1.00	
Education											
No Education	NFHS-2	19.44	3.00	15.52	17.46	18.99	20.90	24.84	1.42	4.79	0.18
	NFHS-3	19.69	3.34	15.55	17.45	19.04	21.24	26.16	1.39	3.62	
Primary	NFHS-2	20.30	3.68	15.74	17.76	19.61	22.02	27.41	1.34	3.15	0.12
	NFHS-3	20.47	3.88	15.74	17.79	19.66	22.34	28.03	1.33	3.30	
Secondary	NFHS-2	21.29	4.10	16.10	18.40	20.48	23.46	29.16	1.14	2.29	-0.26
	NFHS-3	20.91	4.21	15.78	17.93	19.94	23.06	29.18	1.19	1.92	
Higher	NFHS-2	22.89	4.49	16.72	19.64	22.25	25.53	31.05	0.89	1.53	-0.25
	NFHS-3	22.50	4.48	16.40	19.12	21.87	25.22	30.50	0.78	0.85	
Standard of living											
Low	NFHS-2	19.00	2.67	15.37	17.23	18.69	20.40	23.60	1.34	5.64	-0.04
	NFHS-3	18.95	2.74	15.36	17.15	18.52	20.29	23.83	1.54	7.46	
Medium	NFHS-2	20.13	3.40	15.76	17.81	19.54	21.77	26.50	1.33	3.85	-0.29
	NFHS-3	19.73	3.27	15.58	17.51	19.14	21.34	26.02	1.26	3.26	
High	NFHS-2	22.67	4.49	16.68	19.34	21.98	25.31	31.00	0.88	1.24	-0.49
	NFHS-3	21.90	4.49	16.16	18.56	21.05	24.53	30.36	0.93	1.04	
Religion											
Hindu	NFHS-2	20.13	3.58	15.70	17.72	19.44	21.74	27.01	1.42	3.81	0.16
	NFHS-3	20.36	3.85	15.67	17.70	19.50	22.19	27.87	1.32	2.74	
Muslim	NFHS-2	20.58	3.89	15.68	17.90	19.79	22.44	28.13	1.31	2.48	0.02
	NFHS-3	20.62	4.11	15.74	17.74	19.64	22.57	28.72	1.26	2.05	
Christian	NFHS-2	21.37	3.95	16.23	18.56	20.73	23.40	28.77	0.98	1.46	0.14
	NFHS-3	21.58	4.07	16.23	18.68	20.94	23.77	29.30	0.96	1.68	
Sikh	NFHS-2	22.87	4.63	16.62	19.42	22.19	25.53	31.38	0.85	0.88	0.19
	NFHS-3	23.18	5.02	16.65	19.38	22.40	26.23	32.31	0.91	1.26	
Gen and Other	NFHS-2	20.79	4.15	15.63	17.77	19.86	22.82	28.95	1.27	2.82	-0.32
	NFHS-3	20.31	3.80	15.60	17.63	19.49	22.29	27.63	1.17	1.95	
Caste											
ST	NFHS-2	19.16	2.75	15.52	17.33	18.80	20.55	23.92	1.43	5.40	-0.02
	NFHS-3	19.12	2.84	15.43	17.24	18.70	20.48	24.20	1.80	11.7	
SC	NFHS-2	19.57	3.14	15.57	17.48	19.06	21.10	25.37	1.41	4.48	0.21
	NFHS-3	19.87	3.53	15.51	17.46	19.15	21.53	26.71	1.30	2.70	
OBC	NFHS-2	20.18	3.53	15.76	17.80	19.55	21.82	26.86	1.42	4.42	0.12
	NFHS-3	20.36	3.80	15.70	17.74	19.53	22.16	27.79	1.30	2.64	
Other	NFHS-2	20.97	4.10	15.86	18.09	20.12	23.05	28.92	1.19	2.11	0.19
	NFHS-3	21.26	4.35	15.88	18.12	20.31	23.60	29.66	1.11	1.61	

Marital status											
Married	NFHS-2	20.29	3.68	15.74	17.79	19.58	21.96	27.38	1.38	3.45	0.36
	NFHS-3	20.81	4.10	15.81	17.91	19.88	22.90	28.79	1.21	2.14	
Other	NFHS-2	20.08	3.80	15.41	17.55	19.29	21.91	27.40	1.44	3.80	-0.38
	NFHS-3	19.54	3.27	15.46	17.37	18.97	20.98	25.70	1.47	4.23	
Zone											
North	NFHS-2	21.18	4.12	16.23	18.36	20.29	23.08	29.18	1.35	2.74	-0.02
	NFHS-3	21.14	4.24	16.02	18.18	20.20	23.25	29.43	1.30	2.91	
Central	NFHS-2	19.94	3.21	15.91	17.79	19.40	21.36	25.91	1.50	4.38	0
	NFHS-3	19.94	3.42	15.76	17.65	19.25	21.42	26.60	1.41	3.27	
East	NFHS-2	19.48	3.07	15.52	17.48	18.99	20.89	25.31	1.47	5.55	0.18
	NFHS-3	19.73	3.37	15.55	17.45	19.04	21.29	26.26	1.39	3.85	
North-East	NFHS-2	20.24	2.90	16.21	18.41	19.97	21.60	25.09	1.47	6.98	0
	NFHS-3	20.24	3.20	15.98	18.01	19.73	21.93	26.29	1.02	1.85	
West	NFHS-2	20.39	4.12	15.43	17.47	19.46	22.44	28.36	1.36	3.07	0.22
	NFHS-3	20.71	4.29	15.52	17.63	19.68	22.96	29.19	1.15	1.57	
South	NFHS-2	20.75	3.95	15.74	17.91	19.99	22.86	28.28	1.09	1.84	0.33
	NFHS-3	21.24	4.39	15.72	17.99	20.35	23.66	29.61	1.03	1.32	
Total	NFHS-2	20.28	3.68	15.71	17.78	19.56	21.96	27.39	1.39	3.48	0.13
	NFHS-3	20.47	3.93	15.69	17.74	19.59	22.37	28.18	1.29	2.38	

