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Publication Date
2020-12-01

DOI
10.1016/j.pmedr.2020.101257

Peer reviewed

Preventive Medicine Reports 20 (2020) 101257

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Simulating the impact of health behavior interventions in the SNAP-Ed population

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A R T I C L E I N F O

Keywords:
Simulation
Physical activity
Weight loss
Chronic diseases
SNAP
Low-income

A B S T R A C T

In 2020, the US invested $441 million dollars in the Supplement Nutrition Assistance Program Education (SNAP-Ed), a program that encourages a healthy diet and promotes physical activity. Understanding the long-term health outcomes associated with promoting physical activity versus weight loss among the low-income population it serves could help guide the direction of future program efforts. We used the Future Americans Model (FAM), a microsimulation, to model over 10 years the impacts of changes in Body Mass Index (BMI) and exercise interventions on future health outcomes among adults aged 25 and older that could potentially accrue from SNAP-Ed interventions. We applied data from the Panel Study of Income Dynamics and data collected from 2,323 SNAP-Ed eligible adults in Los Angeles County in 2019.

By 2029 interventions that increased vigorous physical activity by 20% would reduce the prevalence of difficulties with activities of daily living (ADL) by 4.72%. Interventions that would reduce BMI by 0.5 could decrease the prevalence of diabetes and heart disease by 5.34% and 0.66%, respectively. Helping people maintain weight loss, even as little as 3–4 lb, results in significant future health benefits. Given continued increases in weight at the population level, weight maintenance should be a focus of future interventions.

1. Introduction

The United States Department of Agriculture allocates funding through the Supplemental Nutrition Assistance Program Education (SNAP-Ed) (USDA, 2020) to localities to implement strategies that address diet and physical activity behaviors among low-income individual and families eligible for SNAP (food stamps). These two modifiable health behaviors are important risk factors for chronic diseases (USDHHS, 2010). Given that the funding represents a significant investment, approximately $441 million in 2020 (USDA, 2019), understanding the impact of this education program will be useful to assess future investments. Focusing on the degree to which changing diet and physical activity can influence long-term health outcomes may help policy makers assess which interventions might produce the highest return on investment.

SNAP-Ed includes many interventions, such as dietary education and nutrition classes, physical activity promotion, and policy, systems, and environmental (PSE) change interventions. Over a three-year period, 24 community-based organizations in Los Angeles County implemented nutrition education and physical activity promotion in SNAP-Ed eligible census tracts; tracts in which greater than 50% of the populations falls below 185% of the Federal Poverty Level. During this effort, nearly twenty-thousand SNAP-Ed nutrition and physical activity promotion classes and community events were estimated to reach two million Los Angeles County residents (LACDPH, 2020). Over 200 SNAP-Ed policy, systems, and environmental (PSE) change strategies were employed to improve access and availability of heathier foods and opportunities for physical activity and were estimated to reach 1.2 million in the county (Babey et al., 2018). The most common PSE interventions included edible gardens, healthy retail, free food distribution, and healthy food procurement. Given the wide variety of interventions and organizations involved in implementing them with their own unique methods, it was not possible to evaluate which of these interventions were the most effective. However, many interventions directly target physical activity and diet, which are the basis for weight management.

There is some evidence that SNAP-Ed has had some success in

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https://doi.org/10.1016/j.pmedr.2020.101257
Received 2 July 2020; Received in revised form 19 October 2020; Accepted 15 November 2020
Available online 9 December 2020

promoting more fruit and vegetable consumption (Molitor et al., 2015, 2020; Williams et al., 2015). Recent work has shown that SNAP-Ed interventions can increase participants physical activity levels as well (Molitor et al., 2015; Koszewski et al., 2011). Nevertheless, the relative benefit of changes in diet quality and physical activity, as well as the magnitude of the change and the necessary reach to have a population-level reduction in the prevalence of chronic diseases have not been specified. Furthermore, understanding the benefit that could be achieved among a local population by accounting for its unique characteristics should be even more useful for local planning.

