A global approach to assess the economic benefits of increased consumption of sugar-free chewing gum

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Abstract: Purpose: To analyze the influence of increasing the average consumption of sugar-free gum (SFG) in 25 industrialized countries on dental expenditures due to caries by the national health care systems. It was assumed that large cost savings were possible, because the regular consumption of SFG significantly reduces the relative risk of caries and therefore, improves dental health, which reduces expenditures on dental treatments. **Methods:** A budget impact analysis (BIA) was performed to model the decrease in the relative risk of caries and the subsequent cost savings for dental care. Annual consumption of SFG, dental expenditures due to caries, chewing frequencies by age groups and the relative risk reduction for caries due to the consumption of SFG were identified and used as model parameters. Three different scenarios for the increase in the number of SFG were calculated. Besides overall results for all countries together, analyses were conducted for countries grouped by regions and the Human Development Index (HDI). **Results**: For the entity of all 25 analyzed countries together, possible annual cost savings range from US$805.77 M in the scenario with the lowest increase of SFG consumption up to US$18,248 billion in the scenario with the biggest increase of SFG consumption. Europe and the USA show potential cost savings of US$1,061 billion and US$2,071 billion per year, respectively, if all chewers increase their consumption of SFG by 1 piece per day. The analysis showed the potential cost savings in dental expenditures due to caries that can be achieved by only slightly increasing the consumption of SFG. The regular consumption of SFG cannot replace good dental hygiene like tooth brushing, but can have a significant impact on dental health, which can lead to increased cost savings for health care systems worldwide. (*Am J Dent* 2017;30:77-83).

Clinical significance: Based on the fact that a regular consumption of sugar-free chewing gum has the beneficial effect of reducing caries prevalence, an increased consumption may not only lead to improved dental health but significant cost savings in expenditures for dental treatment worldwide.

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Introduction

Dental caries is a chronic multifactorial disease caused by bacteria. Bacteria in dental plaque metabolize carbohydrates and produce weak organic acids that lead to demineralization of dental tissues. Both the risk of disease and progression are influenced by several factors, e.g. production of saliva, salivary flow and pH and nutrition. Furthermore, individual health behaviors and social status influence caries development.[1] The main goal of oral health care is to maintain functional natural dentition.

In order to prevent or at least delay progression of the dental caries disease, many preventive measures have been implemented at different levels.[2] Consumption of sugar-free gum (SFG) is one preventive measure at the individual level that enhances dental health. SFG stimulates saliva which in turn promotes clearance of food debris from the mouth, buffers acids and provides calcium, phosphate and fluoride ions to remineralize demineralized enamel.[3,4]

Caries is the most common dental disease in industrial countries and results in both an economic burden and in health related problems. It is the primary cause of oral pain, infections and tooth loss and accounts for lost work days and increasing health care and hospital costs.[1,5-7] Dental health and the associated costs differ between countries, regions, and continents in line with the status of human and economic development. It can be assumed that the total global costs for caries mainly come from the largest industrial countries, as dental health systems, insurance programs and prevention measures are better developed, which allow better than average dental health in the society.[8]

This study chose a global approach to assess the economic benefits of SFG.

Materials and Methods

The following analysis modeled the potential decrease in dental health costs from caries for 25 industrial countries. Costs for each country considered served as a basis for the model, from which potential cost savings will be calculated. Scientific journals and governmental websites served to identify country-specific dental costs. A review of the literature was performed to search for studies that have analyzed the impact of the consumption of SFG on dental health. Four relevant studies were identified and used to calculate one overall scale that models the decrease in the relative incidence of caries based on the number of SFG pieces consumed per year.[9-12] Characteristics and main findings of these studies are summarized in Table 1.

In the absence of any evidence for the impact on the incidence of caries in adults, it was assumed that the same caries benefit observed in (school) children would also apply to adults. This assumption may overstate the benefit of gum chewing in adults, because children are likely to have a greater capacity to benefit from avoiding caries, as caries attack figures

Table 1. Characteristics of included studies for modeling.