2.2.3 Synthetic cohort approach

We use synthetic cohort approach to examine longitudinal change in *BMI* between *NFHS-2* and *NFHS-3*, by matching the age-group level representatives by their birth year. This technique has been widely used by econometricians and involves the creation of a ‘pseudo panel’ from a time series of independent surveys conducted using the same methodology and on the same reference population (Lean *et al.*, 2013 and Robinson *et al.*, 2013). This approach is also useful in epidemiological studies of under nutrition and obesity population. In this study, we have created synthetic cohorts to determine changes in mean *BMI* for same age-groups between 1998-99 (*NFHS-2*) and 2005-06 (*NFHS-3*). For the analysis, age-groups in six-year bands were used to facilitate comparisons between the different time periods. Five cohorts were defined for women, the youngest age-group was 15-21 years, and the oldest age-group was 36-42 years in *NFHS-2* (1998-99). These cohorts were matched with the equivalent cohorts under *NFHS-3* (2005-06). That is, the cohort of women of age-group 15-21 years from *NFHS-2* is matched with women aged 22-28 years from *NFHS-3*, age-group 22-28 years from *NFHS-2* is matched with women aged 29-35 years from *NFHS-3* and so on. Thus, we can estimate longitudinal change in *BMI* for age stratified groups. Mean *BMI* within period are determined for each synthetic cohort. Finally, in order to investigate age period effect in annual *BMI* change, change in mean *BMI* over seven years is annualize by assuming constant annual change within period by using equation (3). The results of change in prevalence of *BMI*

categories and annual gain in mean *BMI* for synthetic cohort by age-groups are reported in Table 3 and Table 4 respectively.

Table 3: Change in prevalence percentage using synthetic cohort approach

Group No.	Survey	Age-group	Weighted prevalence in % with change							
			UW		NW		OW		OB	
			%	Change	%	Change	%	Change	%	Change
1	NFHS-2	15-21	39.0	-3.84	54.4	-15.9	4.4	86.4	2.2	290.9
	NFHS-3	22-28	37.5		45.7		8.2		8.6	
2	NFHS-2	22-28	38.7	-16.8	48.6	-13.6	6.7	53.7	5.9	162.7
	NFHS-3	29-35	32.2		42.0		10.3		15.5	
3	NFHS-2	29-35	34.4	-18.0	45.2	-13.5	9.0	27.8	11.4	85.1
	NFHS-3	36-42	28.2		39.1		11.5		21.1	
4	NFHS-2	36-42	31.0	-17.1	42.4	-11.8	10.3	17.5	16.2	53.1
	NFHS-3	43-49	25.7		37.4		12.1		24.8	
5	NFHS-2	15-42	35.9	-11.1	47.4	-12.0	7.7	32.5	9.0	80
	NFHS-3	22-49	31.9		41.7		10.2		16.2	

Table 4: Mean *BMI* and annual percentage gain in mean *BMI* for synthetic cohorts

Age-group and mean BMI in NFHS-2	Age-group and mean BMI in NFHS-3		Annual gain in mean BMI from NFHS-2 to NFHS-3	
	Same age-group	Cohort age-group	Same age-group	Cohort age-group
15-21 (19.32)	15-21 (19.07)	22-28 (20.04)	-0.18	0.52
22-28 (19.72)	22-28 (20.04)	29-35 (20.89)	0.23	0.82
29-35 (20.44)	29-35 (20.89)	36-42 (21.59)	0.31	0.78
36-42 (21.00)	36-42 (21.59)	43-49 (22.05)	0.39	0.70
15-42 (20.12)	15-42 (20.47)	22-49 (20.98)	0.24	0.60

2.2.4 Fitting of probability distribution to BMI

For many years, prior to year 2000, the distribution of *BMI* was assumed to follow a normal distribution or approximately a bell-shaped curve as this was similar case of measurements of weight and height. Penman and Johnson (2006) has made claim that normal distribution is not appropriate for *BMI* indicating that some positively skewed distribution may be a better fit. Hence, the distributions, exhibiting a positive degree of skewing in the right tail of the data, were fitted using one of the parameter estimation methods namely method of moments, maximum likelihood, least square, and L-moments by Easy-Fit software. The fitted distributions of *BMI* for various *BC* and their estimated parameters using Easy-Fit Software (Easy-Fit) are presented in Table 5 for *NFHS-2* and *NFHS-3*.

