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MODELING THE LONG TERM DYNAMICS OF OBESITY AS A SOCIETAL EPIDEMIC[1]

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ABSTRACT

Obesity has become a serious problem affecting people of all ages, racial and ethnic backgrounds, and socioeconomic status, especially in the last decades. The rapid growth in obesity represents a major public concern because of the negative health consequences of obesity for individuals and society and the associated health expenses. The obesity problem is largely due to the increase in the number of sedentary jobs, relatively high prices of healthy food, and the increase in the accessibility of junk food. We constructed a population-level system dynamics model and initialized/calibrated it using 1970's obesity data of US society. For structural validation, we carried out extreme condition and sensitivity tests that yielded positive results. For behavioral validation, we showed that the model output matches well the real obesity data of US society between 1970 and 2010. We simulated the model for 40 more years after 2010 and observed that the prevalence pattern of obesity continues to increase in the near future as well. Finally, we tried three different scenarios with three different policy interventions to alleviate the obesity problem in the future. We show that a compound scenario that includes all three interventions may stop and revert the obesity prevalence.

Keywords: health modeling; obesity epidemic modeling; obesity factors; obesity in US; anti-obesity policy; population models.

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1. INTRODUCTION

Obesity is defined as a disease resulted from the imbalance between energy intake and expenditure. This imbalance is caused by a variety of factors such as genetic, environmental, psychological, and socioeconomic (Madahian, 2012). In the last few decades, obesity has become a worldwide epidemic problem and people from all ages, racial and ethnic backgrounds, and socioeconomic status are affected by it. At a macro level, the problem is largely due to the increase in urbanization and technological development (Cutler et al., 2003). On the other hand, there are both genetic and social influences of adults on the child obesity dynamics that in turn affects the adult obesity level of future. Such real life feedback factors resulted in 22% and 13% increase in the adult and child obesity levels of US in the last 40 years, respectively (Ogden and Carroll, 2010; Fryar, Carroll and Ogden, 2014).

Even though the individual causes of obesity are recognized well, their effects on the dynamics of the rapid increase of the obesity rate are not well understood. This may be the reason why obesity level still has an increasing rate despite the variety of interventions. Considering this need, our study and model takes into account the interactions of the real life factors such as genetic, socio-economic, governmental, psychological and biological. We build a population-level model, analyze the obesity dynamics as a societal epidemic and discuss some policy interventions to fight it.

2. OVERVIEW OF THE MODEL

The target population is chosen from urbanized regions of US. Using these US data, we construct a hypothetical region with a stable 1,000,000 population size. It is assumed that there is no significant governmental concern about obesity in 1970-2000. At first, the model has been initialized using the relevant initial parameters of 1970 to confirm the obesity prevalence from 1970 to 2000. In 2000, the government intervention effects start operating. We assumed that the government can have an impact on the healthy food prices, junk food supply and junk food advertisement via taxes and other regulations.

In our conceptual model, there are four loops constructing the dynamic flows. A simplified casual loop diagram is presented in Figure 2.1.

