Understanding why caries is still a public health problem

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ABSTRACT

Dental caries is still considered the main pathology to cause tooth loss. It is a chronic disease that can mutilate people for the rest of their lives, negatively affecting their life quality. According to a national survey conducted in Brazil in 2010, older people aged between 65 and 74 years had already lost most of their teeth. Although dental caries etiological factors and prevention procedures are well known, there seems to be a gap between the evidence found in the recent literature and the actual dental care provided in health services in Brazil. The impact of the preventive approach over time does not seem to have been completely understood. Thus, the main objective of this study was to simulate the impact of educational preventive approaches in the maintenance of teeth throughout the lifetime of people. System dynamics modeling involves the development of computer simulations based on conceptual interactions of multiple factors and processes of accumulation and feedback. This is a suitable approach for the dynamic complexity that characterizes many public health issues. Additionally, it may become a useful tool for policymakers when choosing the most appropriate interventions for their populations. This study used data obtained from the National Oral Health Survey conducted in 2010, and qualitative variables from a recent systematic review and some unpublished studies. The dynamic system model was constructed using Vensin software 6.3. This simulation model showed that educational preventive care, through the acquisition of healthy habits by the population, resulted in higher numbers of people with retained teeth and improved life quality. In conclusion, our findings highlights the importance of investments on educational approaches from early childhood to result in an exponential cascade effect for the improvement of the oral health of the Brazilian population.

Key words: system dynamics, dental caries, prevention, health education

INTRODUCTION

Dental caries results from different interactions over time of some specific pathogenic bacteria which metabolize ingested carbohydrates to form acids (Selwitz et al, 2007). This dynamic process results in tooth demineralization, cavity development and, eventually, tooth loss. Dental caries is one of the most prevalent chronic diseases in the population worldwide, affecting 60—90% of school age children, and almost 100% of the adult population (Petersen et al., 2005). It can lead to serious consequences and exert a negative impact on the quality of life of the people affected (Abano et al., 2011, Parisoto et al., 2009). Although dental caries can be controlled, it is still a serious public health problem in Brazil. According to a national survey, while five-year-old children had mean DMFT of 2.43, old people from 65 to 74 years old showed mean DMFT of 27.53 (Brazil, 2012).

Population aging associated with declining birth rates have significantly altered the Brazilian population pyramid. This demographic and epidemiological transition demonstrate that without adequate health care support for the elderly, the morbidity-mortality profile of this population group is changing (Moreira et al., 2005). Consequently, the elderly population is visibly growing with high rates of edentulism, periodontal problems, and decayed teeth. However, although etiological factors and prevention procedures are well known, there is a gap between the evidence found in the recent literature and the actual care provided in oral health services in Brazil.

Several educational preventive interventions have been proposed and studied in order to control caries activity and prevent cavity development and tooth loss. However, little is known about the long-term effects of these interventions, which clearly have the potencial to reduce costs and the prevalence of the disease.

System dynamics is a computer simulation technique already used in many different areas which can assist policy makers to choose the most appropriate interventions for their populations (Andrade et al., 2014; Hirsch et

al., 2012). This approach is suitable for the dynamic complexity that characterizes many public health issues. In a simulation model of interventions designed for early childhood caries, the results showed that the costs involved in treating caries could be drastically reduced if the youngest children and children at the highest risk of caries were targeted. It was concluded that this modelling system can effectively help policymakers to maximize investments on public health and clinical care (Hirsch et al., 2012). Another study, which investigated the participation of older adults in an oral health promotion program in New York City, showed the importance of the integration of different services to improve outcomes and reduce costs (Metcalf et al., 2014). However, there are few studies in the literature on the use of system dynamics in Dentistry as a tool to assist in the planning and prioritization of interventions. The application of such a model could bring important insights on the importance of educational approaches in differents stages of people's lives to prevent tooth loss caused by dental caries.

Therefore, the objective of this study was to simulate the long-term effect of educational preventive interventions in the maintenance of teeth throughout lifetime of people. This model may highlight the importance of preventive approaches to policymakers and health teams, contributing to maintenance of the life quality of the population.

METHODS

The natural history of the population

Our basic model structure considered the natural history of the Brazilian population, from birth to death, separated in different age groups (children/adolescents, adults and the elderly). A fraction of the population will move throughout their lives with adequate oral health and, consequently, improved life quality. In all phases of the history of a person, education can successfully result in the acquisition of healthy habits. Delays in the implementation of educational approaches can lead to the development of dental caries and subsequently to tooth loss, negatively affecting life quality.

Data source

We used multiple data sources obtained from: the National Oral Health Survey (PERES et al., 2013), *Instituto Brasileiro de Geografia e Estatística - IBGE* (Brasil, 2015); a recent systematic review (Suga et al., 2014); and two qualitative studies conducted with dentists, technicians and policymakers regarding their perception about factors that drive people towards dental caries prevention through educational approaches (unpublished data).

System Dynamics Modeling

The model used in this study was created and conducted using Vensim DSS, version 6.3 (Ventana Systems, Incorporation). System Dynamics has been used to describe and analyze complex systems, allowing a better understanding of how key constitutional elements interact to generate specific outcomes in order to find solutions to a particular problem (Sterman, 2000). The model was created using stocks and flows diagrams. Stocks are cumulative resources of a system, while flows represent the rate of change of a stock (Passos et al., 2013). The stocks were represented by "children/adolescents with oral health", "adults with oral health", "the elderly with oral health". All these stocks can flow through their respective evolution phase "with caries" and afterwards "with tooth loss". The model was constructed to continuously reflect the initial distribution of children/adolescents, adults and the elderly groups in the presence and absence of educational interventions.