We observed that commonly best fitted probability distributions of *BMI* of Indian women under different *BC* are: Beta, Burr (4P), Dagum (3P or 4P), Fatigue Life (3P), Gamma (3P), General Gamma (4P), General extreme value, Gumbel Max, Inverse Gaussian (3P), Johnson SB, Johnson SU, and Pearson 6 (4P). These best fitted distributions and their estimated parameters are used to compare changes in the distributions of *BMI* under different age-groups are presented in Figure 1. Probability density functions (*pdfs*) along with parameter description of these distributions are given in Appendix.

Figure 1: Change in distribution of *BMI* from *NFHS-2* to *NFHS-3* among different age groups of women using best fitted distributions (bold line: *NFHS-2*; dotted line: *NFHS-3*)

Table 5: Best fitted probability distributions to *BMI*

Sr. No.	BC	Survey	Distribution	Estimated Parameters
Age-group				
1	15-19	NFHS-2	Burr (4P)	$k = 1.9908, \alpha=4.688, \beta=8.7118, \gamma = 11.85$
		NFHS-3	Burr (4P)	$k = 1.4819, \alpha=4.6931, \beta=8.5143, \gamma = 11.341$
2	20-24	NFHS-2	Burr (4P)	$k = 1.3073, \alpha=4.8995, \beta=8.1063, \gamma = 11.559$
		NFHS-3	Johnson SU	$= -1.7233, =1.9946, \lambda = 3.8559, \xi=15.729$
3	25-29	NFHS-2	Dagum (4P)	$k = 5.2789, \alpha=14.128, \beta=28.396, \gamma = -13.116$
		NFHS-3	GEV	$k = 0.01116, \sigma=2.9148, \mu=19.1$
4	30-34	NFHS-2	GEV	$k = 0.03425, \sigma=2.9243, \mu=19.021$
		NFHS-3	Fatigue Life(3P)	$\alpha=0.34504, \beta=11.29, \gamma=9.5136$
5	35-39	NFHS-2	GEV	$k = 0.02407, \sigma=3.2372, \mu=19.357$
		NFHS-3	Johnson SB	$=3.4372, =2.0883, \lambda = 66.896, \xi=10.596$
6	40-44	NFHS-2	Johnson SB	$=4.2894, =2.1029, \lambda = 85.449, \xi=10.913$
		NFHS-3	Johnson SB	$=3.3016, =2.1798, \lambda = 68.159, \xi=9.6363$
7	45-49	NFHS-2	Johnson SB	$=3.7846, =2.0931, \lambda = 75.194, \xi=10.368$
		NFHS-3	Beta	$\alpha_1=4.4617, \alpha_2=42.786, a=11.875, b=127.82$
Education				
8	No Education	NFHS-2	Dagum (4P)	$k = 2.3745, \alpha=9.4292, \beta=16.458, \gamma = 0.69208$
		NFHS-3	Dagum (3P)	$k=3.7621, \alpha=8.253, \beta=16.05$
9	Primary	NFHS-2	Dagum(3P)	$k=3.6341, \alpha=7.9927, \beta=16.331$

