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Global smoking-attributable burden of periodontal disease in 186 countries in the year 2015

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Abstract

Aim: We aimed to quantify the smoking-attributable burden of periodontal disease (PD).

Methods: The association between smoking and PD was evaluated. Population, smoking and PD data from the Global Burden of Disease Study were used, and the burden in different sex and age groups in 186 countries in 2015 calculated, adjusted for PD prevalence and numbers of cigarettes smoked. No adjustment was performed in a sensitivity analysis.

Results: The global smoking-attributable burden was 251,160 disability-adjusted life years (DALYs; 95% uncertainty interval: 190,721–324,241; sensitivity analysis: 344,041 DALYs) or 38.5 million cases. The burden was lower in females than males, and highest in the age group of the 50- to 69-year-olds. On super-regional level, the burden was highest in South-East Asia, East Asia and Oceania (83,052 DALYs), and high-income North America and Asia Pacific (55,362 DALYs). On regional level, it was highest in East Asia (70,845 DALYs), South Asia (30,808 DALYs) and North Africa and the Middle East (24,095 DALYs). On national level, it was highest in China (69,148 DALYs), India (29,362 DALYs) and the United States (12,714 DALYs). The relative smoking-attributable burden ranged between >25% in Suriname and <1% in Chad.

Conclusions: There is great need to monitor and tackle the smoking-attributable burden of PD.

KEYWORDS

dental, epidemiology, modelling, risk factors, smoking

1 | INTRODUCTION

A large number of studies confirmed an association between tobacco smoking and periodontal disease (PD), with smokers being at significantly increased risk of experiencing periodontitis and, subsequently, losing teeth. As a great range of case definitions (including the extent and severity of PD) is used across different studies, often in various age and sex groups, the exact association, however, remains unclear (Chambrone & Chambrone, 2006; Eke et al., 2016; Fardal, Johannessen, & Linden, 2004; Heasman et al., 2006). Building on systematically compiled and pooled data, one might produce more robust and generalizable estimates of this association.

If such estimates were available, one might assess the smoking-attributable burden of PD in different countries, age and sex groups, allowing comparisons between them. The smoking-attributable burden is the fraction of prevalent cases of PD or the subjective burden generated by PD attributable to smoking. The subjective burden is often measured as disability-adjusted life years (DALYs), whereas one DALY can be interpreted as one year of healthy life lost due to premature death (expressed in years of life lost [YLL]) and/or due to illness (expressed in years lived with disability [YLD]; Murray, Acharya, 1997). In case of non-mortal diseases such as PD, DALYs are calculated as the time suffered from a disease multiplied with its subjective impact (expressed in disability weights). For PD, there have been estimates

of how its symptoms subjectively impact on affected individuals (Salomon et al., 2015).

Quantifying the global smoking-attributable burden of PD should help to monitor patterns in smoking and associated PD outcomes, to identify where interventions towards smoking reduction are, from a dental perspective, most needed, and to evaluate which interventions might be most suitable across countries and populations (Carter et al., 2015; Jha & Peto, 2014). The attributable health burden of, for example, sugar, salt and fat consumption has been quantified (Meier et al., 2015, 2017). For PD, one would need to (1) estimate the association between smoking and PD, (2) quantify the prevalence of smoking in different countries and age groups, (3) quantify the prevalence of PD in these groups and (4) estimate the corresponding population attributable fraction. We aimed to quantify the global smoking-attributable burden of PD in different age and sex groups in 186 countries in 2015.

Clinical Relevance

Scientific rationale for the study: Smoking is a confirmed risk factor for periodontal disease (PD). The global smoking-attributable burden of PD has not been quantified.

Principal findings: With 251,160 disability-adjusted life years (38.5 million cases), the global smoking-attributable burden of PD is substantial. This estimate seems conservative and excludes the burden of tooth loss and edentulism due to periodontitis.

Practical implications: Policymakers, public health activists and clinicians need to increase their efforts for tackling smoking if they want to substantially reduce the burden of PD, especially in countries where individual-level clinical care is not widely available.

2 | METHODS

This study compiled data from the global burden of disease (GBD) 2015 database (https://http://vizhub.healthdata.org/gbd-compare) and data yielded by a systematic review on the association between smoking and periodontitis. Figure 1 displays the dataflow of this study, which was performed in line with the STROBE, GATHER, PRISMA and MOOSE statements (von Elm et al., 2007; Moher, Liberati, Tetzlaff, & Altman, 2009; Moher et al., 2015; Stevens et al., 2016; Stroup et al., 2000). Our analyses were performed on country, regional and super-regional level, with the definitions of these geographic units being in accordance with the GBD studies (Figure 2). Note that in this study, only the smoking-attributable burden of PD was quantified; the closely related burden of tooth loss or edentulism due to PD, again attributable to smoking, was not quantified. Our estimates are thus certainly conservative as to the overall impact of smoking.

2.1 | Population data

We used data from the GBD 2015 studies to estimate the populations aged 15–49, 50–69 and ≥70 years, respectively, stratified for sex, in 186 countries in 2015. These age bands were chosen, as (1) PD is near-absent in younger age groups and (2) these bands were also used to estimate the global burden of PD within the GBD studies (Kassebaum et al., 2017).