Author/Year/ Country	Participants (after dropouts)	Participant age	Follow-up period	Groups	Chewing habits	Increment of DMFS[a]
Alanen[9] /2000/ Estonia	740 (567)	10 yrs	3 years	Xylitol chewing gum Two different xylitol candies Control	2-3 pieces of candy 3x/day; 6 pieces of gum per day chewed for 10 minutes	Mean increment of DMFS in the xylitol chewing gum group was 57.7% lower than in the control group. For the xylitol candies, 61.0% and 37.3% lower than in the control group.
Machiulskiene[10]/ 2001/Lithuania	602 (432)	9-14 yrs	3 years	Sorbitol/carbamide gum Sorbitol gum Xylitol gum Control gum No gum	5 pieces of gum per day chewed for at least 10 minutes	Mean increment of DMFS was lowest in the xylitol gum group (34.7% lower than the no gum group). Sorbitol and control gum were still better than no gum (27.4% and 33.1% lower than no gum).
Peng[11] /2004/ China	1342 (1143)	6-7 yrs	2 years	Oral health education (OHE) OHE + sugar-free chewing gum Control		Mean increment of DMFS was 42.3% lower in the sugar-free chewing gum group than in the OHE or control group.
Szöke[12]/2001/ Hungary	583 (547)	8-13 yrs	2 years	Sorbitol chewing gum Control	3 pieces of gum per day chewed for 20 minutes	Mean increment of DMFS was 38.7% lower in the gum group than in the control group.

a = DMFS = number of decayed, missing, or filled surfaces.

Suppl. Table 1. Consumption of sugar-free chewing gum.

Country	Current PCC[a]	Country	Current PCC[a]
Switzerland	221.70	Argentina	76.69
Sweden	143.70	Mexico	73.74
US	125.75	Italy	66.46
UAE	108.34	Brazil	65.78
Canada	108.12	Turkey	57.37
Germany	101.27	Ukraine	57.20
UK	89.32	Saudi Arabia	49.52
Russia	84.98	Taiwan	40.75
France	82.48	China	26.32
Poland	79.08	South Africa	26.17
Spain	78.62	Indonesia	1.08
Japan	77.21	India	0.38
Australia	76.76		

a: PCC= Per Capita Consumption of sugar-free chewing gum per year.

are highest 0-3 years after eruption of teeth.[9] Analyses from these studies were weighted by age groups, participants, duration and combined into one consolidated result. A consumption of 1,420 pieces of SFG per year was approximated from the average consumption in the studies to equal a reduction in relative risk for caries of 40.7% (derived from a meta-analysis of the reported study outcomes). Relationship between caries risk reduction and annual SFG consumption was assumed to be exponential with the exponential equation:

$$\text{Relative Risk Reduction} = e(\text{annual SFG} * \mu)/100 \text{ with } \mu = 0.00261.$$

Country selection

Worldwide cost calculations (in healthcare) are undertaken primarily in developed countries, which provide strong economies and elaborated healthcare systems. To cover the industrialized world, the G20 nations and five additional countries (due to their gross domestic product) were chosen for the calculation of the global impact of SFG. The European Union was further separated to individual member states to calculate country-specific cost savings. All included countries are listed in Table 2. The total gross domestic product (GDP) of all countries included in the study represented 77.1% of the global total GDP.[13]

Besides a worldwide analysis for all 25 countries together, countries were grouped by continents or the Human Development Index (HDI). The HDI is a relative indicator of the developing status of a country. It classifies human development based on life expectancy, education and per capita income. Based on HDI, cost savings were analyzed for very highly to moderately developed countries.

Only citizens aged 10 years and older were included, as this was the cut-off age for available data.[14] There was no upper age boundary for the consumption of SFG. The total number of people aged 10 years and older in the 25 countries included in the study was 3.86 billion, which represented 52.7% of the global population.