		NFHS-3	GEV	$k=0.03891, \sigma=2.9594, \mu=19.062$
10	Secondary	NFHS-2	GEV	$k=0.01641, \sigma=3.2376, \mu=19.701$
		NFHS-3	GEV	$k=0.03358, \sigma=3.1811, \mu=19.326$
11	Higher	NFHS-2	General Gamma (4P)	$k=0.80816, \alpha=12.035, \beta=0.56067 \gamma = 10.603$
		NFHS-3	Gamma (3P)	$\alpha=6.3654, \beta=1.768, \gamma=11.5$
Standard of living				
12	Low	NFHS-2	Burr (4P)	$k=1.3802, \alpha=4.9739, \beta=8.4372 \gamma = 11.006$
		NFHS-3	Dagum (4P)	$k=3.4888, \alpha=24.151, \beta=41.874 \gamma = -25.829$
13	Medium	NFHS-2	Johnson SU	$= -2.3212, =2.1597, \lambda = 3.9824, \xi=14.585$
		NFHS-3	GEV	$k= -0.02383, \sigma=2.6019, \mu=18.653$
14	High	NFHS-2	General Gamma (4P)	$k=0.78852, \alpha=10.625, \beta=0.57405 \gamma = 11.249$
		NFHS-3	Johnson SB	$=4.1745, =2.2288, \lambda = 81.803, \xi=10.604$
Residence				
15	Rural	NFHS-2	Johnson SB	$=3.5968, =2.056, \lambda = 70.71, \xi=10.604$
		NFHS-3	Dagum(3P)	$k=2.5567, \alpha=9.5454, \beta=17.086$
16	Urban	NFHS-2	Dagum (4P)	$k=1.2426, \alpha=4.1338, \beta=8.362 \gamma = 11.765$
		NFHS-3	Johnson SB	$=4.4382, =2.3263, \lambda = 89.44, \xi=10.083$
Religion				
17	Hindu	NFHS-2	Dagum(3P)	$k=3.5322, \alpha=8.2031, \beta=16.385$
		NFHS-3	GEV	$k= 0.04838, \sigma=3.0192, \mu=19.952$
18	Muslim	NFHS-2	Dagum(3P)	$k=3.202, \alpha=7.8586, \beta=16.79$
		NFHS-3	Pearson 6 (4P)	$\alpha_1=28.33, \alpha_2=11.045, \beta=4.0709, \gamma = 9.7351$
19	Christian	NFHS-2	Dagum(3P)	$k=2.0483, \alpha=9.6398, \beta=18.892$
		NFHS-3	Burr (4P)	$k = 0.79944, \alpha = 8.0183, \beta = 12.125, \gamma = 8.2677$
20	Sikh	NFHS-2	Johnson SB	$=2.7399, =1.8376, \lambda = 56.635, \xi=11.838$
		NFHS-3	Beta	$\alpha_1=4.318, \alpha_2=346.64, a=12.641, b=868.86$
21	Other	NFHS-2	Burr	$k=0.65155, \alpha=13.297, \beta=20.048$
		NFHS-3	Burr (4P)	$k = 1.8415, \alpha=3.552, \beta=10.645, \gamma = 12.36$
Caste				
22	SC	NFHS-2	Dagum(3P)	$k=2.7615, \alpha=9.2195, \beta=16.814$
		NFHS-3	GEV	$k= 0.04855, \sigma=2.8147, \mu=18.585$
23	ST	NFHS-2	Burr (4P)	$k=1.4562, \alpha=4.9002, \beta=9.2934 \gamma = 11.199$
		NFHS-3	Burr (4P)	$k = 1.6694, \alpha=4.498, \beta=9.7852, \gamma = 11.54$
24	OBC	NFHS-2	Johnson SU	$= -2.1535, =2.0391, \lambda = 3.8526, \xi=14.851$
		NFHS-3	GEV	$k= 0.04924, \sigma=2.9525, \mu=18.89$
25	Other	NFHS-2	GEV	$k = 0.03162, \sigma=3.1769, \mu=19.447$
		NFHS-3	Johnson SB	$=3.4178, =1.878, \lambda = 65.837, \xi=11.797$
Marital status				
26	Married	NFHS-2	Dagum(3P)	$k=3.428, \alpha=8.1146, \beta=16.575$
		NFHS-3	Johnson SB	$=3.9161, =1.9673, \lambda = 74.525, \xi=11.752$
27	Other	NFHS-2	Johnson SU	$= -2.9816, =2.2275, \lambda = 3.6218, \xi=13.299$
		NFHS-3	Burr (4P)	$k = 1.315, \alpha=4.2024, \beta=8.6392, \gamma = 11.571$
Zone				
28	North	NFHS-2	GEV	$k = 0.03162, \sigma=3.1769, \mu=19.447$
		NFHS-3	GEV	$k= 0.04371, \sigma=3.2033, \mu=19.438$

29	Central	NFHS-2	Burr (4P)	$k=0.9137, \alpha=5.7572, \beta=8.596 \gamma =10.646$
		NFHS-3	Dagum(3P)	$k=6.8874, \alpha=7.5651, \beta=14.563$
30	East	NFHS-2	Burr (4P)	$k=0.9137, \alpha=5.7572, \beta=8.596 \gamma =10.646$
		NFHS-3	GEV	$k=0.06089, \sigma=2.7207, \mu=18.527$
31	North-east	NFHS-2	Dagum (4P)	$k=0.76817, \alpha=6.7411, \beta=10.158 \gamma =10.812$
		NFHS-3	Burr (4P)	$k = 1.3479, \alpha=5.0223, \beta=10.218, \gamma =9.7551$
32	West	NFHS-2	IG (3P)	$\lambda=65.226, \mu=10.819, \gamma =10.165$
		NFHS-3	IG(3P)	$\lambda=72.461, \mu=11.31, \gamma =9.7551$
33	South	NFHS-2	Johnson SB	$=5.04497, =2.2418, \lambda =97.21, \xi=11.014$
		NFHS-3	Johnson SB	$=3.0867, =1.8248, \lambda =61.081, \xi=11.393$
34	Total	NFHS-2	Dagum (3P)	$k=3.3902, \alpha=8.1104, \beta=16.588$
		NFHS-3	GEV	$k=0.03899, \sigma=3.0607, \mu=19.125$

GEV: General extreme value IG: Inverse Gaussian

2.2.5. Change in distribution of BMI by using partial sums on percentiles

In this section, we suggest using the partial sum plot to demonstrate changes in the distribution of *BMI*. Changes in distribution of *BMI* can be shown through the changes in partial sums of absolute difference between percentiles of *BMI* based on *NFHS-2* and *NFHS-3*. We can compare these values of partial sums for different *BC* with the partial sums of total population or population under other *BC*. The partial sums for some *BC* and for some selected percentiles are reported in Table 6 and shown in Figure 2 (A, B, C and D). The numerical values from the Table 6 and Figure 2 more clearly indicate the magnitude of changes in the distribution of *BMI* of women from *NFHS-2* to *NFHS-3*.