Intervention: Educational preventive approach

Dental caries is a chronic disease, caused by the imbalance between the demineralization and remineralization periods of teeth, which can be controlled. There are many educational preventive measures to help people incorporate healthy habits to control the development of dental caries, preventing the occurrence of a cavity. In our modeling, we considered the educational preventive approach as being successfully implemented when people did not develop any cavity and the disease sequel could be controlled. Although there are many factors that could influence caries development, in this model we isolated the most important factor that directly affects the etiologic factors

involved in caries development (the acquisition of healthy habits) in order to estimate its contribution to future life quality.

Model Calibration and Sensitivity analysis

The oral health model was calibrated according to Table 1.

We hypothesized that each children/adolescents rate reduction obtained with the educational preventive approach could have an impact in reducing tooth loss of 10 times in the adult phase and 20 times in the elderly phase. We also evaluated the impact of a 4% decrease in children/adolescents rate without the educational preventive approach. According to Senge et al. (1990) we could have an exponential impact by investing in education during early childhood.

Table 1: Model Calibration with the estimation values for the educational preventive intervention

MODEL CALIBRATION			
Phase	**Parameter**	**Estimated value**	**Proper interval (degree of uncertainty)**
Children/Adolescents	Decrease in children/adolescents without educational intervention	4%	2 – 4%
Adults	Impact on Adults	10 times	5 – 10 times
Elderly	Impact on the Elderly	20 times	15 – 20 times

RESULTS

The findings from the simulations projected life quality improvement distributed in the differents age groups (children/adolescents, adults and the elderly), and dental caries reduction as a result of the interventions with the

educational approach, as demonstrated in Figure 1. The educational approach targeting the youngest children/adolescents can affect the entire adult and elderly population, leading to greater reductions in caries experiences. Prevention programs provide the greatest leverage, limiting the progression of the disease by treating caries at its early stages, preventing tooth loss.

The comparison of Figure 2 with Figure 3 shows the oral health evolution of the population after 4% optimization in the acquisition of healthy habits through the educational preventive approach. It is clear that the total amount of people with oral health along the years can change exponentially with the proposed intervention.

The sensitivity analysis for each variable studied with 20.000 simulations are demonstrated in Figures 4 to 10 . They show that the calibration of the variables were adequate to run the system. The probability of occurrence was expressed as the mean percent of groups, in yellow color, which indicates that 50% of the results obtained are in this range, 75% of the results are shown in the yellow plus green range, 95% are in the green plus blue plus yellow ranges, while 100% are within all color ranges.

