Forecasting the prevalence of Overweight/Obesity in India to 2040 using a dynamic Markov Model

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1. Background

Approximately 39% of the global adult population were classified as overweight or obese in 2014, a doubling since 1975 (NCD Risk Factor Collaboration 2016). The rising prevalence in rapidly-developing economies has coincided with these countries' progress through both the demographic and epidemiological transition. In India, the prevalence of overweight/obesity[1] has increased from 9 to 19% among men between 2005 and 2015, and from 11 to 21% between 1998 and 2015 among women; a pace of growth faster than the world average (IIPS 2000; IIPS 2007; IIPS 2017). India also has a high burden of infectious diseases, and its health system is plagued with problems of resource scarcity (Siddiqui and Donato 2016), compounding the public health problems presented by the rapid increase in excess adiposity, such as diabetes.

Uncertainty surrounding the future prevalence of overweight/obesity generates uncertainty around the future prevalence of associated diseases and mortality (Technical Panel 2011; Preston et al 2014). Reliable forecasts by demographic and geographical groups are commonly used to identify subpopulations likely to be in most need of public health attention in the future, which in turn informs long term planning of health responses (Soneji and King 2012; Preston et al 2014). However, most studies estimating future trends in overweight/obesity concentrate on high-income countries, whereas, to our knowledge, there are no studies concentrating on India.

In this paper, we forecast the future prevalence of overweight/obesity in India to 2040 among adults 20-69y in India using nationally representative data from a range of sources. Separate forecasts by sex, age category, and residence will be carried out to 2040. Rather than assume a functional form one may expect future overweight/obesity prevalence to follow, for instance, a linear growth, we use a dynamic Markov model. This method allows one to capture the impact of interventions to counter overweight/obesity on future prevalence. Our findings have implications for the allocation of health care resources by identifying subgroups in which the future burden of overweight/obesity is expected to be highest. Additionally, the model will be useful to policy makers aiming in examining the effect of different interventions affecting future incidence on overall prevalence.

2. Data

2.1 Model Inputs

Overweight/Obesity prevalence by age, sex and residence in 2010 (baseline forecast year)

We estimated overweight/obesity prevalence from two nationally representative rounds of the National Family and Health Survey (NFHS), to calculate the prevalence of overweight/obesity in 2010 among men and women aged 20-49y: NFHS 3 (2005-06; n= 124,385 women and 74,369 men) and NFHS 4 (2015-16; n= 625,000 women and 93,065 men) (IIPS 2007; IIPS 2017). Prevalence of overweight/obesity was based on a Body Mass Index (BMI) greater than 24.99kg/m^2. Survey weights were used to account for the complex survey design, and we estimated the 2010 prevalence based on a linear interpolation between the two surveys.

[1] The term overweight/obesity corresponds to a Body Mass index greater than 24.99kg/m^2 (WHO 2017).

Prevalence of overweight/obesity among those aged 50y and over was taken from the nationally representative Study on global AGEing and adult health (SAGE) data wave 1 (2007-10; n=3300 men and 3500 women).

Population in 2010

We estimated the 2010 population by age group, sex and residence by applying average age and sex structure of the urban and rural populations from NFHS 3 and 4 reports (IIPS 2007; IIPS 2017) to estimates of the 2010 urban and rural population from the World Urbanization Prospects (United Nations 2014).

Population aged 20-21 to enter the simulation every time step

We estimated the new entrants aged 20-21 as a fifth of the forecasted Indian population aged 20-24 from the United World Population Prospects (Desa 2013), multiplied by the overall proportion living in urban and rural areas (United Nations 2014).

2.2 Transition Parameters

Current and future age, sex and residence specific mortality rates

We obtained current and historical mortality rates from the Sample Registration System (SRS) of India, which provides sex- and urban/rural- specific abridged period life tables every year from 1997 to 2013 (ORG 2017; ORG 2016; ORG 2015; ORG 2011; ORG 2010; RGI 1998; RGI 2004), and calculated age-specific mortality rates using standard demographic procedures (Preston et al 2000). We used these rates to forecast future mortality and their confidence ranges to 2040 using the Lee Carter method (Lee and Miller 2000, Lee and Carter 1992).

Age-specific incidence of overweight in 2010

For individuals aged 20-49y, we used the prevalence of overweight/obesity in 2005 and 2015 from the NFHS, along with mortality rates in the same years in a system of differential equations, to estimate overweight/obesity incidence in 2010 at the midpoint of an age interval. This method is explained in detail by Brinks et al (2016). For those aged 50-69y, we calculated the incidence of overweight/obesity using longitudinal data from SAGE waves 0 (2002-04) and 1 (2007-10) for men and women separately. Incident cases were assumed to have occurred halfway between the waves, and the calculated incidence rate was assumed to represent the incidence at the average age at which the 50+ population became overweight/obese. We scaled the calculated incidence to obtain urban- and rural-specific incidence estimates based on the average association between rural and urban incidence estimated from the NFHS surveys.