Table 6: Partial sum of absolute differences in the percentiles of distribution of *BMI* in *NFHS-2* and *NFHS-3* for selected *BC*

Background Characteristic(BC)		Partial sum up to Percentiles				
		10 th	20 th	50 th	80 th	98 th
Residence	Rural	0.1	0.35	1.05	2.42	7.77
	Urban	1.03	2.36	6.34	8.21	10.11
	Total	0.12	0.4	0.79	4.42	10.87
Age-group	15-19	2.56	4.97	11.35	17.29	19.34
	20-24	0.49	0.93	2.06	3.76	10.84
	25-29	0.22	0.39	2.95	11.05	21.04
	30-34	0.27	0.37	2.5	11.32	19.05
	35-39	0.58	1.12	5.4	16.45	25.24
	40-44	0.83	2.18	9.83	24.97	36.45
	45-49	1.93	4.08	12.45	27.54	36.32
Education	No Education	0.08	0.16	0.39	3.7	12.33
	Primary	0.12	0.2	0.69	3.42	8.73
	Secondary	1.5	3.58	11.25	18.27	19.53
	Higher	1.91	4.22	10.86	15.34	18.81

Standard of living	Low	0.2	0.57	2.37	4.64	6.18
	Medium	1.08	2.55	7.69	14.32	18.84
	High	2.85	6.44	19.32	32.24	38.06

(A)

(B)

(C)

(D)

Figure 2: Change in distribution using partial sum according to (A) type of residence (B) age-group (C) education and (D) standard of living

2.2.6. Change in distribution of *BMI* using test of equality of percentiles

Student's t-test and analysis of variance are frequently used to test the hypothesis that two or more distributions have same means. However, many random variables such as *BMI* having skewed distributions that are not readily transformed to symmetry, rendering the distributional assumptions that underlie use of these methods inappropriately. The non-parametric tests such as Wilcoxon, Kolmogorov-Smirnov, and median tests are used to test for differences in distributions (Siegel & Castellan, 1988). These tests are not designed to pin-point where the distributions are unequal or simultaneously test for differences in more than one distribution parameter. The t-test and variance-test are powerful for detecting differences in location and scale respectively. The t-test and variance-test have scope to test one parameter only. In these circumstances, it may be of greater interest to compare the distributions in terms of their percentiles rather than their means or an overall test of equivalence. A percentile profile is defined as a set of one or more percentiles. It may be more informative to compare two or more distributions by testing the hypothesis that their profiles of judiciously selected percentiles are equal (Zhang *et al.* 2014).

Zhang *et al.* (2014) had first described the procedure as a generalization of the median test. In median test, we test the equality of the 50th percentile. Instead of testing the equality of only one percentile, the method is extended to simultaneously test multiple percentiles. The method is as follows:

Let Y denote a continuous random variable (in our case Y is *BMI*) and let $Q_1, Q_2, \dots, Q_m$ denote a set of m percentiles that in some sense characterize the distribution of *BMI* across its range. Further let $y_1, y_2, \dots, y_n$ represent a random sample of observations and let $q_1, q_2, \dots, q_m$ represent the usual sample estimates of $Q_1, Q_2, \dots, Q_m$ respectively. Suppose random samples are available from each of k populations with percentiles $Q_{h1}, Q_{h2}, \dots, Q_{hm}, h = 1, 2, \dots, k$. There is interest in testing the hypothesis that the percentile profiles are identical across the k populations; that is to test $H_0: Q_{1i} = Q_{2i} = \dots = Q_{ki} \quad i = 1, 2, \dots, m$. The complete process of testing this hypothesis as an extension of median test was discussed in Zhang *et al.* (2014). We have conducted these tests for $k=2$ (as we have two distributions of *BMI* one each for *NFHS-2* and *NFHS-3*) and $p=5$ (5th, 25th, 50th, 75th and 95th percentiles). The p -values of test of equality of percentiles of *BMI* for five percentiles and for five combined percentiles are reported in the Table 7.