A serial cross sectional pre-post survey of the target population provided some evidence that the Los Angeles County Department of Public Health (LACDPH)-sponsored SNAP-Ed interventions were associated with increases in self-reported fruit and vegetable consumption and physical activity, but there was no evidence that the interventions were associated with decreases in body mass index (Cohen et al., 2019). Nevertheless, increases in physical activity and declines in body mass index among those who are overweight or obese do result in health benefits (Ratner et al., 2005; Wing et al., 2004), so we modeled changes in these outcomes with respect to their impact on chronic health conditions that affect health care costs.

Microsimulations allow estimation of future outcomes by simulating individual event histories associated with key components of a disease process. These simulated life histories can be aggregated to estimate population-level effects of public health interventions on disease outcomes and the comparative effectiveness of interventions (Rutter et al., 2011). When key parameters are specified, such as changes in BMI or exercise, it may be easier to determine which interventions will be most feasible as well as effective. Given the SNAP-Ed eligible population of nearly 3.6 million in LA County (Cantor et al., 2020) and the associated large investment of resources, LACDPH requested an analysis using a dynamic microsimulation to understand the impact of changes in BMI and physical activity on long-term health outcomes using data gathered from the SNAP-Ed eligible population in Los Angeles County. The overall goal was to obtain an appreciation of where investment of future resources may have the largest impact on population health.

2. Methods

We used the Future Americans Model (FAM), a microsimulation, to model the impacts of changes in Body Mass Index (BMI) and exercise interventions on future health outcomes among adults aged 25 and older (Goldman et al., 2016) that could potentially accrue from interventions implemented by LACDPH. We modeled future health outcomes using a 10-year time horizon, a span of time in which a variety of health outcomes could be realized as well as being a time frame in which current planning and investments could be made. Microsimulation models individual life trajectories through calculations of transition probabilities across various health and economic states in two-year increments (e.g. incidence of diabetes). These health and economic transition equations are based on individual socioeconomic (e.g. race, income), behavior (e.g. smoking, exercise), and health (e.g. BMI, past health conditions) characteristics. These transition equations are estimated using the Panel Study of Income Dynamics (PSID), a nationally representative, longitudinal survey (McGonagle et al., 2012; Smeeding, 2018; Stafford and Chiteji, 2012; Panel Study of Income Dynamics, 2015). The PSID includes outcome variables related to physical activity and BMI, but does not include any assessment of diet or fruit and vegetable consumption, precluding the ability to model the impact of specific dietary changes. We applied the national rates of disease trajectories adjusting for local demographic characteristics of the LA County SNAP-Ed eligible population.

The second component of the simulation adds new 25- and 26-year-old individuals as the existing cohort ages. These replenishment cohorts are synthetically generated to match observed correlations between variables, but with trends predicted on population demographics from the census and behavioral changes based on the National Health Interview (National Health Interview Survey, 2020) and the National Health and Nutrition Examination Survey (NHANES) (CDC, 2017).

To account for uncertainty arising from the fact that the transition model parameters are estimated, we employed a nonparametric bootstrap approach. We resampled a subset of individuals from PSID and generated standard deviations by bootstrapping 25 sets of parameter models, each of which was simulated with 100 Monte Carlo replications (Technical documentation for FAM is available at: https://healthpolicy.app.box.com/v/FAMTechdoc.).

We applied the local data on physical activity and BMI collected from 2,323 SNAP-Ed eligible adults recruited outside of 15 grocery stores in 2019 across Los Angeles County. The grocery stores were located in SNAP-Ed eligible census tracts ($\geq$50% population $\leq$ 185% Federal Poverty Level). This component was approved by the institution's Human Subjects Protection Committee.

Shoppers who were enrolled in a social benefits program like Medicaid or CalFresh (California's SNAP program), reflecting a low income were invited to answer a brief survey in English or Spanish and were offered a $5.00 gift card for participation. The response rate was 76.5 percent. Data analysis was also completed in 2019. Participant demographics were 30% Male, 70% female, 77% Latinx, 15% African American, 3% white and 5% other. The average age was 43.8 years.