Dental costs due to caries

For 15 countries, annual health expenditures due to dental treatments were identified from governmental websites, university websites or journals of the International Organization of Scientific Research (IOSR). As the study focused on reduction of dental costs due to caries, the share of dental costs that account for treatment of caries were estimated based on expert opinion or governmental data. This includes 70% costs for dental services and 30% costs for dentures. Calculations were based on German data for dental expenditures[15-17] assigning 60% of dental service costs and 70% of costs for dentures to caries treatment. The rest of the costs consisted of treatments not due to caries, such as periodontal screening, scaling, treatment of hypersensitive teeth, oral hygiene instructions, excisions of mucosa, surgery and follow-up, or extractions for other reasons. Therefore, the percentage of dental costs from caries was estimated as follows:

Costs for dental services * Share of costs for dental services due to caries + Costs for dentures * Share of costs for dentures due to caries = 70%*60%+30%*70%=63%.

In Germany, costs for periodontal treatment are very low compared to the burden of the disease so that applying the 63% to other countries may over- or underestimate the share of dental costs for caries.

For Australia and China, experts assigned only 42% and 44% of dental service costs to caries treatment. For 10 countries, no direct data on dental expenditures could be found. Costs for

treating caries were then estimated as follows:

- For countries for which GDP and dental costs due to caries were available the share of caries dental costs of the GDP was calculated.
- Countries were then grouped by HDI into three groups: very high, high, and medium.
- For each HDI group the average share of dental costs due to caries was calculated.
- This share was then applied to the GDP of the 10 countries where data on dental expenditure was missing.

Annual costs of treating caries and their share of the total dental expenditures for each country are listed in Table 3.

Table 2. List of included countries by continent.

Europe	Americas	Asia	Africa	Australia
France	Argentina	China	South Africa	Australia
Germany	Brazil	India		
Italy	Canada	Indonesia		
Poland	Mexico	Japan		
Russia	United States	Saudi Arabia		
Spain		Taiwan		
Sweden		United Arab Emirates		
Switzerland				
Turkey				
Ukraine				
United Kingdom				

Suppl. Table 2. Potential cost savings. Regional extremes.

Scenario	Country	Current PCC[a]	Increased PCC[a]	Current Costs (in M $)[b]	Costs after increase in SFG consumption (in M $)[b]	Estimated Cost Savings (in M $)	Relative Decrease in Costs
Minimal	USA	188.62	266.07	69,930.00	69,522.72	407.28	0.58%
Health Economically Recommended	USA	188.62	459.73	69,930.00	67,858.69	2,071.31	2.96%
Clinically Recommended	USA	188.62	815.63	69,930.00	61,981.76	7,948.24	11.37%
Minimal	China	39.48	89.10	14,747.44	14,718.17	29.27	0.20%
Health Economically Recommended	China	39.48	213.12	14,747.44	14,598.60	148.84	1.01%
Clinically Recommended	China	39.48	522.28	14,747.44	13,606.72	1,140.72	7.74%
Minimal	Europe	123.17	190.61	49,055.99	48,847.20	208.79	0.43%
Health Economically Recommended	Europe	123.17	359.20	49,055.99	47,994.15	1,061.84	2.16%
Clinically Recommended	Europe	123.17	710.00	49,055.99	44,121.16	4,934.83	10.06%

[a] PCC= Per Capita Consumption of sugar-free chewing gum per year, weighted average by respective group.
[b] costs of treating caries.

Per capita consumption of SFG

The per capita consumption (PCC) shows the individual average annual consumption of chewing gum per country. PCC data was provided by Nielsen/US Census for the year 2014. Only data of sugar-free chewing gum was used for analysis. The PCC of SFG in the different countries is shown in Supplemental Table 1.

