DR. FALK SCHWENDICKE (Orcid ID : 0000-0003-1223-1669)

Article type : Other

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

Falk Schwendicke[1*], Christof E. Dörfer[2], Toni Meier[3,4]

[1] Department of Operative and Preventive Dentistry, Charité – Universitätsmedizin Berlin, Germany

[2] Clinic for Conservative Dentistry and Periodontology, Christian-Albrechts-University Kiel, Germany

[3] Institute for Agricultural and Nutritional Sciences, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany

[4]Competence Cluster for Nutrition and Cardiovascular Health (nutriCARD), Halle-Jena-Leipzig, Germany

**Running title:** Burden of smoking and periodontitis

**Keywords**: dental; epidemiology; modelling; risk factors; smoking

## Conflict of interest and source of funding statement

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/jcpe.12823

The authors have no conflicts of interest. No external funding, apart from the support of the authors' institution, was available for this study.

**Corresponding author:** Dr. Falk Schwendicke

Department of Operative and Preventive Dentistry

Charité – Universitätsmedizin Berlin

Aßmannshauser Str. 4-6

14197 Berlin

Tel.: (+49) 30 450 562 556

Fax: (+49) 30 450 562 932

Email: falk.schwendicke@charite.de

## 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 female than male, and highest in the age group of the 50-69-year-olds. On super-regional level, the burden was highest in Southeast 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 to <1% in Chad.

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

## Clinical Relevance

**Scientific rationale**: 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 implication**: Policy-makers, 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.

## Introduction

A large number of studies confirmed an association between tobacco smoking and periodontal disease (PD), with smokers being at significantly increased risk for experiencing periodontitis and, subsequently, losing teeth. As a great range of case definitions (including the extent and severity of periodontal disease) is used across different studies, often in various age and sex groups, the exact association, however, remains unclear (Chambrone and Chambrone 2006, Fardal et al. 2004, Heasman et al. 2006, Eke et al. 2016). 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 like 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 and Peto 2014). The attributable health burden of, for example, sugar, salt and fat consumption has been quantified (Meier et al. 2017, Meier et al. 2015). 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.

**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 (Stevens et al. 2016, von Elm et al. 2007, Moher et al. 2009, Moher et al. 2015, 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 (Fig. 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.

*Population data*

We used data from the GBD 2015 studies to estimate the populations aged 15-49, 50-69 and ≥70 years old, respectively, stratified for sex, in 186 countries in 2015. These age bands were chosen, as (1) periodontal disease 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).

*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.

*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. 2017, Kassebaum et al. 2014a), i.e. 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. 2017, Kassebaum et al. 2014a).

*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:

- 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). Similar, 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 (like age, sex, socioeconomic stratum, oral hygiene habits, etc.). 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 multi-variable 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.

*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 of 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 were converted to corresponding relative risks (RR) using the following formula:

$$RR = \frac{OR}{1 - p_o + (p_o * OR)}$$ (Grant 2014)

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 were converted into corresponding population attributable risks (PAR) using the following formula:

$$PAR = 1 - \frac{1}{p(RR-1)+1}$$ (Spiegelman et al. 2007)

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 (like 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 et al. 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).

**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, i.e. 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) disability-adjusted life years (DALYs), or 38.5 (95%UI: 29.2-49.7) million cases (Tab. 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 male than female (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 50-69-year-olds (Tab. 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 analyzed on three levels (Fig. 3): On super-regional level, the burden was highest in Southeast 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). On national level, the largest attributable-burden was found in China (69,148 DALYs) and 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%) (Fig. 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 male rather than female, namely the United Arab Emirates, Qatar, Oman, Bahrain and Saudi Arabia (in these countries, more than 75% of the burden was in male, not female). There were only few countries were 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 (Fig. 5a). After age-standardization, the attributable burden was now much higher in males than females in most countries (Fig. 5b,c)

## 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 but 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 male than female, 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 to other smoking-associated diseases the observed disease burden related to PD (251,160 DALYs) in 2015 was of limited relevance. Diseases with the highest absolute burden attributable to smoking were (in descending order): cardiovascular diseases: 62.7 million DALYs, neoplasms/cancer: 40.8 million DALYs, chronic respiratory diseases: 29.1 million DALYs (Reitsma et al. 2017). However,  the observed relative attributable burden of smoking-related PD of 7.1% (that is, its relative share of the total disease burden, expressed in DALYs), was similar to that of other smoking-related diseases (like asthma (7.8%), tuberculosis (7.0%), lower respiratory infections (6.9%)) and ranks on the 23rd position out 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 tobacco products, restrictions on tobacco marketing or warning labels on tobacco products (Jha and Peto 2014, Reitsma et al. 2017). Smoking cessation interventions provided by dentists or dental auxiliary staff 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 (Ramseier and Suvan 2015, Ramseier et al. 2010, Carr and Ebbert 2006). 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 like Denmark, Iceland or Canada, and poorer countries like Suriname, Mauretania or Rwanda. Generally, it was notable the 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 healthcare (Barber et al. 2017), where PD will most likely (as untreated) result 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 et al. 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, under-estimated 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 (Schwendicke et al. 2016, Pretzl et al. 2009). 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 report a clear and consistent dose-response-relationship between cigarettes smoked and the risk of PD (Do et al. 2003, Do et al. 2008, Carasol et al. 2016, Gelskey et al. 1998, Tomar and Asma 2000, Natto et al. 2005). 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 GDP studies, only for severe chronic periodontitis; milder cases were not included. This was, 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 studies building on for our meta-analysis on the association between smoking and PD 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. This was, 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 daily number of cigarettes smoked, or pack-years) were counted as smokers. Last, the smoking prevalence data from the GBD was 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 female than male, and highest in the age group of the 50-69-year-olds. Monitoring this burden helps to identify groups and countries at risk, but also to gauge the possible impact of anti-smoking interventions on PD. Policy-makers, 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.

