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Association between Diabetes and Dental Caries in Spanish Adults: A Cross-Sectional Study Including 23,089 Adults

Louis Jacob ^{1,2}, Jae-Il Shin ^{3,*}, Igor Grabovac ⁴, Josep Maria Haro ², Ai Koyanagi ^{2,5}, Mark A. Tully ⁶, Mike Trott ⁷, Jong Yeob Kim ⁷, Shahina Pardhan ⁸, Lee Smith ^{9,†} and Guillermo F. López Sánchez ^{7,†}

¹ Faculty of Medicine, University of Versailles Saint-Quentin-en-Yvelines, 78180 Montigny-le-Bretonneux, France; louis.jacob.contacts@gmail.com

² Research and Development Unit, Parc Sanitari Sant Joan de Déu, CIBERSAM, Dr. Antoni Pujadas, 42, Sant Boi de Llobregat, 08830 Barcelona, Spain; josepmaria.haro@sjd.es (J.M.H.); ai.koyanagi@sjd.es (A.K.)

³ Department of Pediatrics, Yonsei University College of Medicine, Seoul 03722, Korea

⁴ Department of Social and Preventive Medicine, Centre for Public Health, Medical University Vienna, 1090 Vienna, Austria; igor.grabovac@meduniwien.ac.at

⁵ ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

⁶ Institute of Mental Health Sciences, School of Health Sciences, Ulster University, Newtownabbey BT37 0QB, UK; m.tully@ulster.ac.uk

⁷ Yonsei University College of Medicine, Seoul 03722, Korea; mike.trott@aru.ac.uk (M.T.); crossing96@yonsei.ac.kr (J.Y.K.); guillermo.lopez-sanchez@aru.ac.uk (G.F.L.S.)

⁸ Vision and Eye Research Institute, School of Medicine, Faculty of Health, Education, Medicine and Social Care, Anglia Ruskin University, Cambridge CB1 1PT, UK; shahina.pardhan@aru.ac.uk

⁹ Centre for Health, Performance, and Wellbeing, Anglia Ruskin University, Cambridge CB1 1PT, UK; Lee.Smith@aru.ac.uk

* Correspondence: shinji@yuhs.ac

† Co-last authors: Lee Smith; Guillermo F. López Sánchez.



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Abstract: The aim of the study was to investigate the cross-sectional association between diabetes and dental caries in a representative sample of 23,089 adults residing in Spain. Data from the Spanish National Health Survey 2017 were analysed. Diabetes (independent variable) and dental caries (dependent variable) were evaluated through a self-reported questionnaire. The association between diabetes and dental caries in the overall sample was assessed using logistic regression models adjusted for sex, age, marital status, education, smoking, alcohol consumption, obesity, hypertension, and hypercholesterolemia. The prevalence of dental caries was 20.6% in the overall population and was significantly higher in men and in young (≤ 40 years) and middle-aged adults (41–65 years) than in women and older adults (> 65 years), respectively. After adjusting for control variables, there was a positive and significant association between diabetes and dental caries in the overall population (OR = 1.30, 95% CI = 1.15–1.46). The relationship between diabetes and dental caries was particularly strong in women (OR = 1.45, 95% CI = 1.22–1.71) and in adults aged ≤ 40 years (OR = 1.80, 95% CI = 1.05–3.05). In conclusion, in this large representative sample of Spanish adults, diabetes was associated with having a higher prevalence of dental caries, with females and younger adults at greatest risk. Patients with diabetes and dental practitioners should be aware of these associations and act accordingly. Future research should aim to investigate the mediating factors involved in the observed association between diabetes and dental caries.

Keywords: diabetes; dental caries; oral health; cross-sectional study; Spain

1. Introduction

Diabetes corresponds to a chronic endocrine disease characterized by the impairment of the production and/or the response to insulin, resulting in high glucose levels in the blood [1]. Diabetes can be categorized as type 1 (little to no insulin produced) or type 2 (impaired response to insulin). Approximately 90% of all cases with diabetes are

classified as type 2, which predominantly affects the adult population [1]. Importantly, gestational diabetes can also occur; this is where the mother experiences high levels of blood glucose during pregnancy. However, post-partum blood sugar levels tend to return to pre-pregnancy levels [1].

Diabetes per se is associated with multiple health complications, many of which have been extensively studied, including cancer, heart failure, and cardiovascular disease [2–4]. There is also a substantial body of literature investigating the relationship between diabetes and oral health [5], with people with diabetes more likely to suffer from gum disease, thrush, and dry mouth [6].