Chewing frequencies by age group

To meet different consumer behaviors, five levels of SFG consumption were defined according to the Nielsen/US Census: 'Do not use' (0 chewing occasions per week), 'infrequent (0.5 chewing occasions per week), 'light' (2.5 chewing occasions per week), 'medium' (7 chewing occasions per week) and 'heavy' (14 chewing occasions per week). Chewers were further clustered into different age groups: 10 to 14 years, 15 to 49 years, 50 to 59 years and more than 60 years of age. Data provided by market research firm Harris Interactive covered the first three groups, as well as the total consumption of SFG by all age groups, so the chewing frequency for the fourth age group (60+) could be inferred. Chewing frequencies by age group were modeled individually for each country. For clustered analysis, distribution tables were combined and weighted by population share.

Increase in SFG consumption

To model the impact of an increase in the consumption of SFG, three different scenarios were designed:

Minimal effect scenario (Scenario 1)

The first scenario models the minimal increase that is scientifically relevant from the dental health point of view. In this scenario, the consumption for all people who already consume SFG (i.e. all people who are not in the usage group 'do not use') will increase by two pieces of SFG per week. This scenario is based on the assumption that an increase of two SFG per week for all chewers poses the minimal increase of SFG that has a positive effect on the prevention of caries.

Health economically recommended scenario (Scenario 2)

In this scenario, all chewers (i.e. all people who are not in the usage group 'do not use') increase their consumption by one piece of SFG per day/seven pieces of SFG per week. This scenario combines feasibility with regard to compliance and is also clinically relevant in the sense of expected positive effects on dental hygiene and caries prevention.

Clinically recommended scenario (Scenario 3)

In this scenario, the consumption for all chewers (i.e. all people who are not in the usage group 'do not use') was set to three pieces of SFG per day/21 pieces per week. This is the amount of SFG that has been used in several clinical trials.

Budget impact analysis

By combining national chewing frequencies of SFG with the costs of dental treatments due to caries, savings potentials from the national payers' perspective were modeled if the consumption of SFG increased. The cost savings were identified by a Budget Impact Analysis (BIA). The general assumption is that the costs decrease proportionally to the reduction in the relative risk of caries which depends on the chewing frequencies in different age groups and countries. Therefore, differences in health care systems in the different

Table 3. Identified/estimated annual dental costs per country due to caries.

Country	Estimated costs of treating caries in US$	Share of total dental expenditures due to caries	Source
Argentina	1,593,590,000.00	63%	No data available // estimated by HDI group and GDP
Australia	5,074,999,150.77	42%	http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=60129547594
Brazil	2,494,800,000.00	63%	http://ncohr-rcrsb.ca/knowledge-sharing/working-paper-series/content/garbinneumann.pdf
Canada	7,270,750,886.77	63%	https://www.cihi.ca/en/nhex_2014_report_en.pdf
China	14,747,439,467.45	44%	Estimation based on 3rd National Oral Health Survey (2005) and expert opinion: Costs due to caries were estimated to be 44.2%.
France	7,259,609,802.70	63%	http://www.irdes.fr/EspaceAnglais/Publications/IrdesPublications/QES111.pdf
Germany	10,098,345,396.87	63%	Perspective of the German statutory health insurance system based on BEMA (Assessment Standards for Dental Services) and the subsidies for prosthetic restorations.
India	6,252,500,000.00	63%	No data available // estimated by HDI group and GDP
Indonesia	2,710,230,000.00	63%	No data available // estimated by HDI group and GDP
Italy	11,018,113,678.95	63%	Estimated by the CECDO (The Council of European Chief Dental Officers) database accessed at http://cecdo-test.goeg.at/oral-healthcare/cecdo-database/ and GDP (Gross Domestic Product) numbers by the World Bank: World databank. Accessed at http://databank.worldbank.org
Japan	16,265,438,280.00	63%	http://www.sciencedirect.com/science/article/pii/S1882761613000392
Mexico	1,359,980,000.00	63%	No data available // estimated by HDI group and GDP
Poland	594,113,972.88	63%	Estimated by the CECDO (The Council of European Chief Dental Officers) database accessed at http://cecdo-test.goeg.at/oral-healthcare/cecdo-database/ and GDP (Gross Domestic Product) numbers by the World Bank: World databank. Accessed at http://databank.worldbank.org
Russia	5,478,150,000.00	63%	No data available // estimated by HDI group and GDP
Saudi Arabia	2,219,875,000.00	63%	Saudi Arabia No data available // estimated by HDI group and GDP
South Africa	1,068,194,975.59	63%	http://www.hst.org.za/uploads/files/chap3_07.pdf
Spain	3,641,841,496.12	63%	Estimated by the CECDO (The Council of European Chief Dental Officers) database accessed at http://cecdo-test.goeg.at/oral-healthcare/cecdo-database/ and GDP (Gross Domestic Product) numbers by the World Bank: World databank. Accessed at http://databank.worldbank.org
Sweden	2,083,256,788.04	63%	Estimated by the CECDO (The Council of European Chief Dental Officers) database accessed at http://cecdo-test.goeg.at/oral-healthcare/cecdo-database/ and GDP (Gross Domestic Product) numbers by the World Bank: World databank. Accessed at http://databank.worldbank.org
Switzerland	439,387,200.00	63%	http://www.chuv.ch/bdfm/cdsp/85134.pdf
Taiwan	3,183,050,000.00	63%	No data available // estimated by HDI group and GDP
Turkey	854,466,000.00	63%	No data available // estimated by HDI group and GDP
United Arab Emirates	1,820,445,000.00	63%	No data available // estimated by HDI group and GDP
United Kingdom	7,445,714,075.76	63%	Estimated by the CECDO (The Council of European Chief Dental Officers) database accessed at http://cecdo-test.goeg.at/oral-healthcare/cecdo-database/ and GDP (Gross Domestic Product) numbers by the World Bank: World databank. Accessed at http://databank.worldbank.org
Ukraine	142,994,000.00	63%	No data available // estimated by HDI group and GDP
United States	69,930,000,000.00	63%	https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/downloads/highlights.pdf

