

Systems Thinking and Simulation Modeling to Inform Childhood Obesity Policy and Practice

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Abstract

Objectives: In 2007, 31.7% of Georgia adolescents in grades 9-12 were overweight or obese. Understanding the impact of policies and interventions on obesity prevalence among young people can help determine statewide public health and policy strategies. This article describes a systems model, originally launched in 2008 and updated in 2014, that simulates the impact of policy interventions on the prevalence of childhood obesity in Georgia through 2034.

Methods: In 2008, using information from peer-reviewed reports and quantitative estimates by experts in childhood obesity, physical activity, nutrition, and health economics and policy, a group of legislators, legislative staff members, and experts trained in systems thinking and system dynamics modeling constructed a model simulating the impact of policy interventions on the prevalence of childhood obesity in Georgia through 2034. Use of the 2008 model contributed to passage of a bill requiring annual fitness testing of schoolchildren and stricter enforcement of physical education requirements. We updated the model in 2014.

Results: With no policy change, the updated model projects that the prevalence of obesity among children and adolescents aged ≤ 18 in Georgia would hold at 18% from 2014 through 2034. Mandating daily school physical education (which would reduce prevalence to 12%) and integrating moderate to vigorous physical activity into elementary classrooms (which would reduce prevalence to 10%) would have the largest projected impact. Enacting all policies simultaneously would lower the prevalence of childhood obesity from 18% to 3%.

Conclusions: Systems thinking, especially with simulation models, facilitates understanding of complex health policy problems. Using a simulation model to educate legislators, educators, and health experts about the policies that have the greatest short- and long-term impact should encourage strategic investment in low-cost, high-return policies.

Keywords

childhood obesity, obesity policy, systems modeling

After rising from 5% in 1980 to 18% in 2000, the national prevalence of childhood obesity is now at 17%.^{1,2} Although rates have stabilized, the current prevalence of childhood obesity still predicts an unhealthy and expensive future for today's children.^{3,4} Ameliorating the childhood obesity problem will require action by many segments of society, including federal, state, and local legislative bodies.⁵

Health policymaking "is a difficult, complex riddle."⁶ A legislator's personal experience, available information, and input from advocacy groups may have as much or more influence on policymaking than scientific findings. Preparing and

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communicating data effectively is one way to improve the likelihood of adoption of evidence-based policy.⁷

In this article, we describe the Legislative Health Policy Certificate Program, a training and continuing education program for policy makers that is part of a wider legislative education initiative funded by philanthropic organizations in Georgia.⁶ Legislative Health Policy Certificate Program sessions highlight federal and state health policy and engage legislators in a discussion about relevant data, impacts, and outcomes. The Georgia Health Policy Center at Georgia State University's Andrew Young School of Policy Studies and its academic and health policy partners developed the program to help Georgia legislators develop skills to better understand and manage complex health issues.⁶ Every nonelection year since 2008 (eg, 2009, 2011, 2013), the Georgia Health Policy Center has provided education sessions for legislators serving on health-related committees or with a high interest in health issues and policies. The program currently spans 3-4 months and includes 4 six-hour sessions.

This article focuses primarily on a model simulating the impact of various health policies on the future prevalence of childhood obesity. Models similar to ours have been used to simulate the impact of health policies on other public health issues, such as injury prevention,⁸ smoking,⁹ and cardiovascular disease.¹⁰

Georgia's legislative education initiative is grounded in systems thinking, a detailed explanation of which is available elsewhere.¹¹ Briefly, systems thinking emphasizes prevalence and incidence diagrams (referred to as stock and flow diagrams in systems thinking), trend analysis, time delays in implementing interventions, and feedback loops in which the output either moves the various systems influencing childhood obesity in a positive direction or has a negative impact in determining the outcomes of various obesity-related policy options. During the first years of the education initiative, legislators expressed an interest in obesity among Georgia children, which led to development of the simulation model described herein. We developed the model in 2008 and updated it in 2014.

Methods

In 2008, after 2 years of research and discussions with legislators interested in health policy, the Georgia Health Policy Center implemented an education initiative to help Georgia legislators address the complex health issues they were facing. A key component of the initiative was the Legislative Health Policy Certificate Program, which was designed for legislators on committees tackling health and public health issues who sought a better understanding of the health care and health policy fields.⁶ The first Legislative Health Policy Certificate Program included 8 sessions spanning 9 months and emphasized systems thinking.