Dental caries is one of the most frequent noncommunicable diseases in the world [7]. Based on the findings of the 2015 Global Burden of Disease Study [8], dental caries is the first oral condition worldwide, with the prevalence overreaching 34% for untreated caries in permanent teeth. There is a growing body of literature to suggest that diabetes is associated with dental caries. For example, one study including 60 participants found that the decayed, missing and filled teeth (DMFT) index was significantly higher in people with diabetes than in their counterparts without diabetes [9]. These results were corroborated in another study including 100 adults, as the type 2 diabetes group displayed a higher DMFT score than the control group [10]. Finally, in a sample of 240 patients, it was found that the prevalence of dental caries was around 73% in those with diabetes and 31% in those without diabetes [11]. Interestingly, that same study further revealed that dental caries were more frequent in individuals with uncontrolled diabetes than in those with controlled diabetes (90% versus 43%). Although these studies have advanced the field, one key limitation is that they all utilized small samples (i.e., from 60 to 240 participants), and therefore, the representativeness of the findings is not known. Indeed, no large-scale epidemiological study exists examining the relationship between diabetes and dental caries. Diabetes may be associated with a higher prevalence of dental caries through long-term glucose leakage into saliva, which indirectly increases the metabolic activity of the oral microflora, alters the dental biofilm, and ultimately favors the occurrence of dental decay and periodontal diseases [12].

Given this background, the aim of the present study was to investigate the cross-sectional association between diabetes and dental caries in a representative sample of 23,089 adults residing in Spain. Given that diabetes has a particularly high prevalence in Spain, approximately 13.8% [13], studying the diabetes–dental caries relationship in this country is of utmost importance.

2. Methods

2.1. The Survey

This study was based on data from the Spanish National Health Survey 2017. Previous literature has extensively described the survey [14,15]. Briefly, the Spanish National Health Survey 2017 was undertaken in Spain from October 2016 to October 2017. Data collection relied on a stratified, three-stage sampling design. The first stage corresponded to the selection of census sections, and the probability of selection was proportional to the section size. The second stage corresponded to the selection of family dwellings in each census section, and the probability of selection was proportional to the dwelling size. The third stage corresponded to the selection of an adult aged ≥ 15 years in each family dwelling, and this selection relied on the random Kish method, with all members aged ≥ 15 years of the family dwelling having the same probability to be selected. This methodology allowed the sample to be representative of the adult population living in Spain. Data collection relied on computer-assisted personal interviewing (CAPI), and all interviews were conducted at the home of the participants by trained staff. An informed consent was obtained from each participant. Finally, the research was conducted in accordance with the Declaration of Helsinki.

2.2. Diabetes (Independent Variable)

Diabetes was evaluated through the following yes–no question: “Have you ever been diagnosed with diabetes?” Those who answered affirmatively to the question were considered to have diabetes. Previous research has confirmed the validity of self-reported diagnosis of diabetes (i.e., sensitivity of 73% and specificity of 99%) [16].

2.3. Dental Caries (Dependent Variable)

Dental caries was evaluated through the following yes–no question: “Do you have dental caries?” Those who answered affirmatively to the question were considered to have dental caries. This question is a valid measure of self-referred dental caries [17], while self-reported information on dental caries has been found to have a relatively high sensitivity (i.e., 82%) and specificity (i.e., 78%) compared with clinical examination in young adults [18].

2.4. Control Variables

The selection of the control variables relied on previous studies indicating that these factors are associated with both the independent variable (diabetes) [19–22] and the dependent variable (dental caries) [23–26]. All control variables were self-reported. Sociodemographic variables included sex, age, marital status (married versus single/separated/divorced/widowed) and education (\leq primary (i.e., primary school or less), secondary (i.e., secondary school, baccalaureate, intermediate professional education, or equivalent), \geq tertiary (i.e., university, higher professional education, or equivalent)). Smoking status was self-reported and corresponded to a categorical variable with three outcomes (i.e., never, past, and current smoking). Past-year alcohol consumption was self-reported and included in the analyses as a dichotomous variable (none versus any). Based on the standard definition of the World Health Organization, obesity corresponded to a body mass index (BMI) ≥ 30 kg/m², and BMI < 30 kg/m² was considered no obesity [27]. BMI was calculated as self-reported weight in kilograms divided by self-reported height in meters squared. Finally, hypertension and hypercholesterolemia were evaluated through the following yes–no question: “Have you ever been diagnosed with hypertension/hypercholesterolemia?” Those who answered affirmatively to the question were considered to have hypertension/hypercholesterolemia. Previous research has confirmed the validity and high accuracy of self-reported diagnosis of hypertension/hypercholesterolemia [16].

