Modeling Obesity Prevention Programs to Reduce Overweight Rates at Schools: A Perspective

Lateefat Amao
College of Basic and Applied Sciences, Healthcare Informatics
Middle Tennessee State University
Murfreesboro, TN, United States
lka2w@mtmail.mtsu.edu

Misagh Faezipour*
Department of Engineering Technology
Middle Tennessee State University
Murfreesboro, TN, United States
misagh.faezipour@mtsu.edu

***Abstract*—Childhood obesity is a public health challenge, with many risks affecting a child's long-term health. This paper explores the complexities of childhood obesity. It recognizes the role and influence that schools play in children's behaviors and leverages the school as a micro-environment to implement multiple levels of interventions. This work proposes an intervention to tackle childhood obesity at schools using system dynamics modeling. Its focus is on promoting healthy dieting, increasing physical activity, creating supportive environments, while interacting with multiple sectors and communities. We propose a measurable and sustainable intervention, spanning a three-year time-frame. System dynamics approach accounts for the dynamic nature of schools and pinpoints the need for well-structured and sustainable interventions. This evidence-based dynamic intervention model targets multiple factors that contribute to obesity, involving relevant stakeholders, and implements a long-term intervention to promote long-lasting behavioral changes that decreases the rate of prevalence of childhood obesity.**

***Index Terms*—childhood obesity, BMI, system dynamics, obesity prevention, intervention.**

I. Introduction

Obesity is recognized as a major global public health challenge and is increasingly common among school-age children and adolescents. Childhood obesity poses numerous negative psychological and physical health consequences and is more likely to continue into adulthood [1]. Public health authorities continue to develop effective intervention strategies to prevent childhood obesity and address growing concerns. Schools offer a platform to reach many young people where youth health promotion interventions are often delivered through schools [2].

The factors influencing obesity defy traditional linear approaches and prevention methods, as they interact in intricate ways. Hence, a complex model is required that would offer a more robust and holistic approach and provide a comprehensive framework for design and evaluation while considering the multiple factors involving collective variables and complex feedback loops. This is where system dynamics comes into play.

This paper proposes a perspective on a dynamic intervention model to develop a program to prevent obesity in children.

A. Background and Literature

Despite the presence of physical activity programs in schools, children are not participating in enough physical activity which results in alarming rates of overweight. The prevalence of overweight children and adolescents has grown considerably due to sedentary lifestyles and altered food practices. By operational definitions, obesity and overweight are abnormal or severe fat accumulations that negatively affect or influence health. According to the world health organization (WHO), one of the most significant worldwide issues of the twenty-first century is childhood obesity [3]. Being overweight is a highly complicated condition with several underlying causes [4]. It is generally acknowledged that the increasing rate of obesity is caused by a mismatch between energy consumption and expenditure while hereditary, environmental, and cultural factors also play a role.

According to the Centers for Disease Control and Prevention [5], body mass index (BMI) is a calculation and biomarker for determining whether one is healthy or can benefit from weight gain or loss. BMI depends on the ratio of one's weight to height. The line between overweight and obesity is drawn per particular calculations based on tables with appropriate norms for each age group. A deviation of 1.5 to 2 units using the calculation of BMI identifies excess weight, while more than two units identifies obesity [6]. Excess weight is a more fertile ground for treatment than obesity, as comorbidities are less likely to be attached at this stage [6].

While BMI is the most commonly used predictor of muscle and body fat mass, it is not the most accurate way to determine if one has a healthy amount of fat. This is because it does not consider different physical characteristics, such as muscle mass, bone mass, or lean fat. A more accurate indication of how much fat versus muscle mass an individual carries can be found through bioelectrical impedance analysis (BIA) or underwater (known as hydrostatic) weighing [7]. BIA is a test that runs an invisible current through the body and measures its speed and resistance. It incorporates the results into a mathematical equation to sum up body fat, lean mass, and water. Hydrostatic weighing is performed by immersing a person in a tank of water. The immersion displaces or pushes

979-8-3503-2759-5/23/$31.00 ©2023 IEEE
DOI 10.1109/CSCE60160.2023.00216

out all the air out of the lungs and measures the body weight per unit volume.