Key elements were (1) a 6-question framework that focused thinking on a specific problem, involved and interested parties, trends, leverage points (places in a system [eg,

a state] where shifts can be made to improve a problem [eg, childhood obesity]), mechanisms of action (how the policy will work or affect the problem over time), and timing; (2) change-over-time graphs to demonstrate the importance of understanding not only the current status of a problem but also the direction in which it is headed (eg, improving, worsening); (3) prevalence and incidence diagrams to depict connections (ie, demonstrate how different policies working together affect childhood obesity prevalence) and feedback loops (demonstrate how outputs from one policy [eg, improved behavior due to classroom physical activity] may influence or feed back into the classroom physical activity policy lever); and (4) simulation models to demonstrate how prevalence and incidence diagrams function over time and the potential future impacts of policy changes.

In 2008, a 16-member team comprising state legislators, legislative staff members, and experts in nutrition, physical activity, epidemiology, economics, and systems dynamics attended 16 hours of training in systems thinking and model building. After the training, the group developed a model for predicting the future of childhood obesity in Georgia, drawing on a previous national model.¹² In 2014, a subset of the original group updated the model. The group used the following information to develop and update the model:

1. Population estimates and predictions for Georgia children and adolescents aged ≤ 18 : The group used data from the US Census Bureau and sources drawing on US Census data (eg, KIDS COUNT Data Center).^{13,14}
2. Prevalence estimates for categories of body mass index (BMI) among Georgia children aged ≤ 18 : Categories included underweight (BMI <5th percentile), normal weight (BMI 5th to <85th percentile), overweight (BMI 85th to <95th percentile), obese (BMI 95th to <99th percentile), and very obese (BMI ≥ 99 th percentile). In 2008, the group used prevalence estimates for Arkansas, which, unlike Georgia, had conducted surveys of BMI among children. In 2014, because of legislative actions arising in part from the Legislative Health Policy Certificate Program and the 2008 model, BMI data were available for children in Georgia in kindergarten through 12th grade (hereinafter, K-12); we estimated BMI category prevalence for children aged ≤ 4 using the 2008 model.
3. Predictions of future prevalence of obesity for children in each BMI category assuming no policy interventions: In 2008, the group based predictions on a previous model created by the Centers for Disease Control and Prevention (not published).¹² For the 2014 model, we assumed that the prevalences were stable.²
4. A list of policy interventions to be included and, for each, a quantitative estimate about its impact on

energy balance (the balance between calories taken in and calories expended): The group determined that interventions for which a change in the prevalence of obesity was available but that lacked quantitative information about a change in caloric balance were not usable. The group chose interventions based on legislative feasibility and evidence of efficacy, requiring at least 1 peer-reviewed, published, scientific article enabling a quantitative estimate of change in energy balance. The following interventions were included in the model; those with an asterisk (*) were added in the 2014 update:

- a. Mandate daily physical education for children in grades K-12.
 - b. Require a minimum of 50% of physical education time to be spent in moderate to vigorous physical activity (ie, enhanced physical education).¹⁵
 - c. Mandate daily enhanced physical education for children in grades K-12.
 - d. Incorporate moderate to vigorous physical activity into class time.*
 - e. Mandate 20 minutes of daily recess for children in grades K-5.*
 - f. Improve physical activity opportunities during recess (ie, offer modified recess) by providing playground equipment (eg, slides, swing sets), markings on the playground surface (eg, hopscotch, 4-square, number grid), and equipment that encourages physical activity (eg, balls, Frisbees, hula hoops).^{15*}
 - g. Mandate 20 minutes of modified daily recess for children in grades K-5.*
 - h. Provide after-school programs for all children who would like to participate.
 - i. Require existing after-school programs to include a physical activity component.
 - j. Provide after-school programs for all children who would like to participate and require programs to include a physical activity component.
 - k. Require existing preschool programs to provide quality physical activity and nutrition components.
 - l. Increase the proportion of children who can safely walk or bike to school.
 - m. Require all food served in school cafeteria lines (with the exception of vending machines, food related to fundraising, and school stores) to meet US Department of Agriculture School Nutrition Guidelines.¹⁶
 - n. Provide Medicaid reimbursement for medical nutrition therapy counseling for overweight and obese children.
 - o. Increase the prevalence of “any breastfeeding at 6 months” to 60.6%, a Healthy People 2020 objective.^{17*}
5. Estimates of the proportion of the population to which the policy interventions would newly apply: The group took estimates of the proportion of children already receiving the intervention (eg, traditional school physical education) from administrative or scientific sources; verbal estimates by education and health authorities were accepted when published estimates were not available (eg, the prevalence of preschool programs with quality physical activity components).

