

The association between geographical factors and dental caries in a rural area in Mexico

Caries dental moderada por variables geográficas espaciales en un medio rural en México

Cárie dentária moderada por variáveis geográficas espaciais em uma área rural do México

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Abstract

The aim of this study was to investigate the association between markers of oral disease and geographical factors influencing access to dental care (DMFT score) among school children in Central Mexico. Retrospective data were collected during an international service-learning program between 2002 and 2009. A sample of 1,143 children (55% females; mean age 12.7±13.1 years) was analyzed. The mean DMFT score, represented largely by untreated tooth decay, was 4.02 (4.76). The variables that had the most significant effect on the DMFT score were proportion of paved roads between the community and dental services, and the availability of piped potable water. The DMFT score increased in proportion to the percentage of paved roads. In contrast, the DMFT score decreased with the availability of piped potable water. Similar results were found for untreated tooth decay. The main variable associated with a significant increase in dental fillings was proportion of paved roads. Together with Brazilian reports, this is one of the first investigations of the association between geographical factors and oral health in an underdeveloped setting.

Oral Health; DMFT Index; Child

Resumen

El estudio caracterizó la asociación entre marcadores de salud bucal y de acceso deficiente a servicios dentales con variables geográficas. Se realizó un análisis retrospectivo de datos (recogidos de 2002 a 2009) de 1.143 niños (55% mujeres; edad media 12,7±13,1 años). El CPOD fue 4,02 (4,76), constituido primordialmente por caries sin tratar. Las variables con el mayor efecto sobre el CPOD fueron la proporción de caminos pavimentados entre el término municipal principal y comunidades aledañas, y la disponibilidad de agua potable entubada en estas últimas. El CPOD aumentó conforme lo hizo la proporción de los caminos pavimentados. Por el contrario, el CPOD disminuyó moderadamente conforme la disponibilidad de agua potable aumentó. La caries sin tratar exhibió tendencias similares. La única variable fuertemente asociada a un mayor número de tratamientos dentales fue la proporción de caminos pavimentados. Conjuntamente con informes brasileños, este es uno de los primeros estudios sobre la asociación de factores geográficos y salud bucodental en un entorno menos desarrollado.

Salud Bucal; Índice CPO; Niño

Introduction

Studies in a number of countries have shown a strong association between poor dental health and low socioeconomic status¹. In countries that embrace a typical Western diet, characterized by a high intake of simple sugars, the incidence of dental caries (tooth decay) is generally higher among the poorest segments of the population². The fact that dental caries go undetected and untreated for long periods of time in individuals with poor access to dental care is a possible explanation for the higher-than-average experience of tooth decay among these groups. However, why people with low socioeconomic status are more susceptible to poor health is unclear. Possible explanations include the adoption of unhealthy dietary habits and lifestyles by this segment of the population and exposure to a number of factors that undermine health, or a combination of these factors. However, the socioeconomic factors associated with prevalence of dental caries do not fully explain the reason for the caries phenomenon³, which may be influenced by social, genetic, biological and cultural factors⁴. Tooth decay has been described as a “sentinel disease” for other pediatric conditions¹, with dental care being the most commonly unmet need⁵.

It has been shown that actions such as reducing the cost of dental care for people with low socioeconomic status⁶, changing the unfavorable mix of dental services^{7,8}, or even the provision of free dental care, do not solve the problem of unequal distribution of dental disease or reduce the disparities in access to dental services^{9,10}. The results of programs directed at reducing cost or access barriers show that these obstacles are merely part of this multidimensional dental health problem^{3,11}.

The study of the relationship between geographical location and health has received growing attention in the medical literature and a number of studies in the field of health geography have quantified the association between health and disease characteristics and socioeconomic characteristics^{12,13}. Factors addressed by health geography studies investigating the dynamics of dental health disparities include the following: the geographical distribution of dental professionals^{14,15,16,17}; variables representing socioeconomic status^{18,19,20,21,22,23}; and lifestyle behaviors associated with poor oral health, such as consumption of sugared beverages and dental attendance patterns^{16,24}.