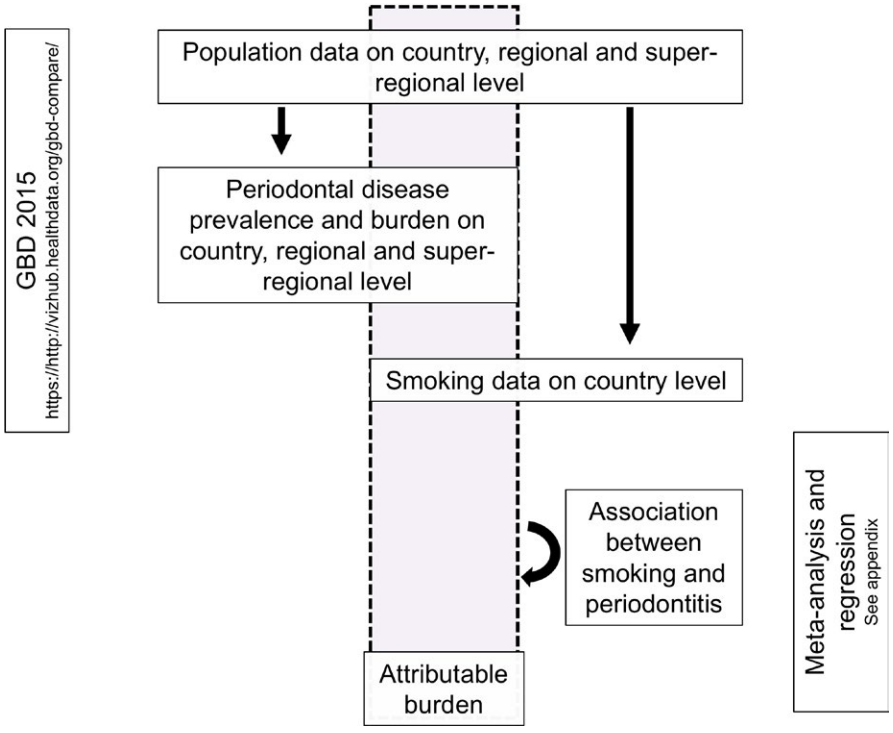


FIGURE 1 Dataflow of this study. Data from the Global Burden of Disease Study (GBD 2015) and data from the performed review and meta-analysis/meta-regression were used to estimate the prevalence and burden of periodontal disease, the prevalence of smoking and number of cigarettes smoked per smoker, and the association between smoking and periodontal disease. As a result, the smoking-attributable burden of periodontal disease on population level was estimated for 186 countries in three age groups, separated for sex, in 2015

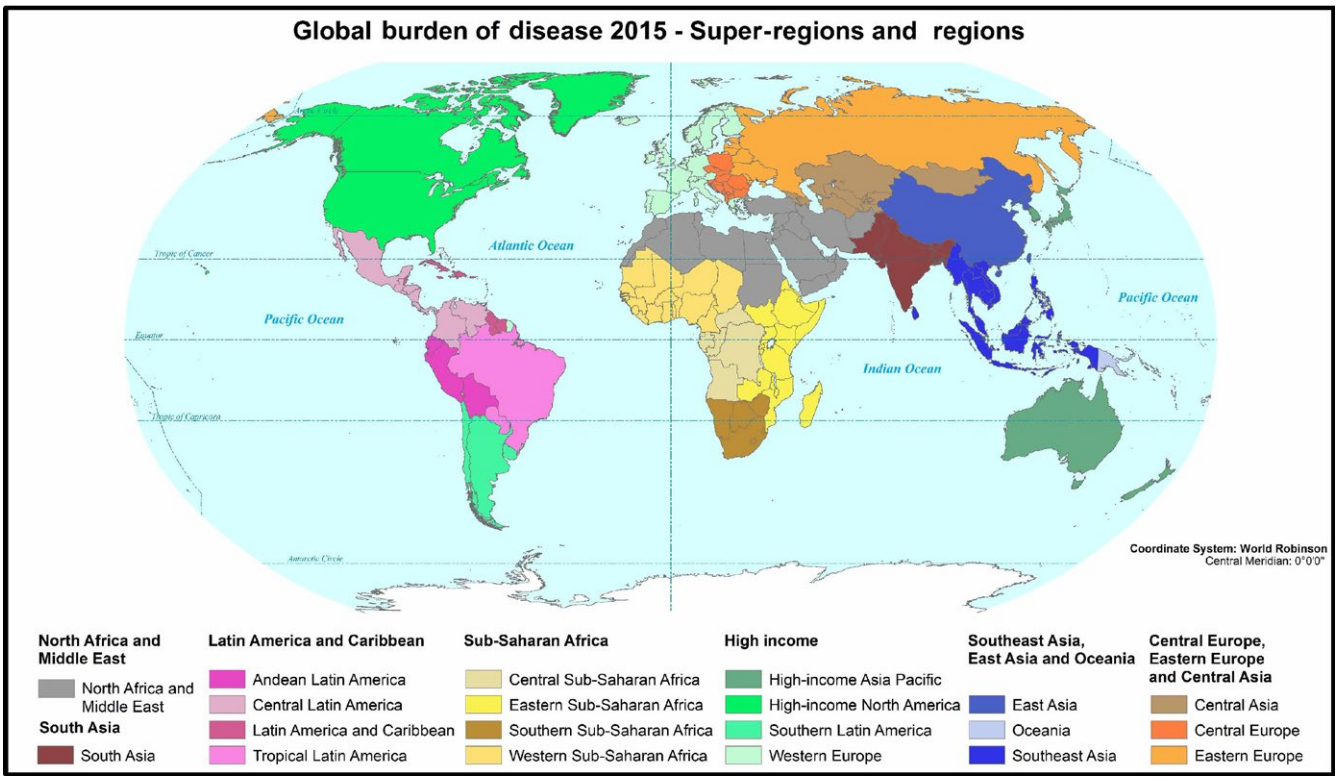


FIGURE 2 The different geographic areas of the GBD studies were used in this study, too

2.2 | Smoking data

From the overall populations, we estimated the smoking prevalence in the respective age groups via GBD 2015 data on prevalent cases in 5-year bands. These were summed up and divided by the total population in each of our three age groups to estimate smoking prevalence, again separated for sex. We additionally estimated the number of cigarettes smoked per smoker using GBD 2015 data (Reitsma et al., 2017). Note that these data only extended until 2012; 2015 estimates were generated via taking the arithmetic mean of annual changes from 2007 to 2012, which were then used to extrapolate the number of smoked cigarettes from 2012 to 2015. Also note that while both population and periodontitis data were available for 199 countries, smoking data were only available for 186 countries, hence the number of evaluated countries in our study.

2.3 | Periodontal disease data

The GBD 2015 studies had estimated the number of prevalent cases of PD, defined as "a gingival pocket depth equal or more than 6 mm, or Community Periodontal Index of Treatment Needs (CPITN) also referred as Community Periodontal Index (CPI) score of 4, or a clinical attachment loss (CAL) more than 6 mm" (Kassebaum et al., 2014a, 2017), that is severe chronic periodontitis. For GBD, a clinical examination was required and only surveys, which had sampled populations representative for the general populations, were included. Each prevalent case of PD was associated with disability according to the GBD definition of symptomatic severe chronic periodontitis constituting "bad breath, a bad taste in the mouth, and gums that bleed a little from time to time, but which does not interfere with daily activities" (Kassebaum et al., 2014a, 2017).