Another biomaker to determine a healthy body is basal metabolic rate (BMR). BMR is the amount of energy (measured in calories) that a person's body burns, while at rest, to perform basic life-sustaining functions like breathing, circulation, and cellular metabolism [8]. The BMR measures the number of calories needed daily to perform basic vital functions. It fluctuates depending on how active one's lifestyle is. Body composition can usually be broken down into muscle mass and body weight. Determining body fat composition and muscle mass is essential for understanding one's overall health [8]. Comprehending these terms, their calculations, and the results will give an insight into the predictors of overall health and serve as a good starting point for determining if an individual is at a healthy weight.

Schools are an essential microenvironment where children spend most of their time. They also play an important role in influencing their local and remote communities, families, and caregivers. Schools provide an opportunity to do more than pass on knowledge to young people [9]. They can create and influence an environment conducive to good health and wellness. Schools offer an environment where multilevel interventions can be developed and evaluated to prevent unhealthy weight gain [10].

Evidence suggests that initiatives that change the curriculum and conditions and involve parents and the community can have a modest but significant impact on outcomes such as BMI, physical activity, and dietary habits [10]. Engaging parents and communities have proven to be more challenging than making small changes to curricula that focus more on health. In addition, the direction of school programs to combat overweight school children corresponds to the system dynamics model, where changes occur within the system and affect all its elements.

Childhood obesity is a complex issue that is often associated with exogenous constitutional factors such as malnutrition and low physical activity. However, in 10% of cases, obesity is syndromic and caused by genetically determined breakdowns or long-term medication use, such as glucocorticoids, which cause subcutaneous fat redistribution [11]. It is imperative for parents to pay attention to their child's health, but it can be challenging for them to objectively assess the problem. As a result, schools can play a crucial role in identifying and preventing childhood obesity. By providing nutrition education, promoting physical activity, and fostering a healthy school environment, schools can help children develop healthy habits that will last a lifetime. Therefore, it is essential for schools to prioritize obesity prevention and provide a supportive environment for children's health and well-being.

Programs aimed at preventing obesity in children must pay attention to the length of school holidays, the availability and accessibility of school facilities, and the importance of increasing time spent in physical education (PE) classes and breaks during school time. By taking these factors into consideration, schools can promote physical activity and healthy lifestyles among children, leading to a lower risk of overweight and obesity in the long term.

Various contextual variables and minor impacts of multilevel interventions should be documented, as they can significantly affect how schools operate and interact with other stakeholders. Furthermore, research is needed that integrates harm prevention within the framework of obesity prevention to ensure that school-based weight prevention practices are effective and do not worsen the mental health impact of being overweight or obese [12]. Since schools are dynamic adaptive entities with varying needs and responses to treatment, it has been suggested that a standardized intervention in a school context is inappropriate.

II. Methodology

A. System Dynamics

The system's overall behavior is constantly changing due to the many decisions that individual agents make every second. According to the basic ideas of system dynamics, the system's structure is represented as interacting flows, and feedback loop interaction is decisive in describing the system dynamics. System dynamics analytical modeling founded its origin from Jay Forrester's work on industrial dynamics at the Massachusetts Institute of Technology [13]. Forrester applied the principles of information feedback to demonstrate that the dynamics of the functioning of complex systems significantly depend on the structure of the cause-and-effect relationships that exist in the system. He believed that complex systems, primarily industrial and social, belong to the systems with multi-loop nonlinear feedback. His proposed method was intended to study complex dynamical systems with nonlinear feedback. This model class is based on system dynamics and focused on modeling systems and processes at a high level of aggregation. The concept of system dynamics is based on the idea of the functioning of the system as an aggregate.