**References**

Barber, R. M., Fullman, N., Sorensen, R. J. D., Bollyky, T., McKee, M., Nolte, E., Abajobir, A. A., Abate, K. H., Abbafati, C., Abbas, K. M., Abd-Allah, F., Abdulle, A. M., Abdurahman, A. A., Abera, S. F., Abraham, B., Abreha, G. F., Adane, K., Adelekan, A. L., Adetifa, I. M. O., Afshin, A., Agarwal, A., Agarwal, S. K., Agarwal, S., Agrawal, A., Kiadaliri, A. A., Ahmadi, A., Ahmed, K. Y., Ahmed, M. B., Akinyemi, R. O., Akinyemiju, T. F., Akseer, N., Al-Aly, Z., Alam, K., Alam, N., Alam, S. S., Alemu, Z. A., Alene, K. A., Alexander, L., Ali, R., Ali, S. D., Alizadeh-Navaei, R., Alkerwi, A. a., Alla, F., Allebeck, P., Allen, C., Al-Raddadi, R., Alsharif, U., Altirkawi, K. A., Martin, E. A., Alvis-Guzman, N., Amare, A. T., Amini, E., Ammar, W., Amo-Adjei, J., Amoako, Y. A., Anderson, B. O., Androudi, S., Ansari, H., Ansha, M. G., Antonio, C. A. T., Ärnlöv, J., Artaman, A., Asayesh, H., Assadi, R., Astatkie, A., Atey, T. M., Atique, S., Atnafu, N. T., Atre, S. R., Avila-Burgos, L., Avokpaho, E. F. G. A., Quintanilla, B. P. A., Awasthi, A., Ayele, N. N., Azzopardi, P., Saleem, H. O. B., Bärnighausen, T., Bacha, U., Badawi, A., Banerjee, A., Barac, A., Barboza, M. A., Barker-Collo, S. L., Barrero, L. H., Basu, S., Baune, B. T., Baye, K., Bayou, Y. T., Bazargan-Hejazi, S., Bedi, N., Beghi, E., Béjot, Y., Bello, A. K., Bennett, D. A., Bensenor, I. M., Berhane, A., Bernabé, E., Bernal, O. A., Beyene, A. S., Beyene, T. J., Bhutta, Z. A., Biadgilign, S., Bikbov, B., Birlik, S. M., Birungi, C., Biryukov, S., Bisanzio, D., Bizuayehu, H. M., Bose, D., Brainin, M., Brauer, M., Brazinova, A., Breitborde, N. J. K., Brenner, H., Butt, Z. A., Cárdenas, R., Cahuana-Hurtado, L., Campos-Nonato, I. R., Car, J., Carrero, J. J., Casey, D., Caso, V., Castañeda-Orjuela, C. A., Rivas, J. C., Catalá-López, F., Cecilio, P., Cercy, K., Charlson, F. J., Chen, A. Z., Chew, A., Chibalabala, M., Chibueze, C. E., Chisumpa, V. H., Chitheer, A. A., Chowdhury, R., Christensen, H., Christopher, D. J., Ciobanu, L. G., Cirillo, M., Coggeshall, M. S., Cooper, L. T., Cortinovis, M., Crump, J. A., Dalal, K., Danawi, H., Dandona, L., Dandona, R., Dargan, P. I., das Neves, J., Davey, G., Davitoiu, D. V., Davletov, K., De Leo, D., Del Gobbo, L. C., del Pozo-Cruz, B., Dellavalle, R. P., Deribe, K., Deribew, A., Des Jarlais, D. C., Dey, S., Dharmaratne, S. D., Dicker, D., Ding, E. L., Dokova, K., Dorsey, E. R., Doyle, K. E., Dubey, M., Ehrenkranz, R., Ellingsen, C. L., Elyazar, I., Enayati, A., Ermakov, S. P., Eshrati, B., Esteghamati, A., Estep, K., Fürst, T., Faghmous, I. D. A., Fanuel, F. B. B., Faraon, E. J. A., Farid, T. A., Farinha, C. S. e. S., Faro, A., Farvid, M. S., Farzadfar, F., Feigin, V. L., Feigl, A. B., Fereshtehnejad, S.-M., Fernandes, J. G., Fernandes, J. C., Feyissa, T. R., Fischer, F., Fitzmaurice, C., Fleming, T. D., Foigt, N., Foreman, K. J., Forouzanfar, M. H., Franklin, R. C., Frostad, J., G/hiwot, T. T., Gakidou, E., Gambashidze, K., Gamkrelidze, A., Gao, W., Garcia-Basteiro, A. L., Gebre, T., Gebremedhin, A. T., Gebremichael, M. W., Gebru, A. A., Gelaye, A. A., Geleijnse, J. M., Genova-Maleras, R., Gibney, K. B., Giref, A. Z., Gishu, M. D., Giussani, G., Godwin, W. W., Gold, A., Goldberg, E. M., Gona, P. N., Goodridge, A., Gopalani, S. V., Goto, A., Graetz, N., Greaves, F., Griswold, M., Guban, P. I., Gugnani, H. C., Gupta, P. C., Gupta, R., Gupta, R., Gupta, T., Gupta, V., Habtewold, T. D., Hafezi-Nejad, N., Haile, D., Hailu, A. D., Hailu, G. B., Hakuzimana, A., Hamadeh, R. R., Hambisa, M. T., Hamidi, S., Hammami, M., Hankey, G. J., Hao, Y., Harb, H. L., Hareri, H. A., Haro, J. M., Hassanvand, M. S., Havmoeller, R., Hay, R. J., Hay, S. I., Hendrie, D., Heredia-Pi, I. B., Hoek, H. W., Horino, M., Horita, N., Hosgood, H. D., Htet, A. S., Hu, G., Huang, H., Huang, J. J., Huntley, B. M., Huynh, C., Iburg, K. M., Ileanu, B. V., Innos, K., Irenso, A. A., Jahanmehr, N., Jakovljevic, M. B., James, P., James, S. L., Javanbakht, M., Jayaraman, S. P., Jayatilleke, A. U., Jeemon, P., Jha, V., John, D., Johnson, C., Johnson, S. C., Jonas, J. B., Juel, K., Kabir, Z., Kalkonde, Y., Kamal, R., Kan, H., Karch, A., Karema, C. K., Karimi, S. M., Kasaeian, A., Kassebaum, N. J., Kastor, A., Katikireddi, S. V., Kazanjan, K., Keiyoro, P. N., Kemmer, L., Kemp, A. H., Kengne, A. P., Kerbo, A. A., Kereselidze, M., Kesavachandran, C. N., Khader, Y. S., Khalil, I., Khan, A. R., Khan, E. A., Khan, G., Khang, Y.-H., Khoja, A. T. A., Khonelidze, I., Khubchandani, J., Kibret, G. D., Kim, D., Kim, P., Kim, Y. J., Kimokoti, R. W., Kinfu, Y., Kissoon, N., Kivipelto, M., Kokubo, Y., Kolk, A., Kolte, D., Kopec, J. A., Kosen, S., Koul, P. A., Koyanagi, A., Kravchenko, M., Krishnaswami, S., Krohn, K. J., Defo, B. K., Bicer, B. K., Kuipers, E. J., Kulkarni, V. S., Kumar, G. A., Kumsa, F. A., Kutz, M., Kyu, H. H., Lager, A. C. J., Lal, A., Lal, D. K., Lalloo, R., Lallukka, T., Lan, Q., Langan, S. M., Lansingh, V. C., Larson, H. J., Larsson, A., Laryea, D. O., Latif, A. A., Lawrynowicz, A. E. B., Leasher, J. L., Leigh, J., Leinsalu, M., Leshargie, C. T., Leung, J., Leung, R., Levi, M., Liang, X., Lim, S. S., Lind, M., Linn, S., Lipshultz, S. E., Liu, P., Liu, Y., Lo, L.