The goal of the group was to be scientifically rigorous but not overly restrictive. (A summary of assumptions and calculations for each proposed policy intervention is available from the corresponding author.) Our goal for the model was and continues to be a product made from the best available evidence that can be modified as new information becomes available.

The system dynamics model includes time delays and prevalence and incidence concepts. The model simulates the potential consequences, if any, of a given policy intervention or combination of policy interventions on the future prevalence of childhood obesity. Because this research project did not involve human subjects, it was considered exempt from institutional review board review.

Results

The childhood obesity model was created by the aforementioned stakeholders to support a dialogue on policy interventions designed to reduce childhood obesity (specifically, BMI for age percentiles). The easy-to-use computer-based model can be used by ≥ 1 person simultaneously testing interventions, allowing for conversation about the policies under consideration and the outcomes suggested by various policy combinations. The interface features labeled buttons that enable the user to select the policy or policies whose impact they would like the model to project. Users can choose from 13 policy interventions (eg, mandate daily physical education, require after-school programs to include time for physical activity) and 3 grade-level ranges (ie, elementary, middle, and high) to which the policies can apply. In addition, sliders allow the user to adjust the expected percentage of children who would be covered by the policy or policies. More than 1000 unique combinations can be selected.

The interface also features 2 model-generated line graphs. One graph shows the projected prevalence of childhood obesity in Georgia from 2014 to 2034. For each policy or combination of policies selected, a new line appears depicting the change, if any, in the prevalence of obesity predicted if the new policies are implemented. The user can add more lines by selecting additional policies or reset the graph for each new policy combination selected. The other graph depicts age group-specific trends during the same period for the policy or policies selected.

The 2014 revised model projects that, with no change in policy, the prevalence of childhood obesity among children

Table. Projected prevalence of childhood obesity among Georgia children and adolescents aged ≤ 18 in 2034, by policy enacted^a

| Policy Intervention | Projected Prevalence of Obesity in 2034, % |
|--|--|
| No policy change | 18 |
| Physical education | |
| Mandate daily physical education in grades K-12 | 12 |
| Implement enhanced physical education ^b in existing physical education classes | 16 |
| Mandate daily enhanced physical education ^b in grades K-12 | 9 |
| Incorporate moderate to vigorous physical activity into classroom activities in grades K-5 | 10 |
| Recess | |
| Mandate 20 min/d of recess in grades K-5 | 18 |
| Implement modified recess ^c in existing recess | 16 |
| Mandate 20 min/d of modified recess in grades K-5 | 16 |
| After-school programs | |
| Provide after-school programs for all children | 17 |
| Require existing after-school programs to include a physical activity component | 17 |
| Provide after-school programs for all who want to participate and require all programs to have a physical activity component | 16 |
| Require existing preschool programs to provide quality physical activity and nutrition components | 16 |
| Increase proportion of students who can safely walk or bike to school | 16 |
| Require all food served in school cafeteria lines to meet the USDA School Nutrition Guidelines | 16 |
| Provide Medicaid reimbursement for medical nutrition therapy counseling for overweight and obese children | 17 |
| Increase the prevalence of "any breastfeeding at 6 months" to 60.6%, a Healthy People 2020 objective ¹⁷ | 16 |
| All of the above policies | 3 |

Abbreviations: K, kindergarten; USDA, US Department of Agriculture.

^aProjections by a systems thinking model developed by the Georgia Health Policy Center at Georgia State University's Andrew Young School of Policy Studies and its academic and health policy partners in 2008 and updated in 2014 as part of an educational initiative to help Georgia legislators develop skills to better understand and manage complex health issues.

^bEnhanced physical education refers to spending a minimum of 50% of physical education time in moderate to vigorous physical activity.

^cModified recess refers to improving physical activity opportunities during recess by providing playground equipment (eg, slides, swing sets), markings on the playground surface (eg, hopscotch, 4-square, number grid), and equipment that encourages physical activity (eg, balls, Frisbees, hula hoops).¹⁵

and adolescents aged ≤ 18 in Georgia will remain at 18% from 2014 through 2034 (Table). However, it projects that most policy interventions, if enacted individually, could reduce the prevalence to about 16% to 17%. Mandating daily physical education at school (which would reduce prevalence to 12%) and integrating moderate to vigorous physical activity into elementary school classrooms (which would

reduce prevalence to 10%) would have the largest projected impact on the prevalence of childhood obesity. Mandating recess in elementary schools would have no impact, presumably because >95% of elementary schools already have recess. However, enacting all proposed policy interventions would reduce the prevalence of childhood obesity from 18% to 3%. For all policy interventions, nearly the entire projected reduction would occur in the first 10 years after implementation.