Waters et al. [14] present the usefulness of complex systems in designing and evaluating school health promotion interventions. Given this context, it is proposed to model an intervention with measurable results to reduce childhood obesity in schools. System dynamics has been applied to many areas covering health concerns [15]–[22].

B. Work in Progress

The essence of the intervention is to develop an initiative to promote the obesity prevention programs in schools and evaluate the results. It will also be critical to ensure the presence of parents in this promotion process.

In order to effectively prevent obesity in preschool and school-age children, it is crucial to implement a comprehensive set of prevention measures that include nutrition education, promotion of physical activity, and behavior change strategies. The importance of such measures is supported by a systematic

review which analyzed 26 randomized interventions aimed at preventing obesity in preschool children ages 2 to 5 years [23].

The importance of parental involvement in promoting healthier behaviors and limiting the emergence of harmful lifestyles in children is highlighted by a study included in a review of obesity prevention interventions [24]. This study found that adolescents who attended schools with more supportive parental involvement had a reduced risk of adult obesity after adjusting for important demographic factors. These findings suggest that involving parents in obesity prevention programs throughout the school period may be crucial to promoting long-term healthy behaviors and reducing the risk of adult obesity. Therefore, it is imperative to involve parents in the implementation of such programs. By working together with parents and schools, a supportive environment can be created that fosters healthy habits and behaviors in children and reduces the risk of obesity in adulthood.

The planned intervention will be grounded in the ten core principles of overweight prevention established by the international obesity task force (IOTF). These principles include promoting healthy diets and physical activity, providing supportive environments, encouraging sustainable policies and programs, adopting a life-course approach, targeting high-risk groups, involving multiple sectors, engaging with communities, using evidence-based interventions, prioritizing equity, and monitoring and evaluating progress [25]. These principles have been widely recognized as key components of effective overweight prevention strategies and will guide the development and implementation of the program. The principles are founded on a health promotion model that is inspiring, collaborative, inclusive, intersectoral, equitable, viable, and multifaceted and serves as the basis for the development and implementation of the program.

The health promoting school framework will also be utilized, which is aligned with a social-environmental framework and based on a health promotion philosophy that has been widely used and improved upon over the past decade to help schools address health concerns [14]. The framework provides valuable background for the planned interventions since it allows for a multilevel approach that considers the social and environmental factors that influence health behavior. Furthermore, the framework promotes a participatory approach that includes the community.

Based on thorough observation and studying these two conceptual models, we proposed a model for evaluating intervention outcomes. For continuous data, means and standard deviations will be used, and for binary variables, proportions will be used to summarize characteristics. An intention-to-treat approach will be used to quantify the impact of the intervention, and participants and schools will be analyzed depending on the treatment group to which they will be randomly assigned.

Public health is focused on increasing knowledge and competence to reduce childhood obesity. Most of the research is focused on personal and intrapersonal transformation, often with interventions lasting less than one year. This, however, is despite increasing school curriculum data. Focusing on the school environment and aiming to be long-term, scientific evidence and inclusive of the actual intricacies of schools, the proposed intervention is expected to last three years and deliver measurable results.

III. Expected Outcome and Conclusions

The critical aspect of controlling obesity is prevention not treatment. It is difficult to treat obesity after its onset, and in many cases, therapy is unsuccessful. In most countries, being overweight in children is more common than obesity. Thus, the target population for the prevention of obesity should be children with overweight and the risk of developing obesity. In addition, schools aimed at educating students and preventing overweight can address the problem of childhood obesity at an early stage.

Programs for the prevention and treatment of childhood and adolescent obesity are based on intervention at the family or school level. However, none of the currently used interventions can stop the obesity epidemic. The problem of childhood obesity requires consideration of environmental factors and critical periods of development when behavioral responses are formed. Prevention of overweight/obesity in preschool children can provide health benefits in both childhood and adulthood. The preschool period is key for lifestyle interventions to promote long-term dietary and active lifestyle habits. This paper proposes a perspective on a dynamic intervention model to develop a program to prevent obesity in children.