FAM uses two definitions of physical activity from the PSID: moderate and vigorous physical activity. These levels are defined by physical activities that cause a slight to moderate increase (moderate) or large increase (vigorous) in breath or heart rate for at least ten continuous minutes (PSID, 2015). For each level of activity, the respondents are asked how many days per week they spend in each physical activity level. For FAM, these variables are recast as a binary variable that capture whether a respondent participated in no moderate or vigorous physical activity (zero days per week) or any moderate or vigorous physical activity (more than zero days per week).

The Los Angeles County SNAP-Ed eligible participants were asked to report the frequency of engaging in moderate and vigorous physical activity in the past week. The majority of SNAP-Ed eligible respondents responded that they had at least performed moderate physical activity (88.5% in 2019), while 67.8% reported performing vigorous activity. Because there was little room for improvement in moderate activity, and vigorous activity is important for improving fitness (Piercy et al., 2018), we updated the FAM model to account only for changes in vigorous physical activity. The new physical activity variable is defined as equal to 1 if a person participated in any vigorous physical activity for at least ten minutes or more once a week and 0 otherwise. Vigorous activity has a greater impact on health than moderate (Piercy et al., 2018; Gralla et al., 2019), so we would expect that increases in vigorous physical activity would yield more positive changes in health outcomes than increases in moderate activity. This component was approved by the RAND Human Subjects Protection Committee.

2.1. Physical activity interventions

Theoretical interventions that could successfully promote vigorous physical activity were modeled in FAM by changing the probability of participation in any vigorous physical activity across the two-year transition cycle. We multiplied the probability of exercising (calculated in the transition module) by the intervention probability. For example, a 5 percent increase in physical activity would be modeled by multiplying the transition probability for physical activity by 1.05. Transition probabilities are individual-specific and depend on the sociodemographic and health characteristics of the individual in the previous period that lead to an individual's rate of any vigorous physical activity. We simulated the impact of intervention of theoretically effective interventions that increased the probability of any vigorous physical activity by 5, 10, and 20 percent.

2.2. Body mass index interventions

For body mass index (BMI) interventions, we started with the initial BMI of the full population in 2015 and then reduced it based on what we might expect a theoretically effective weight intervention to achieve. For example, for a BMI reduction of 0.5, a person with a BMI of 30 kg/m^2 in 2015 was assigned a BMI value of 29.5 kg/m^2. We modeled three interventions targeting BMI to reduce the initial BMI of the SNAP-Ed–eligible population by an average of (1) 0.5 kg/m^2, (2) 1 kg/m^2, and (3) 2 kg/m^2. For a person who is the average weight (173 lb) and height (5 feet 4 in.) from the 2019 SNAP-Ed sample, the resulting BMI is 29.7. A reduction of 0.5 BMI would correspond to a weight of 170.1 (a 2.9-pound weight loss). A reduction of 1 BMI corresponds to a weight of 167.1 (a 5.9-pound weight loss). A reduction of 2 BMI corresponds to a weight of 161.4 (an 11.6-pound weight loss). These are very modest targets considering that the average SNAP-Ed participant is at least 20 lb overweight.

We also modeled two scenarios of weight gain after the initial BMI reduction. The first assumes that an individual first loses weight then slowly regains this weight over the normal BMI transition trajectory. In these scenarios, the average BMI returns to baseline 2019 BMI in 10, 14, and 18 years for the 0.5, 1, and 2 BMI reduction intervention respectively. The second scenario assumes that the individual remains at a stable weight once their BMI has been reduced. The interventions are as follows: 1) 0.5 BMI Unit loss followed by the normal transition function 2) 0.5 BMI Unit loss maintained, 3) 1.0 BMI Unit loss followed by the normal transition function, 4) 1.0 BMI Unit loss maintained, 5) 2.0 BMI Units loss followed by the normal transition function, 6) 2.0 BMI Units loss maintained.

2.3. SNAP-Ed eligible population

As the default, the FAM model produces mean outcomes for the 100 simulations for the entire population. To make the simulation relevant for the Los Angeles County SNAP-Ed population, adjustments were made to the base FAM model. Outcomes were adjusted to present mean results for the local SNAP-eligible population—individuals whose household income was less than 185 percent of the Federal Poverty Level.