2.5. Statistical Analysis

Differences in the sample characteristics by diabetes were assessed using chi-square tests for all variables. Effect size was calculated using phi coefficient and Cramer’s V for dichotomous variables and categorical variables with more than two categories, respectively. The prevalence of dental caries was further studied in the overall population and by sex and age. The association between diabetes (independent variable) and dental caries (dependent variable) in the overall sample was assessed using logistic regression models adjusted for sex, age, marital status, education, smoking, alcohol consumption, obesity, hypertension, and hypercholesterolemia. As the relationship between diabetes and dental caries may differ by sex and age [28–31], interaction analyses were conducted including the product terms “diabetes X sex” and “diabetes X age” in the logistic model. Sensitivity analyses were also conducted in men, women, adults aged ≤ 40 years, those aged 41–65 years, and those aged > 65 years. Sex-stratified analyses were not adjusted for sex. All independent variables were included in the models as categorical variables with the exception of age, which was included as a continuous variable. There were missing data for dental caries ($n = 387$, 1.68%), marital status ($n = 39$, 0.17%), smoking ($n = 22$, 0.10%), alcohol consumption ($n = 26$, 0.11%), and obesity ($n = 1070$, 4.63%). Complete-case analysis was carried out including 21,625 (93.66%) participants after excluding 1464 participants (6.34%) with any missing data. Results from the logistic regression analyses are presented as odds ratios (ORs) and 95% confidence intervals (CIs). The level of statistical

significance was set at $p < 0.05$. The statistical analysis was performed with R 4.1.0 (The R Foundation) [32].

3. Results

There were 23,089 adults living in Spain included in this retrospective study (54.1% of women and 43.9% of participants aged 41–65 years). Male sex, age > 65 years, ≤primary education, past smoking, no alcohol consumption, obesity, hypertension, and hypercholesterolemia were more common in people with than in those without diabetes (Table 1). The prevalence of dental caries was 20.6% in the overall population and was significantly higher in men and in young (≤40 years) and middle-aged adults (41–65 years) than in women and older adults (>65 years), respectively (Figure 1). The results of the logistic regression analyses are displayed in Figure 2. After adjusting for several potential confounding factors (i.e., sex, age, marital status, education, smoking, alcohol consumption, obesity, hypertension, and hypercholesterolemia), there was a positive and significant association between diabetes and dental caries in the overall population (OR = 1.30, 95% CI = 1.15–1.46). Although sex was not a significant interacting factor in the association between diabetes and dental caries, the relationship was found to be significant in women only (OR = 1.45, 95% CI = 1.22–1.71). Furthermore, age significantly interacted with diabetes in its association with dental caries, and the association was particularly strong in adults aged ≤ 40 years (OR = 1.80, 95% CI = 1.05–3.05).

Table 1. Sample characteristics (overall and by diabetes status).

Characteristics	Category	Overall (N = 23,089)	Diabetes		Effect Size ^a	p-Value ^b
			No (N = 20,823)	Yes (N = 2266)		
Sex	Male	45.9	45.5	49.8	0.03	<0.001
	Female	54.1	54.5	50.2		
Age	≤40 years	27.2	29.8	2.7	0.28	<0.001
	41–65 years	43.9	45.3	30.8		
	>65 years	29.0	24.9	66.5		
Marital status	Single/separated/ divorced/widowed	45.9	46.1	44.1	0.01	0.064
	Married	54.1	53.9	55.9		
Education	≤Primary	31.2	27.9	61.7	0.20	<0.001
	Secondary	43.0	44.7	28.2		
	≥Tertiary	25.8	27.5	10.2		
Smoking	Never	50.8	50.7	50.9	0.08	<0.001
	Past	25.8	24.9	34.3		
	Current	23.4	24.3	14.8		
Alcohol consumption	None	35.8	34.0	52.1	0.11	<0.001
	Any	64.2	66.0	47.9		
Obesity	No	82.3	83.9	66.5	0.13	<0.001
	Yes	17.7	16.1	33.5		
Hypertension	No	73.0	77.1	34.8	0.28	<0.001
	Yes	27.0	22.9	65.2		
Hypercholesterolemia	No	76.3	79.9	44.1	0.25	<0.001
	Yes	23.7	20.1	55.9		

Diabetes was assessed with a yes–no question. Values are percentages unless otherwise stated. ^a Effect size was calculated using phi coefficient and Cramer's V for dichotomous variables and categorical variables with more than two categories, respectively. ^b p-values were based on chi-square tests.