-T., Logroscino, G., Lopez, A. D., Lorch, S. A., Lotufo, P. A., Lozano, R., Lunevicius, R., Lyons, R. A., Macarayan, E. R. K., Mackay, M. T., El Razek, H. M. A., El Razek, M. M. A., Mahdavi, M., Majeed, A., Malekzadeh, R., Malta, D. C., Mantovani, L. G., Manyazewal, T., Mapoma, C. C., Marcenes, W., Marks, G. B., Marquez, N., Martinez-Raga, J., Marzan, M. B., Massano, J., Mathur, M. R., Maulik, P. K., Mazidi, M., McAlinden, C., McGrath, J. J., McNellan, C., Meaney, P. A., Mehari, A., Mehndiratta, M. M., Meier, T., Mekonnen, A. B., Meles, K. G., Memish, Z. A., Mengesha, M. M., Mengiste, D. T., Mengistie, M. A., Menota, B. G., Mensah, G. A., Mereta, S. T., Meretoja, A., Meretoja, T. J., Mezgebe, H. B., Micha, R., Millear, A., Mills, E. J., Minnig, S., Mirarefin, M., Mirrakhimov, E. M., Mock, C. N., Mohammad, K. A., Mohammed, S., Mohanty, S. K., Mokdad, A. H., Mola, G. L. D., Molokhia, M., Monasta, L., Montico, M., Moradi-Lakeh, M., Moraga, P., Morawska, L., Mori, R., Moses, M., Mueller, U. O., Murthy, S., Musa, K. I., Nachega, J. B., Nagata, C., Nagel, G., Naghavi, M., Naheed, A., Naldi, L., Nangia, V., Nascimento, B. R., Negoi, I., Neupane, S. P., Newton, C. R., Ng, M., Ngalesoni, F. N., Ngunjiri, J. W., Nguyen, G., Ningrum, D. N. A., Nolte, S., Nomura, M., Norheim, O. F., Norrving, B., Noubiap, J. J. N., Obermeyer, C. M., Ogbo, F. A., Oh, I.-H., Okoro, A., Oladimeji, O., Olagunju, A. T., Olivares, P. R., Olsen, H. E., Olusanya, B. O., Olusanya, J. O., Opio, J. N., Oren, E., Ortiz, A., Osborne, R. H., Osman, M., Owolabi, M. O., Pa, M., Pain, A. W., Pakhale, S., Castillo, E. P., Pana, A., Papachristou, C., Parsaeian, M., Patel, T., Patton, G. C., Paudel, D., Paul, V. K., Pearce, N., Pereira, D. M., Perez-Padilla, R., Perez-Ruiz, F., Perico, N., Pesudovs, K., Petzold, M., Phillips, M. R., Pigott, D. M., Pillay, J. D., Pinho, C., Polinder, S., Pond, C. D., Prakash, V., Purwar, M., Qorbani, M., Quistberg, D. A., Radfar, A., Rafay, A., Rahimi, K., Rahimi-Movaghar, V., Rahman, M., Rahman, M. H. U., Rai, R. K., Ram, U., Rana, S. M., Rankin, Z., Rao, P. V., Rao, P. C., Rawaf, S., Rego, M. A. S., Reitsma, M., Remuzzi, G., Renzaho, A. M. N. N., Resnikoff, S., Rezaei, S., Rezai, M. S., Ribeiro, A. L., Roba, H. S., Rokni, M. B., Ronfani, L., Roshandel, G., Roth, G. A., Rothenbacher, D., Roy, N. K., Sachdev, P. S., Sackey, B. B., Saeedi, M. Y., Safiri, S., Sagar, R., Sahraian, M. A., Saleh, M. M., Salomon, J. A., Samy, A. M., Sanabria, J. R., Sanchez-Niño, M. D., Sandar, L., Santos, I. S., Santos, J. V., Milicevic, M. M. S., Sarmiento-Suarez, R., Sartorius, B., Satpathy, M., Savic, M., Sawhney, M., Saylan, M. I., Schöttker, B., Schutte, A. E., Schwebel, D. C., Seedat, S., Seid, A. M., Seifu, C. N., Sepanlou, S. G., Serdar, B., Servan-Mori, E. E., Setegn, T., Shackelford, K. A., Shaheen, A., Shahraz, S., Shaikh, M. A., Shakh-Nazarova, M., Shamsipour, M., Islam, S. M. S., Sharma, J., Sharma, R., She, J., Sheikhbahaei, S., Shen, J., Shi, P., Shigematsu, M., Shin, M.-J., Shiri, R., Shoman, H., Shrime, M. G., Sibamo, E. L. S., Sigfusdottir, I. D., Silva, D. A. S., Silveira, D. G. A., Sindi, S., Singh, A., Singh, J. A., Singh, O. P., Singh, P. K., Singh, V., Sinke, A. H., Sinshaw, A. E., Skirbekk, V., Sliwa, K., Smith, A., Sobngwi, E., Soneji, S., Soriano, J. B., Sousa, T. C. M., Sposato, L. A., Sreeramareddy, C. T., Stathopoulou, V., Steel, N., Steiner, C., Steinke, S., Stokes, M. A., Stranges, S., Strong, M., Stroumpoulis, K., Sturua, L., Sufiyan, M. B., Suliankatchi, R. A., Sun, J., Sur, P., Swaminathan, S., Sykes, B. L., Tabarés-Seisdedos, R., Tabb, K. M., Taffere, G. R., Talongwa, R. T., Tarajia, M., Tavakkoli, M., Taveira, N., Teeple, S., Tegegne, T. K., Tehrani-Banihashemi, A., Tekelab, T., Tekle, D. Y., Shifa, G. T., Terkawi, A. S., Tesema, A. G., Thakur, J. S., Thomson, A. J., Tillmann, T., Tiruye, T. Y., Tobe-Gai, R., Tonelli, M., Topor-Madry, R., Tortajada, M., Troeger, C., Truelsen, T., Tura, A. K., Uchendu, U. S., Ukwaja, K. N., Undurraga, E. A., Uneke, C. J., Uthman, O. A., van Boven, J. F. M., Van Dingenen, R., Varughese, S., Vasankari, T., Venketasubramanian, N., Violante, F. S., Vladimirov, S. K., Vlassov, V. V., Vollset, S. E., Vos, T., Wagner, J. A., Wakayo, T., Waller, S. G., Walson, J. L., Wang, H., Wang, Y.-P., Watkins, D. A., Weiderpass, E., Weintraub, R. G., Wen, C.-P., Werdecker, A., Wesana, J., Westerman, R., Whiteford, H. A., Wilkinson, J. D., Wiysonge, C. S., Woldeyes, B. G., Wolfe, C. D. A., Won, S., Workicho, A., Workie, S. B., Wubshet, M., Xavier, D., Xu, G., Yadav, A. K., Yaghoubi, M., Yakob, B., Yan, L. L., Yano, Y., Yaseri, M., Yimam, H. H., Yip, P., Yonemoto, N., Yoon, S.-J., Younis, M. Z., Yu, C., Zaidi, Z., El Sayed Zaki, M., Zambrana-Torrelio, C., Zapata, T., Zenebe, Z. M., Zodpey, S., Zoeckler, L., Zuhlke, L. J. & Murray, C. J. L. (2017) Healthcare Access and Quality Index based on mortality from causes amenable to personal health care in 195 countries and territories, 1990–2015: a novel analysis from the Global Burden of Disease Study 2015. *The Lancet*. doi:https://doi.org/10.1016/S0140-6736(17)30818-8.