2.4 | Association between smoking and periodontitis

To obtain robust estimates of the association between smoking status and PD, a systematic review was first performed. The following inclusion criteria were applied as follows:

- Only observational studies (cross-sectional, case–control, longitudinal) were included.
- Data from nationally representative but also non-representative samples were considered.
- Studies needed to report on the association between smoking status and PD. We did not pre-specify how smoking status was defined (categorical as never/former/current, or continuous as number of cigarettes or pack-years). Similarly, the definition of PD was not prespecified. As our aim was to quantify the burden of disease, and as only severe chronic periodontitis has been assigned such subjective burden estimates in the 2015 GBD study, we prioritized studies reporting on severe periodontitis. Note, however, that the definition of severe periodontitis was similarly variable. (Some studies used the maximum attachment loss measured at a specific number of sites, others used probing depths etc.)

- Studies needed to apply multivariable models to account for minimum two other factors besides smoking which might be associated with PD (such as age, sex, socio-economic stratum, oral hygiene habits). We did not specify a priori how the association needed to be reported (OR, HR, RR). However, as we were interested in calculating population-level estimates, only studies reporting on the association between smoking and PD prevalence were included; studies reporting on PD extent or severity (reporting how smoking affected the attachment loss in mm, etc.) were excluded.
- As we aimed to generate estimates applicable to today's population, only studies published from 1990 onwards were included.

The search is described in detail in the appendix and was performed by one reviewer (FS) on 05/01/2017. If more than one study per country was available, we used the study which reported in more detail on the association between smoking and periodontitis, best using sex- and age-specific estimates. In case no such decision was possible, all eligible studies were included and estimates pooled using fixed-effect meta-analysis.

The following data items were extracted from the included studies: the year of publication and the year of study conduct (if this was not reported, we assumed this to be the year prior to publication), the country, the definition of smoking status, smoking prevalence, the definition of PD, PD prevalence, the association between both variables in the total population and in subgroups (of age, sex or smoking status). The extraction was repeated after 2 weeks by the same reviewer as a validation.

The observed association estimates were, in case of HR and RR, then transformed into OR. For studies which reported on the association being non-significant without giving an estimate, we assumed the OR to be 1, while the variance was imputed using the mean value from all other studies. Estimates were pooled using random-effects meta-analysis, as heterogeneity (as indicated by I^2 statistics) was substantial (92%). The unit of meta-analysis was the country. As mentioned, for some countries, more than one study had been included. In this case, fixed-effect meta-analysis of these studies was performed first to yield one estimate for each country, which was subsequently entered into the main meta-analysis.

To explore which parameters (PD prevalence, smoking prevalence, year of study conduct) modified the association between smoking and PD, fixed-effect and inverse variance-weighted meta-regression analyses were performed. Simple bivariate and multivariable models were constructed, and various fits were tested (linear, exponential, logistic). The performance of the yielded models was checked by inspecting the deviations of predicted from measured estimates.

2.5 | Smoking-attributable burden and sensitivity analysis

The smoking-attributable burden was estimated in two scenarios; a base-case and a sensitivity analysis. For the base-case, the association between smoking and periodontitis was assumed to be modified by the PD prevalence as described, with the yielded regression coefficient and intercept being used to tailor the association according to the prevalence in different countries, age and sex groups. In the base-case scenario, we also factored in the average number of cigarettes smoked per capita on country level in the year 2015. To do so, we used the pooled OR obtained in the meta-analysis, which has an average consumption of 22.5 cigarettes as baseline, and calculated the average OR increase in PD per cigarette smoked (which was 0.05 per cigarette). This coefficient was used to then calculate the smoking intensity-adjusted OR on country level, ranging from 1.05 in Chad (average daily cigarette consumption per capita: 0.86) to 6.69 in Suriname (average daily cigarette consumption per capita: 107). In a second step, the OR was converted to corresponding relative risks (RR) using the following formula (Grant, 2014):

$$RR = \frac{OR}{1 - p_o + (p_o * OR)}$$

OR, odds ratio; p_0, base risk; RR, relative risk.

For the calculation of the base risk, the age- and sex-adjusted prevalence rate of PD was used on country level. In a third step, the generated RR was converted into corresponding population attributable risks (PAR) using the following formula (Spiegelman, Hertzmark, & Wand, 2007):

$$PAR = 1 - \frac{1}{p(RR - 1) + 1}$$

PAR, population attributable risk; p, prevalence; RR, relative risk.

To check and to validate the robustness of our model in the sensitivity analysis, we instead did not tailor the association estimates to periodontitis prevalence or cigarettes smoked, but used solely the pooled association from our meta-analysis for all countries and age and sex groups to gauge the significance of the deviation of the base case from the sensitivity scenario.

For all results in both scenarios, 95% uncertainty intervals (95% UI) were calculated. UIs are commonly used in Bayesian statistics (such as confidence intervals in frequentist statistics) to describe the narrowest interval of the prior and posterior distribution that contains a distinct share (in our case 95%) of the probability density (Flaxman, Vos, & Murray, 2015). As priors, all epidemiological data points can be considered, which are used as input variables in the meta-regression framework of the GBD. Within this study, the absolute and relative prevalence as well as corresponding DALYs of PD in 186 countries were used as priors (Kassebaum et al., 2017).

3 | RESULTS

From 722 identified records, 27 studies were included in our systematic review (Appendix Fig. S1). Studies were conducted in 18 countries (Appendix Table S1). The mean (95% CI) association between smoking and PD was OR 2.2 (1.8–2.8) in random-effects meta-analysis (fixed-effects: OR 2.1; 2.0–2.2) (Fig. S2). Meta-regression was performed to

identify parameters predicting this association, to allow adjusting the association for individual countries. The lowest deviation between predicted and observed associations, that is the best fit, was achieved when using linear meta-regression of the inverse variance-weighted odds ratio on the periodontitis prevalence (Fig. S3); the mean deviation was ±0.058.

Using the mean estimate and adjusting it for PD prevalence and the numbers of cigarettes smoked in different countries, we estimated the smoking-attributable burden of PD. The global attributable burden was 251,160 (95%UI: 190,721–324,241) DALYs, or 38.5 (95%UI: 29.2–49.7) million cases (Table 1). In our sensitivity analysis, where no adjustment was performed (Appendix Table S2), we found this burden to be higher (344,041 DALY; 219,649–504,682).

The global smoking-attributable burden of PD was higher in males than females (male: 141,389 [108,008–181,507] DALYs; female: 109,771 [82,705–142,720] DALYs); this was confirmed in our sensitivity analysis. The largest burden was found in the age group 50- to 69-year-olds (Table 1); this was not the case in our sensitivity analysis, where the oldest group (≥70 years) shouldered the largest burden (given the PD prevalence being highest in this group) (Appendix Table S2).