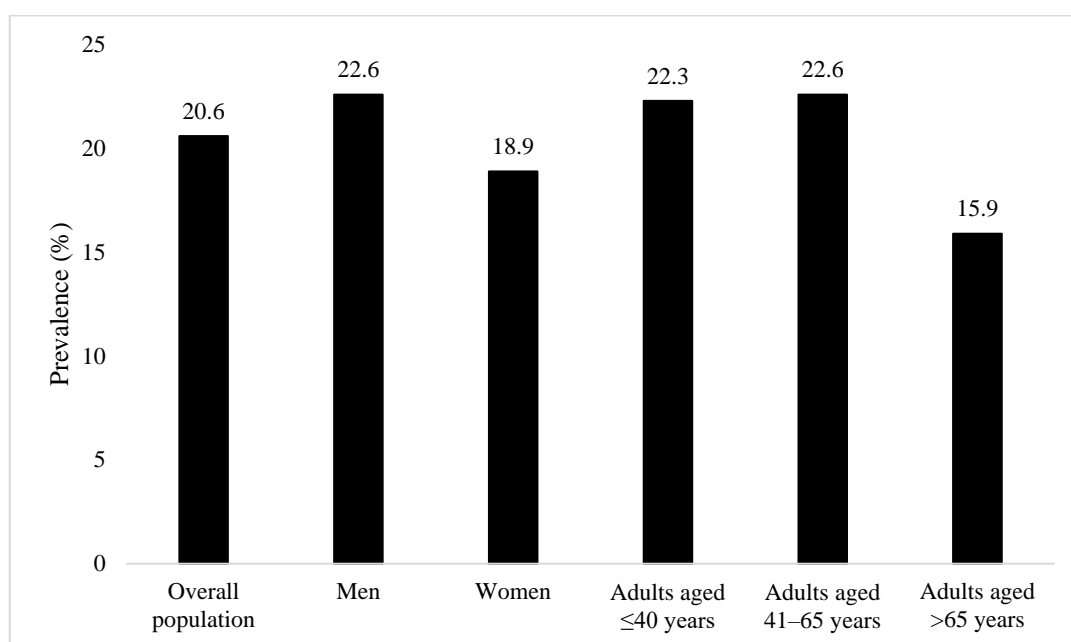


Figure 1. Prevalence of dental caries in the overall population and by sex and age.

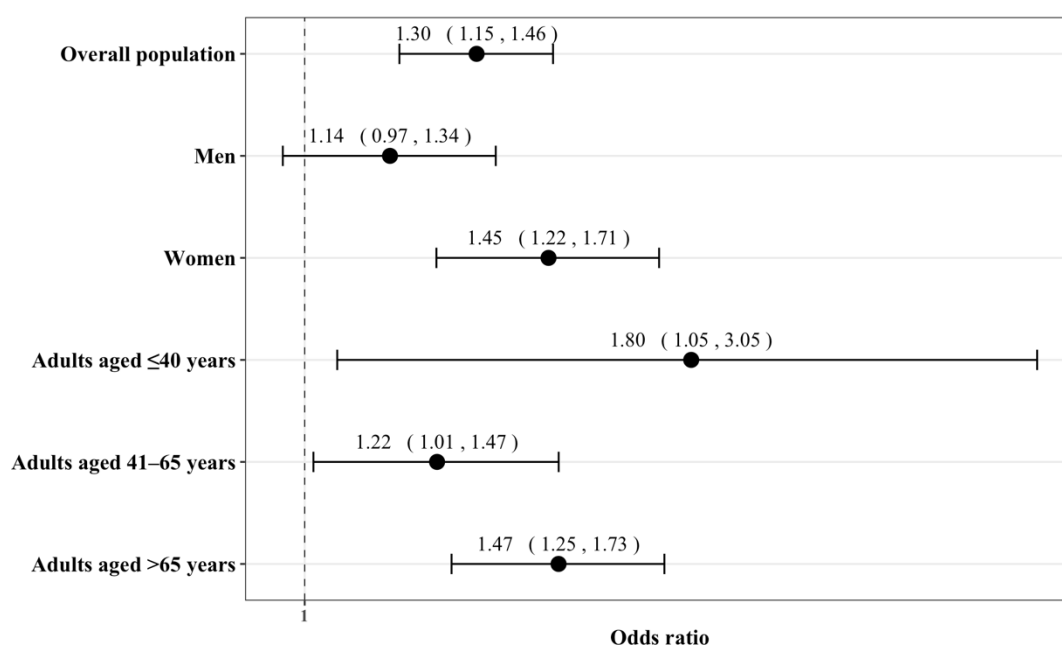


Figure 2. Association between diabetes (independent variable) and dental caries (dependent variable) in the overall population and by sex and age.

