치의과학석사학위논문

Effect of Globalization on Global Dental Caries Trend

글로벌 치아우식증 추세와 세계화의 영향

지도교수 한동헌

2018 년 8 월

서울대학교 대학원

치의과학과 예방치과학전공

Bakr Salem Alsuraimi

Abstract

Effect of Globalization on Global Dental Caries Trend

Bakr Salem Alsuraimi

치의과학과 예방치과학전공

The Graduate School

Seoul National University

Health risk factors classified as international, macro-level and individual (micro-level) risk factors. International factors such as globalization affect health indirectly through macro and micro-level factors. Many studies have investigated how globalization relates with health outcomes such as obesity and cardiovascular diseases. The present study aimed to identify the global trend of dental caries according to countries national income level and to examine the role of globalization, medical services, obesity, and sugar intake on dental caries.

Data for 160 countries were collected for the time period of the 1990s to 2010s and represented by the years (1991, 2000, and 2012). After that, countries with missing data were excluded from the study so that the final sample was 46 countries (21 high income countries (HIC) and 25 middle and low income countries (MLIC)). The main dependent variable was the mean DMFT index as an

indicator of dental caries. Globalization (main independent variable) was measured by economic growth, urbanization and economic freedom. Other independent variables were health service (by health expenditure per capita and public health expenditure as a percentage of GDP) and health related factors (obesity and sugar consumption per capita).

The data were analyzed first using repeated measures analysis of variance (RM-ANOVA) to compare dental caries trends in (HIC) and (MLIC). Then, using multiple linear regression, hierarchical multiple regression and Structural Equation Square Modeling (PLS-SEM), the relationship between globalization, health services, health-related factors and dental caries was examined.

There was no significant interaction between the two groups at all time periods as both groups showed a declined DMFT trend. The results of linear regression and hierarchical multiple regression showed that indicators of globalization such as urbanization had a different role in both groups of countries. The results of PLS-SEM revealed that globalization had a strong direct positive effect on dental caries in High income countries.

The global dental caries trend had a declined pattern, but this pattern has been attenuated in Middle and Low income countries after the new millennium. Globalization had a positive effect on dental health in High income countries. There is a need for policy change and regulations on sugar and processed food trade especially in Middle and Low income countries similar to those in High income countries to diminish the adverse consequences of globalization and improving population dental caries and general health as well.

Keywords: Globalization; High income countries (HIC); Middle and Low income countries (MLIC); Health Related Factors (HRF).

Student Number: 2016-23239

Table of Contents

List of Figures

List of Tables

1. Introduction

Among all chronic diseases, dental caries is the most common diseases in industrial and in most lower income countries in which individuals are vulnerable to this disease all the time of their life (1). In Global Burden of Disease (GBD) 2010 Study, 3.9 billion people were affected by oral diseases, and untreated caries in permanent teeth was assessed as the most common disease with a worldwide prevalence of 35% (2). In both developing and developed countries, poor oral health has a profound effect on general health and quality of life and that the disadvantaged and poor population groups endure a higher burden of oral disease (3). Therefore, dental caries is a health problem that remains as a major concern for people through inequalities related to well-known issues of socioeconomic gap, lack of public oral health programs, immigration and changes of dietary habits (4).

Narrative reviews described a clear decrease in dental caries rates in adults over decades in developed countries in Europe (5, 6). Although it has been controlled in some industrial countries, dental caries has not been eliminated in children (3). In the developing countries, the common impression is that dental caries rates are rising; however, systematic reviews has reported declining and stationary trends in the caries prevalence and severity amongst children in three selected regions by UNICEF for the time period between 1970 and 2004 (7, 8). Whereas, a review has reported a global increase in the prevalence of dental caries (4). Alongside the coexisting burdens of undernutrition and infectious diseases, many of the developing countries have inadequate health-care resources and their infrastructures are insufficient to reach that level of control over the dental caries prevalence comparing with developed countries.

Many individual risk factors such as bad oral health behavior, lack of knowledge and skills and unhealthy diet play an important role on developing dental caries (9). As a result of these individual (micro level) factors, people (victims) used to be blamed for having the disease. However, besides the fact that these behaviors are socially determined, broader social context related to the place which people are born, grow up and live and age determine the chances and constrictions that contour these individual behaviors (10). Focusing more on the micro-level factors than the macro-level factors that affecting dental health do not help improving community oral health and reducing oral health inequality (11, 12). International and macro-level factors are known to be the causes of the causes as they affect dental health by promoting the development of dental caries through alterations to the living environment and food choice which create a cariogenic environment that negatively affect dental health.

Comprehensive frameworks have shown the pathways through which international and macro-level factors such as globalization, development, and media programs and advertising affect health outcomes positively and/or negatively (13, 14). A modified model of these frameworks has been suggested for the way these international factors relate with dental caries (9). Researchers have focused on the pathways that link globalization with general health. These frameworks are ranging between a complex and detailed one(15), to mid-level complexity and simplified frameworks(16, 17).

The Board on Global Health of the Institute of Medicine defined globalization as “the spread of knowledge and science, telecommunication and other information technologies, and cultural and behavioral adaptations” (14). Another definition for

globalization by Rhys Jenkins as “a process of greater integration within the world economy through movements of goods and services, capital, technology and (to a lesser extent) labor, which lead increasingly to economic decisions being influenced by global conditions” (18). Globalization is also known as an umbrella concept that includes rise of the multinational direct investment, expansion of the markets along with homogeneous consumer choices (14). Accordingly, the process of globalization encompasses the increase of the global interconnections between diverse networks and people, cultures, governments, economies and environments (19).

Several indices have been produced to measure globalization, starting with the A.T. Kearney/Foreign Policy Globalization Index (ATK/FP) as one of the first globalization index which used in the period between 2001 and 2006 (20). After that, other indices were launched such as KOF Globalization Index (KOFGI), the index produced by The Center for the Study of Globalization and Regionalization (CSGR) at the University of Warwick for the years 1982-2004 (21). Other indices, The GlobalIndex (22), The Maastricht Globalization Index (MGI) (23), The New Globalization Index (NGI) (24), and lately the DHL Connectedness Index which is concern about measuring connectedness (25). These indices identify three main dimensions of globalization which are the political, economic and social dimensions, whereas some indices added environmental, technological and ecological dimensions (20). Hence, these indices differ either in the dimensions of globalization or indicators used to measure these dimensions.

Globalization has simultaneous positive and negative effects; it led to improvement in many aspects of our life in terms of food security, decrease poverty

level and enhancement in quality of life; however, globalization has led to changes in the countries' policies of trade liberalization which have facilitated rising availability and consumption of processed foods that high in fats and sweeteners and scarce in nutritional value which in turn beside the reduction in physical activity has led to a prompt increase of obesity and diet-related chronic diseases at a global level (14, 26-28). Globalization by its definition involves free trade and movement of goods, services, and technology which has led to nutritional and lifestyle transitions and the resulting diseases (27); however, globalization affects health services by its impact on national income and the trade in health services (29). Although it is difficult to directly link nutrition transition with globalization, macro-level factors that lead to changes in diet and nutrition within social systems are linked to globalization such as urbanization, economic growth, free trade liberalization (17, 30), education (13, 14). Figure1 presents a modified framework of the link between globalization and dental caries.