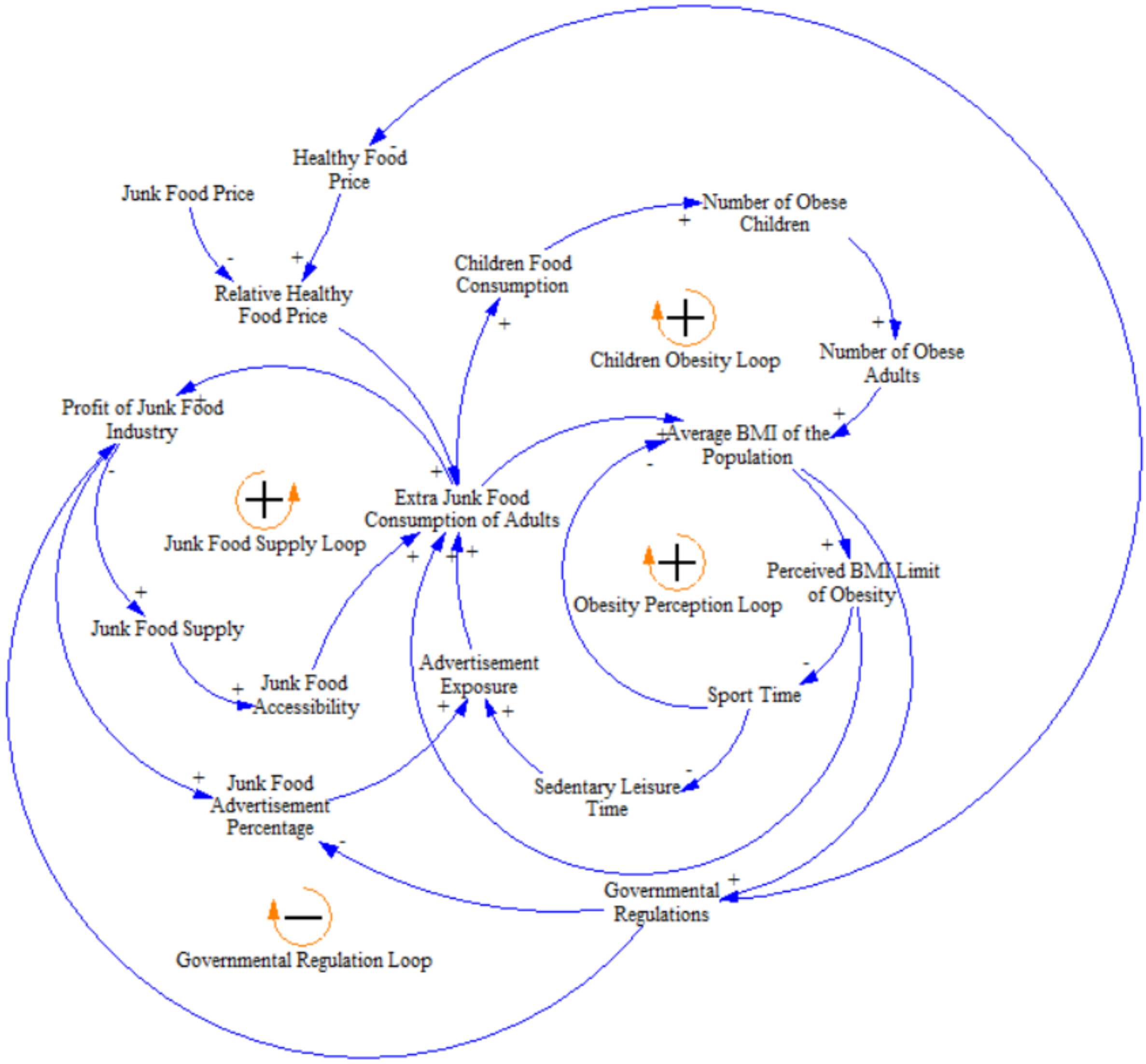

Figure 2.1: Simplified causal loop diagram

The main concern of above loops is the number of obese people in different age groups of the society. Due to this concern, the model is constructed around 10 population stocks created under three age categories, young children aging from 2 to 5, children aging from 6 to 19, and adults aging from 20 to 60, and different obesity categories in each age group, ranging from normal weighted to severely obese. A simplified stock-flow diagram is shown in Figure 2.2.