countries did not influence the validity of the results.

Results

For analysis, countries were grouped in three different ways: all 25 countries combined (worldwide), regional extremes (i.e. USA, China, Europe) and according to their developmental stage (very high HDI, high HDI, medium HDI). For all groups, analyses were conducted for the three scenarios "minimal effect", "health economically recommended" and "clinically recommended" with respective increase of SFG consumption.

Worldwide

In the first scenario, where all chewers increase their consumption by two pieces per week, annual cost savings of US$805.77 M were possible. This means a relative cost decrease of 0.44%. This value is about five times as high (2.23%) in Scenario 2 and yields cost savings of US$4.097 billion. In the third scenario, caries costs of all 25 countries were modeled to decrease by about 10%, which equals savings of US$18.248 billion per year.

Regional extremes

The highest cost savings within Scenario 1 were possible in the USA: US$407.28 M (0.58%) can be saved each year if every chewer increases his or her consumption by two pieces of SFG per week. In China, where the PCC of SFG is relatively low compared to Europe or the USA, 1% of dental health expenditures can be saved in Scenario 2 when all chewers increase their consumption by seven SFG per week. Europe can save US$4.935 billion in the clinically recommended scenario 3, i.e. 10% of annual dental expenditures. The results for the regional extremes (USA, China, and Europe) are summarized in Supplemental Table 2.

Human Development Index

The group of very high HDI countries (well developed) achieved annual cost savings of US$757.19 M if the consumption of SFG increased by two pieces per week for every chewer (Scenario 1). This is a relative decrease in the

Suppl. Table 3. Potential cost savings by Human Development Index (HDI).