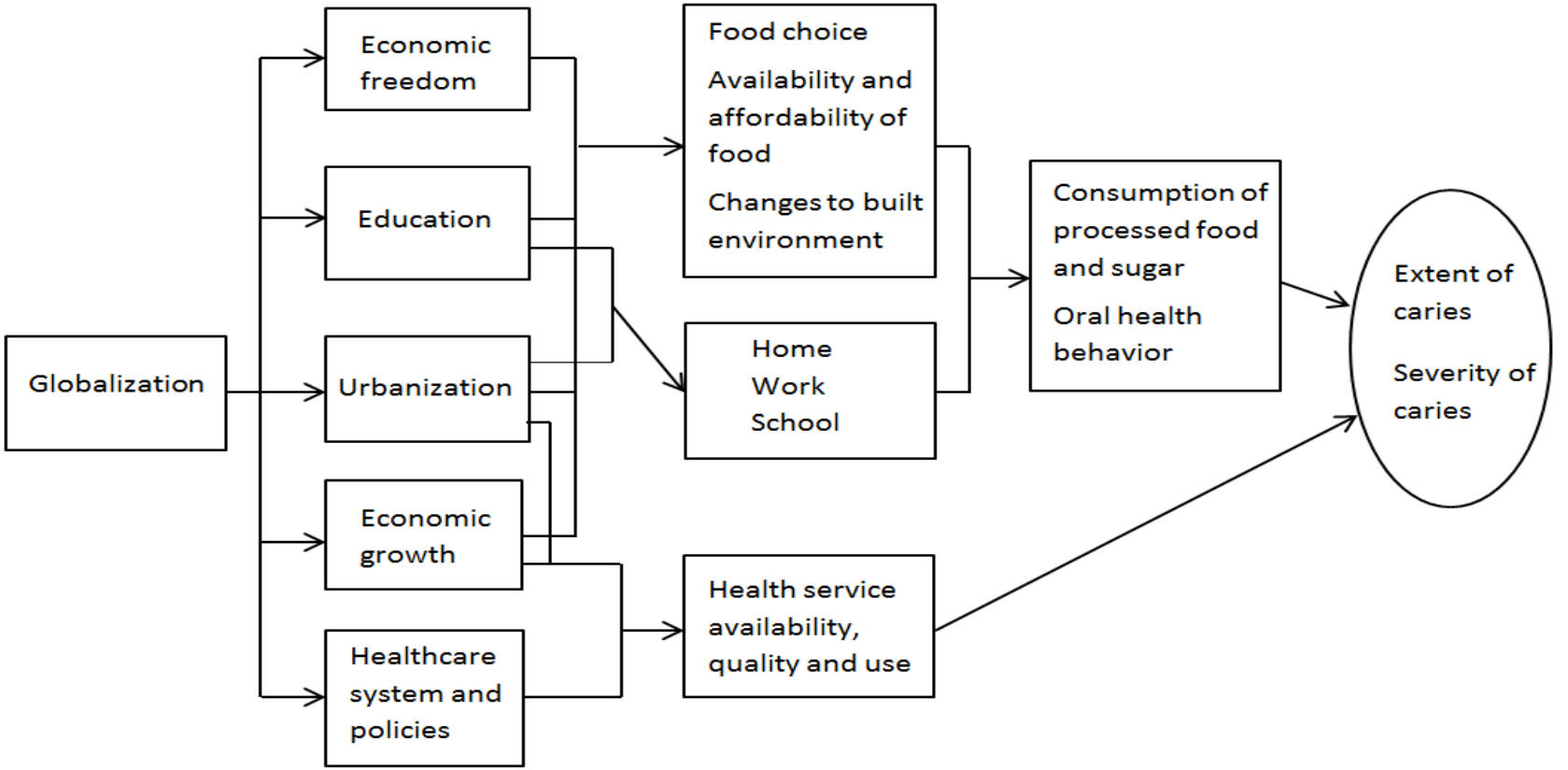

Figure 1 Pathway for the relationship between globalization and dental caries. Modified form (9, 13-17, 30, 31)**.**

Many dimensions and manifestations of globalization are related to economic globalization(17). According to Woodward and colleagues “economic globalization has been the fundamental driving force behind the overall process of globalization over the last two decades” (15). In this study we hypothesize that globalization is related with dental caries through the macro-level factors, economic freedom, economic growth and urbanization as these factors lead to nutritional transitions that ultimately via biological pathways affect dental caries Figure 2.

According to the Swiss Economic Institute, (KOFGI) is the most profoundly adopted and cited globalization index in the literature (20). This index covers three main dimensions of globalization: Economic, social and political. Variable such as international treaties and number of partners in investment treaties are used to measure the political dimension of globalization. Economic freedom involves removing barriers for free trade and foreign investment (32), including investment in the distribution of food and through spreading out of fast-food chains and multinational food companies (33). The liberalization of international food trade and foreign direct investment (FDI) and growth of transnational food corporations (TFCs) beside global food advertising and promotion, all resulted in increased availability of processed foods (fast foods, snacks, soft drinks), and desirability and diversity of food and their price which eventually led to nutritional transition (17). An example of trade liberalization that facilitated the nutrition transition comes from Central America Free Trade Agreement with the United States (28). (KOFGI) measures the economical dimension of globalization using trade and foreign direct investment as a percentage of GDP (20). These two variables have a causal relationship with economic growth (34). Rapidly developing Middle and Low

income countries go through nutrition transition and change on lifestyle at initial stages of economic growth and development (35), as economic growth leads to increase the trade in goods such as animal products, refined grains and sugar (30). One of the measures for the social dimension that (KOFGI) uses is cultural globalization (20), in which it defined as the dispersion of American values (36). The index uses variables such as the number of McDonald's restaurants and IKEA stores in the country to measure cultural globalization. There is a global urban growth as by the year 2008 half of the world population which is 3.3 billion people were living in urbanized areas and it is estimated to reach 5 billion by 2030 (37). That might lead the McDonald's, IKEA and other brands spread widely on urban areas. Urbanization leads to changes in the living environment and lifestyle besides the availability of a range of food choices which all have a direct influence on the quality of diet and energy expenditure (30). Consequently, these macro-level factors; economic freedom, economic growth and urbanization, facilitate the creation of cariogenic diet with the increase in the availability, affordability and diversity of processed foods and increase consumption of the energy-dense food and added sugar. Apart from this, evidences showed that development of dental caries is related to the amount of consumed sugar (38), and that better dental health can be achieved with sugar consumption reduction (39). The present study aimed to identify the global trend of dental caries according to countries national income level and to examine the role of globalization, medical services, obesity, and sugar intake on dental caries.

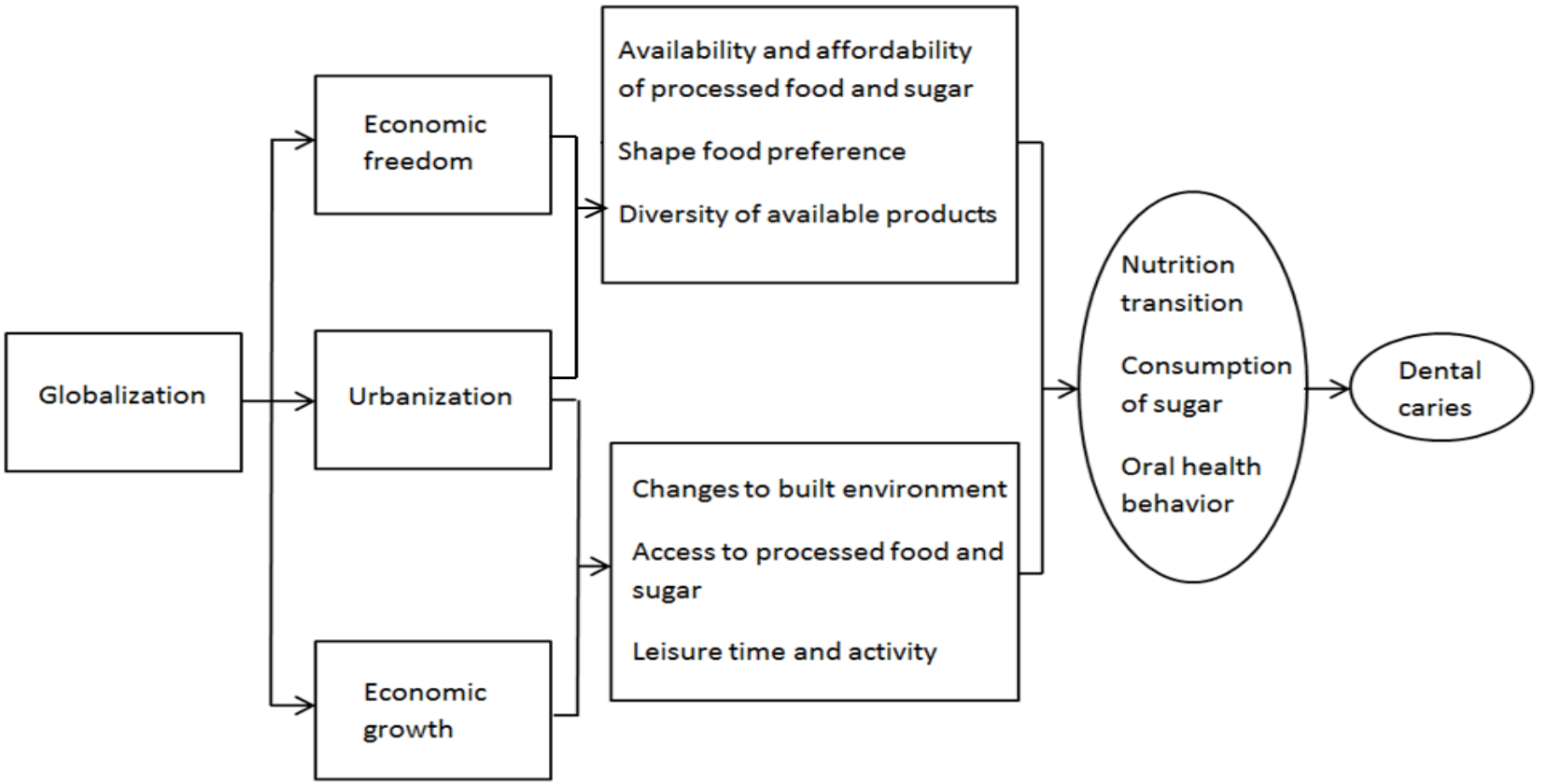

Figure 2 Schematic illustration of the relationship between globalization and dental caries (9, 13-17, 30, 31).