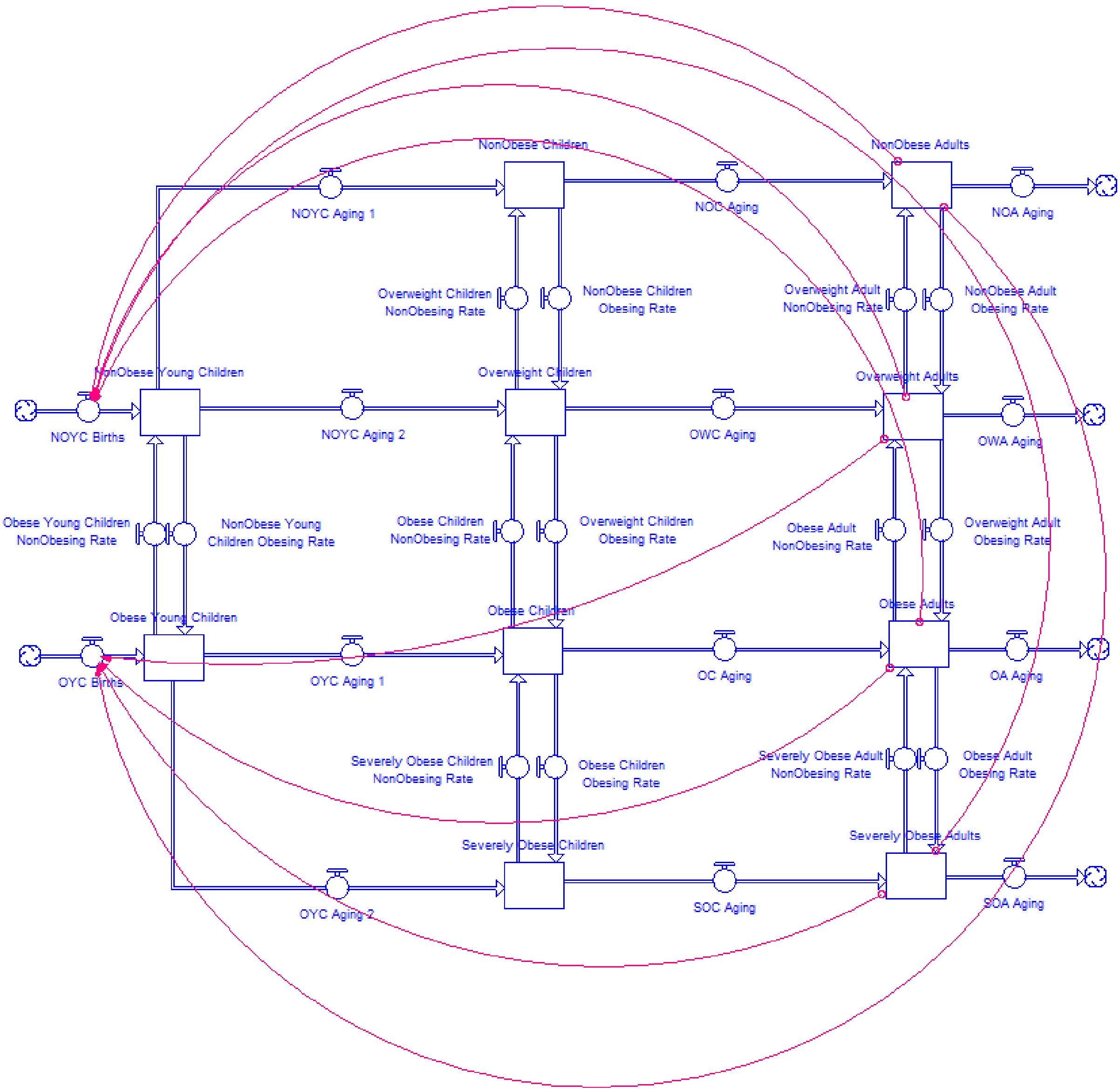

Figure 2.2: The simplified stock-flow structure

3. MODEL BEHAVIOR

The model is simulated by using STELLA 10.0.4 software. The full time horizon of the model is 80 years, which represents real time between 1970 and 2050. The base run of the model depicts the dynamics of sub-population ratios of four different weight groups of adults (see Figure 3.1). In Figure 3.2, the total obese ratios for the three age groups are plotted.

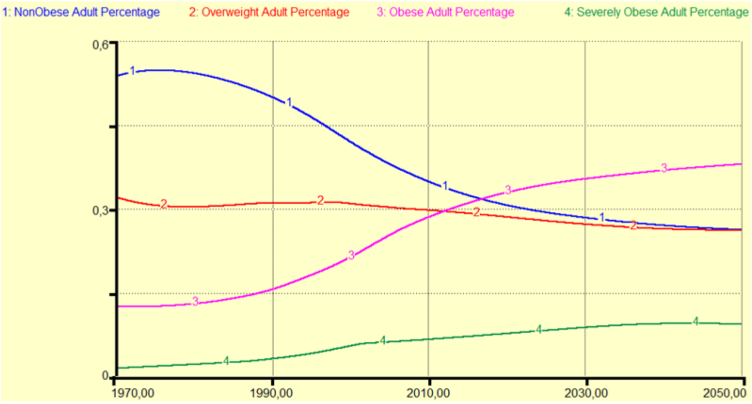

Figure 3.1: Behavior of the ratios of the four adult weight groups (Base Run)

In Figure 3.1, there is a significant decrease in the non-obese adult percentage especially between the years 1990 and 2010. The overweight adult percentage stays almost the same with a minor fluctuation from the beginning until the end of the base run simulation. However, obese and severely obese adult percentages show a significant increase compared to their initial values. The share of the extreme obese in total population sextuples itself at the end of 80 year simulation. As the BMI values of the severely obese are quite high, this also has associated health problems, societal problems, and costs. It is obviously important to prevent such harmful trends. The governmental intervention loops that are mentioned in Section 2 are active after the year 2000, which reflect on the dynamics of the percentages after a delay. The impact of the governmental interventions can be observed in the dynamics of the ratios after the first half of the simulation. As these interventions act against the feedback loops that increase obesity over time, the increase dampens out.

