Social Science Spectrum ISSN 2454-2806
Vol. 9, No. 1, March 2023, pp. 12-22

Co-occurrence of Overweight/Obesity and Anaemia: Evidence from a Nationally Representative Survey of India

Shalem Balla[*], Manali Swargiary[**] & Mayanka Ambade[#]

Abstract

Anaemia and overweight/obese are simultaneous concerns of many countries around the globe. We analysed both men and women samples from the 2005–2006, 2015-2016 and 2019-21 National Family and Health Surveys, India. Bi-variate analyses were performed to see the level of co-occurrence of anaemia and overweight/obese across the states of India. Multivariate logistic regression models were used to establish associations between household and individual characteristics, dietary intake score and co-occurrence of anaemia-OWOB (overweight and obese). Alongside, spatial analysis were conducted to detect the geographical clustering of the co-occurring anaemia-OWOB. India sees an increase in the co-occurrence of anaemia among male and female population from 1.1 per cent and 5.8 per cent in 2004-05 to 3.2 per cent and 12.6 per cent respectively in 2019-21. A number of socio-demographic factors, namely age, gender, type of residence, wealth index, dietary intake score, as well as time, among others correlate with the incidence of co-occurring anaemia-OWOB. The districts in India presents a picture of neighbourhood influence, with high concentration of co-occurring anaemia-OWOB in parts of Southern and Northern region. Combining knowledge on dietary intake and food-fortification/nutritional policies with affordable and accessible nutritional food focusing on adults may contribute consequentially in avoiding the growing public health concern in India.

Keywords: Overweight, obese, anaemia, double burden, India.

I. Introduction

Anaemia is the most prevalent nutritional deficiency faced by the Indian population (Rajpal et al., 2022). The government of India has introduced specific interventions such as the Anaemia Mukt Bharat, National Nutritional Anaemia Prophylaxis Programme and the Weekly Iron Folic Acid Supplementation Programme to mitigate persistently high anaemia among Indians (MoHFW, 2023). Futher, nutritional programmes such as POSHAN Abhiyaan and the Rashtriya Bal Swasthya Karyakram indirectly contribute to reduction of micronutrient deficiencies. Yet, a little or no change has been observed in the prevalene of anaemia among men, women or children in the past two decades. On the contrary, while 51.8 per cent of women in India were anaemic in 1998-99, the prevalence has increased to 57 per cent by 2021. Simultaneously, India has witnessed an increase in body weight in population, with a sharp rise in the past few years. Usually, a reduction in undernutrition should be accompanied by a subsequent decline in micronutrient deficiency. However, evidence suggests that an improper and imbalanced diet often leads to a change in body composition but persistence of micronutrient deficiens such as anaemia. Often times, snacking culture is associated with an increase in the prevalence of an individual level double burden of overweight/obesity and micronutrient deficiency.

Existing evidence does suggest obesity is indeed related to anaemia (Casaneuva et al., 2000; Ausk & Ioannou, 2012; Ornelas et al., 2011; Aigner, Fieldman & Datz, 2014; Augustina et al., 2020;

[*] Shalem Balla, Research Officer, International Institute for Population Sciences, Govandi Station Road, Deonar, Mumbai 400088, India. Email: shalemballa89@gmail.com

[**] Manali Swargiary, Senior Research Fellow, International Institute for Population Sciences, Govandi Station Road, Deonar, Mumbai 400088, India. Email: swargiarymanali@gmail.com

[#] Mayanka Ambade, Assistant Professor, School of Humanities and Social Sciences, Indian Institute of Technology, Mandi 175005, Himachal Pradesh, India. Email: mayanka@iitmandi.ac.in

Acknowledgment: The authors thank the referees of the journal for their comments on the earlier version of the paper.

Crivelli et al., 2018, Anik et al., 2019). In India, a study on southern India points towards a substantial increase in the co-morbid situation of anaemia-OWOB (Little et al., 2020). It is worth noting that evidence from Southeast Asian countries like China (Qin et al., 2013) and Vietnam (Kinyoki et al., 2021) show a lower or nil presence of anaemia-OWOB individual level double burden. We can attribute this to their dietary habit rich in Vitamin C, which is known to improve iron absorption (Mao & Yao, 1992), thus reducing iron deficiency among the overweight or obese population in these regions.

The food intake patterns and dietary habits of most Indian households promote rapidly increasing imbalanced diets. Between 1973 and 2004, the intake of fat-based products increased, leading to a disproportion body weight (Misra et al., 2011). Decrease in the intake of micronutrient-rich food products with increased intake of either only vegetarian products (Vecchio et al., 2014) or only meat products and salt coupled with declining physical activity due to urbanization has escalated the prevalence of obesity and metabolic syndrome, diabetes, and coronary heart disease in Indians (Misra et al., 2011). Expansion of "snacking culture" due to the easy accessibility of cheap snacks has primarily contributed to such a nutritional transition. A survey conducted by the National Sample Survey Office in India revealed that snacking accounts for about 22 per cent of the total food expenditure in the country (NSSO, 2014). Although snacks rich in carbohydrates and sugar may reduce undernutrition, given the diet composition, they will not affect micro-nutrient deficiency. Thus, a nutritional change may increase the number of OWOB population with stagnant numbers of the anaemic. Anaemia may continue to grow among the OWOB, birthing a new public health concern.

However, little is known about individuals with dual burden of anaemia and overweight/obesity in India. Most evidence is localized or specific to females. For example, a study conducted among urban women in Delhi showed that 38 per cent of overweight women had anaemia, compared with 30 per cent of normal weight women (Mamidi et al., 2018). Another study conducted among women in rural Rajasthan showed that 27.8 per cent of overweight women had anaemia, compared with 21.9 per cent of normal weight women (Gupta et al., 2018; Pandey et al., 2019). Further, women with higher socioeconomic status were more likely to have the double burden, highlighting the role of socioeconomic factors in shaping the burden of overweight and anaemia in India.