However, most studies have been limited to contrasts between rural and urban environments and little research has been carried out into the geographical factors that influence access to

dental care and the prevalence of oral conditions^{16,20,23,25,26,27,28,29}. Although some Brazilian and Australian studies have investigated geographical barriers^{22,23,26,27}, we believe that there is still a lack of comprehensive research into these factors. One of the explanations for this gap in research is that most studies in developed nations rightly assume that the distance or time spent traveling to the nearest dental clinic is relatively insignificant compared to the cost of care at the point of delivery; a glaring exception are the long distances involved in visiting the dentist in rural areas in a vast country such as Australia^{26,27}. Conditions in Latin America, which is not only poorer but has a proportionally smaller dental health network than Australia, are altogether different and prevalence of dental caries in rural areas has not replicated the decisive downward trend experienced in the past couple of decades by industrialized countries. The present study attempts to quantify the association between a limited number of specific geographic factors and the dental health status of children living in a dentally underserved setting.

Methods

This multiple cross-sectional study adhered to ethical standards and participants signed an informed consent form (Indiana University IRB # 0202-64).

Description of research location

Indiana University (IU) implemented an International Service-Learning (ISL) program in the State of Hidalgo in Central Mexico that lasted for over a decade. This program focused activities in the capital city, Pachuca, where an academic partnership was developed with the Universidad Autónoma del Estado de Hidalgo (UAEH), and the municipality of Calnali located in a mountainous area of the Huasteca region.

The municipality of Calnali is made up of a number of small communities and the administration of the municipality and health service policy and management are centralized in the town of Calnali. Public and private medical services are unevenly distributed throughout the municipality and the large majority of dental services are available in Calnali. The State of Hidalgo is one of the states where fluoridated salt is available, which comprises the backbone of the state's dental caries prevention program. Water supplies in Mexico are not artificially fluoridated.

Calnali is more developed (in terms of urban infrastructure, public services and per capita

income) than the communities. The region is generally mountainous and communities with different population sizes are located at different altitudes and at varying distances and travel times between the community and Calnali. The road network is made up of dirt and paved roads, thus posing different transport challenges. A number of communities lack piped potable water. Although Hidalgo is considered to a very poor state³⁰, Western-style snacks and beverages are available throughout the municipality.

Oral diseases are considered public health problems in Mexico, and disproportionately affect the poor and disadvantaged^{31,32,33}. Dental health care falls within the ambit of the Ministry of Health and only a fraction of dental services are available through the public dental health system, thus most patients seek private dental care and some are forced to forgo dental care.

Data collection

This is a retrospective analysis of clinical observations from a project that deployed groups of dental, nursing and medical students from IU and UAEH to communities during the ISL program between 2002 and 2009 (Table 1). Elementary school children not using orthodontic appliances that agreed to participate were enrolled in the study after parents signed a written informed consent form. A questionnaire was answered by parents/guardians through a face-to-face interview conducted by bilingual students. Data were collected for different years in different communities due to practical constraints associated with the main objectives of the ISL program which were to provide dental services and raise awareness of the importance of oral health. Although the program prioritized school children, other clients who resided in the community and were seeking care or dental examinations were accepted.

Questionnaires and clinical examinations were carried out during the same visit. Clinical examinations were carried out by standardized dental examiners trained by two calibrated ISL program directors during a semester-long course which included training in data collection, patient data confidentiality, cross-cultural awareness, and standardized diagnostic and management criteria. No formal assessments of intra or inter-examiner reliability were conducted. The present report describes only the status of the crowns of permanent teeth using the DMFT score (decayed, missing due to caries, and filled teeth). Precavitated carious lesions were not scored. The oral examination was conducted under dental lights, using a blunt dental

explorer and a flat dental mirror n. 5. Data were not collected for children that were absent on the day of the examination.

Statistical analysis

DMFT, DT (decayed teeth), and FT scores (filled teeth) were calculated for each individual, and each score was used as a dependent variable. The independent variables were travel distance between Calnali and the community (in kilometers), difference in altitude above sea level between the community and Calnali (in feet), proportion of paved roads between Calnali and the community, travel time between Calnali and the community (in minutes), availability of piped community water supplies, and total population of each community.

Data were analyzed using Poisson and Negative Binomial Regression, since DMFT and its components are not normally distributed and the response variables were counts. Final analysis was carried out using Negative Binomial Regression. Because subjects were grouped into communities and data were grouped into clusters, models were run using generalized estimating equations (GEE negative binomial model) to account for the correlation between study subjects living in the same location³⁴. DMFT, DT and FT scores were then compared using incident rate ratios (RR). The RR value can range between 0 and infinity, where < 1 indicates that the variable has little effect on the score, and > 1 indicates an effect which increases in proportion to the value³⁵. Due to the diversity of ages among study subjects, age was considered as the exposure time for each subject within the regressions. A significance level of 0.05 was used.