Carasol, M., Llodra, J. C., Fernandez-Meseguer, A., Bravo, M., Garcia-Margallo, M. T., Calvo-Bonacho, E., Sanz, M. & Herrera, D. (2016) Periodontal conditions among employed adults in Spain. *J Clin Periodontol* **43,** 548-556. doi:10.1111/jcpe.12558.

Carr, A. B. & Ebbert, J. O. (2006) Interventions for tobacco cessation in the dental setting. *Cochrane Database Syst Rev***,** Cd005084. doi:10.1002/14651858.CD005084.pub2.

Carter, B. D., Abnet, C. C., Feskanich, D., Freedman, N. D., Hartge, P., Lewis, C. E., Ockene, J. K., Prentice, R. L., Speizer, F. E., Thun, M. J. & Jacobs, E. J. (2015) Smoking and Mortality — Beyond Established Causes. *New England Journal of Medicine* **372,** 631-640. doi:10.1056/NEJMsa1407211.

Chambrone, L. A. & Chambrone, L. (2006) Tooth loss in well-maintained patients with chronic periodontitis during long-term supportive therapy in Brazil. *J Clin Periodontol* **33,** 759-764. doi:10.1111/j.1600-051X.2006.00972.x.

Do, G. L., Spencer, A. J., Roberts-Thomson, K. & Ha, H. D. (2003) Smoking as a risk indicator for periodontal disease in the middle-aged Vietnamese population. *Community Dent Oral Epidemiol* **31,** 437-446.

Do, L. G., Slade, G. D., Roberts-Thomson, K. F. & Sanders, A. E. (2008) Smoking-attributable periodontal disease in the Australian adult population. *J Clin Periodontol* **35,** 398-404. doi:10.1111/j.1600-051X.2008.01223.x.

Eke, P. I., Wei, L., Thornton-Evans, G. O., Borrell, L. N., Borgnakke, W. S., Dye, B. & Genco, R. J. (2016) Risk Indicators for Periodontitis in US Adults: NHANES 2009 to 2012. *J Periodontol* **87,** 1174-1185. doi:10.1902/jop.2016.160013.

Fardal, O., Johannessen, A. C. & Linden, G. J. (2004) Tooth loss during maintenance following periodontal treatment in a periodontal practice in Norway. *J Clin Periodontol* **31,** 550-555. doi:10.1111/j.1600-051X.2004.00519.x.

Flaxman, A. D., Vos, D. T. & Murray, C. J. (2015) *An integrative metaregression framework for descriptive epidemiology*. Seattle: University of Washington Press.

Gelskey, S. C., Young, T. K. & Singer, D. L. (1998) Factors associated with adult periodontitis in a dental teaching clinic population. *Community Dent Oral Epidemiol* **26,** 226-232.

Gerritsen, A., Allen, P., Witter, D., Bronkhorst, E. & Creugers, N. (2010) Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual Life Outcomes* **8,** 126.

Grant, R. L. (2014) Converting an odds ratio to a range of plausible relative risks for better communication of research findings. *BMJ* **348**. doi:10.1136/bmj.f7450.

Heasman, L., Stacey, F., Preshaw, P., McCracken, G., Hepburn, S. & Heasman, P. (2006) The effect of smoking on periodontal treatment response: a review of clinical evidence. *J Clin Periodontol* **33,** 241 - 253.

Jha, P. & Peto, R. (2014) Global Effects of Smoking, of Quitting, and of Taxing Tobacco. *New England Journal of Medicine* **370,** 60-68. doi:10.1056/NEJMra1308383.

Kassebaum, N. J., Bernabe, E., Dahiya, M., Bhandari, B., Murray, C. J. & Marcenes, W. (2014a) Global burden of severe periodontitis in 1990-2010: a systematic review and meta-regression. *J Dent Res* **93,** 1045-1053. doi:10.1177/0022034514552491.

Kassebaum, N. J., Bernabe, E., Dahiya, M., Bhandari, B., Murray, C. J. & Marcenes, W. (2014b) Global Burden of Severe Tooth Loss: A Systematic Review and Meta-analysis. *J Dent Res* **93,** 20s-28s. doi:10.1177/0022034514537828.