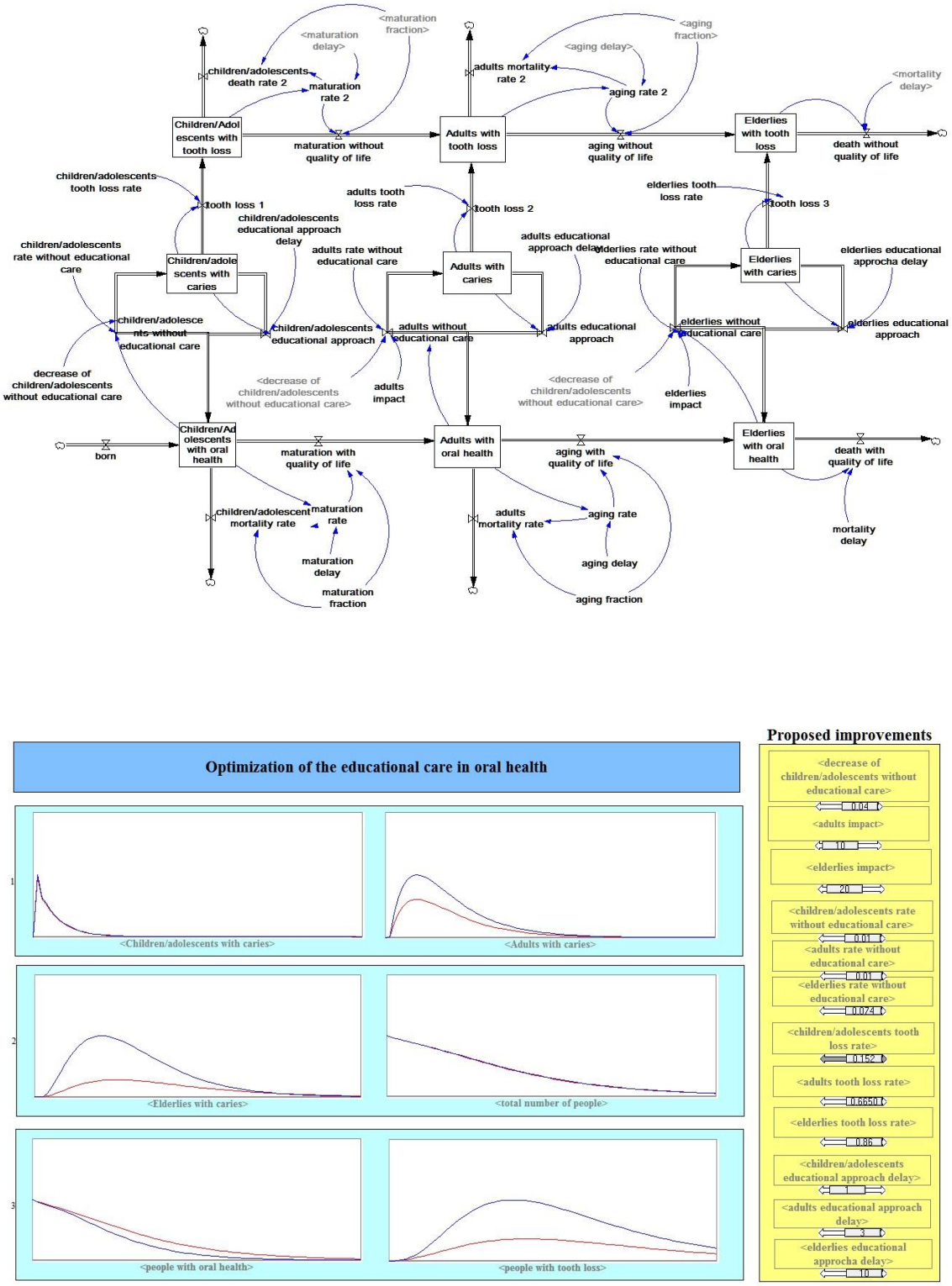

Figure 1: System Dynamic Model of the oral health education optimization

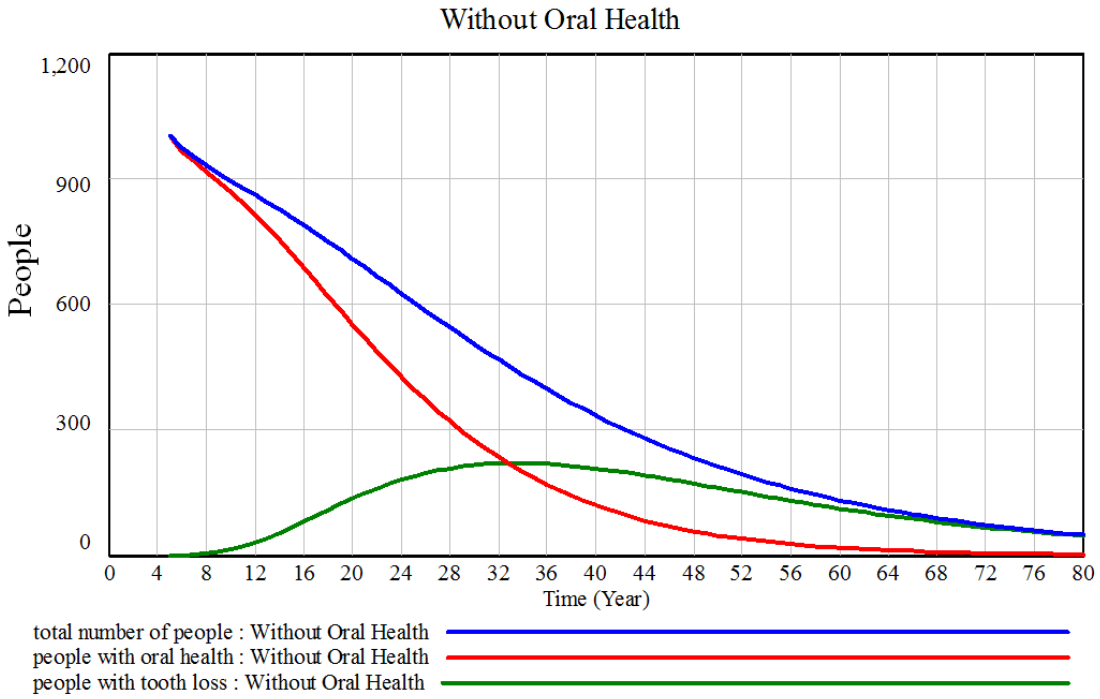

Figure 2: Total of people with or without oral health along their lifetime, without the educational optimization

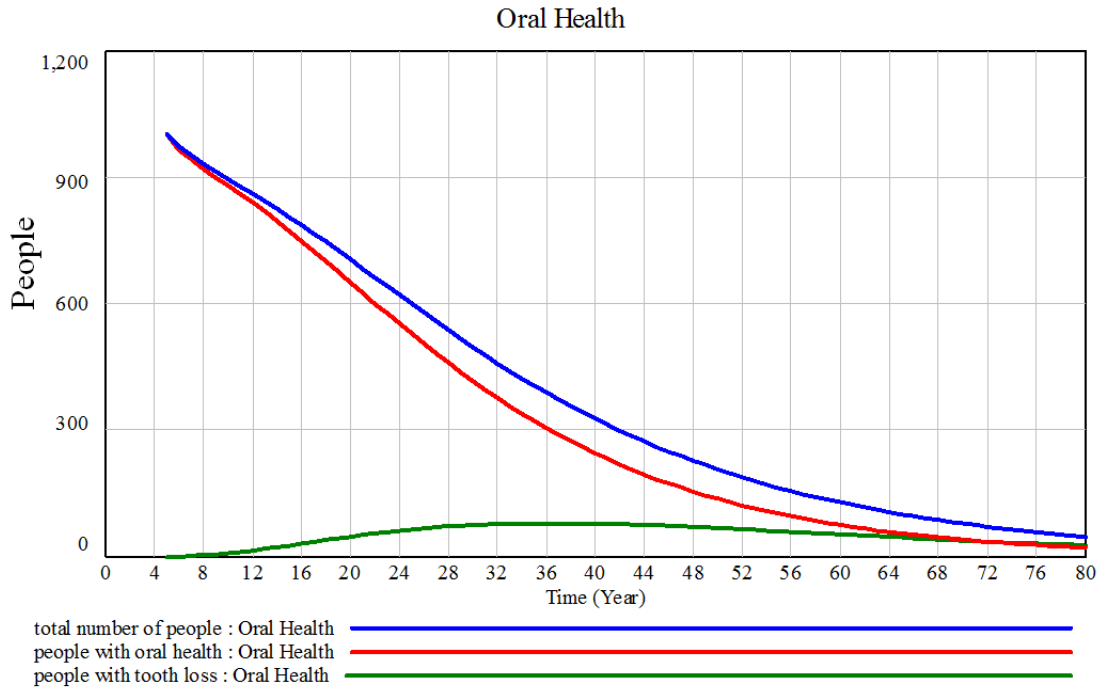

Figure 3: Total of people with oral health along lifetime, with the educational optimization

