Predicting the Impact of Introducing Front of Package Warning Labels on Overweight and Obesity Reduction among Adolescents (15-19 Years) in India using a Stochastic Microsimulation Model

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Overweight and obesity among adolescents in India are rising, with recent estimates suggesting a growing burden alongside high consumption of foods high in fat, sugar, and salt (HFSS). Excessive intake of HFSS foods is a key risk factor for non-communicable diseases. Front-of-Pack Labeling (FOPL), recommended by the World Health Organization, aims to reduce such consumption. This study estimates the potential impact of FOPL on adolescent overweight and obesity in India. Data from the Comprehensive National Nutrition Survey (2018) on consumption of snacks, fried foods, sweets, and aerated drinks were used. Scenarios assuming 8–35% calorie reduction, incorporating partial compensatory intake, were modeled using a dynamic weight-change framework over four years. Changes in overweight and obesity prevalence and associated economic costs (diabetes, asthma, heart disease, cancer) were estimated, along with industry implementation costs. Data from the Comprehensive National Nutrition Survey (2018) on consumption of snacks, fried foods, sweets, and aerated drinks were used. Scenarios assuming 8–35% calorie reduction, incorporating partial compensatory intake, were modeled using a dynamic weight-change framework over four years. Changes in overweight and obesity prevalence and associated economic costs (diabetes, asthma, heart disease, cancer) were estimated, along with industry implementation costs. FOPL is a low-cost, potentially high-impact policy for reducing adolescent obesity in India. However, results depend on key assumptions and limited cost data, highlighting the need for context-specific evidence.

Key Words: FOPL, obesity, India, CNNS, simulation model

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Overweight and obesity are increasing worldwide, affecting 380 million children and adolescents (WHO, 2019). Globally, the proportion of children (5 to 9 years) and adolescents (10 to 19 years) with overweight or obesity is estimated at 21% and 17%, respectively (UNICEF, 2019). Overweight and obese children are more likely to remain obese in adulthood and at life-long risks for non-communicable diseases (NCDs), premature death and disability, and significantly reduced productivity (Zempsky et al., 2020; Ezzati and Riboli, 2013). Simulation-based estimates predict that 80% of severely obese children at the age of 2years will be obese during adulthood (Ward et al., 2017). The rate of increase in childhood overweight and obesity is disproportionally higher among low-middle-income countries (LMICs) than in developed countries (WHO, 2016).

In India, the prevalence of overweight among children is 3.4% (IIPS, 2021). Among 15-19 years, 4.2% of girls and 5.3% of boys were overweight (IIPS, 2021). India will be home to over 27 million children and adolescents (5 to 19 years) living with obesity by 2030 and account for 11% of the global burden (World Obesity Federation, 2022). Interestingly, data from the fifth round of NFHS shows that India is going through a rapid nutrition transition and has reached a phase where prevalence of undernutrition has remained high, but obesity is also increasing rapidly (IIPS, 2021). Not only among children, but the prevalence of obesity has increased among women from 20.6 per cent to 24 per cent while in men from 18.9 per cent to 22.9 per cent (IIPS, 2019-21). As per the fifth round of NFHS, the prevalence of obesity is higher in urban areas among both males (33.2% vs 19.7%) and females (29.8% vs 19.3%), but the change in prevalence over time in rural areas has been higher which implies that obesity is no longer an urban phenomenon (IIPS 2019-21).

There is plenty of evidence that consumption of ultra-processed foods which are HFSS foods is a significant risk factor for obesity (Crimarco et al., 2021; Askari et al., 2020; Elizabeth et al. 2020; Hall et al., 2019; Juul et al., 2015; Canella et al., 2014). For instance, a scientific study using data from 97 countries for the period 2005-2019 found that a one percent increase in the prevalence of obesity was associated with increase in the consumption of soft drinks and carbonated soft drinks by about 2.37 and 1.11 Liter per person/year, respectively after controlling for several demographic and socio-economic confounding factors (Ferretti, 2022). Another study found that an increase in per capita soft drink sales by 1 litre per year was related to an increase of BMI by about 0.009 kg/m2 ($p < 0.1$) in low-middle-high income countries (Goryakin et al., 2017). This can significantly impact health and nutrition outcomes when seen at a population level.

In this respect, policies aimed at summarizing the nutritional value and content of a food product at the point of purchase have emerged as a viable solution to modify people's consumption behaviour (Croker et al., 2020; Song et al., 2021). One of the policy tools to inform consumers about the nutrition content is the Front-of-package labeling (FOPL). FOPL conveys information about detailed nutrient declarations found on the back of food packaging (Kelly and Jewell, 2018).

Due to emerging health concerns, implementation of mandatory warning label FOPL has been observed across countries (Kanter et al., 2018). Potential decrease in consumption of beverages and snacks due to introduction of warning labels has also been observed across several countries. Studies indicate that "high in" front-of-package labels (FOPL) significantly reduce sugar, calorie, and sodium content in purchased food and beverages (Croker et al., 2020). Warning labels on sugary drinks lowered the odds of choosing such beverages by 51% and reduced purchase intentions (An et al., 2021). In Chile, a policy led to a marked decrease in products with high sugar and sodium levels within a year (Reyes et al., 2020).