Not only in India, but several studies around the world have also shown that there is a positive association between obesity and anaemia. Jayawardena et al. (2020) found that individuals with obesity in Sri Lanka were more likely to have anaemia compared with those without obesity. Similarly, Kozlowska et al. (2019) conducted a study in Poland and found that the prevalence of anaemia increased with increasing BMI. Araujo et al. (2016) found a higher prevalence of anaemia among obese women in Brazil. Mithal et al. (2009) suggested that the coexistence of anaemia and obesity may be due to poor dietary quality, low physical activity, and chronic inflammation. Additionally, Rezazadeh et al. (2019) found that individuals with both obesity and anaemia had a higher risk of developing cardiovascular disease compared with those with either condition alone in an Iranian population.

To develop a wider understanding of the double burden, this study explores the association of OWOB with anaemia and the prevalence of such population across geographical regions of India. We further explore the changing risk of double burden of anaemia-OWOB across socio-demographic correlates of men and women for the time period of 1999-2021.

In recent years, the dual burden of anaemia and overweight/obesity has emerged as a significant public health issue in India. This double burden can lead to adverse health outcomes, including an increased risk of chronic diseases and poor cognitive development in children. Furthermore, the co-occurrence of anaemia and overweight/obesity can have a detrimental impact on the quality of life of affected individuals. Given the significant increase in the prevalence of anaemia and overweight/obesity in India, there is a pressing need to understand the risk factors

associated with this double burden and to develop effective interventions to address this growing public health concern. This study aims to contribute to the existing literature by exploring the prevalence and changing risk of the double burden of anaemia-OWOB across different geographical regions and sociodemographic correlates in India.

II. Methodology

Data and sample size

We used the unit-level data of men aged 15-54 years and women aged 15-49 years from the nationally representative National Family and Health Survey (NFHS) conducted in the years 2006, 2016, and 2021. The NFHS is the Indian Demographic and Health Survey that provides information on population, health and nutrition for India and its states and union territories. The NFHS uses a two-stage stratified sampling design for data collection.

In the survey, the anaemia testing was done by collecting blood specimens by health investigators from eligible women aged 15-49 (in the state module subsample of households), men aged 15-54, and children aged 6-59 months. Blood samples were drawn to examine the respondent's haemoglobin (Hb) concentration, and those that were less than 7.0 f/dl were considered having severe anaemia. The weight and height were calculated using the Seca 874 digital scale and Seca 213 stadiometer. According to weight and height readings, Body Mass Index (BMI) was created.

This study is based on a cross-sectional sample of adult men aged 15 to 54 years and adult women aged 15 to 49 years, excluding pregnant and lactating women. We selected a sample of 5,92,057 women and 1,01,695 men from NFHS-5, 5,56,753 women and 1,12,005 men from NFHS-4, and 97,386 women and 69,228 men from NFHS-3. The descriptive statistics are presented in Table 1.

Outcome variables

The outcome variable was the co-occurrence of anaemia and overweight/obesity (anaemia-OWOB). The levels of anaemia were in the categories "not anaemic, mild, moderate, and severe." For the analysis, the mild, moderate, and severe categories were grouped into one category, "anaemic" and the non-anaemic were into another category. The overweight/obesity level was measured using the Body Mass Index (BMI). The BMI was categorized as overweight/obese (>=25) and below 25. The flagged cases from the BMI index were removed from the study. Finally, the outcome was constructed as a compound binary variable that took the value one if a person was anaemic and had BMI above or equal to 25; and zero otherwise.

Predictor variables

We included several household-level socioeconomic covariates, year variable and dietary intake score characteristics associated with adult co-occurrence of anaemia and overweight/obesity. For the dietary intake variable, seven food varieties were considered: dairy products, pulses, leafy fruits, vegetables, eggs, fish, and meat. We calculated a Dietary Diversity Score as a continuous variable taking seven types of food varieties based on the question "How frequently do you consume ….?" Which were categorized as never consumed (0), daily (1), weekly (2), and occasionally (3). This information is self-reported. We restructured the coding to 0 as never, 1 as occasionally, 2 as weekly and 3 as daily. Then the scores were added across seven food groups to get the dietary intake index. The score of this index lies between 0-21. Individuals consuming all the seven items every day received a score of 21, and those who haven't consumed received 0. This variable was taken as a predictor variable to see the influence of diet intake over co-morbid anaemia-OWOB.

Table 2: Descriptive statistics of the study population according to the socio-demographic variables, NFHS 2005-06 to 2019-21