Discussion

Scientific articles using models to simulate the impact of selected policies on the prevalence of childhood obesity commonly focus on the predicted quantitative changes in prevalence. For example, researchers have modeled tax hikes on sugar-sweetened beverages and implementation of after-school physical activity programs that have predicted substantial reductions in the prevalence of childhood obesity.^{18,19} Our model can be viewed from the same perspective. Every policy intervention included in our model except mandated daily recess would be expected to reduce the prevalence of childhood obesity in Georgia during the next 20 years, with most of the reduction occurring by 2024. For most policy interventions, the reduction in prevalence would be about 1 or 2 absolute percentage points below the policy choice of doing nothing (the difference between 18% and about 16%). We expect mandated physical education and incorporating moderate to vigorous physical activity into classroom activities would have the greatest impact, lowering the prevalence of childhood obesity in Georgia from 18% to 12% and 10%, respectively. These findings indicate that multiple policies and actions will be needed to reduce the prevalence of childhood obesity to 5%. Such policies and actions are currently being implemented via the Georgia Shape initiative, a long-term, public-private, multisector, multi-intervention collaboration designed to reduce the prevalence of childhood obesity in Georgia.²⁰

A singular focus on quantitative predictions, however, misses much of the value of this model and the educational initiative in which it was imbedded. The graphs generated using the interactive computer-based model provide visual depictions of the potential reductions in the prevalence of childhood obesity and the period during which those reductions would occur. The buttons and sliders emphasize the various policies and combinations of policies that can be considered. The model enables the user—policy maker, scientist, layperson—to compare the impacts of many policy options.

With these features, the simulation model becomes an excellent translator of complex scientific findings into easily understood outcomes. It is important that the model also facilitates conversation about how and why different policies influence outcomes. The model also may initiate conversations about the benefits of strategies beyond the reduction of childhood obesity, such as the benefits of breastfeeding other than its impact on body composition,²¹ and improved classroom behavior, faster cognition, and higher test scores after

moderate to vigorous physical activity.¹⁵ Using the model with legislators as part of the Legislative Health Policy Certificate Program directly influenced deliberations and passage of a bill in 2009 (the Georgia Student Health and Physical Education Act²²) requiring annual fitness testing and improved implementation of physical education requirements in Georgia.⁶

Other aspects of the childhood obesity systems model that fostered success were the wide array of experts and stakeholders involved in the process. Both builders and users of the model understood that this was the best available science and that refinements would improve the model in the future. Sessions were conducted to encourage discussion and experimentation with the findings. Some ideas could be and were immediately tested by simple modifications to the model. The model's transparency and flexibility were important for its acceptance by users (ie, legislators, scientists, and public health experts).

Strengths and Limitations

Strengths of the simulation model included the visual clarity of the findings and the wide range of policies and policy combinations that can be considered. Users can revise the model by including new scientific findings or expand it to include more policy interventions. The model includes only policy interventions that were deemed as feasible for legislative action. We did not include policies such as reducing time watching television (family policy), modifying the volume and content of food advertisements to children (media and industry policy), or taxation of soft drinks or fast foods (governmental policy), because they were identified as not feasible for legislative action in Georgia by the 16-member team.

Limitations of our model included that some of the effect sizes were based on only a few studies and some of the prevalence estimates were based on limited data or best estimates by authorities knowledgeable in childhood obesity and energy intake and expenditure in children. A larger number of pertinent research articles would bolster confidence in the estimates. The model also assumed that an enacted policy would have an impact equivalent to that reported in the scientific literature, which may not be the case. A policy may lack strength or may not cover the full population, sufficient resources may not be available for full implementation, monitoring and enforcement of implementation may not occur, and the policy may be reinterpreted at the site of implementation.^{21,23,24} The model also likely would have even greater appeal to legislators if more than the limited estimates of economic impact were available.

Conclusions

Systems thinking in general and interactive simulation models in particular facilitate understanding of complex health policy problems. The use of time trend charts, for example,

helps determine the need for policy change and provides context for evaluating new policies. A time trend may already be favorable, suggesting that a new policy may not be needed. A new policy that flattens an unfavorable trend has at least stopped things from getting worse. Incidence and prevalence charts facilitate another level of understanding by encouraging discussion about how interventions influence or may influence the flow, including how various interventions may work either with or against each other. Quantifying the potential impact demonstrates the need for multiple complementary policy interventions. Our model showed that mandated daily physical education and integrating moderate to vigorous physical activity into elementary classrooms would have the largest potential impact on reducing the prevalence of childhood obesity in Georgia. However, a variety of policy interventions will be necessary to significantly reduce childhood obesity.

