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## Original Research

# Obesity trend in the United States and economic intervention options to change it: A simulation study linking ecological epidemiology and system dynamics modeling



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## ABSTRACT

**Objectives:** To study the country-level dynamics and influences between population weight status and socio-economic distribution (employment status and family income) in the US and to project the potential impacts of socio-economic-based intervention options on obesity prevalence.

**Study design:** Ecological study and simulation.

**Methods:** Using the longitudinal data from the 2001–2011 Medical Expenditure Panel Survey (N = 88,453 adults), we built and calibrated a system dynamics model (SDM) capturing the feedback loops between body weight status and socio-economic status distribution and simulated the effects of employment- and income-based intervention options.

**Results:** The SDM-based simulation projected rising overweight/obesity prevalence in the US in the future. Improving people's income from lower to middle-income group would help control the rising prevalence, while only creating jobs for the unemployed did not show such effect.

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**Conclusions:** Improving people from low- to middle-income levels may be effective, instead of solely improving reemployment rate, in curbing the rising obesity trend in the US adult population. This study indicates the value of the SDM as a virtual laboratory to evaluate complex distributive phenomena of the interplay between population health and economy.

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## Introduction

The relationship between the economy and obesity is complex. The prevalence of obesity in developed countries has risen in parallel with increased economic development, such as gross domestic product (GDP).<sup>1,2</sup> International comparison shows the same correlation between GDP and population body mass index (BMI).<sup>3</sup> In addition, worse economic conditions, such as the higher unemployment rate, are associated with lower prevalence of obesity.<sup>4</sup> These imply that obesity prevalence and prosperous economy are positively associated. On the other hand, nevertheless, economic downturns could also result in higher risks of obesity, as evidenced, for example, by the climbing share prices of fast-food companies during the recession in 2008.<sup>5</sup> A Canadian study shows that the prevalence of severe obesity increased with higher unemployment rates.<sup>6</sup> Furthermore, in the US, risk for obesity appears to be higher in the states with lower legal minimum wage.<sup>7</sup> It is, therefore, unclear whether and how prevalence of obesity could be effectively decreased by improving the macro-level socio-economic conditions.

Furthermore, one of the challenges in deciphering this question lies in the potential reciprocal nature of obesity and economics at the individual level. People living with lower income, poverty, or unemployment are more likely to live in areas with higher density of food outlets selling energy-dense but nutrition-poor foods;<sup>10,11</sup> a constrained budget may lead to a higher sensitivity to food price<sup>12,13</sup> and lower physical activity.<sup>14</sup> This, in turn, reinforces the effect that low socio-economic status (SES) has on obesity.<sup>8,9</sup> However, obesity may subsequently influence individual employment, financial standing, and medical costs, explained in part by the elevated chance of absenteeism, medical expenses due to obesity-related disorders, or employment discrimination.<sup>15–18</sup> This complex two-way interaction between weight and economic status can likely give rise to unexpected, emergent macro-economic outcomes.<sup>15</sup> To understand the impact of macro-level economic improvement on obesity trends, there is a need to account for the potential bidirectional relationships between economics and obesity.

Evidence from previous studies is based on static data with limited information on the intertwined dynamics between obesity and SES distributions over time.<sup>1</sup> Even with some studies using time series across countries,<sup>1,2</sup> the underlying transitions across SES and weight status remained unknown. Systems science modeling has the capability of capturing the dynamic relationships between economic factors, such as

income and unemployment, and obesity. In so doing, we can test potential economic intervention strategies *in silico* and explore their impacts on obesity.<sup>19–21</sup> Even though systems modeling has been applied to address different issues related to the obesity epidemics,<sup>22</sup> there has been no study using the approach to test the potential of macro-level economic interventions on obesity prevention and control.

The present study aimed to apply the system dynamics model (SDM) approach to (a) understand the dynamics and interplay between obesity and SES distributions at the population-level based on the empirical US national data from the Medical Expenditure Panel Survey (MEPS, 2001–2011), (b) explore how the future weight status distribution in the US would be affected by changing the population's SES distributions through employment- or income-based strategy, and (c) provide conceptual and methodological insights in future obesity research using systems models.

## Methods

### Study design

This is a simulation experiment that integrates an ecological study of distributional changes in population's weight and SES (employment status and family income level) over time and a system dynamics simulation to explore impact of changing the population's SES on obesity trends. [Fig. 1](#) demonstrates the conceptual framework, which was designed to capture the reciprocal interactions between weight status and SES at the population level. We modeled the distributions of weight and SES ('stock', i.e. percent in each weight and SES state) and the transitions ('flow') between these states over time. There are three subsystems in the model, namely population-level transitions of weight status, employment status, and family income levels ([Supplemental Fig. S1](#)).

### Target population and data set

Using the 2001–2011 MEPS longitudinal panel data (from panel 6 to panel 15), we estimated the annual transition rates and examined the relationships between the stocks and flows among the three subsystems. The MEPS is an ongoing nationally representative survey of families and individuals in the US, based on a multistage, stratified, and clustered sampling design. A new panel starts every year, which is followed up for two years. There are five rounds of household interviews during the two years, collecting individual

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