Characteristics	Category	NFHS-3				NFHS-4				NFHS-5			
		Men		Women		Men		Women		Men		Women	
		Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.
Age group	15-24	33.6	24,997	34.4	33,505	31.5	35,363	32.6	1,81,257	30.9	31122	31.7	190481
	25-34	27.7	20,597	26.9	26,183	27.5	30,776	25.9	1,44,149	27.1	27567	25.5	149908
	35-44	23.4	17,406	28.5	27,715	23	25,821	28.4	1,58,308	22.9	23604	28.7	169106
	45-49	9.08	6,750	10.3	9,983	10.2	11,452	13.1	73,039	10.7	10845	14.1	82562
	50-54	6.21	4,618	-	-	7.77	8,711	-	-	8.46	8557	-	-
Wealth index	Poorest	15.8	11,732	14.4	14,065	14.7	16,437	15.8	88,012	17.3	19,764	17.2	1,13,977
	Poorer	18.1	13,446	17.6	17,131	18.6	20,902	18.8	1,04,620	20.1	22,573	19.6	1,28,835
	Middle	20.4	15,167	20.3	19,725	21.1	23,689	20.7	1,15,117	20.9	21,679	20.8	1,25,716
	Richer	22.2	16,479	22.2	21,621	22.3	24,979	22.1	1,22,920	21.2	20,183	21.4	1,17,683
	Richest	23.6	17,545	25.5	24,844	23.3	26,115	22.7	1,26,085	20.5	17,496	21	1,05,846
Education	No Educn, Preschool	18.5	13,775	37.7	36,659	13	14,592	27.4	1,52,503	10.6	10,968	22	1,34,125
	Primary	17	12,654	14.9	14,522	12.6	14,090	12.2	67,793	12.1	11,946	12.6	74,032
	Secondary	52	38,678	39.3	38,263	57.1	64,008	47.3	2,63,401	58.1	60,829	50.1	3,02,003
	Higher	12.4	9,231	8.15	7,932	17.3	19,432	13.1	73,056	19.2	17,905	15.2	81,772
Place of residemce	Urban	36.5	27,154	36	35,083	38.3	42,955	36.7	2,04,027	33.2	26,383	33.7	1,54,127
	Rural	63.5	47,215	64	62,303	61.7	69,167	63.4	3,52,726	66.9	75,312	66.3	4,37,930
Caste	Scheduled Caste	19.4	13,965	18.2	16,971	89.1	99,923	89.4	4,97,462	21.8	19,814	21.9	1,15,728
	Scheduled Tribe	8.41	6,063	7.65	7,157	6.26	7,019	6.17	34,335	9.79	19,636	9.29	1,09,693
	Other Backward Class	40.3	29,039	40.2	37,562	4.1	4,594	3.82	21,283	42.4	38,005	42	2,21,590
	Others	31.9	23,031	34	31,825	0.52	586	0.66	3,673	26	24,240	26.7	1,45,046
Religion	Hindu	82.1	61,020	80.7	78,606	81.5	91,390	80.9	4,50,132	81.5	76,774	81.4	4,46,830
	Muslim	12.4	9,186	12.9	12,605	13.2	14,790	13.3	74,079	13.2	12,229	13.2	72,611
	Christian	2.27	1,692	2.63	2,566	2.27	2,550	2.47	13,779	2.22	7,332	2.5	42,264
	Other	3.32	2,471	3.71	3,610	3.02	3,391	3.37	18,764	3.11	5,360	2.96	30,352
Region	North	14.1	10,496	13.6	13,282	14.2	15,909	13.7	76,439	14.8	21,111	14.3	1,23,660
	Central	23.4	17,418	21.3	20,731	21.5	24,112	22.9	1,27,411	23.4	23,206	24	1,36,005
	East	20.6	15,347	20.6	20,052	18.8	21,046	20.5	1,14,125	21.4	15,182	21.6	90,704
	Northeast	4.02	2,988	3.82	3,719	3.29	3,692	3.34	18,589	3.81	14,838	3.56	82,163
	West	16.2	12,038	15.8	15,361	18.4	20,583	15	83,433	15.9	11,565	14.7	61,375
	South	21.6	16,082	24.9	24,242	23.9	26,780	24.6	1,36,756	20.7	15,793	21.9	98,150

Statistical analysis

We have used the descriptive statistics, estimated univariate and bivariate Moran's I statistics and a set of regression models in the analyses. Descriptive analyses were performed to show the frequency and the proportion of co-occurrence across various characteristics of the population required for the study.

Univariate Moran's I and LISA Cluster Map were used to detect the geographical spatial clustering and pattern of the prevalence of co-occurrence of anaemia and overweight/obesity. The value of Moran's I usually ranges between -1 and 1 (Jackson et al., 2010). The LISA Cluster Map estimation detected the co-occurrence hotspots using district-level data. Bivariate LISA significance map measured the correlation between the independent and the weighted average of the dependent variable in a particular location. The bivariate analysis first assessed the links between different characteristics and the outcome variable. Multiple-regression models for men, women and combined (men and women both) were then iteratively developed to understand the further relationship between them. The pseudo panel data constructed for the study highlighted time with the co-occurrence of anaemia and OWOB. Variables were retained where the P-value for their coefficient remained ≤ 0.05. The models were tested for heteroscedasticity and multicollinearity. The variance was clustered at the level of the primary sampling unit. The data were analysed using STATA 15.0 and GeoDA software.

III. Results

Table 2 shows the prevalence of anaemia-OWOB according to selected socio-economic background characteristics. Among both men and women, the prevalence is increasing with the age. Prevalence among the richest wealth quintile is higher than the poorest wealth quintile. Prevalence among the Indian population is more in the highly educated section than the uneducated and below primary educated section. Overall, Scheduled tribes have a lower prevalence whereas other backward castes, schedule castes and other categories have a higher prevalence. The prevalence of the co-occurance appears to be higher among residents of urban areas and the southern part of the nation than among their counterparts in both men and women.

Figure 1: District-wise quantile map of prevalence of overweight and obese- anaemia prevalence for the total population, 2015-16 to 2019-21, India.