2. Material and Methods

2.1 Data Source

Data of dental caries, globalization, health service and health related factors for a total number of 160 countries were collected for the time period of 1990s to 2010s and represented by the years (1991, 2000, and 2012). After that, the countries were divided according to their level of income for the year 2010 into two groups, the first group included High Income Countries (HIC) = 147, while the second group included Middle and Low Income Countries (MLIC) = 113 (40). Then, 101 countries without DMFT values; the dependent variable, were excluded from the study. Next, from the remaining 59 countries, 9 countries with missing data of sugar consumption were excluded. Finally, 3 countries without health expenditure data and 2 countries with missing data of economic freedom were ruled out, so that the final number of countries included in the study with complete data was 46, among them HIC = 21 (Australia, Austria, Canada, Cyprus, Czech Republic, Finland, Hungary, Israel, Japan, South Korea, Latvia, Luxembourg, New Zealand, Norway, Portugal, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Sweden and Switzerland), and MLIC = 25 (Albania, Armenia, Belarus, Benin, Brazil, Bulgaria, Cambodia, Chile, Colombia, El Salvador, Ethiopia, Indonesia, Lao PDR, Lithuania, Malaysia, Mexico, Moldova, Nepal, Panama, Philippines, Romania, Russian Federation, Senegal, Thailand and Uganda). These 46 countries were regionally distributed as; Africa (n=4), The Americas (n=7), Eastern Mediterranean (n=1), Europe (n=22), South East Asia (n=3), and Western Pacific (n=9) (41). Figure 3 shows the flow summary of the selection method of countries.

The World Health Organization (WHO) data for sugar consumption per capita was available for the following years (1991, 1994, 1997, 2000, 2005, 2009 and 2012). Therefore, the years 1991, 2000 and 2012 were selected as representative years with an average of 10 years interval between these time points. The year 1991 was a representative of the late 1980s to the mid-1990s; the year 2000 denoted mid-1990s to mid-2000s, while the year 2012 represented the late 2000s and early 2010s, so the data for the adjacent year was used in case of the data was not available for the exact selected year. The data were obtained from WHO online data base (data for DMFT and sugar consumption) (41), Organization for Economic Cooperation and Development (OECD) online data base for countries with missing data of DMFT (42), The World Bank online data base (data for GDP per capita based on purchasing power parity (PPP) (constant 2011 international $)), Health expenditure per capita (PPP) (constant 2011 international $), Public health expenditure as a percentage of GDP, and Urban population (% of total population) (43), Institute for Health Metrics and Evaluation-University of Washington online data base (data for obesity (mean value for the age group 10-14 years) (44), and The Heritage Foundation online data base (data for Economic Freedom) (32).

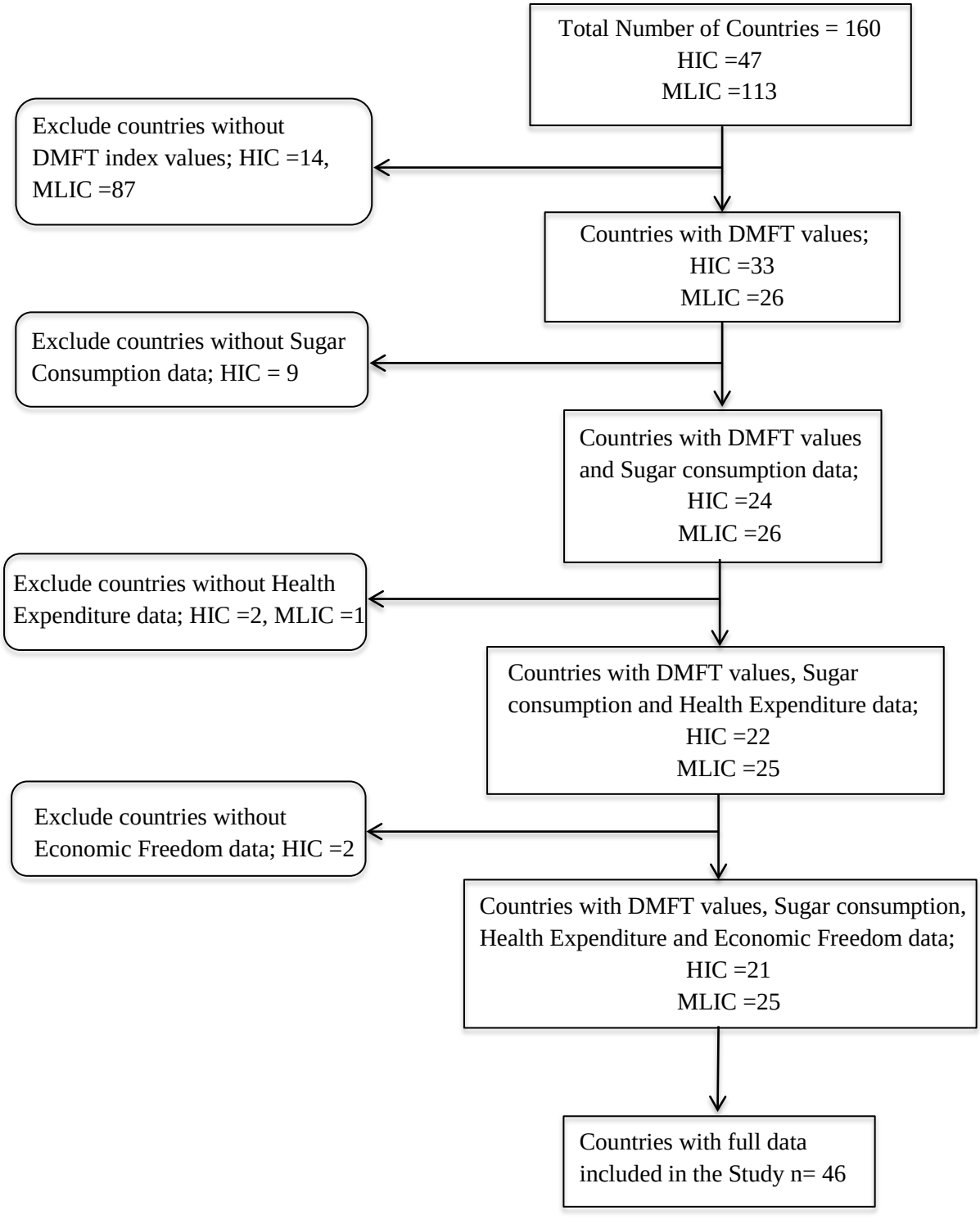

Figure 3 Flow summary of countries selection method.

2.2 Variables

The dependent variable is dental caries. It is a single-item measured construct which was represented by DMFT index values for 12-year-olds which describe the amount - the extent - of dental caries in an individual (9). Globalization; the main independent variable, was measured by GDP per capita as an indicator for economic growth (30), urban population as an indicator for urbanization , and economic freedom. Health service and Health related Factors (HRF) were served as both dependent and independent variables. Health service was measured by health expenditure per capita (PPP) and Public health expenditure (%of GDP), while HRF was measured by sugar consumption and obesity. Eventually, time-variable is represented by the years (1991, 2000, and 2012).

Health service was represented by public health expenditure as a percentage of GDP that reflects government spending on health sector and also represented by health expenditure per capita which shows the peoples' share on the spending on health services which in turn affects their use of these services and their general and dental health. In addition, the percentage of public health expenditure related to oral health is different between industrialized countries and developing countries and it has an economic impact on both as traditional treatment of oral disease is very expensive (3). Sugar consumption and obesity share common risk factors, and both have been associated with dental caries. Therefore, they were selected as indicators for HRF. Increase sugar consumption is one of the outcome of globalization and there is an evidence supports the relationship between the amount of sugars consumed and dental caries development (38). Obesity as well has been associated with dental caries and both share common risk factors (45-47).

2.3 Statistical Analysis

A one-way repeated measure analysis of variance (ANOVA) was applied first to compare the mean DMFT values of HIC and MLIC (between groups comparisons) and comparing these values of the different time period 1991, 2000 and 2012 for each group (within groups comparisons). Then, linear regression was performed to analyze the data to assess for a possible link between the indicators of dependent latent variables and dental caries. Next, using multiple linear regression and hierarchical multiple regression, the variables were adjusted in a serial fashion. The first model included sugar consumption and time (represented by year). Both variables were chosen as the basic model because the association between sugar consumption and dental caries is already proved with evidence and the purpose was to see how other variables affect this association. Model 2 comprised of model 1 and obesity so both variables of health related factors were included. In model 3, health service indicators (health expenditures) were added to model 2. Lastly, in model 4, globalization indicators were added to the other variables in model 3. Repeated measure ANOVA (RM-ANOVA) analysis, linear regression and hierarchical multiple regression were all carried out using the program IBM® SPSS® Statistics for Windows, version 23.0-IBM Corp. Armonk, NY, USA, and the critical level of statistical significance was set at $P<0.05$.