Dental caries were assessed with a yes–no question. The prevalence of dental caries was significantly higher in men and younger (those aged ≤ 40 years) and middle-aged adults (those aged 41–65 years) than in women and older adults (those aged > 65 years), respectively (p -values < 0.001).

Diabetes and dental caries were assessed with yes–no questions. Logistic regression analyses were adjusted for sex (except the sex-stratified analysis), age, marital status, education, smoking, alcohol consumption, obesity, hypertension, and hypercholesterolemia. All independent variables were included in the models as categorical variables, with the exception of age, which was included as a continuous variable. Dots and lines represent odds ratios and 95% confidence intervals, respectively.

4. Discussion

In this large sample of adults residing in Spain, it was found that the prevalence of dental caries was 20.6%. Moreover, overall, those with diabetes were 1.30 times more likely to have dental caries compared with their counterparts without diabetes. Sensitivity analysis further revealed that the association between diabetes and dental caries was significant in women but not in men. Finally, in terms of age, the relationship between diabetes and dental caries was strongest in participants aged ≤ 40 years.

Taken together, these results support and add to previous literature on this topic. It supports previous literature by confirming a positive association between diabetes and dental caries [9–11,33,34]. Importantly, the existing literature is limited through utilizing small and non-representative samples. This study adds to this literature by confirming that the association between diabetes and dental caries still holds in a large representative sample of Spanish adults and that this relationship is particularly strong in females and younger adults.

There is one key driver that likely explains the relationship between diabetes and dental caries. As previously mentioned, long-term glucose leakage into saliva is common in diabetes, and this may lead to an alteration of the dental biofilm and indirectly exacerbate the risk of dental caries and other oral disorders [12]. Indeed, saliva composition plays a major role in the integrity of oral tissues by protecting these tissues against various pathogens, controlling the local demineralization-remineralization equilibrium, and stabilizing pH [33]. Importantly, diabetes is associated with a high prevalence of xerostomia (i.e., dry mouth), and this condition may predispose to a higher risk of dental caries [35].

Other mechanisms may also explain the observed association between diabetes and dental caries. First, diabetes has been found to be associated with a higher risk of poor mental health, particularly depression [36]. Meanwhile, studies have shown that those with poor mental health are at higher risk of worse oral health, including dental caries [37]. Second, literature suggests that those with diabetes in general tend to have poor eating habits [38,39]. In turn, poor eating habits are associated with worse oral health [40]. Third, people with diabetes have lower levels of physical activity than those without diabetes [41,42], and low levels of physical activity are also associated with poor oral health [25].

The finding that women but not men with diabetes are more likely to have dental caries than their counterparts without diabetes is interesting. It is likely explained by a higher prevalence of xerostomia in females [43,44], highlighting the fact that xerostomia may be an important mediating factor in the association between diabetes and dental caries. The finding that the diabetes–dental caries relationship was stronger in younger than in older adults should also be noted, but a plausible explanation is elusive. However, it may be owing to higher rates of poor mental health in younger than older adults [45]. Besides, the consumption of sugar-sweetened beverages, which is associated with both diabetes [46] and dental caries [47], is frequent in young adults [48], and this could explain why the diabetes–dental caries relationship was particularly strong in young adults. More research to further explain this stronger association between diabetes and dental caries in younger adults is required.

The large representative sample and the stratification by age and sex are clear strengths of the present analyses. However, findings must be interpreted in light of the study limitations. First, diabetes, dental caries, and control variables were self-reported and thus subjected to reporting and recall bias, while the use of clinical and biological data would have allowed more detailed analyses. Second, the type of diabetes was not reported, and it is possible that differing associations may be observed for type 1, type 2, and gestational diabetes. As a matter of fact, these types of diabetes affect different populations, and one may hypothesize that these populations do not share the same risk for dental caries. Third, this was a study conducted in a single country (i.e., Spain), and the findings may not be extrapolated to other countries and other regions of the world. Therefore, future multi-country research should aim to investigate the association between diabetes and

dental caries, while more data on the differential relationship between diabetes and dental caries by type of diabetes are warranted.

5. Conclusions

In conclusion, in this large representative sample of adults from Spain, the prevalence of dental caries was around 21%, and after adjusting for a wide range of potential confounding variables, diabetes was positively and significantly associated with dental caries. The relationship between diabetes and dental caries was particularly strong in women and young adults. Patients with diabetes as well as dental practitioners should be aware of these associations, and oral health education and oral hygiene should be promoted in people with diabetes. Finally, future research should aim to investigate the observed association between diabetes type and dental caries.

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