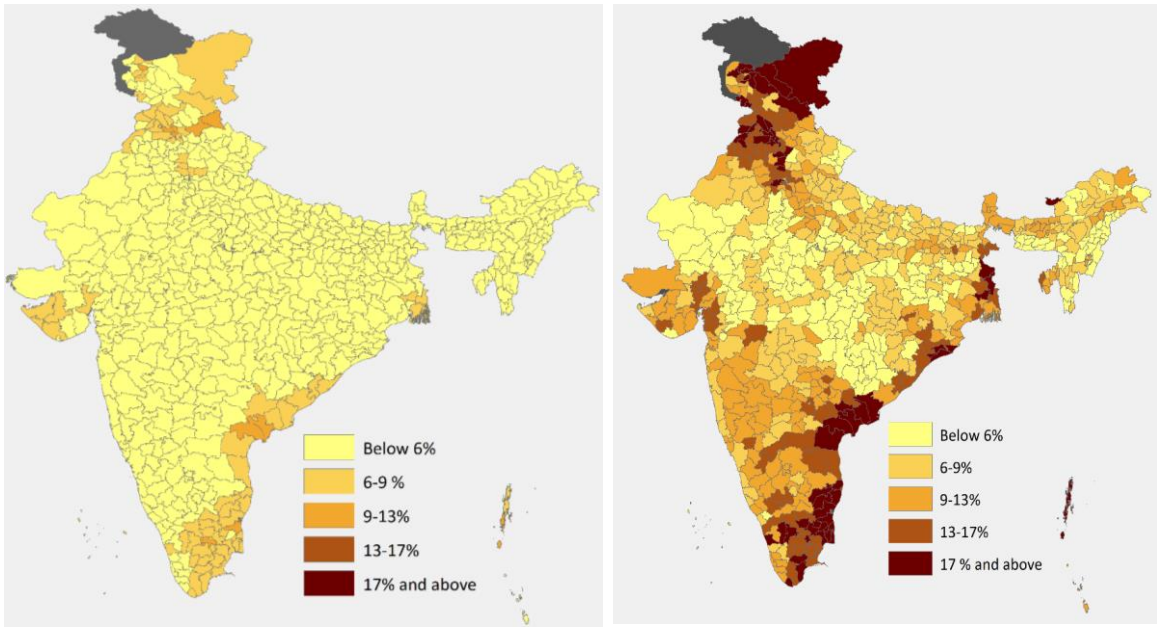

Table 2: Prevalence of overweight and obese-anaemia according to selected background characteristics, India, NFHS 2004-05 to 2019-21.

Variable	Category	NFHS-3		NFHS-4		NFHS-5	
		Male	Female	Male	Female	Male	Female
Age group	15-24	0.31	1.65	0.55	2.93	1.3	3.8
	25-34	0.8	5.76	1.29	10.62	3.3	13.2
	35-44	1.78	9.29	2.1	14.8	4.9	17.6
	45-49	2.29	10.33	2.51	15.78	5.9	17.9
	50-54	2.25	-	3.19	-	5.7	-
Wealth Index	Poorest	0.29	1.12	0.54	2.97	2.44	5.72
	Poorer	0.3	2.16	1.05	5.5	3.06	8.79
	Middle	0.67	3.34	1.28	8.98	3.44	12.16
	Richer	1.2	6.89	2.03	13.34	4.98	15.1
	Richest	2.5	12.04	2.23	16.23	5.03	17.49
Education	No education, preschool	0.6	3.78	1.4	8.7	3.66	11.19
	Primary	0.9	5.84	1.49	11.33	3.77	14.1
	Secondary	1.03	7.01	1.38	10.14	3.83	12.08
	Higher	2.35	9.52	2.07	10.85	4.03	12.08
Place of residence	Urban	1.71	9.96	1.9	14.48	4.41	15.66
	Rural	0.74	3.49	1.28	7.38	3.56	10.35
Caste	Scheduled caste	0.79	4.33	1.38	8.86	3.34	11.25
	Scheduled tribe	0.71	2.1	0.8	5.08	3.44	7.09
	Other backward class	0.91	5.62	1.56	10.12	3.81	11.99
	Others	1.65	7.74	1.74	12.16	4.48	14.86
Religion	Hindu	1.08	5.65	1.54	9.68	3.77	11.91
	Muslim	0.91	6.2	1.39	10.8	3.97	12.54
	Christian	1.4	6.04	1.6	11.7	4.36	14.45
	Others	1.77	8.02	1.5	12.73	4.72	14.85
Region	North	1.52	6.77	1.18	10.36	3.7	12.65
	Central	0.57	3.73	0.87	7.14	2.77	8.55
	East	0.92	4.51	1.53	8.66	4.3	12.17
	Northeast	1.54	4.37	1.02	5.64	4.23	9.45
	West	1.36	6.23	1.55	10.43	4.05	11.69
	South	1.26	8.13	2.33	13.85	4.46	16.46
	Total	1.09	5.82	1.52	9.98	3.84	12.14

Table 3 shows the prevalence of anaemia-OWOB by states/UTs of India. Results show that the prevalence among males has increased from one per cent in 2005-06 to 3.5 per cent in 2019-21. Meanwhile, among the women co-occurance of anaemia-OWOB increased from six per cent in 2005-06 to 12 per cent in 2019-21. According to the latest 2019-2021 data, the prevalence is higher in Puducherry (25.59%), Chandigarh (20.77%), and Andaman and Nicobar Islands (20.75%), and lower among the states in Nagaland (3.7%), followed by Meghalaya (5.58%). Figure 1 shows the district level quantile map of overweight and obese-anaemia prevalence. Results show that Andhra Pradesh, Tamil Nadu, South Gujarat, Haryana, Delhi and some districts of West Bengal have high prevalence.

Table 4 represents the correlates of anaemia-OWOB for total population and separately for men and women. As the age increases from the 15-19 years category to 50-54 years in men and 45-49 years in women, the odds of becoming anaemic-OWOB increases. That is, 12.6 (p=0.001) times more likely to becoming anaemic-OWOB with reference to 15-19 category in the overall population. In men, the odds ratio increased by 1 than the previous category. Same with women also. The odds of becoming anaemic-OWOB for a rural resident is 0.82 (p= 0.001; 7.04, 7.73) which is lower compared with an urban resident. The odds of becoming anaemic-OWOB for women is 7.38 (p= 0.001; 7.04, 7.73) times as large as the odds of men. The odds ratio is increasing by the wealth quintile. The odds of becoming anaemic-OWOB for a person in the richest wealth quintile is 5.15

(p= 0.001; 4.90,5.41) times higher than the poorest person. The same scenario is visualising in the case of men and women. The odds of becoming anaemic-OWOB for women is 1.01 (p= 0.001;