Given the SNAP-Ed eligible population and the intervention outlined above, we projected the total population and their average body mass index as well as the percentage expected to be obese in the next ten years. Based on the FAM model, we also projected the number of adults to be diagnosed with various health conditions (diabetes, heart disease) and the number reporting any difficulties with Activities of Daily Living (ADL). (ADLs are routine activities people do by themselves on a daily basis. The six basic ADLs are eating, bathing, getting dressed, toileting, mobility, and continence.)

3. Results

The projection of chronic disease and body mass outcomes at a national level describing the status quo prediction to the exercise interventions are shown in Table 1. We present the outcomes for years 2019 and 2029 with results for both the number and prevalence of cases.

Absent of intervention, at the national level, diabetes among the SNAP-Ed population is projected to increase over 1.6 percentage points; affecting 14.82% of the SNAP-Ed population in 2019 and 16.45% in 2029. Body mass measures are also on an upward trend: the average body mass index among the SNAP-Ed population is projected to increase from 27.76 in 2019 to 27.94 in 2029. For an individual of height 5 feet 9 in., this corresponds to a weight increase of 1.2 lb. Cases of heart disease are projected to decline over the next 10 years (20.26% in 2019 to 19.56% in 2029). The prevalence of difficulties with ADL is also on a downward trend. In 2019, 18.58% of the SNAP-Ed population has difficulties with ADL while only 17.82% have difficulties in 2029.

The reduction in prevalence of cases as applied to Los Angeles

Table 1
Projected national health outcomes under status quo scenario of no interventions to address physical activity or BMI.

	Estimates under no Intervention Scenario (Means & 95% CI)	
	2019	2029
SNAP-Ed Population Size (Millions)	110.10 [109.90, 110.30]	109.00 [108.80, 109.20]
Average BMI (kg/m^2)	27.80 [27.60, 28.00]	27.90 [27.70, 28.10]
Obesity	33.70 [33.60, 33.80]	36.60 [36.50, 36.70]
Diabetes	16.30 [16.20, 16.40]	17.90 [17.90, 18.10]
Heart Disease	22.30 [22.20, 22.50]	21.30 [21.30, 21.50]
Difficulties with ADL	20.50 [20.40, 20.60]	19.40 [19.30, 19.50]
Prevalence of selected conditions (%)		
Obesity	30.60 [30.50, 30.70]	33.60 [33.50, 33.70]
Diabetes	14.80 [14.70, 14.90]	16.50 [16.40, 16.60]
Heart Disease	20.30 [20.20, 20.40]	19.60 [19.50, 19.70]
Difficulties with ADL	18.60 [18.50, 18.70]	17.80 [17.70, 17.90]

Table 2
Impact of increased vigorous exercise and reduced BMI: change in numbers affected in Los Angeles County (%).