Scenario	HDI[a]	Current PCC[b]	Increased PCC[b]	Current Costs (in M $)[c]	Costs after increase in SFG consumption (in M $)[c]	Estimated Cost Savings (in M $)	Relative Decrease in Costs
Minimal	Very High HDI	143.18	212.00	153,737.10	152,979.91	757.19	0.49%
Health Economically Recommended	Very High HDI	143.18	388.87	153,737.10	149,886.26	3,850.84	2.50%
Clinically Recommended	Very High HDI	143.18	744.91	153,737.10	137,209.43	16,527.67	10.75%
Minimal	High HDI	53.45	107.95	19,599.68	19,553.48	46.20	0.24%
Health Economically Recommended	High HDI	53.45	244.15	19,599.68	19,364.72	234.96	1.20%
Clinically Recommended	High HDI	53.45	573.60	19,599.68	17,931.30	1,668.38	8.51%
Minimal	Medium HDI	2.06	4.06	10,030.92	10,028.54	2.38	0.02%
Health Economically Recommended	Medium HDI	2.06	9.08	10,030.92	10,018.81	12.11	0.12%
Clinically Recommended	Medium HDI	2.06	21.17	10,030.92	9,942.96	87.96	0.88%

[a] HDI = Human Development Index; Very High HDI (>0.8): AUS, ARG, CAN, FRA, GER, ITA, JAP, POL, RUS, KSA, ESP, SWE, SUI, TAI, UAE, UK, USA. High HDI (0.7<HDI<0.8): TUR, MEX, BRA, UKR, CHN, Medium HDI (<0.7): IND, INA, RSA.
[b] PCC= Per Capita Consumption of sugar-free chewing gum per year, weighted average by respective group.
[c] costs of treating caries.

costs of 0.49%. Regions with a high HDI reduced their dental costs by US$46.2 M (0.24%) per year. In countries with a medium HDI, annual cost savings in the amount of US$2.38 M were possible (relative decrease: 0.02%). The decrease in costs for medium HDI countries was relatively small when compared to the higher HDI groups, because the initial consumption of SFG was very low. In Scenario 3, with three pieces of SFG per day, cost savings between US$88.0 M - 16.528 billion (0.88-10.75%) are possible depending on the HDI. Supplemental Table 3 shows cost savings and relative decrease in costs for the three scenarios and the three different groups of HDI.

Discussion

The results of the present budget impact analysis show that an increase in SFG consumption results in significant costs savings for dental treatment due to caries, thus emphasizing the prophylactic benefits of SFG, although it cannot replace regular tooth brushing and other prophylactic programs like fluoridation.

While the effect may vary individually with regard to countries, social status or age, in the present study it was assumed that the beneficial influence of SFG leads to the same relative caries risk reduction in all 25 countries. To overcome this potential drawback, calculations of the relative risk reductions were based upon the most reliable sources which were combined in a meta-analysis to assure precision and accuracy of estimated parameters.

The literature review showed that the Western world lacks studies regarding the caries protective effect of SFG and the impact of SFG benefits in adults. Most of the studies were conducted in Eastern Europe or China and included only children aged 6 to 14 years. Teeth are more susceptible to caries in the first 3 years after eruption, so the likelihood of developing caries is greater in children than in adults.[9] As the mechanisms of caries are independent of age, application of published data to the model poses negligible limitations, although it is possible that the impact of SFG on primary teeth may differ from that on permanent teeth. For this reason, the study from Kovari et al,[18] who evaluated the caries preventive effect of SFG in children aged 3 to 6 years, was excluded. The cut-off date for the present study (2000) led to exclusion of the studies from others[19-21] from the USA and Finland. Morgan et al[22] compared two different kinds of SFG at several schools in Australia, so it was impossible to calculate the singular effect of SFG compared to no gum in the absence of a control group. The study of Tao et al[23] was excluded due to a relatively small sample size of only 157 children. Ultimately, the relative caries risk was calculated based on four studies that combined a total of >3,000 children which provided substantial mathematical support.[9-12]