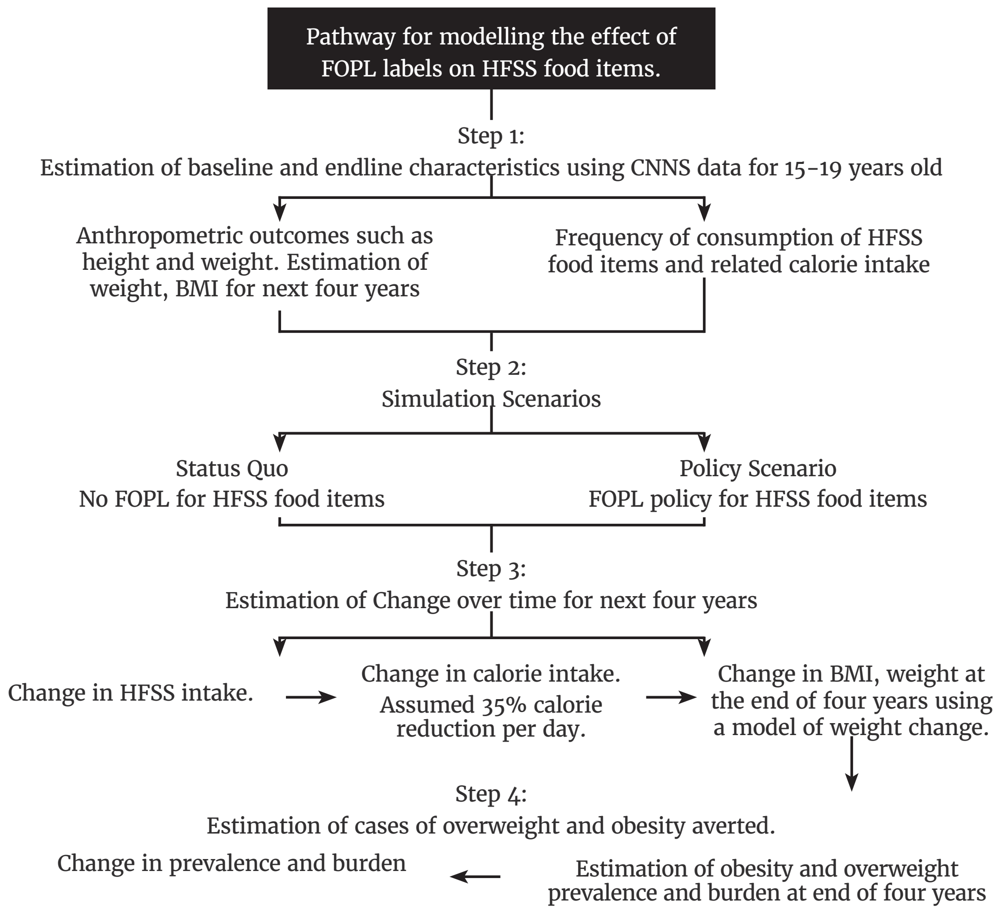
A study based on modelling on the potential impact of mandatory "high in" warning labels in Mexico projected that the initiative may reduce obesity prevalence by 14.7%, or by 1.3 million cases over 5 years (Basto-Abreu, 2020). A simulation study for Canada showed that warning labels led to a 10.5% reduction in the consumption of labeled beverages and a 3.0% reduction in the consumption of labeled snacks. In United States, mandatory FOPL on sugar-sweetened beverages would reduce obesity prevalence by 3.1% in 5 years duration (Grummon, 2019).

A key gap in the existing literature is the limited India-specific evidence on the effectiveness of Front-of-Pack Labeling (FOPL), despite extensive global research demonstrating its potential to reduce consumption of HFSS foods. In this context, adolescents represent a critical group due to their evolving dietary autonomy, susceptibility to marketing, and long-term risk accumulation. Furthermore, as India actively considers FOPL regulations, there is a need to align global evidence with national dietary patterns, consumption behavior, and policy priorities. Given this background, the primary objective of this study is to estimate the impact of introducing front-of-package warning labels on specific food products such as snacks, fried foods, sweets, and beverages on reduction of calorie intake, body mass index (BMI), and consequently on overweight and obesity prevalence among adolescents using a nationally representative dataset for India over a four year period. The secondary objective of this study is to assess the economic implications in terms of potential healthcare costs and cost to the industry.

Data and Methods

Following the methodology adopted by Grummon et al. (2019) to estimate the effect of warning labels on beverages on obesity reduction, we applied a stochastic simulation model to estimate the impact of introducing front-of-package warning labels on snacks and beverages on overweight and obesity reduction among adolescents (15-19 years) in India (Figure 1).

Figure 1: Overall Significance of the Models after Conducting Matching Analysis



Data

The analysis in this study is based on the Comprehensive National Nutrition Survey (2016–18), which contains data on the nutritional status of adolescents (10–19 years) assessed through interviews, anthropometric measures, and biochemical indicators (CNNS, 2019). The prevalence of overweight and obesity for 17440 adolescents (15–19 years) was estimated using the guidelines of WHO and NIH for Asian individuals, which define overweight as a BMI between 23 and 24.9 kg/m2 and obesity as a BMI >25 kg/m2 (Misra, 2015). Although the WHO defines adolescents as 10–19 years old, this simulation exercise focused on the 15–19 age group. This subset was selected because their height is more likely to remain stable. Notably, height was recorded for 16691 individuals, and weight was recorded for 16677 individuals. The final analytical sample size was 16444.