Data were analyzed using Minitab 16.1.0 (Minitab Inc., State College, USA) and Stata/SE (Stata Corp., College Station, USA).

Results

The number of subjects, including participants living in Calnali, was 1,366 (Table 1). A total of 223 participants living in Calnali were excluded, giving a final sample of 1,143 (55% females; overall mean age 12.7 years (SD = 13.1)). The overall mean DMFT score was 4.02 (4.76). No teeth were recorded as missing due to caries, and untreated decay (D) represented the largest part of the DMFT score. The DMFT score for Calnali was 4.07 (5.03), while the mean DMFT score for surrounding communities was 4.02 (4.76) (Table 1).

Table 2 shows the geographical factors in the ten communities in relation to Calnali.

Table 1

Mean DMFT scores broken down into the components decayed, missing, and filled teeth for the town of Calnali and communities, State of Hidalgo, Mexico.

Town	n	Mean age	SD	Mean D	SD	Mean M	SD	Mean F	SD	Mean DMFT	SD
Calnali	223	11.60	± 10.80	3.01	± 4.43	0	± 0	1.12	± 2.50	4.07	± 5.03
Ahuacatlan	26	22.62	± 20.56	8.77	± 5.26	0	± 0	1.58	± 2.73	10.35	± 5.92
Atempa	73	9.08	± 3.48	3.13	± 3.53	0	± 0	0.55	± 1.34	3.69	± 3.53
Coamitla	78	10.13	± 3.78	2.96	± 3.10	0	± 0	0.55	± 1.68	3.51	± 3.21
Coyula	207	15.93	± 17.63	3.257	± 4.90	0	± 0	0.77	± 2.25	4.04	± 5.38
Papatlatla	196	15.26	± 16.09	4.34	± 4.16	0	± 0	0.70	± 2.02	5.04	± 4.84
Pezmatlan	235	7.98	± 3.10	2.77	± 3.41	0.004	± 0.065	0.64	± 1.72	3.41	± 3.96
San Andres	195	14.56	± 14.55	2.90	± 4.72	0	± 0	0.96	± 2.04	3.86	± 5.09
Santa Lucia	40	7.50	± 2.86	1.53	± 3.00	0	± 0	0.98	± 3.38	2.50	± 4.74
Techichico	61	15.03	± 13.55	0.87	± 1.23	0	± 0	1.34	± 2.87	2.21	± 3.04
Tecpaco	32	9.59	± 2.63	5.19	± 5.40	0	± 0	0.22	± 0.71	5.41	5.48
Total without Calnali	1,143	12.746	± 13.13	3.25	± 4.26	0	± 0.029	0.78	± 2.07	4.02	± 4.76
Total with Calnali	1,366	12.56	± 12.79	3.21	± 4.29	0	± 0.027	0.82	± 2.14	4.03	± 4.8

Table 2

Geographical factors in the town of Calnali and communities, State of Hidalgo, Mexico.

Town	n	Mean age	SD	Altitude difference (ft)	Travel distance (km)	Paved roads (%)	Travel time (minutes)	Availability of piped water
Calnali	223	11.6	± 10.8	3,149	0	100	0	Yes
Ahuacatlan	26	22.6	± 20.5	+735	8.1	100	30	Yes
Atempa	73	9.1	± 3.5	-295	13	95	40	Yes
Coamitla	78	10.1	± 3.8	-2,349	14	100	40	Yes
Coyula	207	15.9	± 17.6	-702	11.5	66	40	Yes
Papatlatla	196	15.2	± 16.1	-570	17.1	100	45	Yes
Pezmatlan	235	7.9	± 3.1	-557	6.9	95	15	Yes
San Andres	195	14.5	± 14.5	+676	7.5	100	20	Yes
Santa lucia	40	7.5	± 2.8	-722	15.1	70	80	No
Techichico	61	15	± 13.5	-417	10.9	100	15	No
Tecpaco	32	9.6	± 2.6	+866	12	50	50	No

The variables that had the most significant effect on the DMFT score were proportion of paved roads and availability of piped potable water [RR = 5.02 (1.72) and 0.36 (0.09), respectively (Table 3)]. The DMFT score increased in proportion to the increase in proportion of paved roads. In contrast, there was a moderate decrease in the DMFT score with the availability of piped potable water.