Finally, for the complicated relationships between variables Partial least squares structural equation modeling (PLS-SEM) was conducted using a one-step analysis approach as the measurement and structural sub-models were estimated simultaneously. PLS-SEM is a powerful analytical method because it works

competently with small sample size, can be applied to any data scale, and no distributional assumptions are needed (48). The research models were built up hypothesizing that with time, Globalization affects Dental Caries directly and indirectly via Health Services and HRF. Hypothesis testing was completed by calculating β and P- values of the path models and these values used to evaluate the magnitude and significant of the hypothesized links with P-value less than 0.05 was considered statistically significant. We did not investigate the path from health service towards HRF (obesity and sugar consumption) as there is no evidence for the relation between them. Time has been added to the model to examine its effect on dental caries and compare it with the results of the multiple linear regression and the hierarchical multiple regression. The measurement models; the reliability and validity of the measures, were assessed using Structural Equation Modeling (SEM), implemented using Partial Least Squares (PLS). For the assessment of construct validity and reliability, a Confirmatory Factor Analysis (CFA) was first conducted through which the measurement validation was assessed. Then a bootstrapping technique (N=500) was applied to check the validity of the structural relationships among latent variables. SmartPLS version 3.0 statistical package is used for the assessment of data analysis.

3. Results

3.1 RM-ANOVA

The trend of dental caries showing a continuous decrease in DMFT in HIC, while in MLIC, there is a slight decrease in the DMFT after the new millennium comparing to a more former strident decline, Figure 4. Repeated measure ANOVA was conducted to compare the DMFT value of MLIC to HIC at the different time periods; (1=1991 (baseline), 2=2000, and 3=2012). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated ($P<0.05$), therefore the Huynh–Feldt corrected tests are reported. The results showed that there was no significant interaction between the two groups at all time periods as both groups showed a declined DMFT trend (F (1.85, 81.5) =1.95, P=0.152). However, there was a significant difference between groups in the mean DMFT index only in the year 2012 (P <0.01), Table 1. The mean DMFT index was always higher in MLIC than HIC at each time period. Moreover, the mean difference was significant for all within group comparisons (P <0.05), except for the years 2000 and 2012 in MLIC, Table 2.

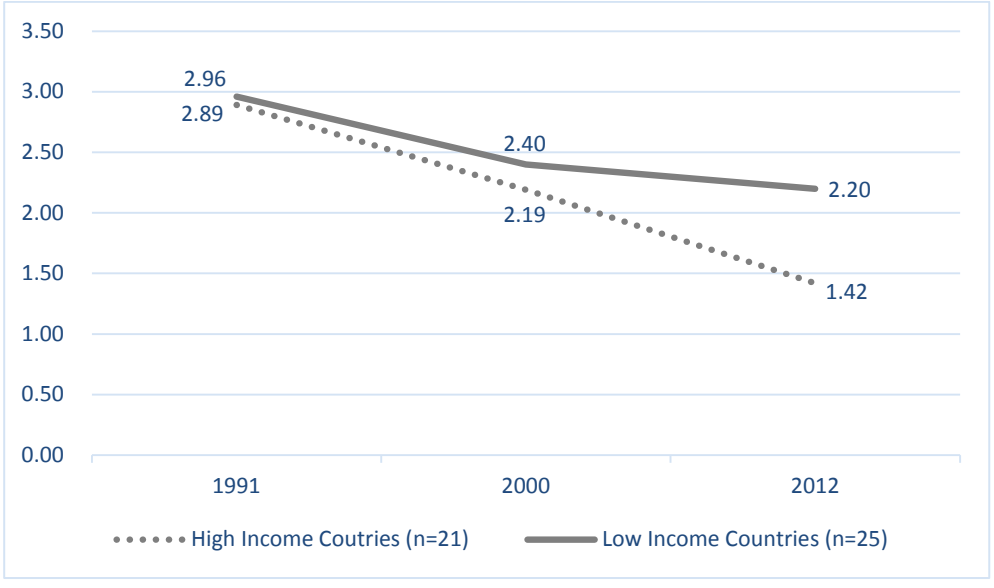

Figure 4 Dental caries trend in High vs Middle and Low income countries.

Table 1 Results of repeated measure ANOVA- between group comparisons

Time point	High Income Countries		Middle and Low Income Countries				
	Mean (SE) N= 21	**SD**	**Mean (SE) N= 25**	**SD**	**Mean difference (95% CI)**	***F* value**	***P* value**
1991 (Baseline)	2.89 (0.34)	1.35	2.96 (0.31)	1.67	0.066 (-0.847, 0.978)	.021	0.89
2000	2.19 (0.26)	1.35	2.4 (0.24)	1.35	0.218 (-0.499, 0.936)	.376	0.54
2012	1.42 (0.2)	0.73	2.2 (0.18)	1.01	0.748 (0.215, 1.281)	8.01	0.007

Note: Estimated marginal means reported.
SE= Standard Error
SD= Standard Deviation

Table 2 Results of repeated measure ANOVA- within group comparisons

Group	Time I (Control)	Time II	Mean difference (95% CI)	*P* value
High Income Countries	1*	2†	0.705 (0.120, 1.290)	0.019
		3‡	1.467 (0.875, 2.058)	0.000
	2	3	0.762 (0.338, 1.186)	0.001
Middle and Low Income Countries	1	2	0.613 (0.016, 1.088)	0.044
		3	0.826 (0.242, 1.326)	0.006
	2	3	0.213 (-0.156, 0.620)	0.235

Note: Estimated marginal means reported.

*1= 1991

†2= 2000

‡3= 2012

3.2 Linear Regression

The results of the serial linear regression for both groups of countries; HIC and MLIC, are shown in Table 3. In model 1, sugar consumption had an opposite association with dental caries in both groups as it was strong, positive and significant association in MLIC, while in HIC it was weak and negative. In model 2, obesity had a trivial effect on the correlations in model 1 in both groups. After adding health service indicators; model 3, the association between sugar consumption and dental caries became stronger and significant in HIC; however, these indicators had a minimal impact on the associations in the model in case of MLIC. The final model included all the variables after that globalization indicators were added to those in model 3. The correlation between sugar consumption and dental caries became weaker and non-significant in both groups of countries.

Table 3 Regression models for the association between different variables and dental caries (DMFT) represented by β coefficient

Country Group	Variable	Model 1	Model 2	Model 3	Model 4
High Income Countries	Year	-.509*	-.512*	-.171 (.185)	-.257 (.053)
	Sugar Consumption	-.199 (.088)	-.199 (.091)	-.204*	-.118 (.253)
	Obesity		.016 (.890)	.049 (.625)	.055 (.577)
	Health expenditure per capita			-.692*	-.164 (.542)
	Public Health expenditure			.256*	-.024 (.879)
	Economic Freedom				-.176 (.208)
	GDP per capita				- .224 (.246)
	Urban population				-.172 (.190)
Middle and Low Income Countries	Year	-.304*	-.303*	-.332*	-.307*
	Sugar Consumption	.434*	.443*	.371*	.150 (.471)
	Obesity		-.017 (.894)	-.030 (.824)	-.075 (.600)
	Health expenditure per capita			.039 (824)	.067 (791)
	Public Health expenditure			.123 (.337)	.048 (.722)
	Economic Freedom				-.045 (.712)
	GDP per capita				-.111 (.666)
	Urban population				.422 (.063)

* $P<0.05$

3.3 Hierarchical multiple regression

The results of the hierarchical multiple regression are displayed in Table 4 and Table 5 for HIC and MLIC respectively. In HIC model, at the first step of hierarchical multiple regression, two predictor variables were entered: year and sugar consumption. This model was statistically significant (F (2, 60) = 10.03; p < .001) and explained 25 % of variance in DMFT; however, only year variable was significant. Entering obesity on step 2 had no effect as there was no change in the variance, in other words, obesity is not improving *R*2 at its point of entry (F (3, 59) = 6.58; p < .01) (R^2 Change = .000; F (1, 59) = .02; P=890). After entry of health service variables at step 3, the model explained 46% of the variance (F (5, 57) = 9.63; p<001). Health service indicators had significant contribution to the model and explained additional 21% of the variance in DMFT (R^2 Change = .21; F (2, 57) = 10.90; p <001). Finally, globalization indicators were entered at step4, the total variance explained by the model as a whole was 54% (F (8, 54) = 8.0; p < .001). The addition of globalization indicators explained extra 9% of variance in DMFT, after controlling for other variables (R^2 Change = .09; F (3, 54) = 3.33; p < .05).