Information on consumption of four food groups which have low nutritional value and could have a detrimental effect on health: fried foods (poori, pakora, vada, samosa, tikki etc.); junk foods (burger, pizza, pasta, instant noodles); sweets (Indian sweets, pastries/cakes, doughnuts) and aerated drinks during the past week was recorded by trained investigators during the survey. Specifically, the adolescents were asked about the number of days the food items were consumed during the past week however, the frequency with which the items were consumed on that day was not collected. The data on the wealth index which is a measure of socioeconomic status based on the possession of a number of common household items was used to create quintiles (poorest, poor, middle, rich, and richest).

Methods

- **Height and weight**

Baseline height and weight provided in CNNS data for adolescents were used to project height and weight for each day till 2022, assuming a growth rate of 3% over the next four years. The assumption was derived by comparing the mean weight of 15–19-years cohort with 20-24 years cohort using NFHS data (IIPS 2019-21).

- **Calorie intake from Snacks and beverages**

Calorie intake for each day was assumed to be 271 calories for fried foods, 217 for junk foods, 436 for sweets and 280 for aerated drinks. The calorie content for each item was obtained from the internet and is presented in Table S1. The calories for the food groups were estimated by taking average calories of items included in that food group. Depending upon the weekly consumption of each individual, calories from consumption of HFSS items for the entire week were calculated. The weekly calorie intake was converted to calorie intake per day by dividing it by 7.

- **Change in Calorie intake from Snacks and beverages**

Based on literature review, we found that introducing warning labels is associated with 11.9-23.3 % and 5.5-11.7% calorie reduction from reduced intake of beverages and snacks, respectively (Basto-abreu et al., 2020). For analyses, we assumed a 35% calorie reduction per day. As sensitivity analysis, two scenarios were created wherein we assumed a 15% and 25% calorie reduction per day. In addition, for the analysis, two samples were created:

1. All the adolescents 15-19 years of age
2. All the adolescents who consumed any of the four food items (snacks, fried foods, aerated drinks, and sweets)

The calculations were conducted for various wealth quintiles and individual states.

- **Change in total energy intake.**

Reducing calorie intake will be accompanied by intake of other health food items which would compensate for the calorie loss. Based on previous literature a compensating factor of 1.84 was used to reflect these changes (Hall, Sacks and Chandramohan; 2011). Here it is worth noting that the compensatory intake assumption reflects the extent to which individuals offset reduced calorie intake from targeted HFSS foods by increasing consumption from other sources. A compensation factor of 1.84 implies that for every unit reduction in calories from HFSS foods, total energy intake falls by a smaller amount due to partial substitution or increased intake elsewhere.

- **Change in body weight**

To estimate a change in body weight a model of weight change dynamics was applied

$$\frac{\partial M(t)}{\partial t} = \frac{[\chi(t) - k(t) * (M(t) - M_o)]}{\tau}$$

Where M is weight, chi (χ) is net change in total energy intake, k is individuals energy expenditure given the resting metabolic rate and physical activity, and τ is the degree of weight change from given calorie intake. The parameters are calculated as follows. The values of parameters used for analysis are presented in table S2.

$$k(t) = \frac{1}{1-d} * (\frac{Y_f + c * Y_l}{1 + c} + P(t)\Big)$$

Where k is individuals energy expenditure and is a function of relative change in mean mass per change in fat mass (c), adaptive thermogenesis parameter (d), resting metabolic rate of fat (Y_f), resting metabolic rate of lean tissue (Y_l) and physical activity level (P).

$$\tau = \frac{n_f + \ p_f + c * n_l + c * p_l}{(1-d) * (1+c)}$$

Where, degree of weight change expected from a given net caloric intake (τ) is a function of Fat synthesis efficiency (n_f), Protein synthesis efficiency (n_l), Energy content per unit change in body fat (p_f), Energy content per unit change in lean tissue (p_l), Relative change in mean mass per change in fat mass (c), and adaptive thermogenesis parameter (d).

- **Calculating change in overweight and obesity prevalence using population fractions.**

To calculate the number of cases of overweight and obesity averted, data from population projection report 2011-2036 was used for 2016 and 2022 for 15–19-year age group (GOI, 2019). We estimated the number of overweight and obese adolescents for 2016 and 2022, and subsequently, the reduction in the number of overweight and obesity cases was calculated.

- **Estimation of cost-of-illness**

Overweight and obesity are risk factors for several chronic diseases. And overweight and obese adolescents have a higher chance of suffering from chronic diseases. Data on prevalence of diabetes, asthma, heart disease and cancer among overweight and obese was obtained from NFHS-5 for 20-24 years age group (IIPS, 2021).