Table 7: Test of equality of percentiles of *BMI* from *NFHS-2* to *NFHS-3*

BC	p-values of test of equality for percentiles					Combined percentiles
	P ₅	P ₂₅	P ₅₀	P ₇₅	P ₉₅	
Age-group						
15-19	< 0.001	< 0.001	< 0.001	<0.002	< 0.001	< 0.001
20-24	0.06	0.47	< 0.001	< 0.001	< 0.001	< 0.001
25-29	0.3535	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
30-34	0.18	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
35-39	0.0010	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
40-44	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
45-49	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Residence						
Rural	0.93	0.33	< 0.001	< 0.001	< 0.001	< 0.001
Urban	< 0.001	< 0.001	< 0.001	0.02	0.94	< 0.001
Education						
No Education	0.29	.0016	< 0.001	< 0.001	< 0.001	< 0.001
Primary	0.27	.0049	< 0.001	< 0.001	< 0.001	< 0.001
Secondary	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Higher	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Standard of living						
Low	0.49	0.05	0.0025	0.51	< 0.001	< 0.001
Medium	< 0.001	< 0.001	< 0.001	< 0.001	0.02	< 0.001
High	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Religion						
Hindu	0.08	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Muslim	0.82	0.34	0.0031	< 0.001	< 0.001	< 0.001
Christian	< 0.001	< 0.001	0.08	0.77	0.59	0.0019
Sikh	0.79	0.54	0.55	.06	0.35	0.36
Other	0.25	< 0.001	0.1008	0.38	0.70	< 0.001
Caste						
SC	0.35	0.04	< 0.001	< 0.001	< 0.001	< 0.001
ST	0.0018	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
OBC	0.19	0.20	< 0.001	< 0.001	< 0.001	< 0.001
Other	0.92	0.0050	< 0.001	< 0.001	< 0.001	< 0.001
Marital status						
Married	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Other	0.64	0.08	< 0.001	< 0.001	< 0.001	< 0.001
Zone						
North	0.0171	0.06	0.05	< 0.001	0.0124	< 0.001
Central	0.01	0.31	0.03	< 0.001	< 0.001	< 0.001
East	0.10	0.0022	< 0.001	< 0.001	< 0.001	< 0.001
North-East	0.09	0.01	< 0.001	< 0.001	< 0.001	< 0.001
West	0.99	0.33	0.55	0.07	0.49	0.53
South	0.94	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Total	0.99	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
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3. Results and Discussion

The weighted and un-weighted prevalence according to different *BC* of Indian women during *NFHS-2* and *NFHS-3* are presented in Table 1. For all Indian women, both the prevalence rates of UW remained almost same and obesity (OW/OB) increased from *NFHS-2* to *NFHS-3*. Under both the surveys, for all women the value of R_1 increased from 1.16 to 1.31, which shows that more than 50% of Indian women were under malnutrition (UW/OW/OB) status under both surveys. For the age-group 15-19 years, prevalence of UW has increased from 38.6% in *NFHS-2* to 46.8% in *NFHS-3*. Age-groups with ages above 25 years have shown decrements in prevalence of UW from *NFHS-2* to *NFHS-3*. In all age-groups prevalence of obesity has increased from *NFHS-2* to *NFHS-3*. Prevalence of obesity has decreased for women with secondary and higher education but total prevalence of obesity in higher education category was still high (40.8%) in *NFHS-3* as compared to 43.8% in *NFHS-2*. Overall it is observed that education levels affected more on prevalence of UW as well as obesity in both surveys. Under both surveys, we observed double burden of UW as well as obesity among women from the religions, Sikh ($R_1=1.72$, $R_2= 2.56$ in *NFHS-3*) and Christian ($R_1=1.18$, $R_2= 1.34$ in *NFHS-3*). High level (46.6%) of UW is observed for ST caste category women in *NFHS-3*. More burdens of UW and obesity are observed for the General and other caste category in *NFHS-3*. In the order of caste categories as ST, SC, OBC and General and other, mean and SD of *BMI* are observed in increasing order. This shows that deprivation of socially backward classes was continued in India till 2006. As per *NFHS-3*, unmarried and other women are more likely (42.8%) to be UW than married women (33%). Prevalence of obesity for married women was 24.4% as compared to 12.3% for unmarried and other class in *NFHS-3*. We observed highest burden of UW (41.9%) in East zone, high level of obesity in South zone (29%) and North zone (26.5%) under *NFHS-3*.

Changes in descriptive statistics of *BMI* according to *BC* over two surveys are presented in Table 2. Mean and SD of *BMI* of all Indian women has increased from 20.28 to 20.47 and 3.68 to 3.93 respectively. For the comparison of the tails of the distribution of *BMI* we observed that major changes occurred at the 95th percentile than at the 5th percentile for many *BC*. In the group of women with high living standard, double burden of UW and obesity was continued from *NFHS-2* to *NFHS-3*. Mean *BMI* increased at high rate for married, women with ages 25-49 and women from south zone of India. Values of coefficient of skewness of the distribution of *BMI* for all Indian women and for many *BC* have decreased but still values were close to one or greater than one under *NFHS-*

3which shows highly positively skewed distributions of *BMI*. For the women age-group 15-19 and women with low standard of living the values of coefficient of skewness of the distribution of *BMI* have increased and observed to be very high.

From Table 3, under synthetic cohort age-groups, we observed negative changes in the prevalence percentages for UW and NW, whereas positive changes are reported for OW and OB classes. High positive changes are reported for women from obese class. We noticed from Table 4 that an annual gain in mean *BMI* was highest (0.82%) for the age-group 22-28 under *NFHS-2* with its cohort group 29-35 under *NFHS-3*. Also, as expected, annual gains in mean *BMI* were higher for cohort groups than same age groups.