The smoking-attributable burden of PD was analysed on three levels (Figure 3): On super-regional level, the burden was highest in South-East Asia, East Asia and Oceania (83,052 DALYs), and high-income North America and Asia Pacific (55,362 DALYs). On regional level, it was highest in East Asia (70,845 DALYs), South Asia (30,808 DALYs), North Africa and the Middle East (24,095 DALYs) and Western Europe (23,675 DALYs). On national level, it was highest in China (69,148 DALYs), India (29,362 DALYs) and the United States (12,714 DALYs).

The relative smoking-attributable burden (in % of total PD burden) was higher than 10% in 46 countries, headed by Suriname (26.1%) and followed by St. Vincent and the Grenadines (22.9%) and Mauritania (17.8%). The lowest relative attributable burden was observed in Chad (0.60%), Timor-Leste (0.63%) and the Solomon Islands (0.86%) (Figure 4). For most countries and regardless of sex, the highest attributable burden was found in the group aged 50–69 years, followed by the group aged 15–49 years. Notable exceptions were Oman, the Gambia, Kuwait and the United Arab Emirates, where the largest attributable burden was found in the youngest group. In certain countries, the attributable burden was highly concentrated in males rather than females, namely the United Arab Emirates, Qatar, Oman, Bahrain and Saudi Arabia. (In these countries, more than 75% of the burden was in males, not females.) There were only few countries where the opposite was true, namely Lesotho, Bulgaria, South Africa and Swaziland.

Using age-standardized estimates, the attributable burden was highest in Canada, Sweden, several countries in Northern Africa and South America (Figure 5a). After age-standardization, the attributable burden was now much higher in males than females in most countries (Figure 5b,c).

4 | DISCUSSION

This study found a strong and consistent association between smoking and PD. We found this association to be possibly modified by PD prevalence, which—in most circumstances—also means being modified by age; in older populations and giving the cumulative nature of the disease, the association with smoking was found to be reduced. In younger populations, however, smoking seemed a significant factor triggering and also possibly aggravating PD. This has implications for both monitoring and also combatting the smoking-attributable burden of PD. This burden, on a global scale, was found to be substantial. Its relative extent, however, was found to vary widely (we found this burden to range between <1% and >25%). On absolute levels, the highest burden was found in Asia, Northern America and Europe, being a function of both absolute population estimates (and with it, prevalent cases of PD) and smoking prevalence. Moreover, the attributable burden was higher in males than females, which is a function of smoking prevalence being unequally distributed between sexes (PD prevalence, in contrast, was higher in females). The attributable burden was also larger in those aged 50–69 years and younger, than older groups. This is notable, as those aged 70 years or above are, at least in richer countries, those suffering the most from PD (Kassebaum et al., 2014a). However, as smoking prevalence declines in older groups, but also given the decreased association between smoking and PD in such high-prevalence groups, the attributable burden was lower in these older than in middle-aged groups. This decreased association in older groups might also reflect the fact that in these groups, smoking-related PD might have led to tooth loss and, consequently, edentulism. This has, as described, not been accounted for in our estimation. In comparison with other smoking-associated diseases, the observed disease burden related to smoking (251,160 DALYs) in 2015 was of limited relevance. Diseases with the highest absolute burden attributable to smoking were as follows (in descending order): cardiovascular diseases: 62.7 million DALYs, neoplasms/cancer: 40.8 million DALYs and chronic respiratory diseases: 29.1 million DALYs (Reitsma et al., 2017). However, the observed relative attributable burden of smoking-related PD of 7.1% (i.e., its relative share of the total disease burden, expressed in DALYs) was similar to that of other smoking-related diseases (such as asthma [7.8%], tuberculosis [7.0%], lower respiratory infections [6.9%]) and ranks on the 23rd position of 38 totally considered smoking-related diseases in the Global Burden of Disease Study (IHME, 2017).

Our findings are relevant from a number of perspectives. First, when evaluated regardless of PD prevalence, we found smokers to be at twice or even higher the risk than non-smokers to experience PD. This calls for dentists and the whole dental domain, including dental public health and dental health policy, to be actively involved in anti-smoking campaigns. Dentistry should thus align with current efforts by the World Health Organization to attain the WHO target of a decreasing smoking prevalence by 30% by 2025. There are a number of active campaigns for combatting smoking, including taxation or bans

TABLE 1 Smoking-attributable DALYs and prevalent cases of periodontal disease in different geographic areas (global, super-region, region), in different age groups in 2015. The geographic areas are those used by the GBD studies and are shown in Figure 2

Geographic area	Age group (years)	DALYs	Lower bound	Upper bound	Prevalent cases	Lower bound	Upper bound
Global	15–49	75,771	53,938	105,852	11,372,510	8,093,835	15,891,419
	50–69	141,434	110,022	176,146	21,705,811	16,877,730	27,042,952
	≥70	33,954	26,751	42,230	5,402,605	4,253,741	6,723,005
Central Europe, Eastern Europe and Central Asia	15–49	3,660	2,751	4,799	548,944	412,626	719,893
	50–69	8,700	6,924	10,689	1,338,873	1,065,538	1,644,764
	≥70	2,599	2,084	3,196	415,719	333,402	511,163
High income	15–49	13,692	10,177	18,232	2,051,103	1,524,531	2,731,367
	50–69	31,684	25,105	38,790	4,845,018	3,838,380	5,931,810
	≥70	9,988	7,912	12,377	1,588,346	1,258,414	1,969,222
Latin America and Caribbean	15–49	10,027	6,832	14,023	1,503,878	1,024,623	2,103,199
	50–69	13,143	9,730	16,724	2,016,529	1,492,881	2,566,088
	≥70	2,215	1,610	2,901	354,152	257,527	464,054
North Africa and Middle East	15–49	9,666	6,787	13,856	1,453,771	1,020,601	2,083,856
	50–69	12,174	9,375	15,231	1,881,195	1,448,362	2,353,960
	≥70	2,255	1,753	2,822	363,415	282,514	454,790
South Asia	15–49	10,622	6,731	15,754	1,602,349	1,015,392	2,376,583
	50–69	17,045	11,580	23,304	2,643,981	1,796,154	3,614,898
	≥70	3,142	2,144	4,313	506,882	346,024	695,803
South-East Asia, East Asia and Oceania	15–49	21,330	16,653	27,799	3,191,943	2,491,968	4,160,312
	50–69	49,882	41,456	59,728	7,617,662	6,330,186	9,122,447
	≥70	11,841	9,966	14,091	1,864,918	1,569,414	2,219,635
Sub-Saharan Africa	15–49	6,773	4,008	11,390	1,020,522	604,094	1,716,209
	50–69	8,800	5,854	11,679	1,362,553	906,229	1,808,985
	≥70	1,916	1,280	2,529	309,173	206,446	408,338
Andean Latin America	15–49	354	238	515	53,085	35,577	77,072
	50–69	491	347	662	75,107	53,182	101,474
	≥70	92	65	125	14,630	10,314	20,094
Central Asia	15–49	611	438	853	91,522	65,634	127,800
	50–69	1,042	791	1,356	159,700	121,249	207,943
	≥70	170	130	220	27,106	20,764	35,160