The number of adolescents suffering from chronic diseases was calculated by multiplying the prevalence of chronic diseases (diabetes, asthma, heart disease and cancer) by number of cases of overweight and obesity, which could be averted due to implementation of policy. Economic burden or cost of illness borne by the society was calculated by multiplying the burden associated with chronic diseases with cost of treatment for the ailments obtained from peer-reviewed articles (Chauhan et al., 2016; Prinja et al., 2023; Kansra et al., 2023; Aneeshkumar et al, 2018).

- **Productivity benefits**

To estimate productivity benefits, we first calculated the Years Lived with Disability (YLDs) by multiplying the disease burden by the corresponding disability weights (DW). The disability weights for the chronic diseases (diabetes, asthma, heart disease and cancer) were obtained from Global Burden of Diseases (GBD, 2019). The productivity benefits were then determined by multiplying the YLDs by the per capita income, obtained from the RBI Handbook.

- **Estimation of Cost-benefit Ratio for Warning Labels**

The primary cost associated with adopting front-of-pack labelling (FOPL) was found to be the cost of labelling. This cost was determined using data from a recent report commissioned by the Australian government, which provided cost information per Stock Keeping Unit (SKU) for the year 2014 (PWC, 2014).

The companies that contribute to a major share of the market for HFSS products were identified by a Google search (Table S9). By utilizing the Wholesale Price Index (WPI) data, we estimated the cost of labelling for the year 2022 (Table S10). These figures were presented in Australian dollars, with an exchange rate of 1 Australian dollar equivalent to 0.64 United States dollars. The cost-benefit ratio was then calculated by dividing the overall cost incurred by the industry by total number of cases of overweight and obesity averted.

Results

- **Consumption Patterns**

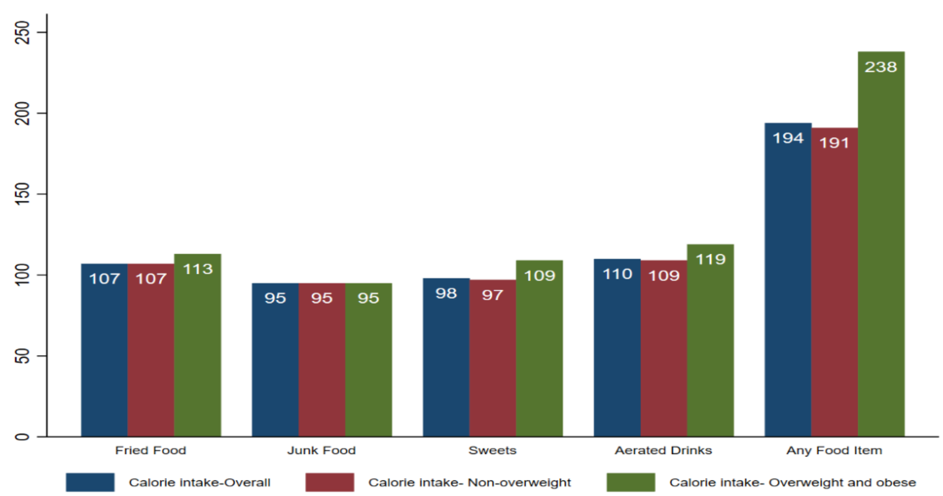
The analysis of consumption patterns of adolescents aged 15-19 for various HFSS food items reveals that 37% consume fried food weekly, 11% consume junk food weekly, 16% indulge in sweets, and 12% drink aerated drinks at least once a week (Table 1, Table S3). The consumption is higher among overweight individuals (Table S4)

Table 1: Consumption of various HFSS food items, CNNS 2016-18

	Fried food		Junk food		Sweets		Aerated Drinks		Consumed Any	
	N	%	N	%	N	%	N	%	N	%
Did not consume	10353	63.0	14581	88.7	13809	84.0	14506	88.2	9,088	55.3
Consumed at least once	6,091	37.0	1,863	11.3	2,635	16.0	1,938	11.8	7,356	44.7
Total	16,444	100	16,444	100	16,444	100	16,444	100	16,444	100

The average daily calorie intake from different food items among adolescents reveals that on average, adolescents consume 194 calories per day from these items (Figure 2). Specifically, the daily calorie intake from fried foods is 107, from junk food is 95, from sweets is 98, and from aerated drinks is 110. Overweight and obese adolescents tend to derive more calories from these items: 113 from fried foods, 109 from sweets, 119 from aerated drinks and 238 from consumption of any of these food items.

Figure 2: Mean Calorie derived from intake of food items for non-overweight and overweight.



- **Impact of introducing warning labels on overweight and obesity reduction**

Introducing the FOPL (Front-of-Pack Labeling) policy is associated with a potential reduction in both overweight (including obesity) and obesity prevalence. After four years, the overall overweight prevalence could decrease from 7.59% to 7.22%, and obesity prevalence could decrease from 3.6% to 3.24%, assuming that introducing FOPL will lead to 35% calorie reduction (Table 2).

A more substantial reduction is observed when considering only the sample of individuals who consume the selected food items affected by the policy. Specifically, overweight (including obesity) could decrease from 7.7% to 3.7% after four years, and obesity could decrease from 4% to 1.9%.

Overall, implementing this policy could potentially avert approximately 470 thousand cases of overweight and obesity, respectively, over a four-year period. In an alternate scenario, where the policy has a broader reach, it could avert approximately 2.7 MN cases of overweight and 1.4 MN cases of obesity over a four-year period.