Best fitted probability distributions for *BMI* of women under different *BC* were decided based on p-values of goodness of fit tests and ranks given by Easy-Fit software. These best fitted distributions are reported in Table 5. Changes in the distribution of *BMI* under different age-groups using best fitted distributions and their estimated parameters are demonstrated in Figure 1. Due to lack of space similar figures for other *BC* are not presented in this manuscript.

From Table 6 and Figure 2, we clearly observed the magnitude of changes in distribution of *BMI* in terms of percentiles of distribution. For urban women, women from older age-groups, women with secondary/higher education and women with high standard of living almost uniform changes in all percentiles are observed, whereas for other *BC* major changes are observed at higher percentiles of *BMI*. From Table 7 we notice that, tests of equality of percentiles of *BMI* showed significant difference in percentile of *BMI* for higher percentiles of *NFHS-2* and *NFHS-3* for many *BC*. Test of equality of percentiles can be accepted for all and combined percentiles for women from Sikh religion and women from West zone of India.

Our results suggest that, rapid increments are observed in mean and higher percentiles of *BMI* among married women, women in the higher age-groups, and women from south zone. This study shows a persistent problem of UW in India, with 35.2% and 35.6% of women population being UW in *NFHS-2* and *NFHS-3* respectively; at the same time the percentage of women who are overweight and obese has increased from 18.4% to 21.2%. This pattern of persisting problems of under nutrition along with a simultaneous rise in obesity was also seen in most of the low to middle income countries (Razaket *al.*, 2013). Using a synthetic cohort approach we have quantified age-specific longitudinal change in *BMI* among Indian women during from *NFHS-2* to *NFHS-3*. The positive changes in prevalence percentages according to *BMI* categories for all synthetic cohort age-

groups are observed for OW/OB categories while negative changes for all synthetic cohort age-groups are observed for UW and NW categories of *BMI*. This shows the impact of ageing on weight gain among Indian women.

Concerning the prevalence of UW and obesity(OW/OB) there is urgent need to make more awareness of consequences of underweight and obesity among highly educated women and women from high standard of living. To overcome the problem of UW, the Indian government has passed the National Food Security Act, 2013 in September 2013. As per the National Food Security Act 2013, all eligible households are entitled to get food grains (5 kg per person per month) at the subsidized prices. This Act will make access for sufficient and nutritious food for 75% of rural and 50% of urban population of India including all poor. There are some more provisions for advancing food security as mentioned in the National Food Security Act 2013, which may also be helpful to improve the nutritional status of Indian women. These provisions include access to (a) safe and adequate drinking water and sanitation; (b) health care; (c) nutritional, health, and education support to adolescents; and (d) adequate pensions for senior citizens, persons with disability, and single women (National Food Security Act, 2013). More awareness programs to control obesity among Indian women are needed. Government may think of providing some incentives to employees for consistently maintaining their *BMI* under NW category.

4. Conclusion

In all age-groups except 15-19 years, the distribution *BMI* shifted to the right and become more right skewed and extent of shift is greatest for the older age-groups. Women with low standard of living the prevalence of underweight had increased from 46.9% to 49.7% during the period *NFHS-2* to *NFHS-3*. Also, prevalence of obesity (OW/OB) among all women increased from 18.4% to 21.2%. For many *BC* major changes in higher percentiles of distribution of *BMI* are observed from *NFHS-2* to *NFHS-3*. This shows the right shift of the distribution of *BMI*. As per *NFHS-3*, problem of obesity was still serious or started becoming serious among urban women, rich and highly educated women, women from south and north zone, women belonging to general and other caste category, and among married women.

The major limitation of this study is that, as the respondents are not same from *NFHS-2* and *NFHS-3*, hence carrying out longitudinal study to demonstrate change in distribution of *BMI* based on synthetic cohorts may not be proper approach. However, we have used this approach because sample sizes are very large in both nationwide surveys, so the distribution of *BMI* was properly reflected. An advantage of this study is that the best fitted probability

distributions can be used to plot cumulative distribution function of *BMI* under different *BC*. Also, in future, researchers can use these fitted probability distributions to study longitudinal changes in the distribution of *BMI* of Indian women.

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Appendix: Probability density functions of distribution fitted for BMI