(Continues)

TABLE 1 (Continued)

Geographic area	Age group (years)	DALYs	Lower bound	Upper bound	Prevalent cases	Lower bound	Upper bound
Central Europe	15–49	1,484	1,109	1,956	222,181	165,942	292,774
	50–69	3,525	2,799	4,329	541,853	430,214	665,405
	≥70	1,054	833	1,310	168,058	132,877	208,925
Central Latin America	15–49	3,103	2,140	4,376	464,832	320,572	655,574
	50–69	4,152	3,063	5,391	636,514	469,442	826,469
	≥70	757	558	996	121,031	89,168	159,206
Central Sub-Saharan Africa	15–49	530	333	836	80,203	50,490	126,681
	50–69	830	562	1,166	129,534	87,743	182,085
	≥70	179	123	250	29,230	20,050	40,750
East Asia	15–49	17,931	14,277	22,856	2,682,287	2,135,648	3,418,891
	50–69	42,619	36,029	50,265	6,502,600	5,497,151	7,669,349
	≥70	10,295	8,806	12,072	1,618,301	1,384,346	1,897,746
Eastern Europe	15–49	1,565	1,204	1,991	235,241	181,050	299,319
	50–69	4,134	3,335	5,004	637,320	514,075	771,416
	≥70	1,376	1,122	1,667	220,555	179,761	267,078
Eastern Sub-Saharan Africa	15–49	2,300	1,228	4,346	345,980	184,812	654,120
	50–69	3,206	1,907	4,401	495,312	294,352	680,139
	≥70	782	464	1,055	125,670	74,511	169,683
High-income Asia Pacific	15–49	2,976	2,285	3,826	444,235	341,116	571,150
	50–69	7,162	5,857	8,578	1,088,976	890,501	1,304,276
	≥70	2,506	2,050	3,049	395,492	323,533	481,093
High-income North America	15–49	3,563	2,591	4,822	534,731	388,824	723,789
	50–69	9,857	7,624	12,379	1,515,401	1,172,024	1,903,225
	≥70	2,645	2,053	3,337	425,590	330,377	536,850
Latin America and Caribbean	15–49	696	466	990	104,614	69,918	148,670
	50–69	1,078	792	1,372	165,010	121,254	210,148
	≥70	251	185	327	39,981	29,382	51,947
North Africa and Middle East	15–49	9,666	6,787	13,856	1,453,771	1,020,601	2,083,856
	50–69	12,174	9,375	15,231	1,881,195	1,448,362	2,353,960
	≥70	2,255	1,753	2,822	363,415	282,514	454,790
Oceania	15–49	146	12	459	21,912	1,749	69,036
	50–69	104	12	247	16,237	1,939	38,496
	≥70	15	2	40	2,521	346	6,356

(Continues)

TABLE 1 (Continued)

Geographic area	Age group (years)	DALYs	Lower bound	Upper bound	Prevalent cases	Lower bound	Upper bound
South Asia	15–49	10,622	6,731	15,754	1,602,349	1,015,392	2,376,583
	50–69	17,045	11,580	23,304	2,643,981	1,796,154	3,614,898
	≥70	3,142	2,144	4,313	506,882	346,024	695,803
South-East Asia	15–49	3,252	2,364	4,483	487,744	354,571	672,385
	50–69	7,157	5,413	9,216	1,098,825	831,096	1,414,602
	≥70	1,532	1,158	1,979	244,096	184,722	315,533
Southern Latin America	15–49	886	673	1,146	132,543	100,759	171,500
	50–69	1,651	1,348	1,965	251,670	205,569	299,609
	≥70	450	367	543	70,878	57,841	85,602
Southern Sub-Saharan Africa	15–49	183	120	278	27,784	18,123	42,162
	50–69	296	201	427	46,141	31,236	66,651
	≥70	80	56	113	13,007	9,039	18,430
Tropical Latin America	15–49	5,873	3,989	8,142	881,347	598,556	1,221,883
	50–69	7,423	5,529	9,299	1,139,898	849,003	1,427,997
	≥70	1,114	803	1,453	178,510	128,663	232,807
Western Europe	15–49	6,262	4,627	8,437	939,594	693,832	1,264,928
	50–69	13,021	10,277	15,868	1,988,971	1,570,286	2,424,700
	≥70	4,385	3,440	5,449	696,386	546,663	865,677
Western Sub-Saharan Africa	15–49	3,761	2,327	5,930	566,555	350,669	893,246
	50–69	4,469	3,185	5,685	691,566	492,898	880,110
	≥70	875	637	1,111	141,266	102,846	179,475