Assuming a 25% reduction in calorie intake, the prevalence of overweight (including obesity) could decrease from 7.7% to 4.7%, and obesity could decrease from 4% to 2.3% over the next four years. Considering only the sample of overweight and obese, 2.1MN cases of overweight and 1MN cases of obesity can be averted (Table S5). Even if a 15% reduction is assumed, sizeable benefits can be realized (Table S6).

Table 2: Estimated impact of introducing warning labels on overweight and obesity reduction assuming 35% calorie reduction per day, 2018-2022

	Entire Sample			Sample-Consuming specified food items		
	Baseline (2018)	**Endline (2022) Usual scenario**	**Endline (2022) After introducing warning labels**	**Baseline (2018)**	**Endline (2022) Usual scenario**	**Endline (2022) After introducing warning labels**
Weight	47.1	48.5	44.7	47.8	49.2	40.8
BMI	18.9		18.0	19.1		16.3
Overweight (%)	7.59	7.59	7.22	7.7	7.7	3.7
Obese (%)	3.61	3.61	3.24	4.0	4.0	1.9
N	16444	16444	16444	7697.0	7697.0	7697.0
15-19 population	12,68,23,000		12,68,23,000	6,97,52,650		6,97,52,650
Overweight	96,25,866		91,56,621	53,84,905		26,01,774
Obese	45,78,310		41,09,065	27,76,155		13,32,276
Change Overweight		4,69,245			27,83,131	
Change obese			4,69,245			14,43,880

Note: N here is unweighted N

Impact of introducing warning labels on overweight and obesity reduction by wealth quintiles

Consumption of various HFSS food items by wealth quintile reveals that the percentages of individuals consuming fried food, junk food, sweets, and aerated drinks are relatively higher in fourth and fifth quintile groups. Overall, 54.4% in the fifth quintile and 51.9% in fourth quintile consume any of these four items at least once per week (Table 3).

Table 3: Consumption of various food items at least once per week by wealth quintile, CNNS 2016–18

	Fried food	Junk food	Sweets	Aerated Drinks	Consumed any of these four food items	
	%	%	%	%	%	N
Quintile 1	30.6	5.0	9.5	4.3	34.9	2,935
Quintile 2	31.3	6.7	11.5	7.5	36.6	3,143
Quintile 3	36.1	9.2	15.3	10.7	43.6	3,457
Quintile 4	41.9	13.9	19.7	15.7	51.9	3,503
Quintile 5	43.7	20.6	22.8	19.2	54.4	3,406
Total	37.0	11.3	16.0	11.8	44.7	16,444

Introducing the FOPL policy is associated with a potential reduction in both overweight (including obesity) and obesity prevalence across all the quintile groups (Table 4 and S7). The overall prevalence of overweight and obesity could decrease from 15.2% to 7.4% and 8.7% to 4.1% in samples consuming specific food items, respectively.

Table 4: Estimated impact of introducing warning labels on overweight reduction by wealth quintile assuming 15%, 25% and 35% calorie reduction per day

	Overall Sample					Sample-Consuming specified food items				
	N	Baseline	15%	25%	35%	N	Baseline	15%	25%	35%
Quintile 1	2,935	1.4	3.1	3.0	3.0	1,072	0.7	0.7	0.7	0.7
Quintile 2	3,143	4.4	4.9	4.8	4.7	1,205	2.2	1.8	1.6	1.2
Quintile 3	3,457	5.8	6.8	6.2	6.0	1,578	4.7	3.6	2.4	1.8
Quintile 4	3,503	10.5	11.1	10.0	9.4	1,902	10.0	8.1	6.1	5.0
Quintile 5	3,406	14.7	14.6	13.3	12.2	1,940	15.2	11.6	9.3	7.4
Total	16,444	7.6	8.3	7.7	7.2	7,697	7.7	6.1	4.7	3.7

- **State-wise impact of introducing warning labels on overweight and obesity reduction**

Table 5 presents the State wise reduction in prevalence of overweight and obesity due to introduction of FOPL policy. Before the intervention, states like Goa and Kerala exhibited high rates of overweight and obesity, with Goa recording high prevalence in both categories (Overweight: 15.2%, Obesity: 9.2%). Conversely, regions like Jharkhand, Madhya Pradesh, Chhattisgarh, and Telangana had relatively lower rates of overweight and obesity (Overweight: 3.3% to 5.6%, Obesity: 1% to 1.8%).

After the intervention, Himachal Pradesh showed one of the highest prevalence rates of overweight (6.9%), while Goa remained high for both overweight (11.6%) and obesity (6.5%). Jharkhand and Haryana had lower prevalence rates after the intervention (Overweight: 2.3% to 7.4%, Obesity: 1.2% to 2.9%).

The largest reduction will be observed for overweight for states such as Jammu and Kashmir (5), Delhi (4.5), Goa (3.5), Kerala (3.7) and Tamil Nadu (3.5). Similarly, the reduction in obesity will be large for Jammu and Kashmir (1.6) and Delhi (2.7). State-wise distribution of consumption patterns of food items indicates that consumption of these items is higher across Delhi, Goa, Gujarat, Telangana, Tamil Nadu, and Karnataka.