In case of MLIC, the first model was statistically significant (F (2, 72) = 11.72; p < .001) and explained 25 % of variance in DMFT; both variables (year and sugar consumption) were significant. At step 2 obesity did not improve *R*2 (F (3, 71) = 7.72; p < .001) (R^2 Change = .000; F (1, 71) = .02; P=894). After entry of health service variables at step 3, the model explained 26% of the variance (F (5, 69) = 4.85; p<01) in which health service indicators had no significant contribution to the model and explained only 2% of the variance in DMFT (R^2 Change = .02; F (2, 69)

= .66; p =.52). Lastly, at step 4, the model explained 30% of the total variance (F (8, 66) = 3.54; p < .01). Whereas, globalization indicators explained 4% of variance in DMFT, after controlling for other variables (R^2 Change = .04; F (3, 66) = 1.26; p =.29).

Table 4 Hierarchical Regression Model of DMFT for High Income Countries

	R	***R^2***	***R^2 Change***	***B***	***SE***	***β***	***t***
Step 1	.50	.25***					
Year				-.81	.18	-.51***	-4.42
Sugar consumption				-.02	.01	-.20	-1.73
Step 2	.50	.25	.000				
Year				-.81	.19	-.51***	-4.3
Sugar consumption				-.02	.01	-.20	-.172
Obesity				.81	5.80	.02	.14
Step 3	.68	.46***	.21***				
Year				-.27	.20	-.17	-1.34
Sugar consumption				-.02	.01	-.20*	-2.03
Obesity				2.47	5.03	.05	.50
Health expenditure per capita				-.001	.000	-.70***	-4.62
Public health expenditure				.17	.08	.256*	2.07
Step 4	.73	.54*	.09*				
Year				-.41	.21	-.26	-1.98
Sugar consumption				-.01	.01	-.12	-1.16
Obesity				2.74	4.89	.06	.56
Health expenditure per capita				.000	.000	-.16	-.61
Public health expenditure				-.02	.10	-.02	-.15
Urban population				-.02	.01	-.172	-1.3
GDP per capita				-1.8	.000	-.22	-1.17
Economic Freedom				-.03	.02	-.18	-1.27

Note. Statistical significance: *p < .05; **p < .01; ***p < .001

R^2= Amount of variance explained by IVs

R^2 Change= Additional variance in DV

B= Unstandardized coefficient

SE=Standard Error

β=Standardized coefficient

t= Estimated coefficient

Table 5 Hierarchical Regression Model of DMFT for Middle and Low Income Countries

	R	***R^2***	***R^2 Change***	***B***	***SE***	***β***	***t***
Step 1	.49	.25***					
Year				-.48	.16	-.30**	-2.95
Sugar consumption				.04	.01	.43***	4.20
Step 2	.49	.25	.000				
Year				-.48	.17	-.30**	-2.89
Sugar consumption				.04	.01	.44**	3.57
Obesity				-.96	7.16	-.02	-.13
Step 3	.51	.26	.01				
Year				-.53	.20	-.33**	-2.70
Sugar consumption				.03	.01	.37*	2.54
Obesity				-1.70	7.62	-.30	-.22
Health expenditure per capita				.000	.001	.04	.22
Public health expenditure				.12	.13	.12	.97
Step 4	.55	.30	.04				
Year				-.49	.20	-.31*	-2.47
Sugar consumption				.01	.02	.15	.72
Obesity				-4.30	8.16	-.08	-.53
Health expenditure per capita				.000	.001	.07	.27
Public health expenditure				.05	.13	.05	.36
Urban population				.03	.01	.42	1.89
GDP per capita				-2.30	.000	-.11	-.43
Economic Freedom				-.01	.02	-.05	-.37

Note. Statistical significance: *p < .05; **p < .01; ***p < .001

R^2= Amount of variance explained by IVs

R^2 Change= Additional variance in DV

B= Unstandardized coefficient

SE=Standard Error

β=Standardized coefficient

t= Estimated coefficient

3.4PLS-SEM

The results of measurement models assessment for both groups; HIC and MLIC, are shown in Table 6. Composite reliability, convergent validity and discrimination validity were used to assess the reliability and validity of the measures. Reliability was evaluated using composite reliability and Cronbach's alpha. All constructs in the models fulfilled the requirement for reliability (Cronbach's alpha greater than 0.7 and composite reliability between 0.6 and 0.9) except for HRF in the HIC model (49). Convergent validity was assured by the assessment of the outer loadings. All outer loadings were significant ($P<.05$) except HRF indicators in HIC model, and all exceeded the minimum threshold of 0.4 for exploratory research as suggested by the study of Hulland (1999) (50). The AVE (average variances extracted) of the constructs in the proposed models were all more than adequate; over 0.5, except for HRF in the HIC model which was very close to the minimum level (AVE= 0.48) (51). For the discriminant validity assessment, all indicators had the highest loading in their corresponding construct in the model and the square roots of AVEs of each construct were greater than the correlation of the specific construct with any of the other constructs in the model; indicating that each item loaded most highly on its own construct than on other constructs except for globalization as it was highest with HRF in the MLIC model (52).

Table 6 Results of measurement models assessment

Country Group	Constructs	Items	Composite reliability	Cronbach's α	AVE
High Income Countries	Globalization	Economic Freedom Economic Growth Urbanization	0.87	0.79	0.7
	Health Service	Health Expenditure PC Public Health Expenditure	0.84	0.75	0.74
	Heath Related Factors	Sugar Consumption Obesity	0.64	-0.1	0.48
Middle and Low Income Countries	Globalization	Economic Freedom Economic Growth Urbanization	0.85	0.74	0.66
	Health Service	Health Expenditure PC Public Health Expenditure	0.87	0.71	0.77
	Heath Related Factors	Sugar Consumption Obesity	0.87	0.71	0.77

AVE= Average Variance Extracted

Hypothesis testing was done by the assessment of structural models Table 7, Figure 5 and Figure 6. A bootstrapping technique with 500 adjusted samples was used to estimate the significance of the path coefficient. The results of the preliminary collinearity check showed that all VIFs below 5.0. The f^2 effect size of each path for HIC model reveals that the paths from globalization to dental caries and health service had large effect size; however, the path to HRF had weak effect size. The paths from health service and time to dental caries had weak effect size, while the path from HRF to dental caries had no effect. On the other hand; the f^2 effect size of each path for MLIC model shows that the paths from globalization to health service and HRF had large effect size and the path to dental caries had no effect. Whereas the path from time to dental caries had medium effect size, the paths from health service and HRF had no effect (49).

Table 7 Results of structural models assessment

Country Group	Independent variables	Dependent variables	Standardized causal effects			*T*-statistics	f^2 Effect size
			Direct	Indirect	Total		
High Income Countries	Globalization	Health Service	0.574		0.574	7.958***	0.491
		Heath Related Factors	0.156		0.156	1.26	0.025
		Dental Caries	-0.512	-0.085	-0.596	8.804***	0.362
	Health Service	Dental Caries	-0.141		-0.141	1.115	0.02
	Heath Related Factors	Dental Caries	-0.023		-0.023	0.167	0.001
	Time	Dental Caries	-0.224		-0.224	2.104*	0.069
Middle and Low Income Countries	Globalization	Health Service	0.783		0.783	26.749***	1.580
		Heath Related Factors	0.876		0.876	32.669***	3.313
		Dental Caries	0.244	0.189	0.433	4.952***	0.012
	Health Service	Dental Caries	0.111		0.111	0.659	0.006
	Heath Related Factors	Dental Caries	0.117		0.117	0.673	0.004
	Time	Dental Caries	-0.381		-0.381	3.584**	0.154