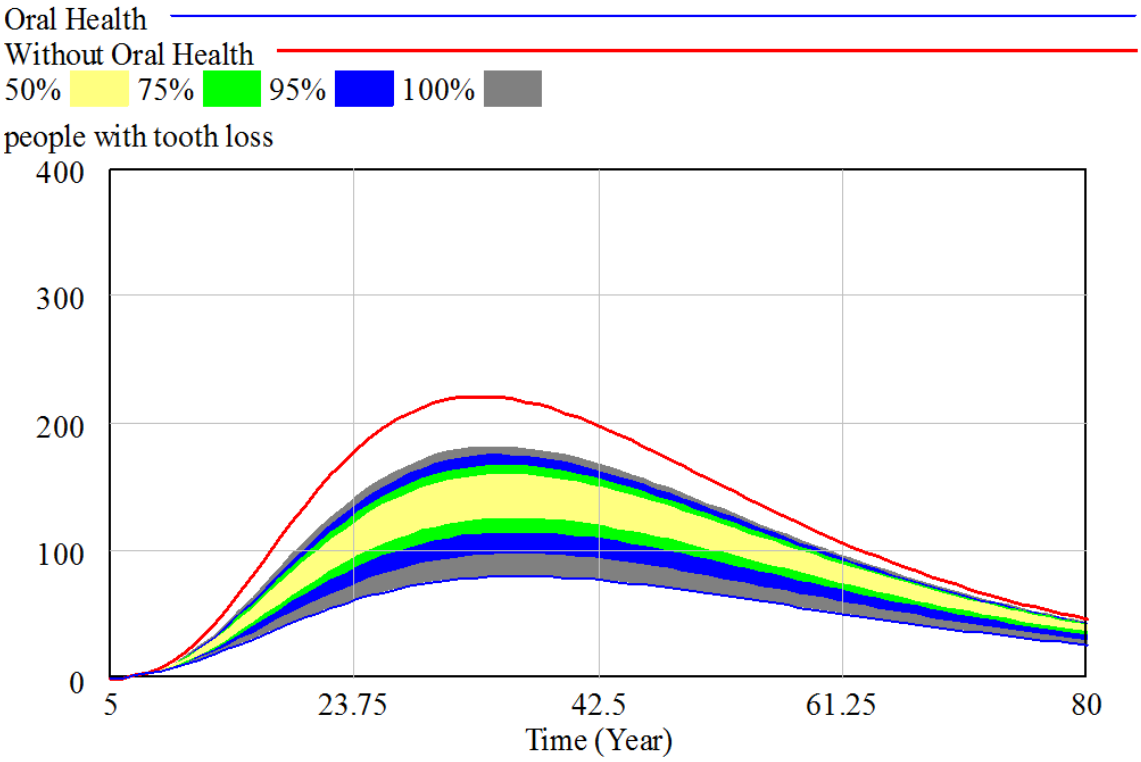

Figure 4: Sensitivity Analysis with 20,000 simulations: significant decrease of people with tooth loss.