% Change Relative to Baseline Trajectory with No Intervention	Change in Average BMI in 10 Years % [95% CI]	Change in Obesity in 10 Years (%) [95% CI]	Change in Diabetes in 10 Years N (%) [95% CI]	Change in Heart Disease in 10 Years N (%) [95% CI]	Change in Difficulties with ADL 10 Years N (%) [95% CI]
Increase vigorous physical activity by 5%	−0.01 {0.07, 0.04]	−785 (−0.06) [−0.47, 0.34]	−1,792 (−0.30) [−0.96, 0.35]	−1,743 (−0.25) [−0.84, 0.34]	−7,676 (−1.21) [−1.83, −0.59]
Increase vigorous physical activity by 10%	−0.02 [−0.08, 0.03]	−1,473 (−0.12) [−0.53, 0.29]	−3,519 (−0.60) [−1.25, 0.06]	−3,561 (−0.51) [−1.10, 0.09]	−14,808 (−2.36) [−3.00, −1.73]
Increase vigorous physical activity by 20%	−0.05 [−0.11, 0.01]	−3,050 (−0.25) [−0.66, 0.16]	−7,093 (−1.21) [−1.86, −0.56]	−6,313 (−0.90) [−1.50, −0.31]	−28,830 (−4.72) [−5.37, −4.06]
Reduce BMI by 0.5; regain weight slowly	−0.63 [−0.68, −0.57]	−34,596 (−2.95) [−3.37, −2.53]	−12,821 (−2.21) [−2.85, −1.58]	−2,277 (−0.32) [−0.92, 0.27]	−4,847 (−0.76) [−1.37, −0.15]
Reduce BMI by 1.0; regain weight slowly	−1.26 [−1.32, −1.21]	−67,169 (−5.90) [−6.30, −5.51]	−24,586 (−4.34) [−4.96, −3.72]	−4,539 (−0.65) [−1.26, −0.04]	−9,045 (−1.43) [−2.03, −0.83]
Reduce BMI by 2.0; regain weight slowly	−2.55 [−2.61, −2.50]	−123,592 (−11.56) [−11.94, −11.18]	−47,520 (−8.80) [−9.38, −8.22]	−8,906 (−1.28) [−1.88, −0.68]	−17,562 (−2.82) [−3.41, −2.22]
Reduce BMI by 0.5 and keep it off	−2.35 [−2.39, −2.31]	−162,966 (−16.06) [−16.32, −15.80]	−29,949 (−5.34) [−5.91, −4.78]	−4,617 (−0.66) [−1.28, −0.04]	−6,882 (−1.08) [−1.71, −0.46]
Reduce BMI by 1.0 and keep it off	−3.51 [−3.56, −3.47]	−195,372 (−20.27) [−20.53, −20.00]	−45,088 (−8.30) [−8.88, −7.72]	−6,670 (−0.96) [−1.56, −0.35]	−12,681 (−2.02) [−2.64, −1.40]
Reduce BMI by 2.0 and keep it off	−5.84 [−5.88, −5.80]	−237,041 (−26.78) [−27.02, −26.53]	−69,329 (−13.54) [−14.13, −12.95]	−11,651 (−1.68) [−2.29, −1.07]	−23,217 (−3.76) [−4.36, −3.16]

County and the percentage change in cases for each intervention relative to baseline in 2029 is shown in Table 2. Increasing the probability of vigorous exercise by 5%, reduces the prevalence of diabetes in the population slightly (0.30% less in 2029) and results in 0.25% fewer cases of heart disease. The portion of the population experiencing difficulties with ADL will be reduced by 1.21% in 2029 while average BMI will remain essentially unchanged with a 0.01% decrease by 2029.

A 20% increase in vigorous physical activity would result in 0.90% fewer cases of heart disease by 2029 and a larger decrease of 1.21% in the prevalence of cases of diabetes by 2029. The average BMI will be reduced 0.05%, or a 0.14-pound reduction for a person 5 feet 9 in. tall. while difficulties with ADL will be reduced by 4.72%.

A weak BMI intervention (0.5 BMI loss) with weight regain will realize a 2.21% reduction of cases of diabetes while an intervention with no weight regain saw a 5.34% reduction in cases. A strong BMI intervention (2.0 BMI loss) with weight gain saw an 8.80% reduction in cases of diabetes, but a reduction of 13.54% cases of there is no weight regain.

BMI interventions where the weight is kept off results in a larger reduction in heart disease than BMI intervention where weight is regained. For a BMI reduction of 0.5 and 2.0 with maintained weight loss, heart disease is reduced by 0.66% and 1.68% respectively. For BMI interventions where weight loss is maintained, average BMI is reduced by 2.35% and 5.84% when BMI is reduced by 0.5 and 2.0 respectively. BMI reductions of 0.5 and 2.0 units correspond respectively to a 4.5- and 11.1-pound weight loss in a person 5 feet 9 in. tall.

Under BMI interventions, whether weight is regained or weight loss maintained, the decrease in difficulties with ADL is less than with exercise interventions. When BMI is reduced by 0.5 and 2.0 and weight loss is maintained, the population living with difficulties with ADL is reduced by 1.08% and 3.76%, respectively, by 2029.