Kassebaum, N. J., Smith, A. G. C., Bernabé, E., Fleming, T. D., Reynolds, A. E., Vos, T., Murray, C. J. L., Marcenes, W., Abyu, G. Y., Alsharif, U., Asayesh, H., Benzian, H., Dandona, L., Dandona, R., Kasaeian, A., Khader, Y. S., Khang, Y. H., Kokubo, Y., Kotsakis, G. A., Lalloo, R., Misganaw, A., Montero, P., Nourzadeh, M., Pinho, C., Qorbani, M., Blancas, M. J. R., Sawhney, M., Steiner, C., Traebert, J., Tyrovolas, S., Ukwaja, K. N., Vollset, S. E. & Yonemoto, N. (2017) Global, Regional, and National Prevalence, Incidence, and Disability-Adjusted Life Years for Oral Conditions for 195 Countries, 1990–2015: A Systematic Analysis for the Global Burden of Diseases, Injuries, and Risk Factors. *J Dent Res* **96,** 380-387. doi:10.1177/0022034517693566.

Mack, F., Schwahn, C., Feine, J., Mundt, T., Bernhardt, O., John, U., Kocher, P. & Biffar, R. (2005) The impact of tooth loss on general health related to quality of life among elderly Pomeranians: results from the study of health in Pomerania (SHIP-O). *Int J Prosthodont* **18,** 414 - 419.

Meier, T., Deumelandt, P., Christen, O., Riedel, K., G., S. & Langer, M. (2017) Global burden of sugar-related dental diseases in 168 countries and corresponding healthcare costs (article submitted).

Meier, T., Senftleben, K., Deumelandt, P., Christen, O., Riedel, K. & Langer, M. (2015) Healthcare Costs Associated with an Adequate Intake of Sugars, Salt and Saturated Fat in Germany: A Health Econometrical Analysis. *PLoS One* **10,** e0135990. doi:10.1371/journal.pone.0135990.

Moher, D., Liberati, A., Tetzlaff, J. & Altman, D. (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* **6,** e1000097.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P. & Stewart, L. A. (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews* **4,** 1. doi:10.1186/2046-4053-4-1.

Natto, S., Baljoon, M. & Bergstrom, J. (2005) Tobacco smoking and periodontal health in a Saudi Arabian population. *J Periodontol* **76,** 1919-1926. doi:10.1902/jop.2005.76.11.1919.

Pretzl, B., Wiedemann, D., Cosgarea, R., Kaltschmitt, J., Kim, T. S., Staehle, H. J. & Eickholz, P. (2009) Effort and costs of tooth preservation in supportive periodontal treatment in a German population. *J Clin Periodontol* **36,** 669-676. doi:10.1111/j.1600-051X.2009.01409.x.

Ramseier, C. A. & Suvan, J. E. (2015) Behaviour change counselling for tobacco use cessation and promotion of healthy lifestyles: a systematic review. *J Clin Periodontol* **42 Suppl 16,** S47-58. doi:10.1111/jcpe.12351.

Ramseier, C. A., Warnakulasuriya, S., Needleman, I. G., Gallagher, J. E., Lahtinen, A., Ainamo, A., Alajbeg, I., Albert, D., Al-Hazmi, N., Antohe, M. E., Beck-Mannagetta, J., Benzian, H., Bergstrom, J., Binnie, V., Bornstein, M., Buchler, S., Carr, A., Carrassi, A., Casals Peidro, E., Chapple, I., Compton, S., Crail, J., Crews, K., Davis, J. M., Dietrich, T., Enmark, B., Fine, J., Gallagher, J., Jenner, T., Forna, D., Fundak, A., Gyenes, M., Hovius, M., Jacobs, A., Kinnunen, T., Knevel, R., Koerber, A., Labella, R., Lulic, M., Mattheos, N., McEwen, A., Ohrn, K., Polychronopoulou, A., Preshaw, P., Radley, N., Rosseel, J., Schoonheim-Klein, M., Suvan, J., Ulbricht, S., Verstappen, P., Walter, C., Warnakulasuriya, S., Wennstrom, J., Wickholm, S. & Zoitopoulos, L. (2010) Consensus Report: 2nd European Workshop on Tobacco Use Prevention and Cessation for Oral Health Professionals. *Int Dent J* **60,** 3-6.