*P<0.05; **P<0.01;***P<0.001

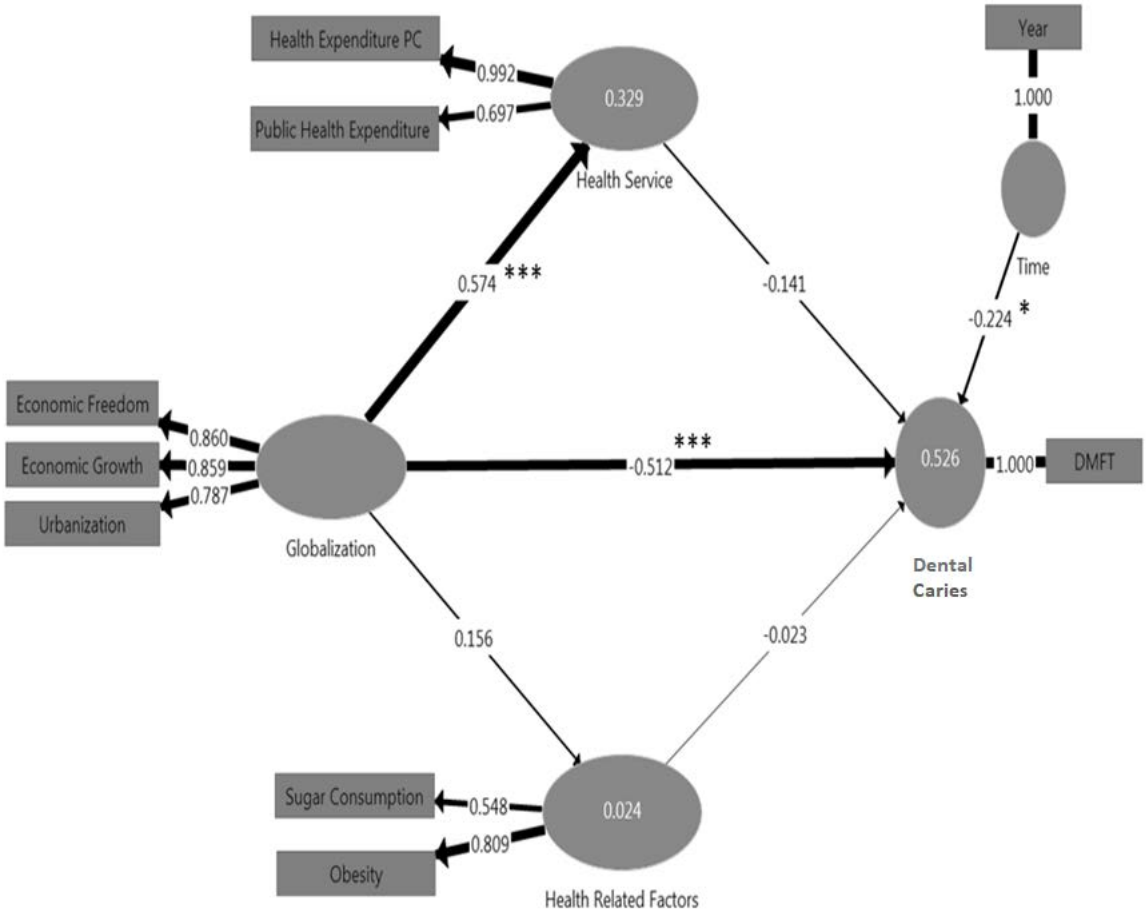

Figure 5 Path diagram of High income countries showing the path coefficient with significance level was set at *P<0.05; **P<0.01;***P<0.001

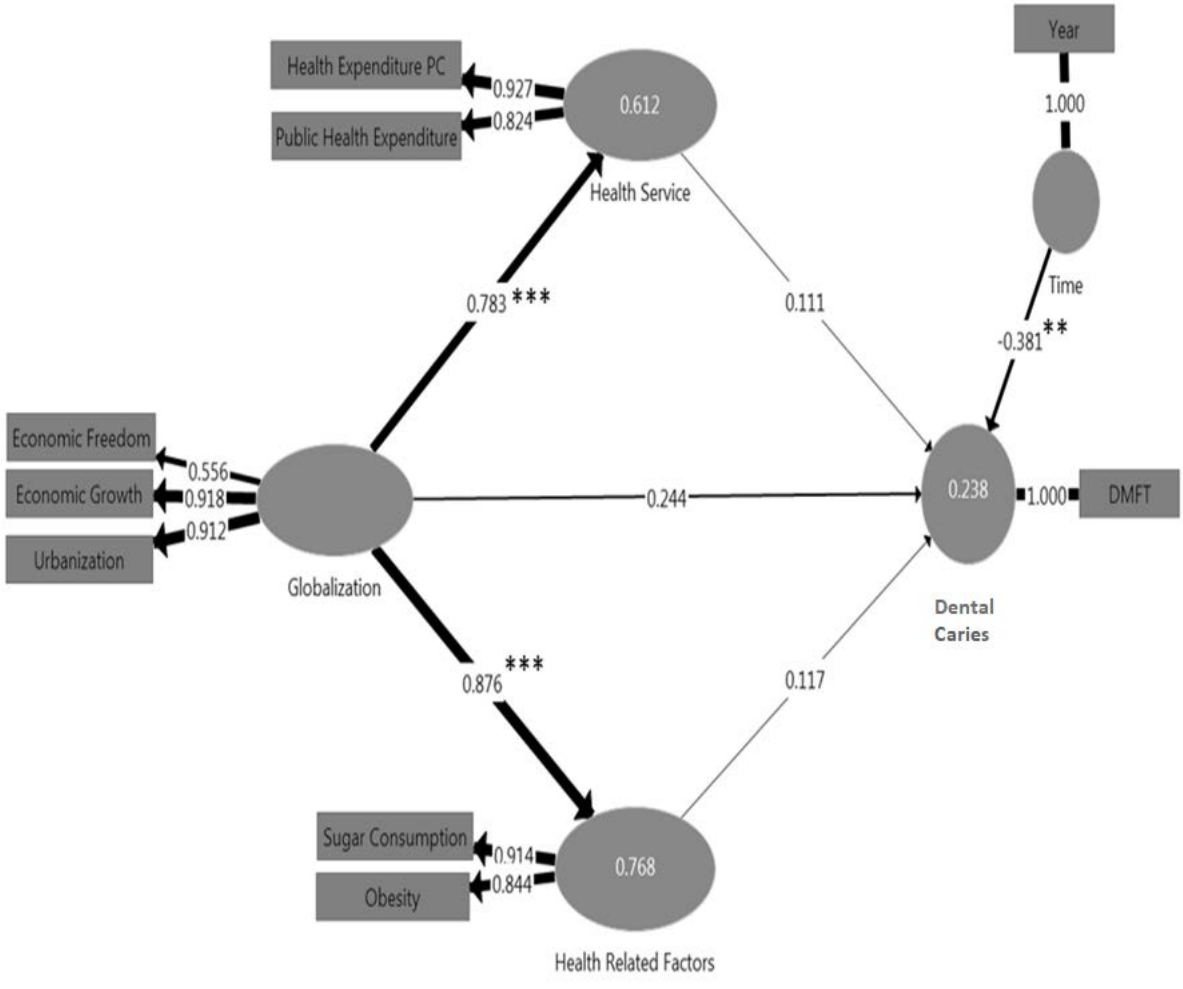

Figure 6 Path diagram of Middle and Low income countries showing the path coefficient with significance level was set at *P<0.05; **P<0.01;***P<0.001

The exploratory path models that were tested in this study demonstrated the hypothesized relationships between the independent latent variables and dental caries. Figure 5 and Figure 6 show the pathways parameters for the HIC model and in the MLIC model respectively. In HIC, globalization had a strong negative and significant association with dental caries (β= -512, P<0.001), meaning globalization has a good effect on dental caries as it decreases when countries become more globalized, however, that was not the case for MLIC as globalization has positive non-significant association with dental caries (β=0.244, P>0.05). In the HIC model, health service had a negative non-significant association with dental caries (β= -141, P>0.05), whilst HRF had negligence negative association with dental caries (β= -0.023, P>0.05). On the contrary, both health service and HRF had a positive non-significant association with dental caries (β=0.111, P>0.05) (β=0.117, P>0.05) in MLIC. Lastly, similar to the results of the multiple linear regression and the hierarchical multiple regression, time had a strong negative and significant correlation with dental heath in HIC and MLIC (β=-0.224, P<0.05) (β=-0.381, P<0.01) respectively.

Globalization in relation to health service and HRF, it had a strong positive and significant association with health service (β=0.574, P<0.001) in HIC; means that countries will have better health service as they become more globalized. However, the association with HRF was weaker and non-significant (β=0.156, P>0.05). In MLIC, globalization had a very strong positive and significant correlation with both health service and HRF (β=0.783, P<0.001) (β=0.876, P<0.001) respectively, means that health service improves as countries become more globalized, however, HRF in terms of sugar consumption and obesity also increase with globalization.

In case of the relation of health service and HRF with dental caries, both had a negative association with dental caries in HIC, whereas the association was positive in MLIC.

The explanatory power with R^2 values (adjusted R^2) and the predicative relevance with Q^2 values of the proposed models are shown in Table 8. In the HIC model, the independent latent variables; globalization, health service, HRF and time, explain 52.6% of the variance in dental caries, which indicative of a very strong explanatory power (52). On the other hand, MLIC model explained 23.8% of the variance in dental caries, which revealed a moderate explanatory power. Furthermore, both models have acceptable predicative relevance with over zero Q^2 value (51).