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References

1. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. *JAMA*. 2002;288(14):1728-1732.
2. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-814.
3. Finkelstein EA, Graham WC, Malhotra R. Lifetime direct medical costs of childhood obesity. *Pediatrics*. 2014;133(5):854-862.
4. Freedman DS, Serdula MK, Khan LK. The adult health consequences of childhood obesity. In: Chen C, Dietz WH, eds. *Obesity in Childhood and Adolescence*. Philadelphia, PA: Lippincott Williams & Wilkins; 2002:63-82.
5. Institute of Medicine. *Preventing Childhood Obesity: Health in the Balance*. Washington, DC: National Academies Press; 2005.
6. Minyard KJ, Ferencik R, Phillips MA, Soderquist C. Using systems thinking in state health policymaking: an educational initiative. *Health Syst (Basingstoke)*. 2014;3(2):117-123.
7. Brownson RC, Chiqui JF, Stamatakis KA. Understanding evidence-based public health policy. *Am J Public Health*. 2009;99(9):1576-1583.
8. Ferencik R, Minyard K. Systems thinking in injury prevention: an innovative model for informing state and local policies. *West J Emerg Med*. 2011;12(3):273-274.

9. Levy DT, Bauer JE, Lee HR. Simulation modeling and tobacco control: creating more robust public health policies. *Am J Public Health*. 2006;96(3):494-498.
10. Homer J, Wile K, Yarnoff B, et al. Using simulation to compare established and emerging interventions to reduce cardiovascular disease risk in the United States. *Prev Chronic Dis*. 2014;11: E195.
11. Sterman JD. Learning from evidence in a complex world. *Am J Public Health*. 2006;96(3):505-514.
12. Homer J, Milstein B, Dietz W, Buchner D, Majestic E. Obesity population dynamics: exploring historical growth and plausible futures in the US. Paper presented at: 24th International Conference of the System Dynamics Society; July 23-27, 2006; Nijmegen, The Netherlands.
13. US Census Bureau, American FactFinder. Annual estimates of the resident population for selected age groups by sex for the United States, states, counties, and Puerto Rico commonwealth and municipios: April 1, 2010, to July 1, 2013. <https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk>. Published 2013. Accessed May 9, 2015.
14. KIDS COUNT Data Center. Child population by gender. Georgia, 2011-2015. <http://datacenter.kidscount.org/data/tables/102-child-population-by-gender?loc=12&loct=2#detailed/2/12/false/573,869,36,868,867/14,15,65/421,422>. Published 2014. Accessed May 9, 2015.
15. Institute of Medicine. *Educating the Student Body: Taking Physical Activity and Physical Education to School*. Washington, DC: National Academies Press; 2013.
16. US Department of Agriculture. Nutrition standards in the National School Lunch and School Breakfast Programs; final rule. *Fed Reg*. 2012;77:4088-4167. Codified at 7 CFR §210 and §220.
17. US Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Healthy People 2020 topics and objectives: maternal, infant, and child health. <http://www.healthypeople.gov/2020/topics-objectives/topic/maternal-infant-and-child-health/objectives>. Accessed October 23, 2015.
18. Kristensen AH, Flottemesch TJ, Maciosek MV, et al. Reducing childhood obesity through US federal policy: a microsimulation analysis. *Am J Prev Med*. 2014;47(5):604-612.
19. Levy DT, Friend KB. Simulation modeling of policies directed at youth sugar-sweetened beverage consumption. *Am J Community Psychol*. 2013;51(1-2):299-313.
20. Georgia Shape. About Georgia Shape. <http://www.georgia.shape.org>. Accessed November 4, 2015.
21. American Academy of Pediatrics, Section on Breastfeeding. Policy statement: breastfeeding and the use of human milk. *Pediatrics*. 2012;129(3):e827-e841.
22. Official Code of Georgia Annotated §20-2-776 (2009).
23. Amis JM, Wright PM, Dyson B, Vardaman JM, Ferry H. Implementing childhood obesity policy in a new educational environment: the cases of Mississippi and Tennessee. *Am J Public Health*. 2012;102(7):1406-1413.
24. Smith EM, Wilburn G, Estabrooks PA. The quality of school physical activity policies within Maryland and Virginia. *J Phys Act Health*. 2015;12(4):500-505.