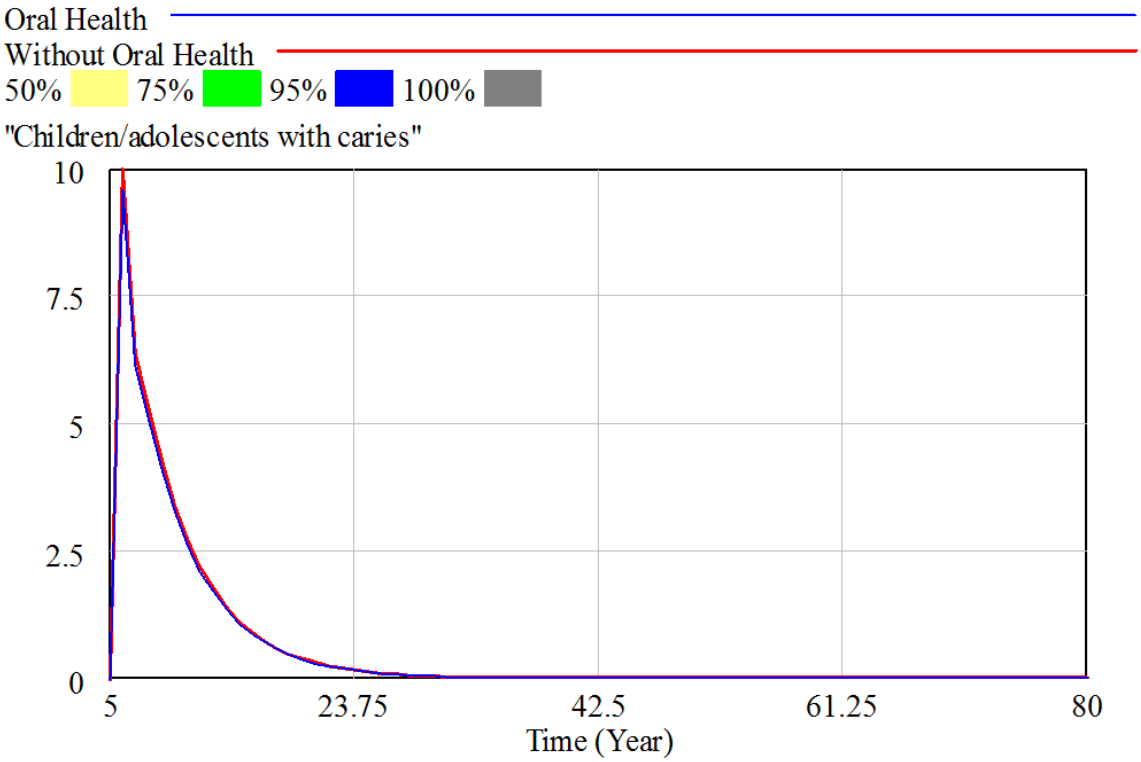

Figure 5: Sensitivity Analysis with 20,000 simulations: children/adolescents with caries