Table 3: Prevalence of overweight/obese-anaemia by states/UTS, India, NFHS 2004-05 to 2019-21

State	NFHS-3		NFHS-4		NFHS-5	
	Male	Female	Male	Female	Male	Female
Andaman & Nicobar Islands	-	-	6.01	20.44	4.63	20.75
Andhra Pradesh	1.74	8.57	3.35	17.12	3.66	20
Arunachal Pradesh	1.54	5.14	1.17	6.46	4.53	7.66
Assam	1.63	4.76	1.04	5.35	4.28	9.66
Bihar	1.22	2.93	1.29	7.04	2.96	9.74
Chandigarh			0.78	26.4	2.9	20.77
Chhattisgarh	0.44	2.65	0.46	4.4	2.55	7.42
Dadra and Nagar Haveli	-	-	2.24	13.72	3.89	15.62
Daman and Diu	-	-	2.45	16.91	-	-
Goa	1.14	5.97	1.53	9.13	2.51	12.88
Gujarat	1.86	7.33	1.37	11.19	3.01	12.93
Haryana	1.72	9.03	1.19	12.01	3.36	17.49
Himachal Pradesh	1.76	5.49	1.32	14.26	4.5	15.89
Jammu and Kashmir	1.65	7.7	1.89	12.96	8.19	17.69
Jharkhand	0.55	3.24	1.05	6.45	3.27	7.05
Karnataka	0.94	6.03	2.25	9.23	4.34	12.47
Kerala	0.54	7.54	1.08	10.59	5.63	12.82
Lakshadweep	-	-	0.56	15.75	1.99	7.35
Madhya Pradesh	0.47	3.61	0.75	6.34	2.46	7.46
Maharashtra	1.1	5.68	1.68	10.06	4.17	11.14
Manipur	0.82	3.79	0.52	5.59	1.14	8.62
Meghalaya	2.52	2.03	1.69	6.11	3.52	5.58
Mizoram	1.82	2.55	0.61	4.33	3.22	6.51
Nagaland	-	-	0.64	3.16	1.4	3.7
Delhi	1.55	7.92	1.49	13.23	2.9	17.63
Odisha	0.83	3.38	1.05	6.73	4.02	12.93
Puducherry	-	-	0.89	19.89	6.39	25.59
Punjab	2.11	8.9	1.67	16.02	4.18	20.19
Rajasthan	1.15	4.58	0.61	5.3	2.39	6.08
Sikkim	2.59	7	1.98	7.16	5.05	11.83
Tamil Nadu	1.3	9.9	2.78	15.91	4.23	19.47
Tripura	0.9	4.76	0.74	8.34	5.3	14.49
Uttar Pradesh	0.63	3.95	1.00	7.9	2.4	9.17
Uttarakhand	1.02	6.11	0.98	8.57	1.79	11.34
West Bengal	0.85	6.61	2.08	11.65	5.26	15.6
Telangana	-	-	1.15	14.23	2.89	15.06
India	1.09	5.82	1.52	9.98	3.52	12.16

1.00,1.01) times as large as the odds of men. For every 1 unit increase in the dietary diversity score, the likelihood that the person becoming anaemic-OWOB increases by approximately 1.1 times. The odds of becoming anaemic-OWOB in 2015 and 2019 is 1.64 (p= 0.001; 1.59,1.68) times as large as the odds in 2004. The odds of a person living in the southern region becoming anaemic-OWOB living is 1.32 (p= 0.001; 1.27,1.36) times as higher than the northern region. Among both men and women also the odds among the southern region is higher.

IV. Discussion

Our study has three essential findings. First, the overall prevalence of anaemia-OWOB co-occurrence in India has increased from 1.09 to 3.52 per 100 males and 5.82 to 12.14 per 100 females between 2004 and 2019-21. Second, the individual level dual burden of OWOB and anaemia is strongly and positively associated with age and wealth, and with higher likelihood of such co-

occurance among females. Third, anaemia-OWOB prevalence is higher in Southeast India (mostly in Tamil Nadu) and parts of Northwest India. Dietary habits with higher reliance on carbohydrate

Table 4: Pooled OLS estimates: Correlates of overweight and obese-anaemia, India, NFHS 2004-05 to 2019-21.