We smoothed age-specific incidence using splines and took the fitted rates for those aged 25, 35, 45, 55, and 65 years to represent the incidence rate among those aged 20-29, 30-39, 40-49, 50-59 and 60-69, respectively.

Relative risk of mortality for overweight individuals compared to those who are not overweight

We adjusted mortality rates to account for differential mortality between overweight/obese individuals compared to those who are not. We extract relative risks of mortality based on BMI group from Pednekar et al (2008) who report a relative risk of 0.89 for overweight individuals and 1.22 for obese individuals in Mumbai.

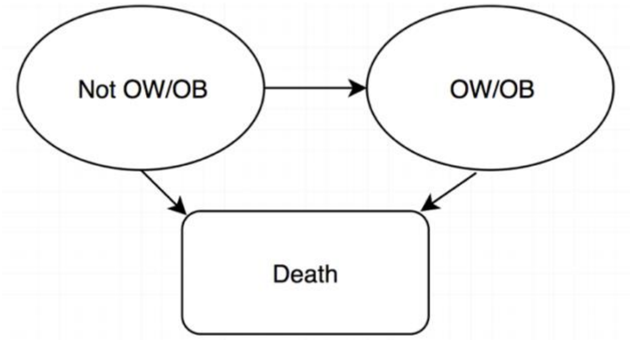
3. ***Methods***

In our dynamic Markov model, individuals move through mutually exclusive health states depending on transition probabilities, and overweight/obesity prevalence is estimated every year between 2010 and 2040. The model has three states: “Not OW/OB”, “OW/OB”, and “Death” (Figure 1). Each year, a new cohort of 20-21-year olds enter the simulation. Transition parameters were estimated for both sexes, in urban and rural areas, and nationally, by five age groups (20-29, 30-39, 40-49, 50-59, 60-69), for each of the 31 forecast years.

We made a number of simplifying assumptions in our model. Firstly, we assumed the proportion of the 'OW/OB' category who are obese remains constant over time. Secondly, we assumed that once an individual has transitioned to the 'OW/OB' state, they are unable to transition back. Thirdly, we assumed that new entrants aged 20-21y have the same prevalence of overweight/obesity as in the baseline year. Finally, we assumed that the age-specific incidence of overweight/obesity remains constant over the forecast period.

We performed 5000 Monte Carlo simulations, selecting a random vector of parameter values drawn from their uncertainty range. We report the median estimate of the simulations as the final point estimate, and the range of estimates provides an uncertainty bound. We conducted the analyses using the R statistical software package.

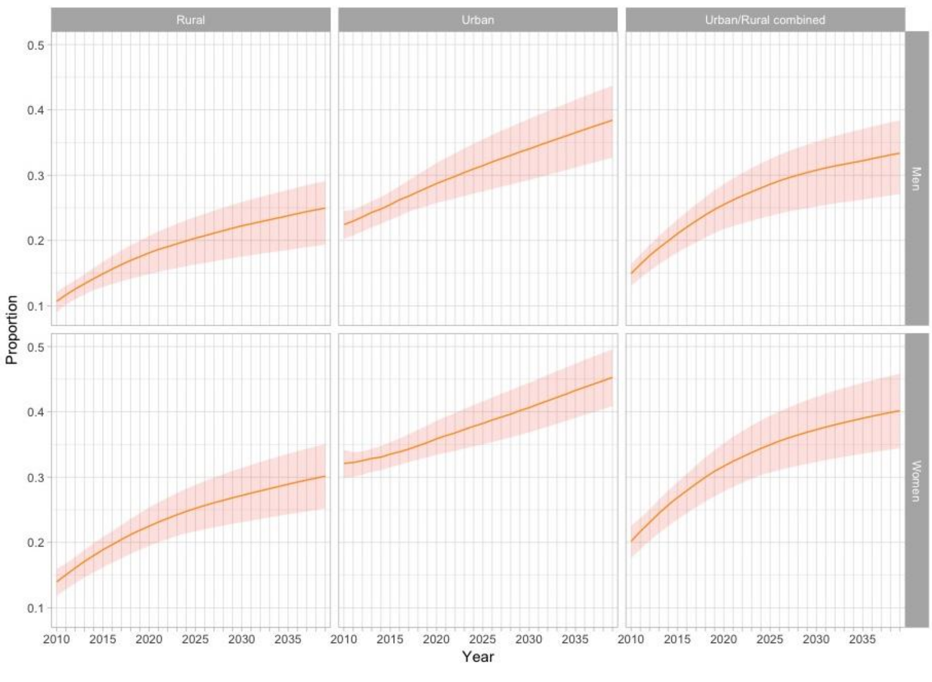
Figure 1. Markov model to predict future Overweight/Obesity prevalence