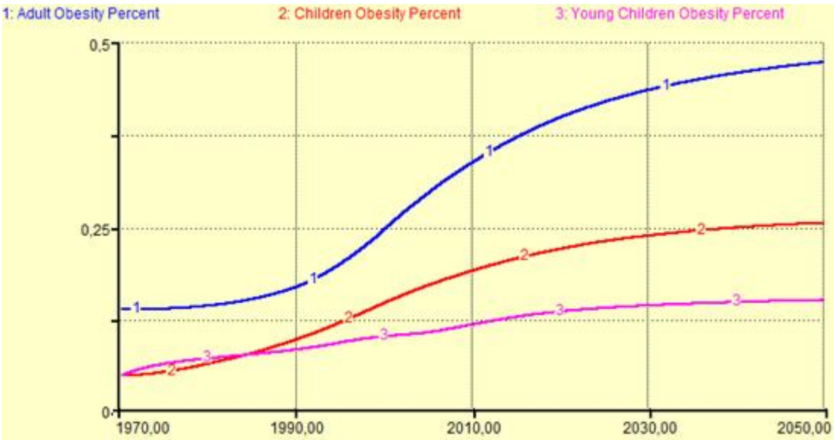

Figure 3.2: Total obese ratios in population for the three age groups (Base Run)

Starting with 14%, 5% and 5% obesity levels in year 1970, each age category of the model reaches 47%, 26% and 15% in year 2050, after following an S-shaped behavior. The reason for higher increase in years between 1990 and 2010 is the power of the positive feedback loops described in Section 2. The explanation for the tapering of the rate of increase around year 2000 is the damping effect of the governmental intervention loops.

4. MODEL VALIDATION

In order to validate the model, structural and behavioral validity tests are applied. As structural validity test, extreme condition tests and sensitivity analysis are conducted. Additionally, to analyze the behavior validity, behavior of the model for the time interval of 1970 – 2010 is compared to the real data.