- **Cost-of-illness associated with overweight and obesity**

The prevalence of health conditions among adolescents who are overweight varies, with 0.67% having diabetes and 1.4% having asthma among the overweight, while among the obese, the prevalence increases to 0.97% for diabetes and 3.5% for asthma. The annual projected number of cases among obese adolescents which could be avoided with the intervention is as follows: 14,035 cases of diabetes, 51,229 cases of asthma, 1,040 cases of any heart disease, and 5,689 cases of cancer. The economic burden associated with these conditions is substantial, with a total treatment cost of ₹79 crore for diabetes, ₹132 crore for asthma, ₹125 crore for heart disease, and ₹252 crore for cancer.

In dollar terms, the economic burden for diabetes will be USD 9.6 million and for asthma, it will be USD 16.1 million per year. In comparison, the economic burden due to any heart disease and cancer would be around USD 15.2 million and USD 30.7 million, respectively. The economic burden for diabetes patients for the lifetime treatment could be $441 million, assuming the individual will be on treatment for 46 years.

Diabetes shows the highest reduction in YLDs under a 35% reduction scenario, amounting to 30,597 years saved, followed closely by Cancer (10,102 years), Asthma (28,670 years), and Heart Disease (5,693 years). or a 35% reduction, Diabetes yields the highest productivity benefit at $60M, followed by Asthma at $56M, Cancer at $20M, and Heart Disease at $11M. Sizeable benefits are observed even if 15% and 25% reduction is assumed (Table S9).

Table 5: State-wise reduction in overweight and obesity

	Overweight			Obesity		
	Before	**After**	**Difference**	**Before**	**After**	**Difference**
Jammu and Kashmir	15.3	10.3	-5.0	7.2	5.6	-1.6
Himachal Pradesh	5.3	6.9	1.6	3.5	4.4	0.9
Punjab	14.8	17.0	2.2	6.7	8.8	2.1
Uttarakhand	10.5	9.5	-1.1	3.8	3.5	-0.2
Haryana	8.2	7.4	-0.9	3.5	3.0	-0.5
NCT of Delhi	13.2	8.7	-4.5	6.3	6.4	0.1
Rajasthan	4.0	4.4	0.4	1.6	1.9	0.3
Uttar Pradesh	3.6	4.9	1.3	1.7	1.9	0.2
Bihar	4.8	5.7	0.8	1.7	2.5	0.8
Sikkim	14.3	12.9	-1.4	7.5	6.5	-1.0
Arunachal Pradesh	17.0	15.5	-1.5	6.0	7.3	1.4
Nagaland	11.8	15.0	3.1	2.8	2.7	0.0
Manipur	13.6	12.3	-1.3	5.0	5.1	0.1
Mizoram	14.1	13.0	-1.1	5.5	5.2	-0.3
Tripura	12.2	11.6	-0.6	5.5	6.1	0.6
Meghalaya	5.8	7.0	1.2	1.1	2.6	1.5
Assam	6.6	6.8	0.2	1.7	1.6	-0.1
West Bengal	12.2	9.8	-2.4	6.2	4.3	-1.9
Jharkhand	3.3	2.3	-1.0	1.7	1.2	-0.4
Odisha	10.7	9.3	-1.5	5.6	4.1	-1.5
Chhattisgarh	5.3	5.9	0.6	2.8	3.0	0.1
Madhya Pradesh	5.7	7.1	1.4	1.4	1.0	-0.4
Gujarat	10.3	8.4	-1.9	5.9	4.1	-1.8
Maharashtra	8.7	6.2	-2.5	4.9	3.8	-1.0
Andhra Pradesh	12.7	12.4	-0.3	6.9	5.9	-1.0
Karnataka	11.2	9.4	-1.8	5.8	6.1	0.3
Goa	15.2	11.6	-3.6	9.2	6.5	-2.7
Kerala	16.3	12.6	-3.7	9.0	7.7	-1.3
Tamil Nadu	13.7	10.2	-3.5	7.1	5.0	-2.1
Telangana	11.5	10.0	-1.5	5.8	4.8	-1.0
Total	7.6	7.2	-0.4	3.6	3.2	-0.4

Table 6: Economic cost of chronic conditions related to consumption of HFSS items, assuming 35% reduction

	Among overweight		Among obese		Cost of treatment per year in ₹	Economic burden in $ (overall cost in million)	YLDs =DW*LE	Productivity benefits= Cases *DW*LE* Income per capita (overall cost in million)
	%	**Cases**	**%**	**Cases**				
Diabetes	0.67	9021	0.97	14035	34100	9.6	30597	60
Asthma	1.44	19344	3.55	51229	18737	16.1	28670	56
Any heart disease	0.30	4087	0.07	1040	90000	15.2	5693	11
Cancer	0.14	1923	0.39	5689	331177	30.7	10102	20

Note: In $ assuming exchange rate of ₹82/$, Disability weight assumed to be 0.049 for Diabetes, 0.015 for Asthama, 0.041 for Any heart disease and 0.049 for Cancer. Income per capita assumed to be 161424 and Life expectancy assumed to be 27 years. Cases computed as percentage of additional number of overweight cases which can be averted because of the intervention.