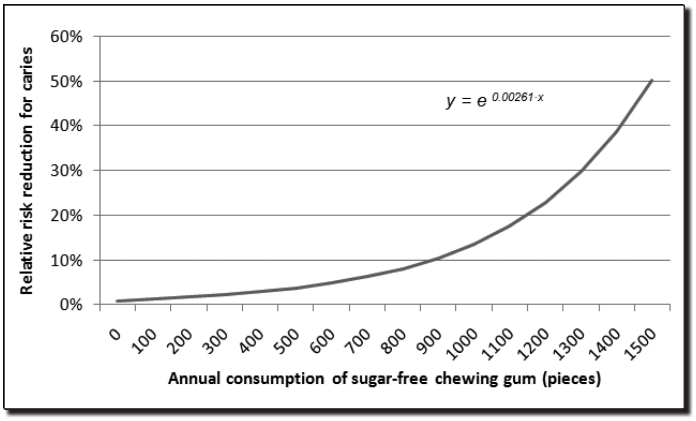

Figure. Relationship between annual SFG consumption and relative risk reduction for caries. Exponential approach.

Since expenditures for dental treatments due to caries were not available for all countries, total dental costs were identified for 14 countries and inferred for the remaining 11 countries by their share of the GDP. The percentage of dental costs due to caries was based on expert opinion as the best possible estimate. In third world countries it is likely that the share of costs for treating caries on overall dental costs is greater than the 63% (42% for Australia and 44% for China) estimated for the majority of countries. It was generally assumed that the costs for dental treatments drop proportionally to the reduction of the caries risk. Although this represents the most logical relationship, other mathematical relationships are plausible.

An important basis for the model is the relationship between the number of SFG consumed and the relative caries risk reduction. This dose-relationship was presumed to be exponential, as the initial slope is flatter than with a linear approach (Figure), so that the more pieces of SFG consumed annually, the greater the increase in risk reduction. For a linear

Table 4. Potential cost savings worldwide.

Scenario	Country	Current PCC[a]	Increased PCC[a]	Current Costs (in M $)[b]	Costs after increase in SFG consumption (in M $)[b]	Estimated Cost Savings (in M $)	Relative Decrease in Costs
Minimal	Worldwide	59.73	101.10	183,367.70	182,561.94	805.77	0.44%
Health Economically Recommended	Worldwide	59.73	204.53	183,367.70	179,269.79	4,097.91	2.23%
Clinically Recommended	Worldwide	59.73	435.59	183,367.70	165,083.69	18,248.01	9.95%

[a] PCC= Per Capita Consumption of sugar-free chewing gum per year, weighted average by respective group.
[b] costs of treating caries.

approach the benefit of an additional piece would be irrespective of the annual amount consumed. This exponential dose-response relationship was modeled based on data from clinical trials.[9-12] Clinical data of real-life patients are needed, to confirm or refute this approach and to generate realistic risk reduction rates.

It should be emphasized that the present study focused on the benefits of chewing SFG on dental health. Sugar-containing gums provide a source of sugar that gradually releases during consumption and could promote development of caries despite increased saliva flow, as confirmed by studies showing a direct relation between sugar intake and caries.[24] Thus, dental expenditures would rise. Global data provided by the Nielsen/ US Census showed that in 2015, 85.1% of gum chewers used SFG, the number increasing steadily over the years.

Social status plays a major role in dental health.[1] Access to oral hygiene and dental treatment depends on socio-economic factors, such as education or income, and place of residence that differ between countries.[25] For people with low social status and household income, who do not have regular dental exams, SFG may be the main oral health treatment besides tooth brushing. Therefore, the benefit from chewing SFG may vary across groups and significant impacts are possible in low-income people.

According to Sischo & Broder,[26] oral health-related quality of life (OHRQoL) can have an influence on five different dimensions: oral health, social and emotional well-being, dental functioning, environment and treatment expectations. Children in particular may suffer from lowered self-esteem or well-being due to caries-related morbidities,[27] while severe caries in children may require surgical tooth extractions, further increasing dental costs and poses a risk for (painful and costly) complications. For both adults and children, co-morbidities associated with caries may lead to pain and lost work or school days.[6] Conversely, improved dental health reduces time-consuming dental visits, leaving more leisure time for patients. Perhaps even fear of dental visits would be reduced, if no painful treatments are necessary due to improved oral health. Furthermore, patients with good dental health feel more attractive and more likely take part in social activities.[26] Thus, benefits from SFG consumption may reach beyond the budgetary factors, with additional intangible social benefits accompanying the theoretical caries reductions and cost savings.