4. Discussion

When applied to the Los Angeles County SNAP-Ed population, the implementation of interventions to decrease BMI and maintain the weight loss would have the largest impact on all health outcomes, except for improvements with ADL. While increases in vigorous physical activity would result in no change in obesity and small declines in chronic conditions (diabetes, heart disease), exercise interventions will do more to decrease difficulties with ADL than weight loss. Over 28,000 fewer SNAP-Ed eligible populations would experience ADL difficulties in the 20% increase scenario by 2029 in Los Angeles County alone.

We find no evidence that increased vigorous exercise alone will halt the increase in average body mass index of the SNAP-Ed population. Even for the greatest increase in vigorous activity, average BMI was reduced by 0.02 (less than a quarter pound for an average height individual). The almost nonexistent change may result from the broad way in which physical activity is measured in FAM. Since the model captures only whether a person has completed no vigorous physical activity versus completing any vigorous physical activity (a minimum of ten minutes once a week), these interventions may indicate only tiny changes in actual physical activity among the SNAP-Ed eligible population.

While these estimates provide a plausible picture of SNAP-Ed eligible population health outcomes, there are sources of uncertainty in the simulation process. The limited impact of physical activity on health outcomes may be in part because of the crude measurement of physical activity, which was self-reported, expressed as a dichotomous variable, and thus did not account for duration and frequency of physical activity. Furthermore, participants reported a relatively high level of vigorous physical activity, when accelerometer- measured vigorous physical activity indicates that most people rarely engage in that level of intensity (Troiano et al., 2008). A more precise measure of physical activity could potentially yield different results.

We assumed that the physical activity interventions are constant over the simulation period and are present for the entire SNAP-Ed population. However, since the physical activity increases are specific to individuals, they are less likely to overinflate the propensity for certain groups to engage in vigorous physical activity (elderly, extreme obesity, etc.). The transition parameters for individual life cycles are also estimated and, therefore, contain statistical uncertainty. We assessed this source of uncertainty using nonparametric bootstrapping, though using a relatively small number of replications due to computational intensity. However, we have not accounted for the uncertainty in our replenishing cohorts that use census population size predictions and health behavior trends based on the National Health and Nutrition Examination survey and the National Health Interview Survey.

Although the overall impact of weight maintenance is of a significant magnitude higher in disease prevention compared to physical activity promotion and weight loss followed by slow weight regain, this simulation model does not point to a specific intervention that will yield weight maintenance. Indeed, this has been a challenge globally. Meeting the challenge of stemming the tide of weight gain at a population level will require designing entirely new approaches or strengthening existing policy or practice interventions that modify the food environment in a more strategic, meaningful way (Galea and Vaughan, 2019; Cohen, 2014). Experimentation with these different policies and programs is needed to find optimal methods that can promote widespread weight control over the long term. Simultaneously, especially for physical activity interventions, continuous efforts to maintain present infrastructures for children and adults (e.g., physical education laws, park infrastructure) should be undertaken vigorously so that past gains in this area are not rolled back to the detriment of those at most risk for obesity and chronic disease such as the SNAP-Ed population. Further, our model only accounts for interventions targeting adults, and so may underestimate the impact of interventions on children who would also be affected.

Finally, we acknowledge the economic impact of the recent Coronavirus Disease 2019 pandemic (Bartsch et al., 2020), which likely will increase the size of the SNAP-Ed eligible population in Los Angeles County beyond our calculations. However, the short-term effects of this pandemic on the microsimulation's core assumptions is currently unknown, but likely will not significantly impact the model's longer-term estimates.

Because the trajectory of weight gain is so prevalent, with most people gaining an average of 1–2 lb annually (Hutfless et al., 2013), and weight gain is associated with a host of chronic diseases, interventions that simply helped people maintain their current weight would be powerful boosts to future population health.

Author contributions

All the authors participated in the conceptualization of the study, data interpretation and manuscript preparation. Joshua Russell-Fritch performed the simulation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This project was in part supported by a contract from the California Department of Public Health to the Los Angeles County Department of Public Health (#16-10148) for work related to the United States Department of Agriculture's Supplemental Nutrition Assistance Program Education.

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