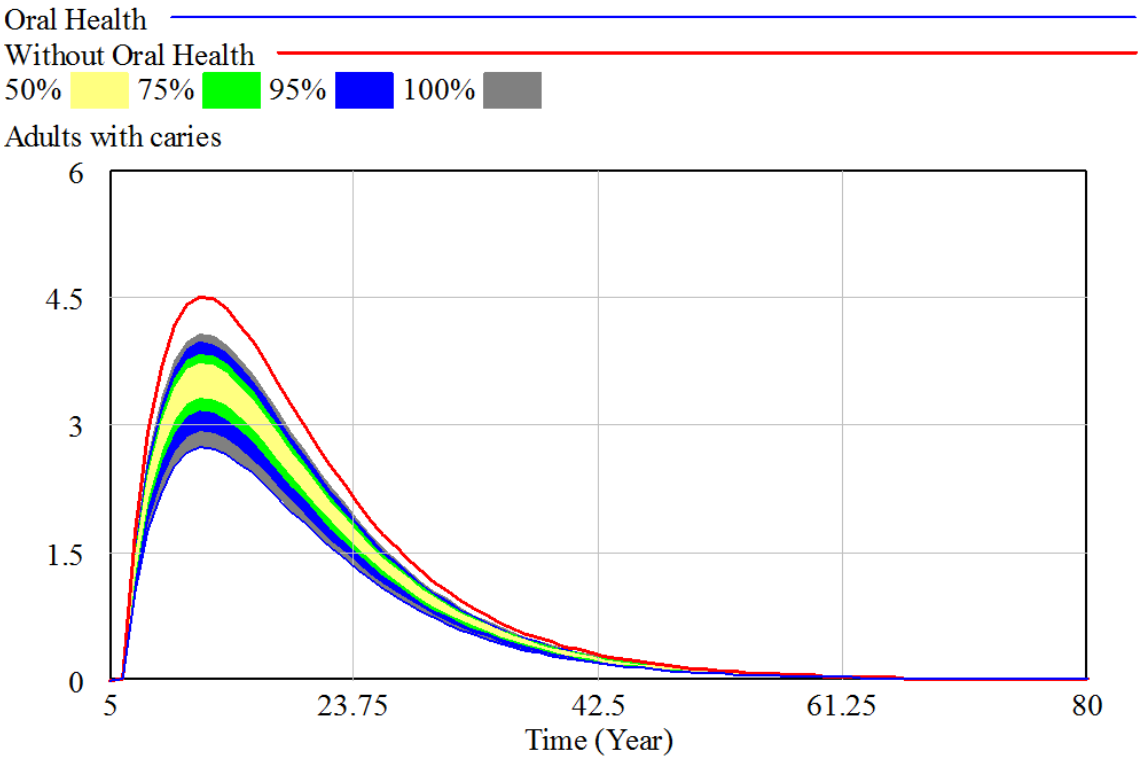

Figure 6: Sensitivity Analysis with 20,000 simulations: adults with caries

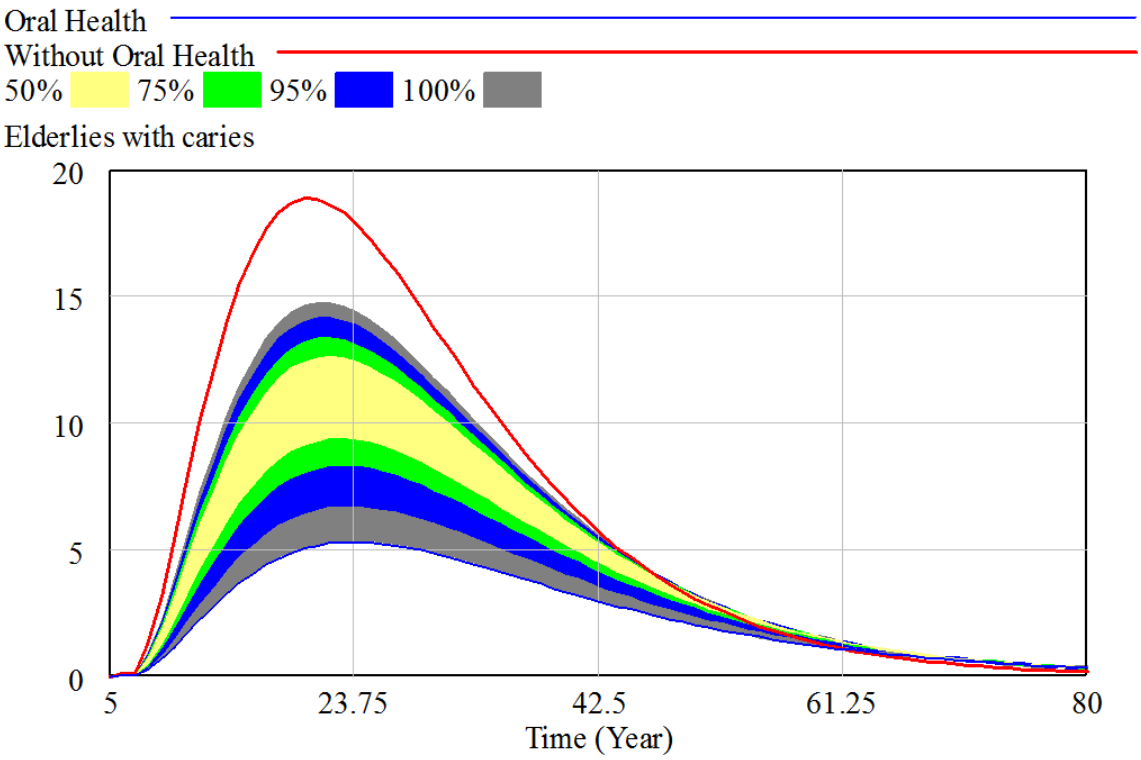

Figure 7: Sensitivity Analysis with 20,000 simulations: elderly with caries

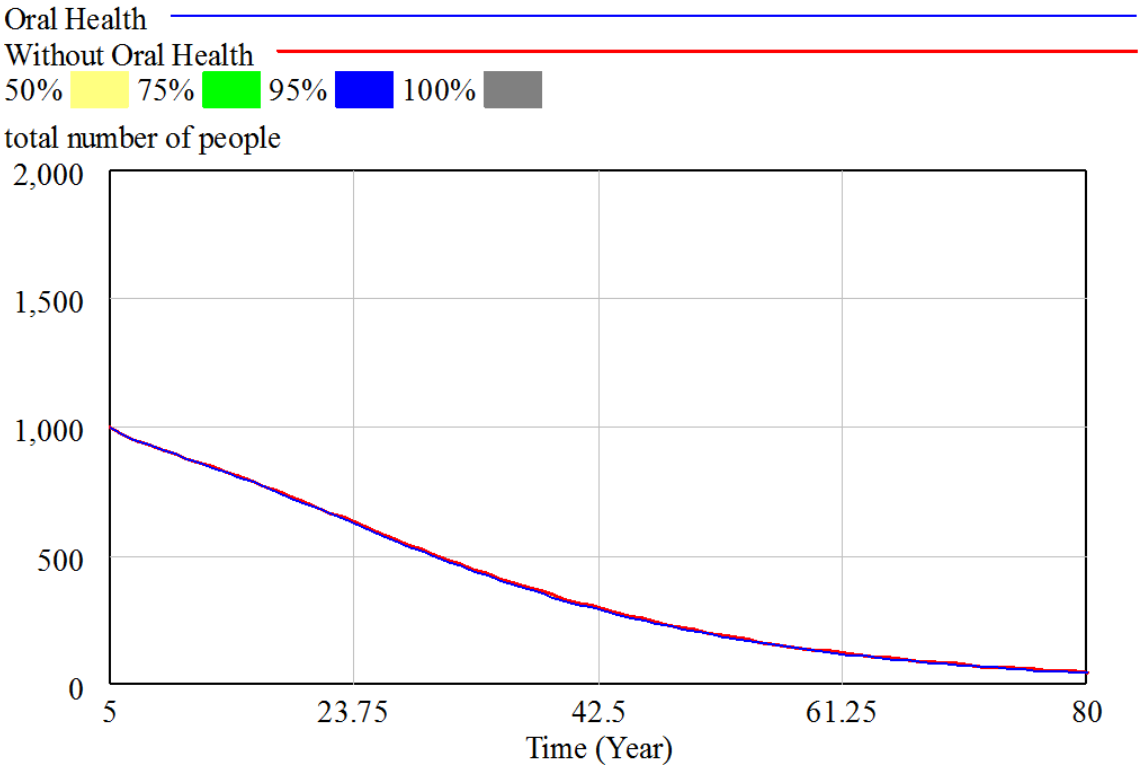

Figure 8: Sensitivity Analysis with 20,000 simulations: total number of people

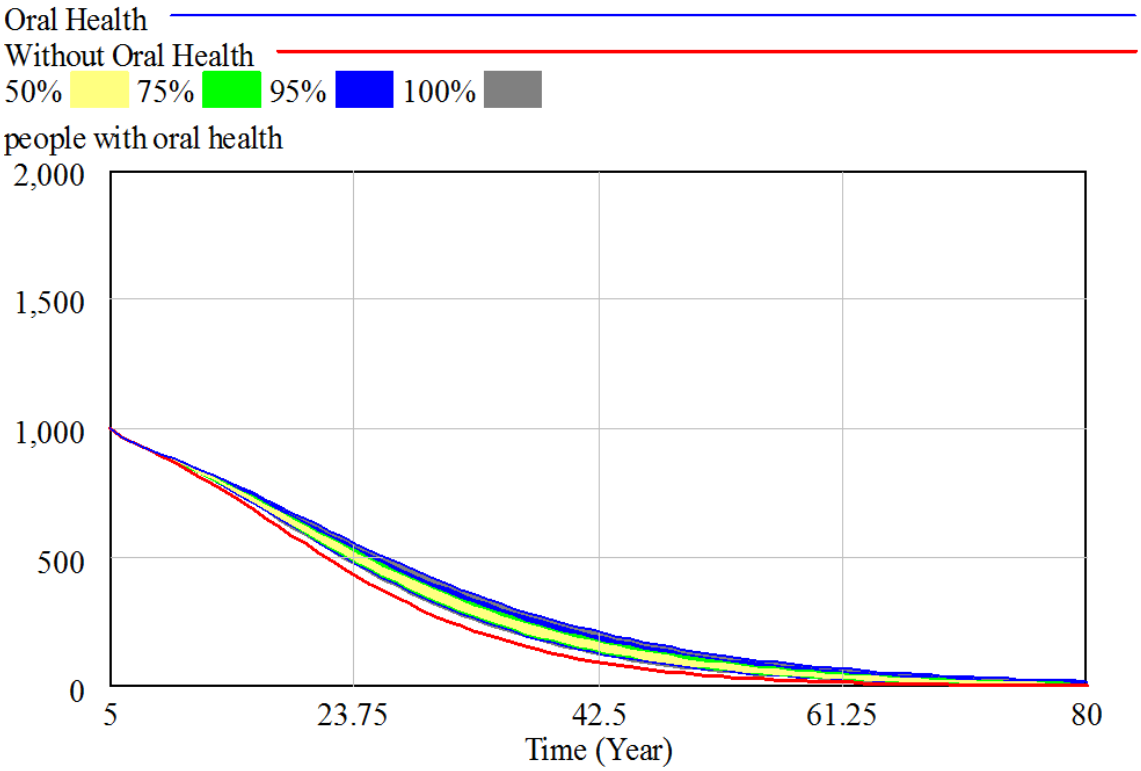

Figure 9: Sensitivity Analysis with 20,000 simulations: people with oral health

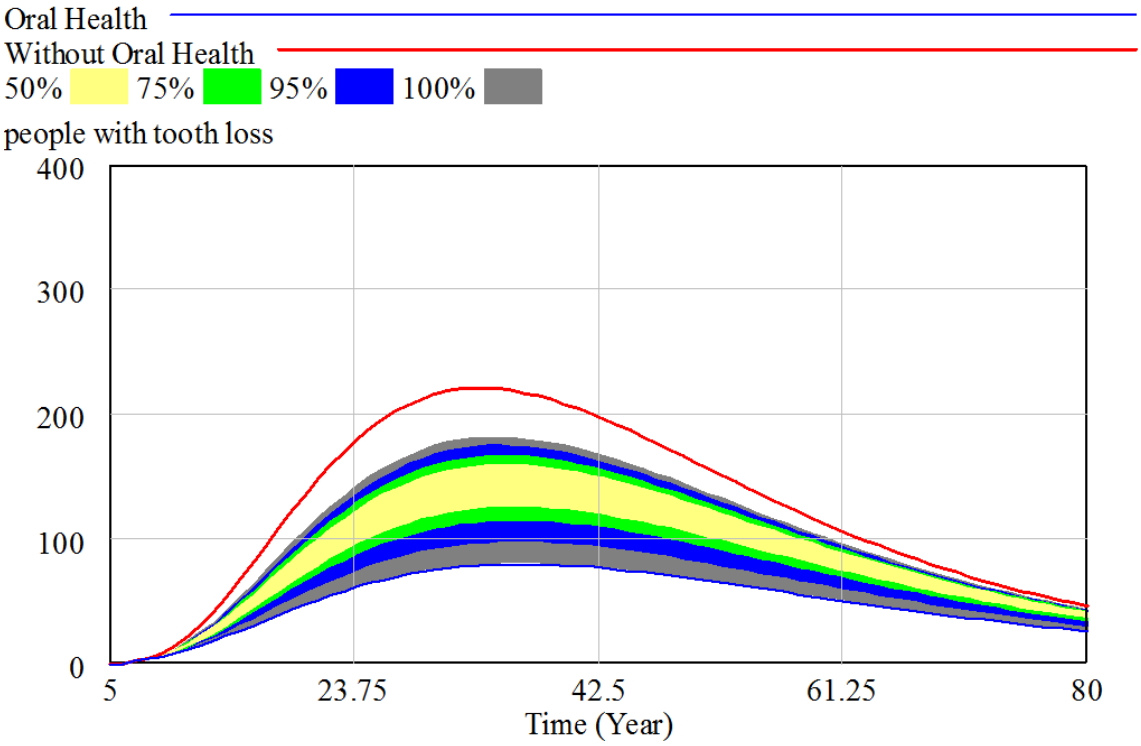

Figure 10: Sensitivity Analysis with 20,000 simulations: people with tooth loss

DISCUSSION

This is the first study to simulate the impact of an educational approach on the maintenance of oral health throughout the lifetime of people, starting from childhood, the most important period of life to establish healthy habits. With the results of this model, policymakers and health teams could allocate resources and time on interventions to improve health care provision and, as a consequence, benefit communities, families and patients.

Dental caries is still a serious public health problem among the Brazilian population, as indicated in the last national survey. Caries development can vary according to the socioeconomic status, mostly affecting the population with the lowest levels of education and income. The high cost of restorative treatments can be avoided if interventional educational approaches and preventive measures are considered as priority. Educational approaches can play an important role in the retention of teeth over time.