This study represents a solid and substantial approach to the accurate calculation of cost savings in industrial countries that would arise from increased SFG consumption. Three scenarios of SFG usage increase have been presented: a minimal increase scenario (Scenario 1: two additional pieces of gum per week), a scenario recommended by health economics; (Scenario 2: seven additional pieces of gum per week); and a clinically recommended scenario (Scenario 3: consumption of 21 pieces of gum per week). With regard to the clinical studies in Table 1, three or more pieces of SFG per day are needed for a statistically proven effect in caries reduction. Scenario 3 thus represents the clinically recommended scenario that has the highest prophylactic effect for the patient. Consequently, dental health improves much more in this scenario which leads to the highest cost savings. However, depending on the current consumption in the country, a vast increase in SFG consumption is needed to reach three pieces per day. In anticipation that parts of the population will not accomplish this high set goal of consumption, two additional scenarios were developed. Scenario 2 puts the focus on cost savings rather than dental health (therefore called 'Health Economically Recommended'). As the cost savings are directly linked to the relative caries risk reduction which in turn is linked to the SFG consumption, health economists agreed that an increase of one additional piece per day would lead to a significant cost reduction of dental expenditures. As it is possible that a critical threshold exists, beyond which the caries protective effects of SFG set in, Scenario 1 was implemented to represent the least increase in consumption that could be scientifically relevant.

The total cost savings for treating caries that can be achieved by all 25 countries range from US$805 M for the minimal increase scenario to US$18 billion for the clinically recommended scenario (Table 4). The potential cost reductions vary substantially, depending on the current consumption per country, as well as the proportion of gum consumers (i.e. people who chew SFG). Not all countries included in the study have a public health care system that pays for dental treatment, but, overall, cost savings are substantial for both national payers and individuals. Unfortunately, the additional payments for dental treatments borne by the individual were not examined in the study; this should be subject to further research. The current average price of SFG in the US ranges from US$7.00-7.25 for 100 pieces, with bulk packaging being cheaper. Therefore the cost to the individual in the US could be up to US$80.00 per year for consumption of the clinically recommended three pieces daily. If the additional payment savings exceed this amount, SFG therapy is even cost effective for the individual, apart from societal and health benefits. For the public health care systems of all 25 economies combined, the overall annual cost savings per capita range from US $0.21 for the minimal effect scenario up to US$4.74 for the clinically recommended scenario. Countries that already have a high level of SFG consumption profit the most from the increased consumption of SFG. The United States for example shows the third highest

consumption of SFG, with a PCC of 125.7 pieces per year. According to the model presented, an increase in SFG consumption of one piece per day (non-chewers excluded) could result in cost savings of 3% of all dental costs caused by caries.

This budget impact analysis is focused on costs, and parameters of effectiveness due to SFG consumption were not evaluated. The country-specific prevalence of caries is accounted for by the costs, because the model assumes that countries with poor dental health are likely to show higher costs for the treatment of caries. However, the data does not cover the relationship between the prevalence of caries and costs for caries within the countries, as there are no cost data available for subgroups [for example subgroups with different scores for decayed, missing, or filled surfaces (DMFS)]. Therefore, it is not possible to make a statement on potential cost savings by subgroups of dental health.

Taken together, the results demonstrate significant potential cost savings in industrialized countries as a result of increased SFG consumption. It should be remembered that the consumption of SFG cannot replace general measures for good dental hygiene like tooth brushing or flossing, but it is rather a low-cost preventive measure at the individual level that requires little effort, but which can have great influence on the relative risk reduction of caries.[28] It is undisputed that the regular consumption of SFG can positively influence dental health and the findings of this evaluation indicate that implementing SFG as a preventive measure for caries seems reasonable in terms of cost savings. Nevertheless, real-world data are needed in order to assess the real impact of SFG on global healthcare expenditures.

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