Distribution	Probability density function	Range	Parameters
Beta	$f(x) = \frac{1}{B(\alpha_1, \alpha_2)} \frac{(x-a)^{\alpha_1-1} (b-x)^{\alpha_2-1}}{(b-a)^{\alpha_1+\alpha_2-1}}$ <p>where B is a beta function</p>	$a \leq x \leq b$	α_1 continuous shape parameter ($\alpha_1 > 0$) α_2 continuous shape parameter ($\alpha_2 > 0$) a, b continuous boundary parameters ($a < b$)
Burr (4P)	$f(x) = \frac{\alpha k \left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}}{\beta + \left(1 + \left(\frac{x-\gamma}{\beta}\right)^\alpha\right)^{k+1}}$	$\gamma \leq x < +\infty$	k continuous shape parameter α continuous shape parameter β continuous shape parameter γ continuous location parameter
Dagum (4P)	$f(x) = \frac{\alpha k \left(\frac{x-\gamma}{\beta}\right)^{\alpha k-1}}{\beta \left(1 + \left(\frac{x-\gamma}{\beta}\right)^\alpha\right)^{k+1}}$	$\gamma \leq x < +\infty$	k continuous shape parameter α continuous shape parameter β continuous shape parameter γ continuous location parameter ($\gamma = 0$ yields 3 para Dagum distribution)
Fatigue Life	$f(x) = \frac{\sqrt{\frac{x-\gamma}{\beta}} + \sqrt{\frac{\beta}{x-\gamma}}}{2\alpha(x-\gamma)} \Phi\left(\frac{1}{\alpha} \left(\sqrt{\frac{x-\gamma}{\beta}} - \sqrt{\frac{\beta}{x-\gamma}}\right)\right)$ <p>where Φ is the PDF of the standard normal distribution</p>	$\gamma \leq x < +\infty$	α - continuous shape parameter ($\alpha > 0$) β - continuous scale parameter ($\beta > 0$) -continuous location parameter ($\gamma = 0$ for 3 para Fatigue Life distribution)
Gamma(3P)	$f(x) = \frac{(x-\gamma)^{\alpha-1}}{\beta^\alpha \Gamma_\alpha} \exp(-(x-\gamma)/\beta)$	$\gamma \leq x < +\infty$	α – continuous shape parameter ($\alpha > 0$) β – continuous scale parameter ($\beta > 0$) – continuous location parameter
Generalized Gamma(4P)	$f(x) = \frac{k(x-\gamma)^{k\alpha-1}}{\beta^{k\alpha} \Gamma_\alpha} \exp\left(-\left(\frac{x-\gamma}{\beta}\right)^k\right)$	$\gamma \leq x < +\infty$	k- continuous shape parameter ($k > 0$) α - continuous shape parameter ($\alpha > 0$) β - continuous scale parameter ($\beta > 0$) γ - continuous location parameter

Distribution	Probability density function	Range	Parameters
Generalized Extreme Value	$f(x) = \begin{cases} \frac{1}{\sigma} \exp(-(1 + kz)^{-1/k}) (1 + kz)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma} \exp(-z - \exp(-z)) & k = 0 \end{cases}$ <p>where $z = \frac{x-\mu}{\sigma}$, $1 + \left(\frac{x-\mu}{\sigma}\right) > 0$ for $k \neq 0$,</p>	$-\infty < x < +\infty$	k-continuous shape parameter σ -continuous scale parameter ($\sigma > 0$) μ -continuous location parameter
Gumbel Max	$f(x) = \frac{1}{\sigma} \exp(-z - \exp(-z)) \quad \text{where } z = \frac{x-\mu}{\sigma}$	$-\infty < x < +\infty$	σ -continuous scale parameter ($\sigma > 0$) μ -continuous location parameter
Inverse Gaussian (3P)	$f(x) = \sqrt{\frac{\lambda}{(2\pi(x-\gamma)^3)}} \exp\left(\frac{(\lambda(x-\gamma-\mu)^2)}{(2\mu^2)(x-\gamma)}\right)$	$\gamma \leq x < +\infty$	λ continuous parameter ($\lambda > 0$) μ continuous parameter ($\mu > 0$) continuous location parameter
Johnson SB	$f(x) = \frac{\delta}{\lambda\sqrt{2\pi z(1-z)}} \exp\left(\left(-\frac{1}{2}\left(\gamma + \delta \ln\left(\frac{z}{(1-z)}\right)\right)\right)^2\right) \text{ where } z = \frac{x-\xi}{\lambda}$	$\xi \leq x \leq \xi + \lambda$	-continuous shape parameter continuous shape parameter (> 0) λ - continuous scale parameter ($\lambda > 0$) ξ - continuous location parameter
Johnson SU	$f(x) = \frac{\delta}{\lambda\sqrt{2\pi}\sqrt{z^2+1}} \exp\left(-\frac{1}{2}\left(\gamma + \delta \ln\left(z + \sqrt{z^2+1}\right)\right)^2\right)$ <p>where $z = \frac{x-\xi}{\lambda}$</p>	$-\infty < x < +\infty$	-continuous shape parameter continuous shape parameter (> 0) λ - continuous scale parameter ($\lambda > 0$) ξ - continuous location parameter
Lognormal (3P)	$f(x) = \frac{\exp\left(-\frac{1}{2}\left(\frac{\ln(x-\gamma)-\mu}{\sigma}\right)^2\right)}{(x-\gamma)\sigma\sqrt{2\pi}}$	$\gamma \leq x < +\infty$	σ -continuous parameter ($\sigma > 0$) μ -continuous parameter -continuous location parameter
Pearson Type 6 (4P)	$f(x) = \frac{((x-\gamma)/\beta)^{\alpha_1-1}}{\beta B(\alpha_1, \alpha_2)(1+x/\beta)^{\alpha_1+\alpha_2}}$	$\gamma \leq x < +\infty$	α_1 -continuous shape parameter ($\alpha_1 > 0$) α_2 -continuous shape parameter ($\alpha_2 > 0$) β -continuous scale parameter ($\beta > 0$) -continuous location parameter