The DT score increased significantly with an increase in the proportion of paved roads, and there was a strong decrease in the score with

availability of piped potable water. The DT score also decreased slightly with an increase in travel distance between the community and Calnali [RR = 6.28 (3.53), 0.18 (0.07), and 0.79 (0.04), respectively (Table 3)].

The variables associated with a significant increase in FT scores were proportion of paved roads and availability of piped potable water [RR = 3.74 (1.06) and 5.21 (2.16), respectively (Table 3)]. Availability of piped potable water and a larger proportion of paved roads were associated with an increase in the number of filled teeth.

Table 3

Results of the general estimating equations (GEE) applied to DMFT scores and two of its components for Calnali town and communities, State of Hidalgo, Mexico.

Independent variable	Coefficient	± SE	RR	±SE	95%CI
GEE negative binomial model results for DMFT score					
Distance from Calnali	-0.121	± 0.040	0.88	± 0.03	0.84-0.94
Altitude difference	0.000	± 0.000	1.00	± 0.00	1.00-1.00
Proportion of paved roads	1.643	± 0.504	5.02	± 1.72	2.57-9.83
Availability of piped water	-0.954	± 0.436	0.36	± 0.09	0.22-0.60
Population	0.000	± 0.000	1.00	± 0.00	1.00-1.00
Travel time between community and Calnali	0.028	± 0.007	1.03	± 0.01	1.02-1.04
GEE negative binomial model results for DT score					
Distance from Calnali	-0.23	± 0.044	0.79	± 0.04	0.72-0.87
Altitude difference	-0.001	± 0.000	1.00	± 0.00	1.00-1.00
Proportion of paved roads	1.837	± 0.591	6.28	± 3.53	2.09-18.88
Availability of piped water	-1.688	± 0.323	0.18	± 0.07	0.09-0.39
Population	0.001	± 0.000	1.00	± 0.00	1.00-1.00
Travel time between community and Calnali	0.039	± 0.009	1.04	± 0.01	1.02-1.06
GEE negative binomial model results for FT score					
Distance from Calnali	0.074	± 0.057	1.06	± 0.03	1.00-1.12
Altitude difference	0.000	± 0.000	1.00	± 0.00	1.00-1.00
Proportion of paved roads	1.388	± 1.249	3.74	± 1.06	2.15-6.52
Availability of piped water	2.030	± 0.778	5.22	± 2.16	2.31-11.74
Population	-0.001	± 0.000	1.00	± 0.00	1.00-1.00
Travel time between community and Calnali	0.015	± 0.166	1.01	± 0.01	0.99-1.02

DT: decayed teeth; FT: filled teeth; 95% CI: 95% confidence interval.

Discussion

The present results indicate that even in a largely underserved population there were significant differences in terms of caries experience associated with specific geographical factors. Socioeconomic status and relative household wealth are similar throughout the study area and the standard of living of the region is considered poor by Western standards. The establishment of small locations in mountainous areas in many parts of Latin America have consistently followed a pattern in which those groups lower in the lower socioeconomic status (often of higher Amerindian heritage) are relegated to the least desirable lands, farther away from rivers and flatlands. If the range of socioeconomic status is as narrow as we believe it is, and if the population is ethnically homogeneous (thereby minimizing the role genetic variability plays in caries vulnerability), then it is possible that the observed differences in caries experience are ascribable to greater exposure to decay-inducing agents and/or varied access to dental care. The variables presence of piped potable water and the proportion of paved

roads were associated with a significant increase in the filled component of the DMFT score, indicating that when decay is severe enough to require dental fillings, access to Calnali seems to be an important determining factor for experience of restorative dental care.

Higher prevalence of untreated caries was also associated with better roads and shorter travel distance between the community and Calnali, which is the distribution center for Western-type foods and beverages (Table 3), thus suggesting that improved road conditions may facilitate the transport of decay-inducing snacks and beverages to communities. The increased availability of more decaying-inducing snacks and beverages appears to hold a dynamic trade-off with the strong decrease simultaneously seen when community water supplies were available in a given community: the inverse proportions of liquid intake made up by high-calorie, cariogenic beverages and by potable water have been highlighted for Mexico at large³⁵. Although the rate of consumption of soft drinks in rural areas of the State of Hidalgo is somewhat lower than in urban settings and the more affluent Mexico City

and Northern border regions³⁶, its population nevertheless contributes to the fact that Mexico is second in the world soft drink consumption ranking³⁷, and studies shows that the majority of children in the municipality of Calnali consume sugared beverages^{38,39}. However, whether better roads are in fact associated with easier access to cariogenic foods and beverages remains uncertain. A separate study of a homogeneously deprived area in Detroit found a strong positive association between caries severity and the proportion of grocery stores¹⁶, which are sources of cariogenic snacks and beverages, therefore lending credence to the “ease of access” hypothesis.