Variable	Category	Total population		Male		Female	
		Adjusted odds ratio	95% confidence interval	Adjusted odds ratio	95% confidence interval	Adjusted odds ratio	95% confidence interval
Age group	15-19 ®						
	20-24	2.29***	[2.16,2.43]	1.40**	[1.08,1.80]	2.35***	[2.21,2.49]
	25-29	4.73***	[4.49,4.98]	2.30***	[1.82,2.90]	4.89***	[4.64,5.16]
	30-34	6.94***	[6.61,7.30]	3.45***	[2.75,4.32]	7.16***	[6.81,7.54]
	35-39	8.50***	[8.10,8.93]	4.88***	[3.92,6.06]	8.72***	[8.29,9.17]
	40-44	10.0***	[9.60,10.6]	5.39***	[4.33,6.70]	10.37***	[9.86,10.9]
	45-49	10.2***	[9.77,10.80]	6.92***	[5.58,8.59]	10.46***	[9.93,11.0]
	50-54	12.6***	[11.1,14.37]	7.27***	[5.82,9.07]		
Household size		0.99*	[0.99,0.99]	0.97**	[0.95,0.99]	0.99	[0.99,1.00]
Place of residence	Urban ®						
	Rural	0.82***	[0.80,0.83]	1.03	[0.93,1.13]	0.81***	[0.79,0.82]
Gender	Male ®						
	Female	7.38***	[7.04,7.73]	-	-	-	-
Wealth Index	Poorest ®						
	Poorer	1.70***	[1.62,1.78]	1.55***	[1.23,1.94]	1.70***	[1.62,1.79]
	Middle	2.64***	[2.52,2.76]	2.02***	[1.62,2.52]	2.66***	[2.54,2.79]
	Richer	3.83***	[3.66,4.02]	2.96***	[2.38,3.69]	3.87***	[3.69,4.06]
	Richest	5.15***	[4.90,5.41]	4.53***	[3.60,5.70]	5.17***	[4.91,5.44]
Education	No Education, Preschool ®						
	Primary	1.18***	[1.14,1.22]	1.13	[0.94,1.35]	1.18***	[1.14,1.22]
	Secondary	1.23***	[1.20,1.27]	1.18*	[1.01,1.37]	1.24***	[1.20,1.27]
	Higher Secondary	1.037	[0.99,1.07]	1.25*	[1.05,1.50]	1.02	[0.98,1.06]
Caste	Sc ®						
	St	0.77***	[0.74,0.80]	1.14	[0.95,1.35]	0.75***	[0.72,0.79]
	Obc	0.97*	[0.94,0.99]	0.99	[0.86,1.12]	0.96*	[0.94,0.99]
	Others	1.05***	[1.02,1.08]	1.16*	[1.01,1.32]	1.05***	[1.02,1.08]
Dietary diversity score		1.01***	[1.00,1.01]	0.99	[0.97,1.00]	1.01***	[1.00,1.01]
Time	2004 ®						
	2015	1.64***	[1.59,1.68]	1.20***	[1.10,1.31]	1.69***	[1.64,1.74]
	2019	1.83***	[1.78,1.87]	1.31***	[1.21,1.42]	1.75***	[1.69,1.80]
Regions	North ®						
	Central	0.97	[0.94,1.00]	0.84*	[0.73,0.98]	0.97	[0.95,1.00]
	East	1.22***	[1.18,1.26]	1.38***	[1.17,1.62]	1.21***	[1.17,1.25]
	Northeast	0.71***	[0.68,0.74]	0.93	[0.78,1.11]	0.69***	[0.66,0.72]
	West	0.93***	[0.90,0.97]	0.96	[0.82,1.12]	0.93***	[0.90,0.97]
	South	1.32***	[1.27,1.36]	1.44***	[1.25,1.66]	1.31***	[1.26,1.35]

®- Reference category, 95% confidence intervals in brackets, * p<0.05, ** p<0.01, *** p<0.001.

and fat based food could contribute to such trends. Low prevalence of the same is noted in Northeast India, indicating balanced dietary habits in the region.

Mechanisms underlying the relationship between anaemia and obesity are complex and not fully understood. However, it is thought that obesity may contribute to anaemia through several pathways, including inflammation, altered iron metabolism and impaired erythropoiesis (the process of red blood cell formation) (Huang et al., 2019). Additionally, some studies suggest that obesity-related insulin resistance may contribute to anaemia through a reduction in erythropoietin (a hormone that stimulates erythropoiesis) production (Huang et al., 2019).

The double burden of anaemic-OWOB can have significant health consequences, including an increased risk of chronic diseases and decreased quality of life. Therefore, prevention and

management of both conditions are crucial to improve health outcomes. Lifestyle modifications such as healthy eating habits and regular physical activity can help prevent and manage both anaemia and obesity (WHO, 2022a; WHO, 2022b). Additionally, healthcare providers can screen and diagnose both conditions and develop individualised treatment plans for their patients (WHO, 2022a & 2022b).

A low variation in the dietary diversity score shows that nutritional habits of the Indian population are skewed with higher reliance on carbohydrates and fats and low uptake of micro-nutrient rich food like dairy, pulses, plant and animal-based products rich in protein, calcium and iron (Krishnan et al., 2008; Misra et al., 2011; Rammohan et al., 2012; Vecchio et al., 2014). Higher subsidies on fats and carbohydrate food products reinforce these habits. Even today subsidies are provided for sugar in place of pulses through the public distribution system. The easy availability and accessibility of cheap snacks (even in remote geographical locations) further aggravates the skewed nutritional uptake.

These dietary habits that make a population vulnerable to high BMI also limit their micronutrient uptake, thus making them susceptible to micronutrient deficiencies like anaemia. Such co-occurrence of anaemic-OWOB can have serious public health repercussions later. For instance, high BMI and anaemia are both responsible for pregnancy and delivery complications. With the rising number of females susceptible to both, we may experience increased pregnancy complications or maternal deaths. Further, if co-occurrence increases rapidly, it will be challenging to mitigate it as stringent food policies will have to be adopted that may adversely affect many self-employed people's economic stability. Therefore, it is necessary to address the growing prevalence of anaemia among the OWOB population at this stage. Well-designed nutritional and dietary policy needs to be brought about with higher reliance on generating awareness and public support regarding a balanced diet. Men and women in urban areas, especially the employed, who rely highly on outside food, should be encouraged to adopt healthier food habits. Rationing the prices of vegetables, pulses, and dairy products and increasing their marketability should be the prime focus. This will make healthy foods economically lucrative and easily accessible. However, most of all, we must begin with the acceptance that our nutritional policies focus too much on under-nutrition and too little on a balanced diet.

It is important to note that anaemia-OWOB co-occurrence is not limited to India but is a global issue. The World Health Organization has identified the coexistence of overweight/obesity and anaemia as a double burden of malnutrition that affects many low- and middle-income countries (WHO, 2020). Therefore, the findings of this study may have implications for other countries facing similar challenges. The prevalence of anaemia-OWOB co-occurrence in India is likely to have significant economic implications. This dual burden of disease could lead to increased healthcare costs, reduced productivity and decreased quality of life among the affected individuals. Addressing this issue could have a positive impact on the overall economy of the country.