Reitsma, M. B., Fullman, N., Ng, M., Salama, J. S., Abajobir, A., Abate, K. H., Abbafati, C., Abera, S. F., Abraham, B., Abyu, G. Y., Adebiyi, A. O., Al-Aly, Z., Aleman, A. V., Ali, R., Al Alkerwi, A. a., Allebeck, P., Al-Raddadi, R. M., Amare, A. T., Amberbir, A., Ammar, W., Amrock, S. M., Antonio, C. A. T., Asayesh, H., Atnafu, N. T., Azzopardi, P., Banerjee, A., Barac, A., Barrientos-Gutierrez, T., Basto-Abreu, A. C., Bazargan-Hejazi, S., Bedi, N., Bell, B., Bello, A. K., Bensenor, I. M., Beyene, A. S., Bhala, N., Biryukov, S., Bolt, K., Brenner, H., Butt, Z., Cavalleri, F., Cercy, K., Chen, H., Christopher, D. J., Ciobanu, L. G., Colistro, V., Colomar, M., Cornaby, L., Dai, X., Damtew, S. A., Dandona, L., Dandona, R., Dansereau, E., Davletov, K., Dayama, A., Degfie, T. T., Deribew, A., Dharmaratne, S. D., Dimtsu, B. D., Doyle, K. E., Endries, A. Y., Ermakov, S. P., Estep, K., Faraon, E. J. A., Farzadfar, F., Feigin, V. L., Feigl, A. B., Fischer, F., Friedman, J., G/hiwot, T. T., Gall, S. L., Gao, W., Gillum, R. F., Gold, A. L., Gopalani, S. V., Gotay, C. C., Gupta, R., Gupta, R., Gupta, V., Hamadeh, R. R., Hankey, G., Harb, H. L., Hay, S. I., Horino, M., Horita, N., Hosgood, H. D., Husseini, A., Ileanu, B. V., Islami, F., Jiang, G., Jiang, Y., Jonas, J. B., Kabir, Z., Kamal, R., Kasaeian, A., Kesavachandran, C. N., Khader, Y. S., Khalil, I., Khang, Y.-H., Khera, S., Khubchandani, J., Kim, D., Kim, Y. J., Kimokoti, R. W., Kinfu, Y., Knibbs, L. D., Kokubo, Y., Kolte, D., Kopec, J., Kosen, S., Kotsakis, G. A., Koul, P. A., Koyanagi, A., Krohn, K. J., Krueger, H., Defo, B. K., Bicer, B. K., Kulkarni, C., Kumar, G. A., Leasher, J. L., Lee, A., Leinsalu, M., Li, T., Linn, S., Liu, P., Liu, S., Lo, L.-T., Lopez, A. D., Ma, S., El Razek, H. M. A., Majeed, A., Malekzadeh, R., Malta, D. C., Manamo, W. A., Martinez-Raga, J., Mekonnen, A. B., Mendoza, W., Miller, T. R., Mohammad, K. A., Morawska, L., Musa, K. I., Nagel, G., Neupane, S. P., Nguyen, Q., Nguyen, G., Oh, I.-H., Oyekale, A. S., Pa, M., Pana, A., Park, E.-K., Patil, S. T., Patton, G. C., Pedro, J., Qorbani, M., Rafay, A., Rahman, M., Rai, R. K., Ram, U., Ranabhat, C. L., Refaat, A. H., Reinig, N., Roba, H. S., Rodriguez, A., Roman, Y., Roth, G., Roy, A., Sagar, R., Salomon, J., Sanabria, J., de Souza Santos, I., Sartorius, B., Satpathy, M., Sawhney, M., Sawyer, S., Saylan, M., Schaub, M. P., Schluger, N., Schutte, A. E., Sepanlou, S. G., Serdar, B., Shaikh, M. A., She, J., Shin, M.-J., Shiri, R., Shishani, K., Shiue, I., Sigfusdottir, I. D., Silverberg, J. I., Singh, J., Singh, V., Slepak, E. L., Soneji, S., Soriano, J. B., Soshnikov, S., Sreeramareddy, C. T., Stein, D. J., Stranges, S., Subart, M. L., Swaminathan, S., Szoeke, C. E. I., Tefera, W. M., Topor-Madry, R., Tran, B., Tsilimparis, N., Tymeson, H., Ukwaja, K. N., Updike, R., Uthman, O. A., Violante, F. S., Vladimirov, S. K., Vlassov, V., Vollset, S. E., Vos, T., Weiderpass, E., Wen, C.-P., Werdecker, A., Wilson, S., Wubshet, M., Xiao, L., Yakob, B., Yano, Y., Ye, P., Yonemoto, N., Yoon, S.-J., Younis, M. Z., Yu, C., Zaidi, Z., El Sayed Zaki, M., Zhang, A. L., Zipkin, B., Murray, C. J. L., Forouzanfar, M. H. & Gakidou, E. (2017) Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the Global Burden of Disease Study 2015. *The Lancet* **389,** 1885-1906. doi:https://doi.org/10.1016/S0140-6736(17)30819-X.

Salomon, J. A., Haagsma, J. A., Davis, A., de Noordhout, C. M., Polinder, S., Havelaar, A. H., Cassini, A., Devleesschauwer, B., Kretzschmar, M., Speybroeck, N., Murray, C. J. L. & Vos, T. (2015) Disability weights for the Global Burden of Disease 2013 study. *The Lancet Global Health* **3,** e712-e723. doi:10.1016/S2214-109X(15)00069-8.

Schwendicke, F., Plaumann, A., Stolpe, M., Dorfer, C. E. & Graetz, C. (2016) Retention costs of periodontally compromised molars in a German population. *J Clin Periodontol* **43,** 261-270. doi:10.1111/jcpe.12509.

Shelley, D., Wright, S., McNeely, J., Rotrosen, J., Winitzer, R. F., Pollack, H., Abel, S. & Metsch, L. (2012) Reimbursing dentists for smoking cessation treatment: views from dental insurers. *Nicotine Tob Res* **14,** 1180-1186. doi:10.1093/ntr/nts010.

Spiegelman, D., Hertzmark, E. & Wand, H. C. (2007) Point and interval estimates of partial population attributable risks in cohort studies: examples and software. *Cancer Causes Control* **18,** 571-579. doi:10.1007/s10552-006-0090-y.

Stevens, G. A., Alkema, L., Black, R. E., Boerma, J. T., Collins, G. S., Ezzati, M., Grove, J. T., Hogan, D. R., Hogan, M. C., Horton, R., Lawn, J. E., Marušić, A., Mathers, C. D., Murray, C. J. L., Rudan, I., Salomon, J. A., Simpson, P. J., Vos, T. & Welch, V. (2016) Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *The Lancet* **388,** e19-e23. doi:10.1016/S0140-6736(16)30388-9.

Stroup, D., Berlin, J., Morton, S., Olkin, I., Williamson, G., Rennie, D., Moher, D., Becker, B., Sipe, T. & Thacker, S. (2000) Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* **283,** 2008 - 2012.

Tomar, S. L. & Asma, S. (2000) Smoking-attributable periodontitis in the United States: findings from NHANES III. National Health and Nutrition Examination Survey. *J Periodontol* **71,** 743-751. doi:10.1902/jop.2000.71.5.743.

von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C. & Vandenbroucke, J. P. (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* **147,** 573-577.

**Figure legends**

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 the present study, too.

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

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 male (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.

**Tables**

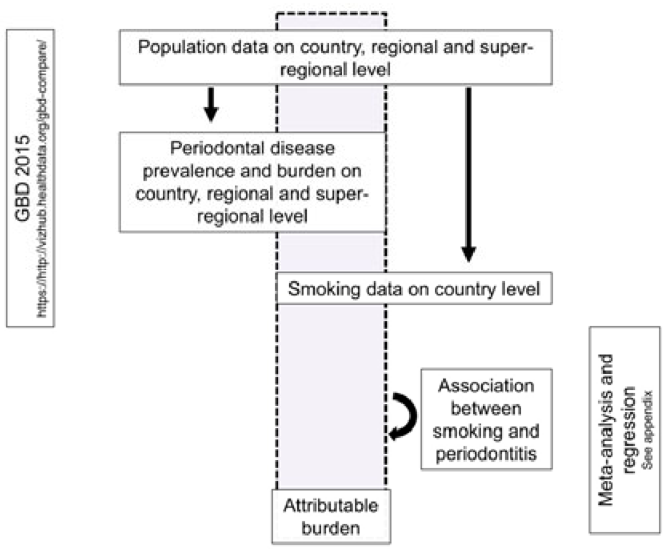
Table 1: Smoking-attributable DALYs and prevalent cases of periodontal disease in different geographic areas (global, super-region, region), in different age groups in 2015. The geographic areas are those used by the GBD studies and are shown in Figure 2.