The proposed system dynamics model suggests that the preventive process of obesity is a fixed structure consisting of accumulators, with levels identified based on an analysis of the overall picture of the causes of being overweight in school children. The levels are quantities defined as state variables of the system, and the rate shows how they change over a time interval, which in the proposed model can be three years for the proposed interventions.

This model suggests that preventing childhood obesity is a complex and dynamic process involving multiple factors and accumulators, such as the school's readiness level to carry out preventive measures and the general introduction of changes in the structure of teaching a healthy lifestyle. The model also suggests that the levels within the system are interdependent and that changes in one level can affect other levels and the overall situation with preventing obesity in children and adolescents.

Therefore, the proposed dynamic intervention model to prevent obesity in children aims to modify environmental risk factors and behavioral responses during critical periods of development, such as the preschool period, to promote long-term dietary and active lifestyle habits. The program uses a multidisciplinary approach that covers antenatal life, infancy,

school life, family, and cultural backgrounds, combined with support from parents and teachers. By implementing this dynamic intervention model, the proposed program aims to deliver measurable results and contribute to the prevention of childhood and adolescent obesity.

IV. Future Work

The field of modeling obesity prevention using system dynamics has solid potential for further advancements and research. Existing models must be evaluated, refined, and further built upon. With new technology available, applying real-life data and empirical evidence can make the models more accurate and increase the predictability. Reliability and validity of the models can be enhanced by using observed data to calibrate the model parameters [26]. New technologies help to capture data better in real-time, whether it is wearable devices to capture data on physical activities [27], behavioral patterns, or dietary information.

Future work in this field can only be properly achieved by effective collaboration among researchers and research teams, educators, policy advisors and policy makers. Valuable partnerships that promote healthy diverse perspectives and knowledge sharing can develop into actionable interventions, policies, and legal frameworks that address the complex dynamics which is childhood obesity.

References

[1] M. H. Park, C. Falconer, R. M. Viner, and S. Kinra, "The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review," *Obesity reviews*, vol. 13, no. 11, pp. 985–1000, 2012.

[2] H. S. Yuksel, "Experiences of prospective physical education teachers on active gaming within the context of school-based physical activity," *European Journal of Educational Research*, vol. 8, no. 1, pp. 199–211, 2019.

[3] WHO, "Who guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age," *World Health Organization*, vol. 11, pp. 1–101, 2019.

[4] M. I. Jongenelis, M. Scully, B. Morley, I. S. Pratt, and T. Slevin, "Physical activity and screen-based recreation: Prevalences and trends over time among adolescents and barriers to recommended engagement," *Preventive medicine*, vol. 106, pp. 66–72, 2018.

[5] C. for Disease Control and Prevention, "Assessing your weight," retrieved June 2, 2023, from https://www.cdc.gov/healthyweight/assessing/index.html.

[6] D. Hamilton, A. Dee, and I. J. Perry, "The lifetime costs of overweight and obesity in childhood and adolescence: A systematic review," *Obesity reviews*, vol. 19, no. 4, pp. 452–463, 2018.

[7] V. Heyward, *Advanced fitness assessment and exercise prescription*. Human Kinetics, 2010.

[8] "Basal metabolic rate: What is BMR and how do I calculate it?" https://www.acefitness.org/education-and-resources/lifestyle/blog/5101/basal-metabolic-rate-what-is-bmr-and-how-do-i-calculate-it, accessed: June 2, 2023.

[9] N. Almutari and R. Orji, "How effective are social influence strategies in persuasive apps for promoting physical activity? a systematic review," in *Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization*. ACM, June 2019, pp. 167–172.

[10] J. H. van de Kop, W. G. van Kernebeek, R. H. Otten, H. M. Toussaint, and A. P. Verhoeff, "School-based physical activity interventions in prevocational adolescents: a systematic review and meta-analyses," *Journal of Adolescent Health*, vol. 65, no. 2, pp. 185–194, 2019.