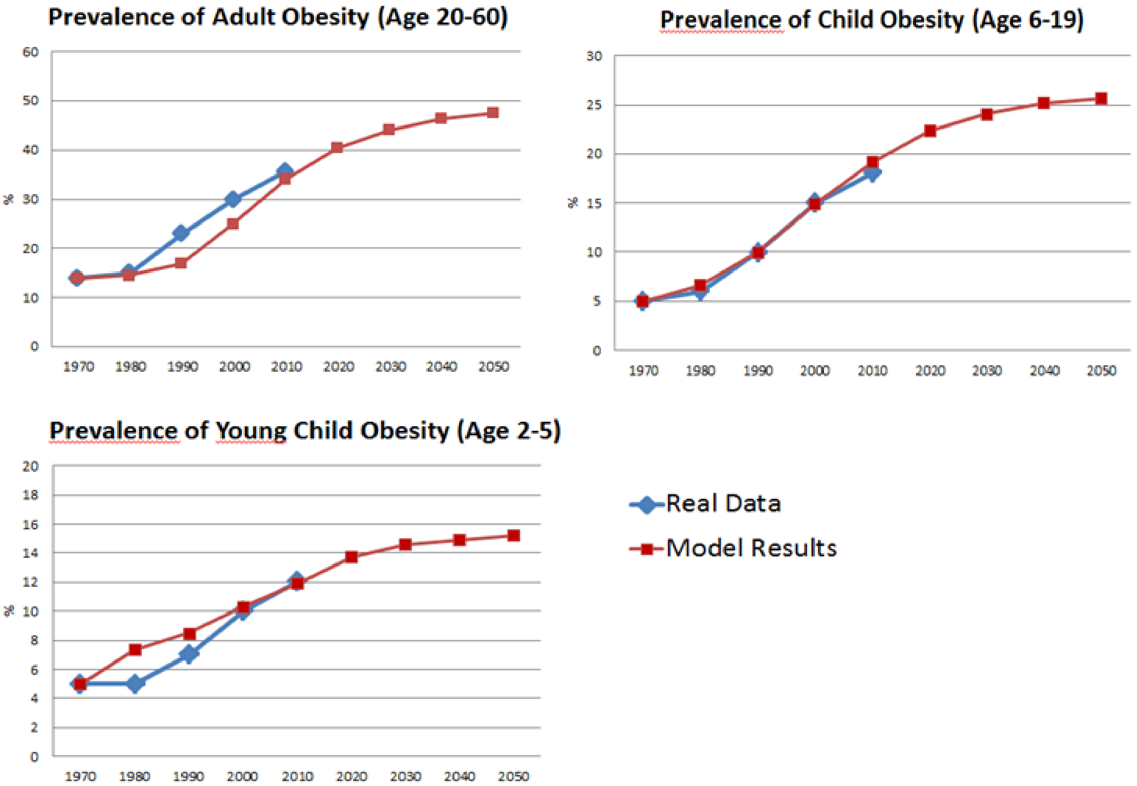

Figure 4.1: Prevalence of obesity within different age groups
[data is obtained from Ogden & Carroll (2010) and Fryar, Carroll & Ogden (2014)]

In Figure 4.1, we present real US data and model generated output in a comparative way for behavioral validation. The simulation results for the time interval of 1970 – 2050 are given, where the future predictions generated by the model can also be seen.

5. SCENARIO ANALYSIS

In the base model, government intervention loop starts from year 2000 and becomes more intense as the obesity ratios increase. However, the base run of our model reveals that the current moderate intervention by the government is not strong enough to prevent almost half of the population becoming obese in year 2050. Therefore, we have tested stronger governmental interventions for scenario analysis. First, we assume a more responsive intervention by the government in reducing taxes on healthy food. Secondly, we assume a more responsive intervention in increasing taxes on the junk food supply. Thirdly, we assume a more responsive intervention by the government in limiting the advertisement of junk food. However, the most effective one was to have a combination of all the three scenarios together. As a result, adult obesity ratio goes to around 22% (see Figure 5.1).

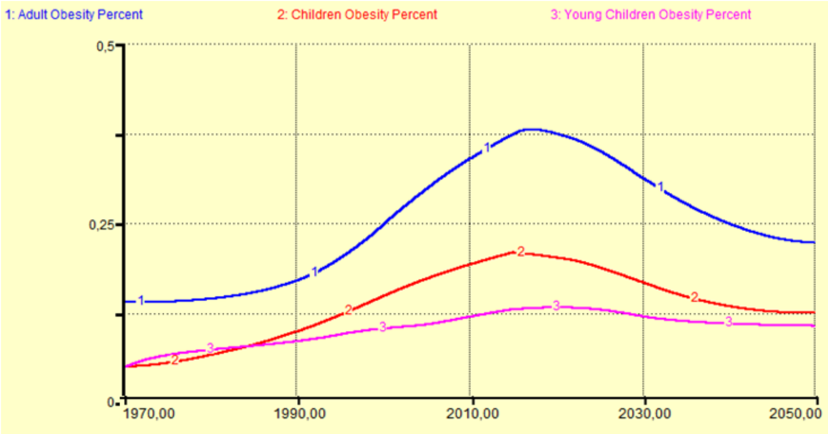

Figure 5.1: Results
(Three strong policy interventions applied together)

6. CONCLUSION

We constructed a population-level system dynamics model of obesity dynamics. The model is initialized and calibrated using 1970's obesity data of US society. Using these US data, we construct a hypothetical region with a stable 1,000,000 population size. The obesity problem is hypothesized to be influenced primarily by the number of sedentary jobs, relatively high prices of healthy food, and the increase in the accessibility of junk food. There are three major reinforcing loops involving these obesity factors that play critical roles in obesity prevalence. The model also has a government intervention loop, an anti-obesity control loop that is activated after year 2000. There are three age groups and four weight (BMI) categories in the model. For structural validation, we carried out extreme condition tests and sensitivity tests. For behavioral validation, we showed that the model output matches well the real obesity data of US society between 1970 and 2010. We simulated the model for 40 more years after 2010 and observed that the prevalence pattern of obesity exists in the future as well. This means that the current government intervention loop is not strong enough to overcome the obesity reinforcing loops. In scenario analysis, alternative, stronger policy interventions are tested. As a further research, we will continue to analyze different scenarios and intervention policies, including their realism. There is also a potential value in turning the model into an interactive policy game and make it available for experimentation by policy makers and other stakeholders.

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