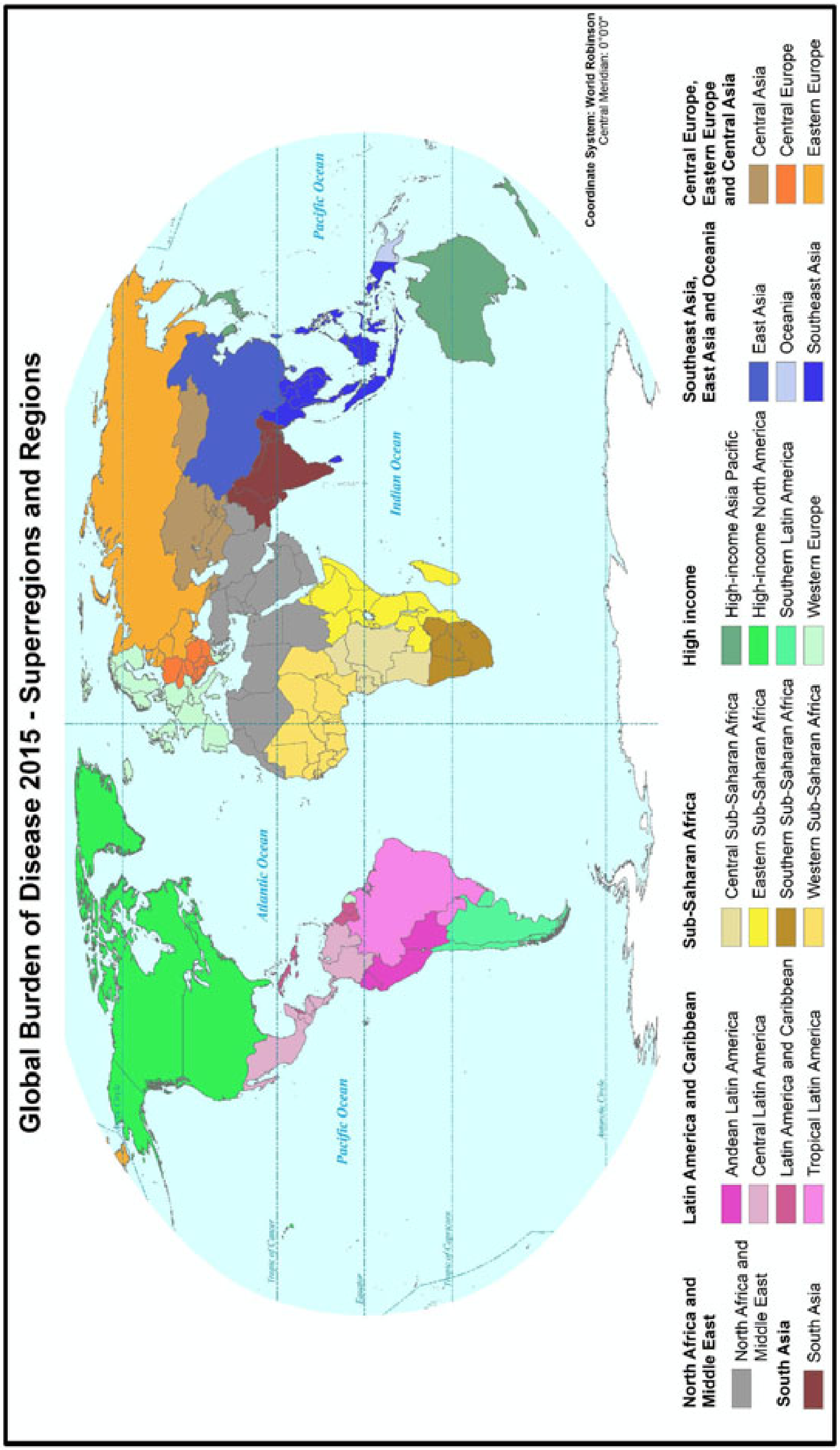
| Geographic area | Age group (years) | DALYs | Lower bound | Upper bound | Prevalent cases | Lower bound | Upper bound |
|---|---|---|---|---|---|---|---|
| Global | 15-49 | 75771 | 53938 | 105852 | 11372510 | 8093835 | 15891419 |
| | 50-69 | 141434 | 110022 | 176146 | 21705811 | 16877730 | 27042952 |
| | ≥70 | 33954 | 26751 | 42230 | 5402605 | 4253741 | 6723005 |
| Central Europe, Eastern Europe, and Central Asia | 15-49 | 3660 | 2751 | 4799 | 548944 | 412626 | 719893 |
| | 50-69 | 8700 | 6924 | 10689 | 1338873 | 1065538 | 1644764 |
| | ≥70 | 2599 | 2084 | 3196 | 415719 | 333402 | 511163 |
| High-income | 15-49 | 13692 | 10177 | 18232 | 2051103 | 1524531 | 2731367 |
| | 50-69 | 31684 | 25105 | 38790 | 4845018 | 3838380 | 5931810 |
| | ≥70 | 9988 | 7912 | 12377 | 1588346 | 1258414 | 1969222 |
| Latin America and Caribbean | 15-49 | 10027 | 6832 | 14023 | 1503878 | 1024623 | 2103199 |
| | 50-69 | 13143 | 9730 | 16724 | 2016529 | 1492881 | 2566088 |
| | ≥70 | 2215 | 1610 | 2901 | 354152 | 257527 | 464054 |
| North Africa and Middle East | 15-49 | 9666 | 6787 | 13856 | 1453771 | 1020601 | 2083856 |
| | 50-69 | 12174 | 9375 | 15231 | 1881195 | 1448362 | 2353960 |
| | ≥70 | 2255 | 1753 | 2822 | 363415 | 282514 | 454790 |
| South Asia | 15-49 | 10622 | 6731 | 15754 | 1602349 | 1015392 | 2376583 |
| | 50-69 | 17045 | 11580 | 23304 | 2643981 | 1796154 | 3614898 |
| | ≥70 | 3142 | 2144 | 4313 | 506882 | 346024 | 695803 |
| Southeast Asia, East Asia, and Oceania | 15-49 | 21330 | 16653 | 27799 | 3191943 | 2491968 | 4160312 |
| | 50-69 | 49882 | 41456 | 59728 | 7617662 | 6330186 | 9122447 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≥70 | 11841 | 9966 | 14091 | 1864918 | 1569414 | 2219635 |
| Sub-Saharan Africa | 15-49 | 6773 | 4008 | 11390 | 1020522 | 604094 | 1716209 |
| | 50-69 | 8800 | 5854 | 11679 | 1362553 | 906229 | 1808985 |
| | ≥70 | 1916 | 1280 | 2529 | 309173 | 206446 | 408338 |
| Andean Latin America | 15-49 | 354 | 238 | 515 | 53085 | 35577 | 77072 |
| | 50-69 | 491 | 347 | 662 | 75107 | 53182 | 101474 |
| | ≥70 | 92 | 65 | 125 | 14630 | 10314 | 20094 |
| Central Asia | 15-49 | 611 | 438 | 853 | 91522 | 65634 | 127800 |
| | 50-69 | 1042 | 791 | 1356 | 159700 | 121249 | 207943 |
| | ≥70 | 170 | 130 | 220 | 27106 | 20764 | 35160 |
| Central Europe | 15-49 | 1484 | 1109 | 1956 | 222181 | 165942 | 292774 |
| | 50-69 | 3525 | 2799 | 4329 | 541853 | 430214 | 665405 |
| | ≥70 | 1054 | 833 | 1310 | 168058 | 132877 | 208925 |
| Central Latin America | 15-49 | 3103 | 2140 | 4376 | 464832 | 320572 | 655574 |
| | 50-69 | 4152 | 3063 | 5391 | 636514 | 469442 | 826469 |
| | ≥70 | 757 | 558 | 996 | 121031 | 89168 | 159206 |
| Central Sub-Saharan Africa | 15-49 | 530 | 333 | 836 | 80203 | 50490 | 126681 |
| | 50-69 | 830 | 562 | 1166 | 129534 | 87743 | 182085 |
| | ≥70 | 179 | 123 | 250 | 29230 | 20050 | 40750 |