A recent systematic review on the factors that drive dentists towards caries preventive measures demonstrated that further education and training can

change the balance towards prevention (Suga et al., 2014). There are different tools and strategies to show and educate dentists on the importance of preventive measures, among which we find the system dynamics modelling. System dynamics is a methodology that can help to understand complex public health problems which have persisted for years (Homer and Hirsch, 2006). It may also be helpful to understand the main variables involved in caries development and anticipating the effect of interventions in complex situations.

This simulation model showed the importance of health education, which includes monitoring and evaluating the acquisition of healthy habits, i.e., adequate oral hygiene and proper diet. The investment in educational preventive approaches during early childhood could have an exponential effect in terms of improving oral health in the population as a whole. Hirsch et al. (2012) formulated a system dynamics model to assess and compare early childhood caries (ECC) interventions that provide the greatest effect in the reduction of caries and costs in the five-year-old children population of Colorado.

This analytical process for the comprehension of different issues, through the simulation of problems and situations that present dynamic behaviors, has been neglected in the definition and guidance of policies and investments, resulting in poor allocation of resources. Although this model didn't include some important variables such as water fluoridation, oral health care, and the use of fluoridated products, it showed the impact of the educational approach itself and the need to promote oral health and prevent tooth loss. However, future studies should include new variables to better understand the complex processes of caries development in the population. We suggest the use of the configurational comparative technique, which associates the qualitative and quantitative approaches (Ragin, 1987), known as the Qualitative Comparative Analysis (QCA). This technique offers the advantage of analysing samples in small-N situations, forming sets of variables based on half logical/mathematical criteria (Andrade et al., 2014).

CONCLUSION

In conclusion, our findings highlight the importance of investments on educational approaches from early childhood to result in an exponential cascade effect for the improvement of the oral health of the Brazilian population.

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REFERENCES

Andrade L, Lynch C, Carvalho E, Rodrigues CG, Vissoci JRN, Passos GF, Pietrobon R, Nihei OK, Carvalho MDB. System Dynamics Modeling in the Evaluation of Delays of Care in ST-Segment Elevation Myocardial Infarction Patients within a Tiered Health. PLoS ONE 9(7): e103577, 2014 doi:10.1371/journal.pone.0103577

Abanto J, Carvalho TS, Mendes FM, Wanderley MT, Bönecker M, Raggio DP. Impact of oral diseases and disorders on oral health-related quality of life of preschool children. Community Dent Oral Epidemiol. 39(2):105-14, 2011

Barbato PR, Peres MA. Perdas dentárias em adolescentes brasileiros e fatores associados: estudo de base populacional. Rev Saude Publica. 43(1):13-25, 2009. DOI: 10.1590/S0034-89102009000100003

Brasil. Ministério da Saúde. Secretaria de Atenção à Saúde. Secretaria de Vigilância em Saúde. SB Brasil 2010: Pesquisa Nacional de Saúde Bucal: resultados principais / Ministério da Saúde. Secretaria de Atenção à Saúde. Secretaria de Vigilância em Saúde – Brasília: Ministério da Saúde. 116 p., 2012

Hirsch GB, Edelstein SM, Frosh M, Anselmo T. A Simulation Model for Designing Effective Interventions in Early Childhood Caries. CDC - Preventing Chronic Disease: Volume 9, 2012.

Homer JB, Hirsch GB. System Dynamics Modeling for Public Health: Background and Opportunities. American Journal of Public Health Vol 96, No. 3, 2006.

Instituto Brasileiro de Geografia e Estatística - IBGE (Brasil, 2015). Fonte: http://brasilemsintese.ibge.gov.br/populacao/taxas-brutas-de-mortalidade.html. Access:

Moreira RS, Nico LS, Tomita NE, Ruiz T. A saúde bucal do idoso brasileiro:revisão sistemática sobre o quadro epidemiológico e acesso aos serviços de saúde bucal. Cad. Saúde Pública, Rio de Janeiro, 21(6):1665-1675, 2005

Passos, GF, Chamovitz I, Theodoulidis B. Organizational Responsibility Model: Dealing with demand for services higher than installed capacity. Article accepted for presentation at the IEEE SMC 2013 Conference (SMC: Systems Science), October, 2013.

Passos GF, Chamovitz I, Theodoulidis B. System Dynamics & Agent-Based approaches to face HR constraints. Article accepted at System Dynamics Case Repository as cases where system dynamics has made a big impact, available at link: http://cases.systemdynamics.org/system-dynamics-agent-based-approaches-to-face-hr-constraints/, September, 2014.

Peres MA, Barbatoll PR, Reis SCGB, Freitas CHSM, Antunes JLF. Tooth loss in Brazil: analysis of the 2010 Brazilian Oral Health Survey. Rev Saúde Pública 47(Supl 3):78-89, 2013

Petersen PE, Bourgeois D, Ogawa H, Estupinan-day S, Ndiaye C. The global burden of oral diseases and risks to oral health. Bull World Health Organ 83:661—9, 2005

Ragin CC. The comparative method: Moving beyond qualitative and quantitative strategies. Berkeley: University of California Press, 1987

Selwitz RH, Ismail AI, Pitts NB. Dental caries. Lancet 369:51—9, 2007;

Sterman JD. Business Dynamics: Systems thinking and modeling for a complex world. McGraw Hill, 2000

Senge P. M. The Fifth Discipline: The Art & Practice of Learning Organization. New York, NY: Doubleday, 1990