- **Cost to the industry**

A total of 43 companies that contribute to a major share of the market for the HFSS products were identified (Table S10). The cost incurred by each of the 43 companies was assumed to be $2,048 (Table S11). The total cost to the industry for all these companies is USD 2.6 MN for each scenario. The implementation of HFSS is assessed by the number of potential cases of overweight and obesity averted: a 15% calorie reduction is estimated to avert 1,129,993 cases, a 25% reduction averts 2,113,505 cases, and a 35% reduction averts 2,783,131 cases. Cost per case of overweight and obesity averted ranges from less than a dollar to $2.3 across the scenarios.

Table 7: Impact on overweight and obesity; and cost benefit ratio under various scenarios assuming 15%, 25% and 35% calorie reduction per day

	15%	**25%**	**35%**
Cost of designing label per company (in $)	2048	2048	2048
Total companies	43	43	43
Total products	30	30	30
Total cost to industry	2641920	2641920	2641920
Cases of overweight and obesity averted	1129993	2113505	27,83,131
Cost per case of Overweight averted	2.3	1.3	0.9
Cost of illness averted in MN	27.4	55.0	71.7
Cost of YLDs averted in MN	55	114	148
Benefit cost ratio	31	64	83

The potential economic savings from reduced healthcare expenses could be around $27.4M, $55.0M, and $71.7M for 15%, 25%, and 35% scenarios, respectively. Similarly, the cost of YLDs averted ranges from $55M at 15% to $114M at 25% and $148M at 35%. The benefit-cost ratio indicate that with every $1 spent yields $31 in benefits at 15%, $64 at 25%, and $83 at 35% calorie reduction per day.

Discussion

The objective of this study was to assess the potential effects of introducing warning labels on specific food items, such as beverages and snacks, on the prevalence of overweight and obesity in India. An attempt was also made to estimate the healthcare economic costs associated with overweight and obesity. The following are five salient findings from this study. First, more than one-third of adolescents aged 15-19 in India regularly consume unhealthy foods, including fried foods, junk food, sweets, and aerated drinks. This dietary pattern contributes to their daily calorie intake, with an average of 194 calories per day from these items. Overweight and obese adolescents derive 238 calories per day from these food items. While comprehensive data on the consumption of junk foods in India is limited, several small-scale studies have been conducted in the country, shedding some light on the issue. For instance, a mixed-methods study conducted in Mumbai revealed that as many as 50% of children under the age of 6 consume junk food and sugary tea daily (Athavale et al., 2020). Another nationwide study spanning across India found that among children aged 9-14 years, a substantial 93% included packed foods in their diets, 68% consumed sweetened beverages, and 25% indulged in ultra-processed foods more than once a week (Singh et al., 2021). These findings collectively suggest an ongoing shift in dietary habits, indicating that the consumption of junk food may be even more prevalent than what our study has estimated. In fact, the consumption of HFSS food items is higher among those belonging to higher wealth quintiles. In addition, Euromonitor sales show a significant, annualized increase of 15% per annum in sale of ultra-processed food between 2011 and 2021, which also indicates that this current estimate is quite conservative (WHO, 2023).

Second, introducing a Front-of-Pack Labeling (FOPL) policy focused on warnings for HFSS is associated with a potential reduction in both overweight and obesity prevalence among adolescents. Assuming a 35% calorie reduction due to FOPL, the overall overweight prevalence could decrease from 7.59% to 7.22%, and obesity prevalence could decrease from 3.6% to 3.24% over the next four years. A more substantial reduction is observed when considering only the sample of individuals who consume the affected food items. In the overall health impact assessment, with a broader policy reach, a total of 2.7 MN cases of overweight and 1.4MN cases of obesity can be averted.

Our results are in line with similar microsimulation modelling studies for Mexico and the US. For instance, a modelling study on the potential impact of mandatory “high in” warning labels in Mexico predicts a reduction in obesity prevalence by 14.7%, or by 1.3 MN cases over 5 years (Basto-Abreu, 2020). In the United States, mandatory FOPL on sugar-sweetened beverages is estimated to reduce obesity prevalence by 3.1% in 5 years duration (Grummon, 2019). Another study based on agent-based simulations showed how warning labels on sugar-sweet beverages may decrease overweight and obesity prevalence in the range of 1.5 to 4% (Lee et al., 2018). In particular, Chile's Food Labeling and Advertising Law led to a more significant reduction in the purchase of high-sugar beverages compared to standalone policies, including sugar-sweetened beverage taxes in Latin America.

Third, different scenarios of calorie reduction (25% and 15%) due to the FOPL policy show varying degrees of impact on overweight and obesity prevalence. Even with a 15% reduction, substantial benefits in terms of cases of overweight and obesity averted can be realized, emphasizing the importance of calorie reduction as a key driver of the policy's success. Experience of Chile also shows that more than 20% reduction can be expected once the warning labels are introduced. (Taillie et al., 2020). Similarly, a systematic review of warning labels found that nutrient warning was associated with a 16% reduced purchase of fat intake from unhealthy products (Song et al., 2021). However, a couple of reviews on nutrition labels have indicated that the reduction in calorie intake could be marginal but also suggests that the effectiveness of FOPL could depend on design, food types and context (Braesco and Drewnowski, 2023; Taillie et al., 2020).