V. Conclusion

Given the rising individual-level dual burden of anaemia and overweight among men and women of reproductive ages, a comprehensive nutritional policy for the adults of our nation is imperative. Such an approach should first identify the adult population with a low dietary diversity score and over-reliance on carbohydrates and fats, followed by designing an approach to influence the social norms against snacking and encouraging the adult population to pursue a better diet regime. This needs to be substantiated with economic policies that will allow adults to afford and easily access healthy foods.

References

Agustina, R., Nadiya, K., Andini, E. A., Setianingsih, A. A., Sadariskar, A. A., Prafiantini, E., ... & Raut, M. K. (2020). Associations of meal patterning, dietary quality and diversity with anemia and overweight-obesity among Indonesian school-going adolescent girls in West Java. *PLoS One*, *15*(4), e0231519.

Aigner, E., Feldman, A., & Datz, C. (2014). Obesity as an emerging risk factor for iron deficiency. *Nutrients*, *6*(9), 3587-3600.

Anik, A. I., Rahman, M. M., Rahman, M. M., Tareque, M. I., Khan, M. N., & Alam, M. M. (2019). Double burden of malnutrition at household level: A comparative study among Bangladesh, Nepal, Pakistan, and Myanmar. *PloS one*, *14*(8), e0221274.

Araujo, T. L., Lopes, M. S., Sampaio, H. A., & Ferreira, M. D. (2016). Prevalence of anemia and associated factors in obese women. *Revista Brasileira de Hematologia e Hemoterapia*, *38*(*3*), 200–204. https://doi.org/10.1016/j.bjhh.2016.04.002

Ausk, K. J., & Ioannou, G. N. (2008). Is obesity associated with anemia of chronic disease? A population-based study. *Obesity*, *16*(10), 2356-2361.

Bhan, N., Millett, C., Subramanian, S. V., Dias, A., Alam, D., Williams, J., & Dhillon, P. K. (2017). Socioeconomic patterning of chronic conditions and behavioral risk factors in rural South Asia: a multi-site cross-sectional study. *International Journal of Public Health*, *62*(9), 1019-1028.

Casanueva, E., Pfeffer, F., Drijanski, A., Fernández-Gaxiola, A. C., Gutiérrez-Valenzuela, V., & Rothenberg, S. J. (2003). Iron and folate status before pregnancy and anemia during pregnancy. *Annals of Nutrition and Metabolism*, *47*(2), 60-63.

Crivelli, M., Wyss, K., Grize, L., Matthys, B., Aebi, T., & Zemp, E. (2018). Are overweight and obesity in children risk factors for anemia in early childhood? Results from a national nutrition survey in Tajikistan. *International Journal of Public Health*, *63*, 491-499.

Dutta, M., Selvamani, Y., Singh, P., & Prashad, L. (2019). The double burden of malnutrition among adults in India: evidence from the National Family Health Survey-4 (2015-16). *Epidemiology and Health*, 41.

Gupta, V., & Gupta, P. (2018). Prevalence of anemia among normal and overweight/obese women in rural Rajasthan, India. *Journal of Mid-life Health*, *9*(3), 123-128.

Health & Family Welfare-Government of India, M. O. (n.d.). Weekly Iron Folic Acid Supplementation(WIFS) :: National Health Mission. Weekly Iron Folic Acid Supplementation(WIFS) :: *National Health Mission*. https://nhm.gov.in/index1.php?lang=1&level=3&sublinkid=1024&lid=388

Huang, J., Schriefer, J. M., & Zamudio, S. (2019). Anemia and obesity: current concepts. *World Journal of Clinical Cases*, *7*(17), 2354-2361.

International Institute for Population Sciences (IIPS) and ICF. 2017. National Family Health Survey (NFHS-4), 2015-16: India. Mumbai: IIPS.

International Institute for Population Sciences (IIPS) and ICF. 2017. National Family Health Survey (NFHS-3), 2005-06: India. Mumbai: IIPS.

International Institute for Population Sciences (IIPS) and ICF. 2017. National Family Health Survey (NFHS-2), 1998-99: India. Mumbai: IIPS.

International Institute for Population Sciences and ICF. National Family Health Survey (NFHS-4), 2015-16: India, 2016.

International Institute for Population Sciences and ICF. National Family Health Survey (NFHS-5), 2020–121, 2021.

International Institute for Population Sciences and Macro International. National Family Health Survey (NFHS-3), 2005–06: India, volume 1, 2007.

Jackson, M. C., Huang, L., Xie, Q., & Tiwari, R. C. (2010). A modified version of Moran's I. *International Journal of Health Geographics*, *9*(1), Article number: 33, 1-10.

Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P., & Hills, A. P. (2020). Prevalence, trends and associated socio-economic factors of obesity and overweight in Sri Lanka: A systematic review and meta-analysis. *BMC Public Health*, *20*(1), 257. https://doi.org/10.1186/s12889-020-8333-6

Kinyoki, D., Osgood-Zimmerman, A. E., Bhattacharjee, N. V., Kassebaum, N. J., & Hay, S. I. (2021). Anemia prevalence in women of reproductive age in low-and middle-income countries between 2000 and 2018. *Nature medicine*, *27*(10), 1761-1782.

Kozłowska, L., Roszkowska-Blaim, M., & Gebala, A. (2019). Anemia in obesity: Etiology, clinical significance and treatment. *Advances in Clinical and Experimental Medicine*, *28*(9), 1289–1295. https://doi.org/10.17219/acem/104458

Krishnan, A., Shah, B., Lal, V., Shukla, D. K., Paul, E., & Kapoor, S. K. (2008). Prevalence of risk factors for non-communicable disease in a rural area of Faridabad district of Haryana. *Indian Journal of Public Health*, *52*(3), 117-124.

Kroker-Lobos, M. F., Pedroza-Tobías, A., Pedraza, L. S., & Rivera, J. A. (2014). The double burden of undernutrition and excess body weight in Mexico. *The American Journal of Clinical Nutrition*, *100*(6), 1652S-1658S.