Table 8 The explanatory power and predicative relevance of structural models

Country Group		***R^2 =(Adj. R^2)***	***Q^2***
High Income Countries	Dental Caries	0.526(0.493)	0.444
	Health Service	0.329(0.318)	0.147
	Health Related Factors	0.024(0.008)	-0.017
Middle and Low Income Countries	Dental Caries	0.238(0.194)	0.167
	Health Service	0.612(0.607)	0.429
	Health Related Factors	0.768(0.765)	0.561

4. Discussion

This study explored the dental caries trend for two groups of countries; HIC and MLIC, and the results of the repeated measure ANOVA showed that there was no significant group-by-time interaction effect for DMFT ($P>0.05$) as the dental caries trend for both groups showed continues declination, and this go in line with previous studies (5-8). However, there was a significant difference between groups in the mean DMFT index after the new millennium ($p <0.01$). This illustrates that although dental caries trend is showing declination pattern overtime; this pattern has been attenuated in MLIC after the new millennium indicating that an event has caused this broken pattern. Then, using PLS-SEM, this study explored the time effect of globalization, health service and HRF on dental caries as the hypothesized explanation for the change of dental caries trend in MLIC and for the differences in the results of between and within-group comparisons of RM-ANOVA.

The results of the linear regression and the hierarchical multiple regression results were consistent and showed that health service (health expenditure indicators) had a greater impact on the association between sugar consumption and dental caries in HIC than MLIC. That could be referred to the higher expenditures for health service, and that a high percentage of these expenditures being directed towards dental health in HIC more than MLIC and that these expenditures are invested in treatment and preventive oral care in HIC and used mostly for emergency oral care and pain relief in MLIC (3, 53). The results also showed that globalization had no dramatic role on dental caries trend; however, globalization indicators such as urbanization had a different role in both groups of countries. Therefore linear regression cannot show the role of globalization on the change of population dental health. That is because linear regression cannot account for the

complicated relationships among different variables. The hierarchical multiple regression described the changed of the variance in DMFT; however, both the linear regression and the hierarchical multiple regression show the individual effect of these variables not a combined one. Since then, we used PLS-SEM as it offers a great potential to test relationships as a comprehensive means.

Turning to the results of PLS-SEM, globalization had a great positive and significant impact on the dental caries reduction in HIC; however, it had a negative influence in MLIC. This is might be due to the availability and affordability of fluoridated toothpaste and preventive products in highly urbanized countries which make them widely used beside the high GDP for these countries which increase the household income, and that leads to better use of these products and health services. But this is not the case in MLIC in which these products are not commonly used due to either they are not available or not affordable (54), alongside the low household income which results in less use of health services .

Globalization has led to a high increase of health expenditure in both groups of countries especially MLIC as a result of economic growth and the increase of GDP. In relation with HRF, globalization had very strong influence on the increase of the rate of sugar consumption and obesity in MLIC as economic freedom and policies of trade liberalization lead to raise the availability of sugar and processed food with low nutritional value which associated with increased rates of obesity and non-communicable diseases (26, 28). While in HIC, globalization had a weak impact on HRF as these countries have more regulations and restrictions on unhealthy food comparing with MLIC.

The results of PLS-SEM also showed that the association between health service and dental caries in HIC was negative but not significant. That may be due to that the DMFT scores were represent the F component of the index (demonstrates treated caries) which is an indication of greater access to dental services in developed countries. Another possible explanation is that dental caries is higher among the lower socio-economic class who has inadequate access to dental services in HIC. The result of PLS-SEM of the relation between health service and dental caries in HIC was different from those of the linear regression and the hierarchical multiple regression. Further research on the actual relation between health service and dental caries is needed. On the other side, health service had a positive association with dental caries in MLIC. That might be due to that the share of dental health expenditure from total health expenditure is low in MLIC and it used mostly for emergency oral care and pain relief while in HIC the dental health expenditure is higher that these expenditures are invested in treatment and preventive oral care (3, 53). HRF had contrasting associations with dental caries as they were negatively associated with dental caries in HIC and positively in MLIC, this could be due to inadequate exposure to fluorides and absence or limited public health measures with the increase of sugar consumption and processed food in MLIC (3).

The strength of this study is that it is the first to explore the role of globalization on the global dental caries trend in comparison between HIC and MLIC. This study used different statistical methods to analyze the data starting with repeated measure ANOVA then linear regression, hierarchical multiple regression and finally used Partial least squares structural equation modeling PLS-SEM which is a powerful

analytical method that is used to examine the complicated relationships between variables. Besides that, we used all the available data by WHO, World Bank, OECD, the Institute for Health Metrics and Evaluation-University of Washington, and The Heritage Foundation. Globalization may have a role on dental health through oral health programs, education and oral health behavior, but we cannot test this role due to lack of data. The interaction between globalization and oral health programs, education and oral health behavior can be a subject for future research. In case of PLS-SEM, all items were maintained in the models and that is because of: (1) this is an exploratory research, (2) used for comparison propose between two groups and (3) that the data used were secondary data.

5. Conclusion

This study explored the dental caries trend in HIC and MLIC and found that the trend is showing declination pattern overtime (before and after the new millennium) in both groups but this pattern has been attenuated after the new millennium in MLIC. Globalization had a positive effect on dental health in High income countries. In addition, Globalization had a strong positive effect in improving health service in both groups especially in MLIC. Moreover, globalization had a very strong influence on the increase of sugar consumption and obesity in MLIC. Therefore, based on these findings, this study suggests that although globalization has led to improvements in many aspects of life, regulations and policy change related to the trade of sugar and processed food has to be implemented, especially in MLIC as they considered the favorite market for big food companies. Also, more concern has to be directed to the share of dental expenditure from the total health expenditure. Further research is needed to explore the actual role of health services on dental health. In addition, future research is to be directed to examine the role of oral health behavior, measures and educational programs, and type of health and political systems on the relation between globalization and dental health.

References

1. Selwitz RH, Ismail AI, Pitts NB. Dental caries. Lancet. 2007;369(9555):51-9.

2. Marcenes W, Kassebaum NJ, Bernabe E, Flaxman A, Naghavi M, Lopez A, et al. Global burden of oral conditions in 1990-2010: a systematic analysis. J Dent Res. 2013;92(7):592-7.

3. 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. 2005;83(9):661-9.

4. Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries. A pending public health crisis. American Journal of Dentistry. 2009;22(1):3-8.

5. Marthaler T. Changes in dental caries 1953–2003. Caries research. 2004;38(3):173-81.

6. Reich E. Trends in caries and periodontal health epidemiology in Europe. Int Dent J. 2001;51(6 Suppl 1):392-8.

7. Cleaton-Jones P, Fatti P. Dental caries trends in Africa. Community Dent Oral Epidemiol. 1999;27(5):316-20.

8. Cleaton-Jones P, Fatti P. Dental caries trends in 5- to 6-year-old and 11- to 13-year-old children in three UNICEF designated regions - Sub Saharan Africa, Middle East and North Africa, Latin America and Caribbean 1970–2004. International Dental Journal. 2006;56(5):294-300.

9. Fejerskov O, Nyvad B, Kidd E. Dental caries: the disease and its clinical management. 3rd ed. Oxford: Wiley Blackwell; 2015.

10. Chin NP, Monroe A, Fiscella K. Social determinants of (un)healthy behaviors. Educ Health (Abingdon). 2000;13(3):317-28.

11. RG W. From victim blaming to upstream action: tackling the social determinants of oral health inequalities. Community Dent Oral Epidemiol. 2007;35.

12. RG W. Social determinants of oral health inequalities: implications for action. Community Dent Oral Epidemiol. 2012;40.

13. Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ, Public Health Approaches to the Prevention of Obesity Working Group of the International Obesity Task F. Obesity prevention: the case for action. Int J Obes Relat Metab Disord. 2002;26(3):425-36.

14. Fuster V, Kelly BB. Promoting Cardiovascular Health in the Developing World: A Critical Challenge to Achieve Global Health. Washington, DC: The National Academies Press; 2010.

15. Woodward D, Drager N, Beaglehole R, Lipson D. Globalization and health: a framework for analysis and action. Bulletin of the World Health Organization. 2001;79:875-81.

16. Labonte R, Torgerson R. Frameworks for analyzing the links between globalization and health. Draft report to the World Health Organization Saskatoon, SPHERU, University of Saskatchewan. 2002.

17. Labonte R, Schrecker T, Packer C, Runnels V. Globalization and Health: Pathways, Evidence and Policy. New York Routledge; 2009.

18. Jenkins R. Globalization, production, employment and poverty: debates and evidence. Journal of International Development. 2004;16(1):1-12.

19. Brown GW, Labonte R. Globalization and its methodological discontents: Contextualizing globalization through the study of HIV/AIDS. Globalization Health. 2011;7.

20. Gygli S, Haelg F, Sturm J-E. The KOF Globalisation Index – Revisited. KOF Swiss Economic Institute, ETH Zurich; 2018.