Fourth, not only do overweight and obese adolescents derive higher calories from junk food items, but they are more likely to have non-communicable diseases. Some of the recent studies for India have found a strong association between a higher prevalence of diabetes and hypertension and with consuming junk food (Vispute et al., 2022; Nagarathna et al., 2021; Baskar et al., 2022). In addition, the economic burden of these conditions is substantial, with considerable healthcare costs for treatment. A couple of recent studies estimated the cost savings associated with obesity to be around USD 1.8 billion and USD 0.69 billion for the USA because of implementing FOPL on snacks and beverages (Basto-Abreu et al., 2020; An et al., 2022). Therefore, addressing the root causes of overweight and obesity through policy interventions like FOPL can have broader economic benefits for India by reducing the financial burden of associated health conditions. Here, it is worth mentioning that the cost estimates presented in this study are underestimated since we have only considered the age group 15-19 for which prevalence of non-communicable diseases is low. In the long term, the benefits could be manyfold.

Fifth, the impact of the FOPL policy varies significantly across states in India. States with initially high rates of overweight and obesity may still experience reductions, while states with lower initial rates may see more substantial improvements.

Delhi, Goa, and other southern states such as Karnataka and Tamil Nadu show higher consumption patterns of unhealthy foods, indicating a need for targeted interventions. Although the prevalence of overweight and obesity is still low among adolescents as compared to some of the other developed countries, There is a need to establish robust monitoring and evaluation mechanism to track the impact of FOPL in future. The involvement of local communities, schools, and other stakeholders can lead to culturally sensitive and effective programs that can combat unhealthy dietary practices among adolescents. While FOPL is a cost-effective measure to curb the prevalence of obesity, the impact could be more pronounced if FoPL is implemented as a part of a more comprehensive policy package that includes HFSS taxation and marketing restrictions to children and adolescents as recommended by WHO (WHO, 2023).

There are a few limitations to this study. Unavailability of data on consumption of various junk and fast-food items and the frequency with which a particular item is consumed are some of the key challenges. There could be reporting bias, which could affect the model's predictions. Therefore, the results should be interpreted with caution. Second, we adopted a novel approach by assuming calorie intake for the food items. However, going forward, there is a need to triangulate these findings using other data sources which provide more comprehensive information on consumption of overall food items, junk and fast-food items and calories derived from them. Longitudinal data will allow for the analysis of long-term and behavioural changes that can capture the changing dynamics of food behaviour. Third, the analysis is restricted to the 15-19 age group, which is essential since the BMI during initial years can affect the growth trajectory. However, more studies are required to unravel the patterns in the prevalence of obesity and consumption of junk foods and beverages across other age groups. Fourth, the simulation model is based on a lot of assumptions which might not cover the real-world conditions which might undermine the reliability of the model. For instance, we assumed 35% reduction in calorie intake but in case of India the nature of products is different. There are products which are ready to eat and require no packaging. Given these aspects, it is possible that we might have overestimated the impact of FOPL implementation. Furthermore, we have focused only on weight change. But it is possible that there could be unaccounted for effects. For instance, reduction in consumption of HFSS can prevent risk of non-communicable disease such as heart diseases and cancer among adolescents who are not overweight which have not been considered in this analysis. Lastly, a key limitation of the study is that industry cost estimates for implementing FOPL are derived from Australian data, which may not be directly transferable to the Indian context due to differences in market structure and regulatory environments. Moreover, there are very few costing studies available, making it difficult to identify comparable and context-specific estimates, which may affect the robustness of the cost-benefit analysis.

In addition, there are many indirect effects for a person with overweight or obese status. They include increased absenteeism, reduced productivity at work, disability, and early retirement (Goettler et al., 2017; Menon et al., 2022; Trogdon et al., 2008). Given the majority of those overweight and obese in India are found in higher education and income status groups, these costs to society and the economy could be quite high.

The implementation of FOPL can impose certain costs, which can be broadly categorized as food industry costs (labelling and packing changes), government costs (administration, education, enforcement, oversight), and legislative costs (mandatory scenario only). A study conducted in Australia on cost of changing labels found that the cost could be marginal, and industry will bear the major cost, but it could be subsequently passed on to consumers (Herrera et al., 2018). However, the benefits will outweigh the cost of changing labels in the long run.

To conclude, India being committed to WHA Global Nutrition target of no increase in childhood overweight and with two years to the targets finish line, has not yet set national obesity prevention targets for children and adolescent. The study shows that the consumption of ultra processed food is high among adolescents. This sends a strong message for setting these targets, highest political commitment to act and data availability for children and adolescents to tackle the problem and its risk factors. In addition to FOPL policy interventions, India needs to focus on a few research priorities like developing nationally representative estimates for physical activity among pre-school, school-aged children and adolescents, undertaking in-depth analyses of social and cultural influences on body weight and lifestyle choices, investigating the impact of fiscal policies (taxation, marketing controls) on overweight and obesity prevention and more robust longitudinal data collection could provide insights into understanding the risk factors and prevention of childhood obesity.

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