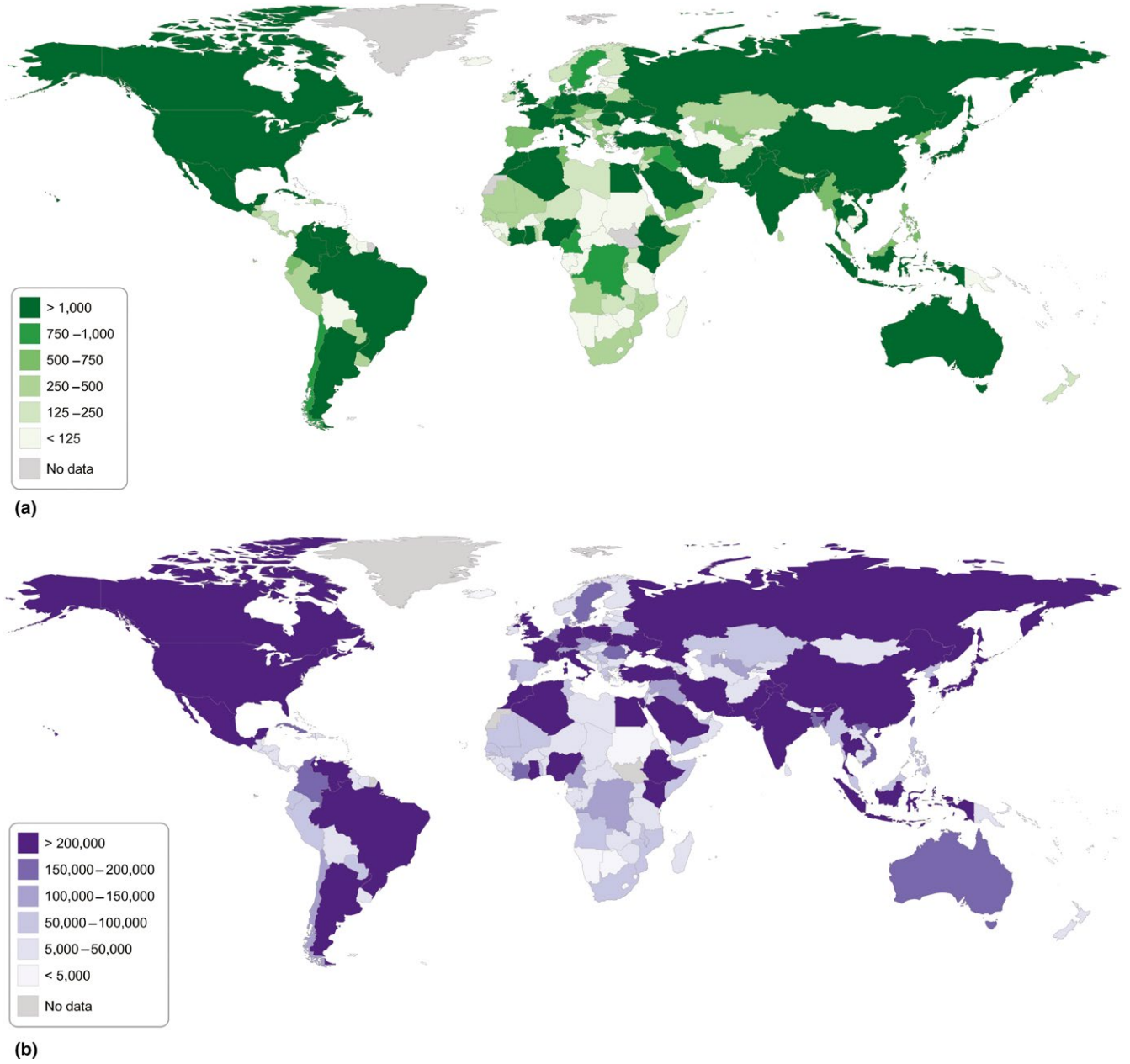


FIGURE 3 Smoking-attributable DALYs (a) and prevalent cases of periodontal disease (b) in 2015

tobacco products, restrictions on tobacco marketing or warning labels on tobacco products (Jha & Peto, 2014; Reitsma et al., 2017). Smoking cessation interventions provided by dentists or dental auxiliary staff members might be added to that list. Given the limited evidence for the efficacy of such clinical–dental interventions, greater efforts are needed to provide dentists or dental care personnel with the capacities for providing cessation advice effectively (Carr & Ebbert, 2006; Ramseier & Suvan, 2015; Ramseier et al., 2010). Moreover, there might be the need to actively incentivize providing such advice in clinical care (instead of remunerating the therapy of non-avoided PD) (Shelley et al., 2012).

Second, on a global level, the attributable burden of smoking-related PD affects nearly 40 million individuals. As can be expected when considering population estimates, the largest absolute attributable burden stemmed from China, India and the United States. In contrast, the highest burden in relative terms was found in a very different set of countries, including both richer countries such as Denmark, Iceland or Canada, and poorer countries such as Suriname, Mauretania or Rwanda. Generally, it was notable that relative attributable burden was limited in (especially Sub-Saharan) Africa, mainly as smoking prevalence was relatively low. For example, the attributable burden was <5% in Uganda, Chad, Burkina Faso or Namibia; notable exemptions were Mauritania, Rwanda, Eritrea and Gabon (burden > 14%). Given that a substantial share of the global burden came from countries with limited access to dental health care (Barber et al., 2017), where PD will most likely (as untreated) result