21. Lockwood B, Redoano M. The CSGR globalisation index: An introductory guide. Centre for the Study of Globalisation and Regionalisation Working Paper. 2005;155(04):185-205.

22. Raab M, Ruland M, Schonberger B, Blossfeld HP, Hofacker D, Buchholz S, et al. GlobalIndex: A sociological approach to globalization measurement. Int Sociol. 2008;23(4):596-631.

23. Figge L, Martens P. Globalisation Continues: The Maastricht Globalisation Index Revisited and Updated. Globalizations. 2014;11(6):875-93.

24. Vujakovic, Petra. How to Measure Globalisation? A New Globalisation Index (NGI). WIFO Working Papers. Vienna: Austrian Institute of Economic Research (WIFO); 2009.

25. Ghemawat P, Altman SA. DHL Global Connectedness Index 2016 - The State of Globalization in an Age of Ambiguity.2016.

26. Hawkes C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. Global Health. 2006;2:4.

27. Popkin BM. Technology, transport, globalization and the nutrition transition food policy. Food Policy. 2006;31(6):554-69.

28. Thow AM, Hawkes C. The implications of trade liberalization for diet and health: a case study from Central America. Global Health. 2009;5:5.

29. Woodward D, Drager N, Beaglehole R, Lipson D. Globalization, global public goods, and health. Geneva, Switzerland: Department of Health in Sustainable Development, World Health Organization, ; 2002.

30. Malik VS, Willett WC, Hu FB. Global obesity: trends, risk factors and policy implications. Nat Rev Endocrinol. 2013;9(1):13-27.

31. Huynen MM, Martens P, Hilderink HB. The health impacts of globalization: a conceptual framework. Global Health. 2005;1:14.

32. Economic Freedom [Internet]. The Heritage Foundation. 2017 [cited 11/16/2017]. Available from: http://www.heritage.org/index/explore?view=by-region-country-year.

33. Kearney J. Food consumption trends and drivers. Philos Trans R Soc Lond B Biol Sci. 2010;365(1554):2793-807.

34. Dritsaki M, Dritsaki C, Adamopoulos A. A causal relationship between trade, foreign direct investment and economic growth for Greece. American Journal of Applied Sciences. 2004.

35. Ezzati M, Vander Hoorn S, Lawes CM, Leach R, James WP, Lopez AD, et al. Rethinking the "diseases of affluence" paradigm: global patterns of nutritional risks in relation to economic development. PLoS Med. 2005;2(5):e133.

36. Saich T. Globalization, Governance, and the Authoritarian Westphalian State: The Case of China. Kennedy School of Government; 2000.

37. UNFPA. State of World Population 2007: Unleashing the Potential of Urban Growth. UNFPA; 2007.

38. Freeman R. Moderate evidence support a relationship between sugar intake and dental caries. Evid Based Dent. 2014;15(4):98-9.

39. Olczak-Kowalczyk D, Turska A, Gozdowski D, Kaczmarek U. Dental Caries Level and Sugar Consumption in 12-Year-Old Children from Poland. Adv Clin Exp Med. 2016;25(3):545-50.

40. Classifications of Countries Basedon their Level of Development : How it is Done and How it Could Be Done(2011).

41. Country Oral Health Profiles: WHO Regions [Internet]. MALMÖ UNIVERSITY [cited 11/16/2017]. Available from: https://www.mah.se/CAPP/Country-Oral-Health-Profiles/.

42. Health Status: Dental Health [Internet]. 2017 [cited 11/16/2017]. Available from: http://stats.oecd.org/Index.aspx?DataSetCode=HEALTH_STAT.

43. World Development Indicators [Internet]. 2017 [cited 11/16/2017]. Available from: http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators&Type=TABLE&preview=on#.

44. Global Health Data Exchange [Internet]. Institute for Health Metrics and Evaluation-University of Washington. 2017 [cited 1/26/2018]. Available from: http://ghdx.healthdata.org/record/global-burden-disease-study-2015-gbd-2015-obesity-and-overweight-prevalence-1980-2015.

45. Hayden C, Bowler JO, Chambers S, Freeman R, Humphris G, Richards D, et al. Obesity and dental caries in children: a systematic review and meta-analysis. Community Dent Oral Epidemiol. 2013;41(4):289-308.

46. Li LW, Wong HM, McGrath CP. Longitudinal Association between Obesity and Dental Caries in Adolescents. J Pediatr-Us. 2017;189:149-+.

47. Palmer CA. Dental caries and obesity in children: different problems, related causes. Quintessence Int. 2005;36(6):457-61.

48. Cassel C, Hackl P, Westlund AH. Robustness of partial least-squares method for estimating latent variable quality structures. Journal of Applied Statistics. 1999;26(4):435-46.

49. Joseph F Hair J, Hult GTM, Ringle CM, Sarstedt M. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Second edition ed: SAGE Publications, Inc.; 2017.

50. Hulland J. Use of partial least squares (PLS) in strategic management research: A review of four recent studies. Strategic Management Journal. 1999;20(2):195-204.

51. Henseler J, Ringle CM, Sinkovics RR. The Use of Partial Least Squares Path Modeling in International Marketing. Advances inInternationalMarketing. 2009;20:277–319.

52. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Second Edition ed. United States of America: Lawrence Erlbaum Associates; 1988.

53. Listl S, Galloway J, Mossey PA, Marcenes W. Global Economic Impact of Dental Diseases. J Dent Res. 2015;94(10):1355-61.

54. Goldman AS, Yee R, Holmgren CJ, Benzian H. Global affordability of fluoride toothpaste. Global Health. 2008;4:7.

국문초록

글로벌 치아우식증 추세와 세계화의 영향

서울대학교 대학원 치의과학과 예방치과학전공
(지도교수 : 한 동 헌)

Bakr Salem Alsuraimi

건강 위험 요소는 국제, 거시적 수준 및 개별 (미시적) 위험 요소로 분류된다. 세계화와 같은 국제적 요인은 거시적 요인과 미시적 요인을 통해 간접적으로 건강에 영향을 미친다. 그동안 많은 선행 연구에서는 세계화가 비만 및 심혈관 질환과 같은 전신 건강에 미치는 영향을보고하였다. 본 연구의 목적은 국가 소득수준별 치아우식증 추세를 파악하고, 세계화, 의료서비스, 비만, 설탕섭취량이 치아우식증에 미치는 역할을 검증하는 것이다.

1990 년대부터 2010 년대를 대표하는 연도(1991 년, 2000 년, 2012 년)의 160 개국에 대한 데이터를 수집하였다. 누락된 데이터가 있는 국가는 연구에서 제외하고, 최종적으로 46 개국(21 개의 고소득 국가와 25 개의 중저소득 국가)을 분석 대상으로 삼았다. 종속 변수는 구강건강지표로서 우식경험영구치지수였다. 주요 독립변수인 세계화는 경제성장률, 도시화 인구비율 및 경제적 자유도로 측정되었다. 다른 독립 변수는 의료서비스(총 의료서비스 예산, 공공 의료서비스 예산)와 건강 관련 요소(비만, 1 인당 설탕섭취량)였다.

데이터는 먼저 고소득 국가와중저소득 국가의 치아 우식 경향을 비교하기 위해 반복 측정 분산 분석 (RM-ANOVA)을 사용하여 분석되었다. 그런 다음 다중 회귀 분석, 계층 다중 회귀 분석 및 구조 방정식 모델링 (PLS-SEM)을 사용하여 세계화, 보건 서비스, 건강 관련 요인 및 치아 충치 사이의 관계를 조사했다.

연구 결과 두 그룹 모두에서 DMFT 추세는 감소한 것으로 나타 났으며 두 그룹 간에는 유의한 상호작용이 없었다. 선형 회귀와 계층 다중 회귀의 결과 두 그룹 모두에서 도시화와 같은 세계화 지표가 치아우식증에 영향을 미친다는 것이 나타났다. PLS-SEM 의 결과에 따르면 세계화는 고소득 국가의 치아 우식에 직접적인 긍정적 영향을 미쳤다.

1990 년대에서 2010 년까지 치아 우식증 경향은 감소된 패턴을 보였으나, 이 패턴은 2000 년 이후 중동 및 저소득 국가에서 약화되었다. 그리고 세계화는 고소득 국가의 구강건강에 강화된 긍정적 영향을 미쳤다. 고소득 국가에서의 세계화는 국가의 설탕 및 가공 식품 거래 정책의 변경 및 규제에 영향을 미쳤을 것이라 고려된다. 따라서 중동 및 저소득 국가에서로 세계화 구준으로 설탕 및 가공 식품의 정책변경을 도모하여, 치아우식증 감소와 구강건강을 증진 해야 할 필요가 있다.

주요어 : 세계화, 고소득 국가 (HIC), 중 / 저소득 국가 (MLIC), 건강 관련 요인 (HRF).

학 번 : 2016-23239