4. ***Results***

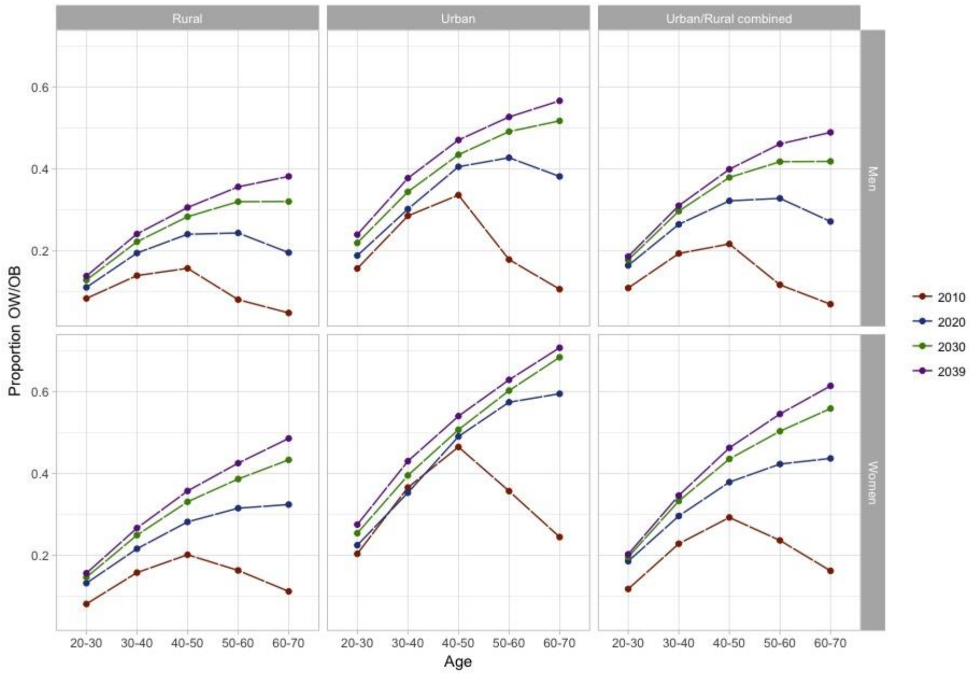
Our model predicts that overweight/obesity prevalence of will increase to 2040 in all Indian subpopulations (Figure 2). Nationally, the prevalence among women is expected to increase from 20% in 2010 to 40% by 2040, and from 15% to 33% by 2040 among men. We expect a continuation of higher prevalence in urban areas compared to rural areas, however we predict a faster increase in prevalence among rural compared to urban residents. Specifically, our model predicts that overweight/obesity prevalence will increase from 33% to 45% among urban women and 23% to 38% among urban men between 2010 and 2040. In rural areas, we expect an increase from 14% to 30% among women and from 11% to 25% among men.

Figure 2. Forecasted prevalence of Overweight/Obesity to 2040



From age-specific forecasts, we expect overweight/obesity prevalence to increase with age, with the highest prevalence in 2040 among the 60-69-year-old age group among both men and women, irrespective of residence (Figure 3). This represents the age group with the largest expected increase in prevalence between 2010 and 2040, where nationally, the model predicts the prevalence to increase from 19% to 49% among men and 20% to 59% among women aged 60-69. The model also predicts that the youngest age group in our model (20-29 years) will experience the smallest increase in prevalence, arguably due to our assumption of a constant prevalence among new entrants into the model.

Figure 3. Forecasted prevalence of Overweight/Obesity to 2040 – age specific estimates



5. Conclusion

This is one of the first studies to predict future overweight/obesity in India using publicly available data from a range of sources. Preliminary analyses suggest that overweight/obesity will grow among all Indian adults, particularly among the elderly population, women and urban residents. The 60-69y age group is expected to experience the largest increase over the forecast period. At older ages, the prevalence of underweight typically increases due to frailty or morbidity. Our finding of the largest increase in prevalence among older ages could reflect a real trend, whereas frailty may be more common in ages beyond age 69. This finding however may also be an overestimation due to our zero-remission assumption, which may be more unrealistic at older ages. Overall, the increasing prevalence of overweight/obesity will have serious implications for future trends in overweight/obesity related diseases, including diabetes, in addition to the allocation of scarce health resources.

Our assumptions that the cohort entering the model each year has a prevalence equal to their age group in 2010, and that the age-specific incidence of overweight/obesity remains constant over the forecast period are likely to make our results relatively conservative. Conversely, we may overestimate our results due to the assumption that that the proportion of obese individuals making up the 'OW/OB' category remains constant over time if the proportion who are obese, in reality, increases. This is because the mortality of the 'OW/OB' group would increase at a faster rate than assumed in the model.

6. Additional work ahead of the conference

Ahead of the conference, we will perform sensitivity analysis in which we will assume a 0.5% and a 1.0% annual increase in OW/OB incidence over the forecast period. Additionally, we will present preliminary results of an additional study using our OW/OB forecasts to predict future Diabetes prevalence in India.

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