Kushitor, S. B., Owusu, L., & Kushitor, M. K. (2020). The prevalence and correlates of the double burden of malnutrition among women in Ghana. *Plos one*, *15*(12), e0244362.

Little, M., Humphries, S., Dodd, W., Patel, K., & Dewey, C. (2020). Socio-demographic patterning of the individual-level double burden of malnutrition in a rural population in South India: a cross-sectional study. *BMC Public Health*, *20*, 1-14.

Malhotra, P., Kumari, S., Kumar, R., & Varma, S. (2004). Prevalence of anemia in adult rural population of north India. *Journal-Association of Physicians of India*, *52*, 18-20.

Mao, X., & Yao, G. (1992). Effect of vitamin C supplementations on iron deficiency anemia in Chinese children. *Biomedical and Environmental Sciences*: BES, *5*(2), 125-129.

Mamidi, R. S., Kulkarni, B., Singh, A., Juneja, V., Chugh, P., & Sharan, M. (2018). Prevalence and determinants of anemia and its association with obesity among urban women in Delhi. *Journal of Family Medicine and Primary Care*, *7*(6), 1383-1387.

Mengesha, M. B., & Dadi, G. B. (2019). Prevalence of anemia among adults at Hawassa University referral hospital, Southern Ethiopia. *BMC Hematology*, *19*(1), 1-7.

Misra, A., Singhal, N., Sivakumar, B., Bhagat, N., Jaiswal, A., & Khurana, L. (2011). Nutrition transition in India: secular trends in dietary intake and their relationship to diet-related non-communicable diseases. *Journal of Diabetes*, *3*(4), 278-292.

Mithal, A., Kaur, P., & Malik, R. S. (2009). Anemia in obesity: A challenge for all ages. *Indian Journal of Pediatrics*, *76*(11), 1137–1138. https://doi.org/10.1007/s12098-009-0188-y

National Sample Survey Office (NSSO). (2014). Household Consumption of Various Goods and Services in India 2011–12.

Qin, Y., Melse-Boonstra, A., Pan, X., Yuan, B., Dai, Y., Zhao, J., ... & Shi, Z. (2013). Anemia in relation to body mass index and waist circumference among Chinese women. *Nutrition Journal*, *12*(1), 1-3.

Pande, S., Ranjan, R., & Kratasyuk, V. A. (2019). Is Body Mass Index a potential biomarker for anemia in obese adolescents?. *Journal of Nutrition & Intermediary Metabolism*, *15*, 1-2.

Popkin, B. M. (2015). Nutrition transition and the global diabetes epidemic. *Current Diabetes Reports*, *15*(9), 1-8.

Rajpal S, Kumar A, Rana MJ, Kim R, Subramanian SV. Small area variation in severe, moderate, and mild anemia among women and children: A multilevel analysis of 707 districts in India. *Front Public Health*. 2022;10:945970. Published 2022 Sep 20. doi:10.3389/fpubh.2022.945970

Rammohan, A., Awofeso, N., & Robitaille, M. C. (2012). Addressing female iron-deficiency anaemia in india: is vegetarianism the major obstacle?. *International Scholarly Research Notices*, 2012.

Rezazadeh, E., Mohammadzadeh, A., & Gargari, B. P. (2019). Anemia and obesity: A review of the literature. *Journal of Obesity and Overweight*, *5*(1), 1–7. https://doi.org/10.11648/j.ijo.20190501.11

Rhodes, E. C., Suchdev, P. S., Narayan, K. V., Cunningham, S., Weber, M. B., Tripp, K., ... & Williams, A. M. (2020). The co-occurrence of overweight and micronutrient deficiencies or anemia among women of reproductive age in Malawi. *The Journal of Nutrition*, *150*(6), 1554-1565.

Rhodes, E. C., Suchdev, P. S., Narayan, K. V., Cunningham, S., Weber, M. B., Tripp, K., ... & Williams, A. M. (2020). The co-occurrence of overweight and micronutrient deficiencies or anemia among women of reproductive age in Malawi. *The Journal of Nutrition*, *150*(6), 1554-1565.

Rivera, J. A., Pedraza, L. S., Martorell, R., & Gil, A. (2014). Introduction to the double burden of undernutrition and excess weight in Latin America. *The American Journal of Clinical Nutrition*, *100*(6), 1613S-1616S.

Sarmiento, O. L., Parra, D. C., González, S. A., González-Casanova, I., Forero, A. Y., & Garcia, J. (2014). The dual burden of malnutrition in Colombia. *The American Journal of Clinical Nutrition*, *100*(6), 1628S-1635S.

Torres Ornelas, P., Evangelista Salazar, J. J., & Martínez-Salgado, H. (2011). Coexistence of obesity and anemia in children between 2 and 18 years of age in Mexico. *Boletín médico del Hospital Infantil de México*, *68*(6), 431-437.

Vecchio, M. G., Paramesh, E. C., Paramesh, H., Loganes, C., Ballali, S., Gafare, C. E., Verduci, E., & Gulati, A. (2014). Types of food and nutrient intake in India: a literature review. *The Indian Journal of Pediatrics*, *81*(1), 17-22.

World Health Organisation, *Health Topics: Anaemia. 2021*. https://www.who.int/health-topics/anaemia. [accessed: 5 Feb, 2021].

World Health Organization. (2008). *Worldwide prevalence of anaemia 1993-2005: WHO global database on anaemia*.

World Health Organization. (2020). WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789240015128

World Health Organization. (2022a). *Anemia*. Retrieved from https://www.who.int/news-room/q-a-detail/anemia

World Health Organization. (2022b). *Obesity*. Retrieved from https://www.who.int/news-room/q-a-detail/obesity.