Travel distance and time between communities and Calnali differed slightly, while variation in altitude was remarkably large for such a small area (Table 1). Easier access due to shorter distances, decreased travel time²⁵, and less changes in altitude (i.e.: less steep roads) could theoretically facilitate access to dental services. The FT scores largely reject this hypothesis, while the DT scores show a modest decrease with increasing distances between Calnali and the communities.

The aggregate DMFT scores (missing teeth were almost non-existent) essentially replicated the DT scores.

The findings of the present research should be viewed in the context of the study’s strengths and weaknesses to fully understand their significance. This study is a multiple cross-sectional collection of data from a large region in rural Mexico over a nine year period. While training was carried out to standardize data collection, emphasis was given to service delivery. We did not measure exposure of individuals to fluoride; however, fluoride concentrations have been shown to be negligible³⁹. Although differences between naturally occurring fluorides in water and fluoridated domestic salt are unlikely, we cannot completely rule out the differential role of fluoride levels in caries prevention across communities. However, this role is unlikely to be significant. Furthermore, it is crucial to resist at-

tempts to extrapolate findings to larger populations. It is not possible to confirm with absolute certainty the association between oral health and the following significant factors: better access to dental care services available in Calnali; greater availability of decay-inducing agents in the communities; availability of potable water (as opposed to bottled beverages); or a combination of these factors. Finally, the temporal ambiguity of cross-sectional designs precludes ascribing cause-effect relationships to variables.

On the other hand the solid modeling approach adopted by this study provided increased knowledge of geographic markers and dental health in rural Latin America and our findings will help guide subsequent studies. The present study adopted a research framework in which data from an area comprising various communities was used to establish whether an association can be made between dental health indicators and a priori geographic markers (travel distance and time between community and dental services, ease of transport and geographic remoteness, and ease of access for transport of decay-inducing snacks and drinks to distant communities). We did not specifically investigate possible variations ascribed to nuances in socioeconomic status because data were derived from a generally homogenous, socioeconomically deprived rural location.

In conclusion, our findings suggest a marked association between caries experience (and the treatment of carious lesions) and two markers of a higher degree of urbanization. Further detailed research into the role of these factors in other rural locations and less mountainous areas is necessary to establish whether these variables may be considered potential predictive geographic markers for other areas. Emphasis should be given to the characterization of mechanisms underlying the variables “proportion of paved roads between community and dental services”, and “availability of piped community water supplies”.

Resumo

O objetivo deste estudo foi investigar a associação entre marcadores de doença bucal e fatores geográficos que influenciam o acesso aos cuidados dentários (índice CPOD) entre crianças escolares na região central do México. Dados retrospectivos foram coletados durante um programa de service-learning internacional entre 2002 e 2009. Uma amostra de 1.143 crianças (55% meninas; idade média 12,7±13,1 anos) foi analisada. A pontuação média do CPOD, representado em grande parte por cárie não tratada, foi de 4,02 (4,76). As variáveis que tiveram o efeito mais significativo na pontuação do CPOD foram a proporção de estradas pavimentadas entre a comunidade e os serviços odontológicos, e a disponibilidade de água encanada potável. A pontuação do CPOD aumentou em proporção com a quantidade de estradas pavimentadas. Em contraste, o CPOD diminuiu com a disponibilidade de água canalizada potável. Resultados semelhantes foram encontrados para a cárie dentária não tratada. A principal variável associada com um aumento significativo em obturações dentárias foi proporção de estradas pavimentadas. Esta é uma das primeiras investigações sobre a associação entre fatores geográficos e saúde bucal em um ambiente subdesenvolvido.

Saúde Bucal; Índice CPO; Criança

Contributors

G. Maupome contributed to study design, data analysis and drafting this manuscript. E. Angeles Martínez-Mier, contributed to study design, data collection and drafting this manuscript. A. Holt, Andrés Mantilla-Rodríguez and B. Carlton contributed to the manipulation of data and data analysis and to drafting this manuscript. C. E. Medina-Solís contributed to methodological design, data analysis and interpretation and drafting this manuscript.

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