[11] H. R. Milner and K. Lomotey, *Handbook of Urban Education*. Routledge, 2021.

[12] M. Hawkins, E. Watts, S. I. Belson, and A. Snelling, "Design and implementation of a 5-year school-based nutrition education intervention," *Journal of nutrition education and behavior*, vol. 52, no. 4, pp. 421–428, 2020.

[13] J. W. Forrester, "Industrial dynamics: A major breakthrough for decision makers," *Harvard Business Review*, vol. 39, no. 4, pp. 37–66, 1961.

[14] E. Waters, L. Gibbs, M. Tadic, O. C. Ukoumunne, A. Magarey, A. D. Okely, A. de Silva, C. Armit, J. Green, T. O'Connor *et al.*, "Cluster randomised trial of a school-community child health promotion and obesity prevention intervention: findings from the evaluation of fun 'n healthy in moreland!" *BMC public health*, vol. 18, no. 1, pp. 1–16, 2018.

[15] M. R. Davahli, W. Karwowski, and R. Taiar, "A system dynamics simulation applied to healthcare: A systematic review," *International Journal of Environmental Research and Public Health*, vol. 17, no. 16, p. 5741, 2020.

[16] N. Darabi and N. Hosseinichimeh, "System dynamics modeling in health and medicine: a systematic literature review," *System Dynamics Review*, vol. 36, no. 1, pp. 29–73, 2020.

[17] M. Faezipour and M. Faezipour, "System dynamics modeling for smartphone-based healthcare tools: Case study on ecg monitoring," *IEEE Systems Journal*, vol. 15, no. 2, pp. 3036–3045, 2020.

[18] M. Faezipour and M. Faezipour, "Efficacy of smart EEG monitoring amidst the covid-19 pandemic," *Electronics*, vol. 10, no. 9, p. 1001, 2021.

[19] S. Pourreza, M. Faezipour, and M. Faezipour, "Eye-scor: A supply chain operations reference-based framework for smart eye status monitoring using system dynamics modeling," *Sustainability*, vol. 14, no. 14, p. 8876, 2022.

[20] C.-T. Hsiao, C.-C. Chen, L.-K. Lin, and C.-S. Liu, "A systems view of responding to the covid-19 pandemic: A causal loop model for taiwan's approach," *Systems Research and Behavioral Science*, vol. 40, no. 1, pp. 194–206, 2023.

[21] A. Yinusa, M. Faezipour, and M. Faezipour, "A study on ckd progression and health disparities using system dynamics modeling," *Healthcare*, vol. 10, no. 9, p. 1628, 2022.

[22] J. F. Uleman, R. J. Melis, E. Ntanasi, N. Scarmeas, A. G. Hoekstra, R. Quax, M. G. O. Rikkert, and A. D. N. Initiative, "Simulating the multicausality of alzheimer's disease with system dynamics," *Alzheimer's & Dementia*, 2023.

[23] J. Lanigan, "Prevention of overweight and obesity in early life," *Proceedings of the Nutrition Society*, vol. 77, no. 3, pp. 247–256, 2018.

[24] L. Li, Y. Lin, T. Xia, and Y. Zhu, "Effects of electronic cigarettes on indoor air quality and health," *Annual review of public health*, vol. 41, pp. 363–380, 2020.

[25] "Obesity and the SDGs: an opportunity hidden in plain sight," https://www.worldobesity.org/news/blog-obesity-and-the-sdgs-an-opportunity-hidden-in-plain-sight, accessed: June 2, 2023.

[26] Y. Zhou and D. Zhang, "The impact of screen time on children's weight status: Evidence from a national survey in china," *BMC public health*, vol. 20, no. 1, 2020.

[27] W. Wang, J. Cheng, W. Song, Y. Shen *et al.*, "The effectiveness of wearable devices as physical activity interventions for preventing and treating obesity in children and adolescents: Systematic review and meta-analysis," *JMIR mHealth and uHealth*, vol. 10, no. 4, p. e32435, 2022.