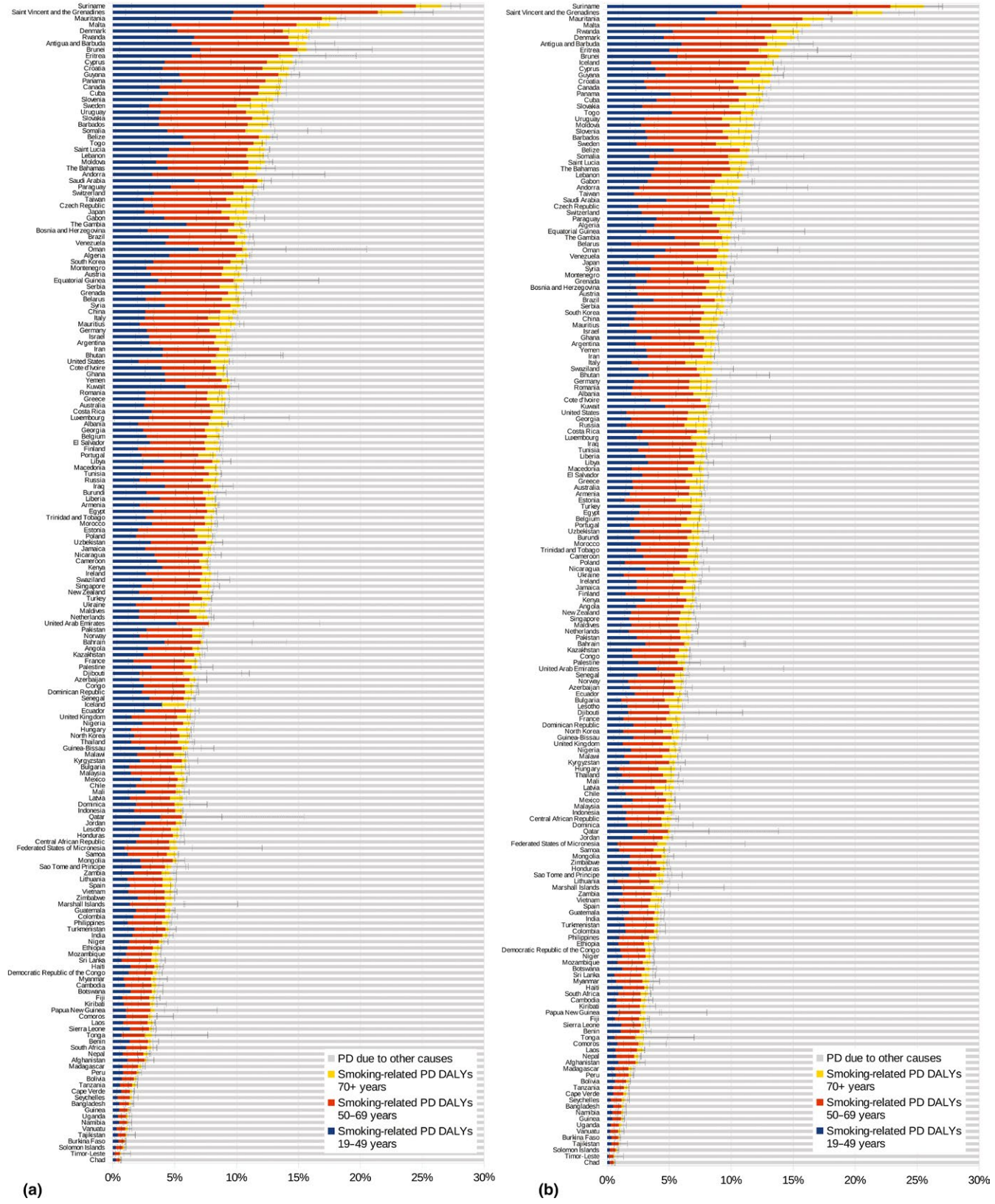
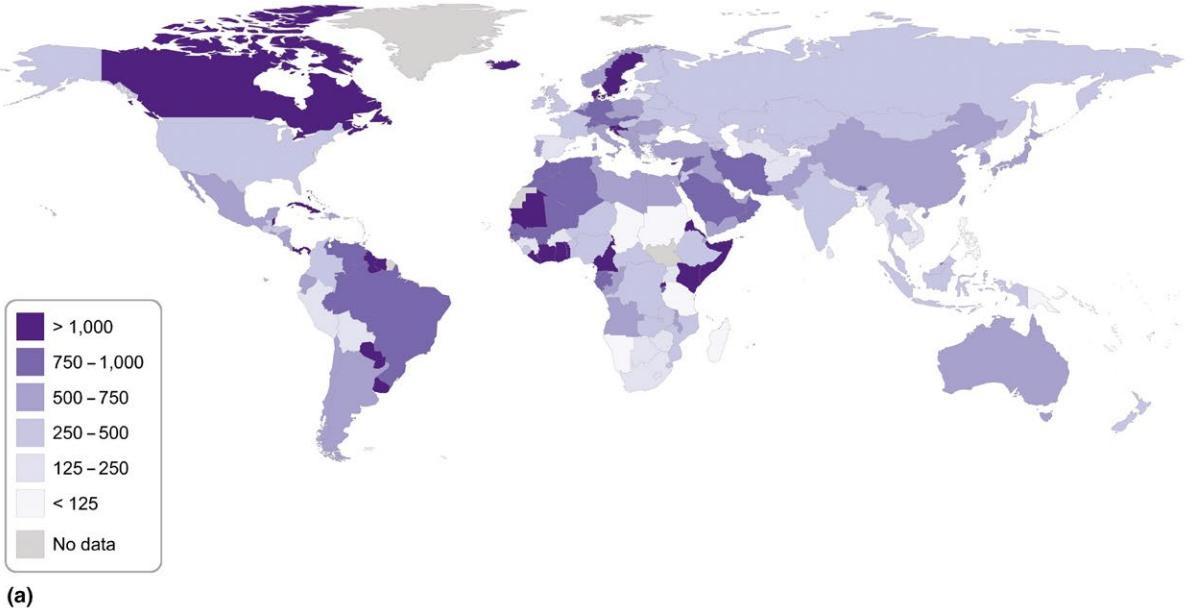
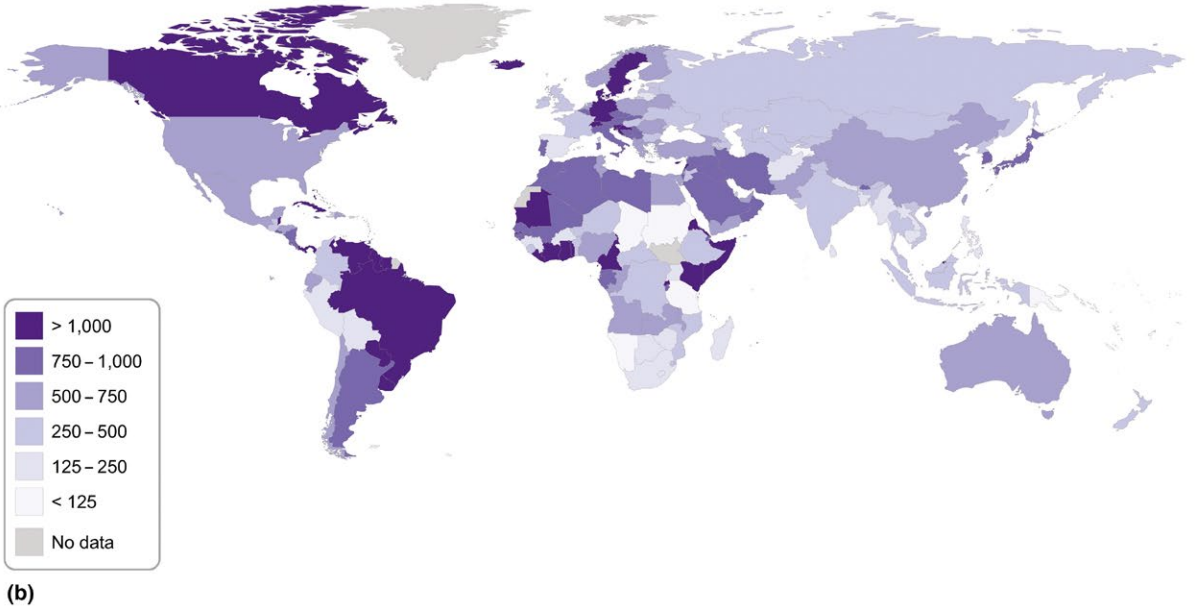


FIGURE 4 Relative smoking-attributable burden of periodontal disease (PD) (in % of total DALYs) in different age groups and countries in 2015, ranked from highest to lowest, in males (a) and females (b). Uncertainty intervals are indicated by whiskers

FIGURE 5 Age-standardized smoking-attributable prevalent cases of periodontal disease per 100,000 in 2015. (a) Both sexes pooled, (b) male, (c) female


> 1,000
750 – 1,000
500 – 750
250 – 500
125 – 250
< 125
No data

(a)


> 1,000
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500 – 750
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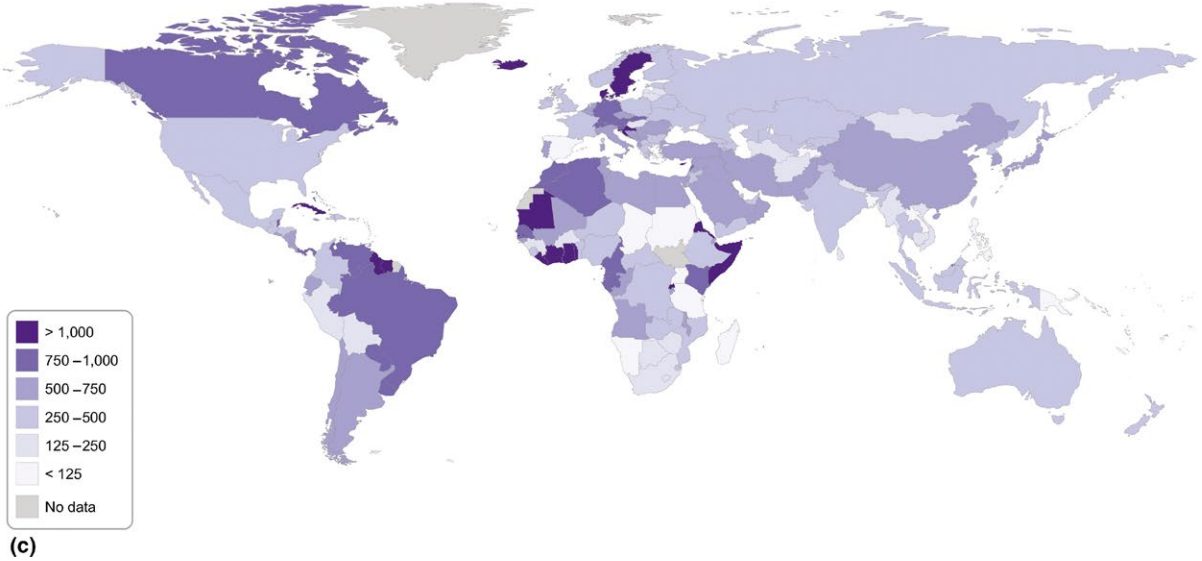
125 – 250
< 125
No data

(b)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500 – 750
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125 – 250
< 125
No data

(c)

in tooth loss in many cases, smoking will also be responsible for a large number of people with tooth loss-associated masticatory, but also phonetic and aesthetic impairments (Gerritsen, Allen, Witter, Bronkhorst, & Creugers, 2010; Kassebaum et al., 2014b; Mack et al., 2005). It should be noted that we have not measured these sequels of PD and thus, most likely, underestimated the overall oral smoking-attributable burden. In countries with wide or even universal access to dental care, tooth loss might be avoided when thorough and systematic active and supportive periodontal therapy is provided; however, such therapy generates substantial costs (Pretzl et al., 2009; Schwendicke, Plaumann, Stolpe, Dorfer, & Graetz, 2016). Avoiding PD by tackling smoking on public health level might reduce these costs. Moreover, and considering the unequal distribution of both PD prevalence, but more so of smoking, this will also decrease inequalities in PD between different populations (different social, age or sex groups).

This study has a number of limitations. First, the compiled estimates on the association between smoking and PD showed high heterogeneity, not only across but also (where available) within countries. This highlights that study design aspects (including target population and PD prevalence, but also PD case definition and smoking prevalence) heavily affect the found associations. We accounted for that by (1) pooling estimates using random-effects models (however, the yielded estimates did not greatly differ from those generated with fixed-effect models) and (2) by performing different analyses. In our base-case, we adjusted associations for PD prevalence and the number of cigarettes smoked. The latter was justified, as a number of studies reported a clear and consistent dose–response relationship between cigarettes smoked and the risk of PD (Carasol et al., 2016; Do, Slade, Roberts-Thomson, & Sanders, 2008; Do, Spencer, Roberts-Thomson, & Ha, 2003; Gelskey, Young, & Singer, 1998; Natto, Baljoon, & Bergstrom, 2005; Tomar & Asma, 2000). However, the exact association remains unclear, which is why in a second analysis, no adjustment at all was performed. Given that this second analysis found the global burden to be even higher, we consider our base-case results to be conservative. Second, the PD burden was estimated, in accordance with the GBD studies, only for severe chronic periodontitis; milder cases were not included, as milder cases might not produce a subjective burden of disease. Similarly, we have not quantified the subsequent burden of tooth loss emanating from PD (edentate individuals were not included in most analyses of the studies compiled in our review). Again, we will have underestimated the total absolute burden, which should be born in mind. Also, note that the included studies did not uniformly assess severe, but also other forms of PD. Third, we did not account for smokeless tobacco products and e-cigarettes or second-hand smoking, as only very few studies have evaluated the association of such tobacco intake and PD. Fourth, the definition of smoking exposure varied, as mentioned above, between studies; in a number of studies, for example, both current and former smokers were classified as "smokers," while in others, only severe current smokers (e.g., according to the daily number of cigarettes smoked or pack-years) were counted as smokers. Last, the smoking prevalence data from the GBD were largely self-reported; the inherent risk of reporting bias is thus present.

In conclusions, and within the limitations of this study, the global smoking-attributable burden of PD is substantial, with nearly 40 million prevalent cases and over 250,000 DALYs in 2015. The burden was lower in females than males, and highest in the age group of the 50- to 69-year-olds. Monitoring this burden helps to identify groups and countries at risk, but also to gauge the possible impact of antismoking interventions on PD. Policymakers, public health activists and clinicians need to increase their efforts for combatting smoking if they want to substantially reduce the burden of PD, especially in countries where individual-level clinical care is not widely available.

CONFLICT OF INTEREST

The authors have no conflict of interest.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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