| East Asia | 15-49 | 17931 | 14277 | 22856 | 2682287 | 2135648 | 3418891 |
| | 50-69 | 42619 | 36029 | 50265 | 6502600 | 5497151 | 7669349 |
| | ≥70 | 10295 | 8806 | 12072 | 1618301 | 1384346 | 1897746 |
| Eastern Europe | 15-49 | 1565 | 1204 | 1991 | 235241 | 181050 | 299319 |
| | 50-69 | 4134 | 3335 | 5004 | 637320 | 514075 | 771416 |
| | ≥70 | 1376 | 1122 | 1667 | 220555 | 179761 | 267078 |
| Eastern Sub-Saharan Africa | 15-49 | 2300 | 1228 | 4346 | 345980 | 184812 | 654120 |
| | 50-69 | 3206 | 1907 | 4401 | 495312 | 294352 | 680139 |
| | ≥70 | 782 | 464 | 1055 | 125670 | 74511 | 169683 |
| High-income | 15-49 | 2976 | 2285 | 3826 | 444235 | 341116 | 571150 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Asia Pacific | | | | | | | |
| | 50-69 | 7162 | 5857 | 8578 | 1088976 | 890501 | 1304276 |
| | ≥70 | 2506 | 2050 | 3049 | 395492 | 323533 | 481093 |
| High-income North America | 15-49 | 3563 | 2591 | 4822 | 534731 | 388824 | 723789 |
| | 50-69 | 9857 | 7624 | 12379 | 1515401 | 1172024 | 1903225 |
| | ≥70 | 2645 | 2053 | 3337 | 425590 | 330377 | 536850 |
| Latin America and Caribbean | 15-49 | 696 | 466 | 990 | 104614 | 69918 | 148670 |
| | 50-69 | 1078 | 792 | 1372 | 165010 | 121254 | 210148 |
| | ≥70 | 251 | 185 | 327 | 39981 | 29382 | 51947 |
| North Africa and Middle East | 15-49 | 9666 | 6787 | 13856 | 1453771 | 1020601 | 2083856 |
| | 50-69 | 12174 | 9375 | 15231 | 1881195 | 1448362 | 2353960 |
| | ≥70 | 2255 | 1753 | 2822 | 363415 | 282514 | 454790 |
| Oceania | 15-49 | 146 | 12 | 459 | 21912 | 1749 | 69036 |
| | 50-69 | 104 | 12 | 247 | 16237 | 1939 | 38496 |
| | ≥70 | 15 | 2 | 40 | 2521 | 346 | 6356 |
| South Asia | 15-49 | 10622 | 6731 | 15754 | 1602349 | 1015392 | 2376583 |
| | 50-69 | 17045 | 11580 | 23304 | 2643981 | 1796154 | 3614898 |
| | ≥70 | 3142 | 2144 | 4313 | 506882 | 346024 | 695803 |
| Southeast Asia | 15-49 | 3252 | 2364 | 4483 | 487744 | 354571 | 672385 |
| | 50-69 | 7157 | 5413 | 9216 | 1098825 | 831096 | 1414602 |
| | ≥70 | 1532 | 1158 | 1979 | 244096 | 184722 | 315533 |
| Southern Latin America | 15-49 | 886 | 673 | 1146 | 132543 | 100759 | 171500 |
| | 50-69 | 1651 | 1348 | 1965 | 251670 | 205569 | 299609 |
| | ≥70 | 450 | 367 | 543 | 70878 | 57841 | 85602 |
| Southern Sub-Saharan Africa | 15-49 | 183 | 120 | 278 | 27784 | 18123 | 42162 |
| | 50-69 | 296 | 201 | 427 | 46141 | 31236 | 66651 |
| | ≥70 | 80 | 56 | 113 | 13007 | 9039 | 18430 |
| Tropical Latin America | 15-49 | 5873 | 3989 | 8142 | 881347 | 598556 | 1221883 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50-69 | 7423 | 5529 | 9299 | 1139898 | 849003 | 1427997 |
| | ≥70 | 1114 | 803 | 1453 | 178510 | 128663 | 232807 |
| Western Europe | 15-49 | 6262 | 4627 | 8437 | 939594 | 693832 | 1264928 |
| | 50-69 | 13021 | 10277 | 15868 | 1988971 | 1570286 | 2424700 |
| | ≥70 | 4385 | 3440 | 5449 | 696386 | 546663 | 865677 |
| Western Sub-Saharan Africa | 15-49 | 3761 | 2327 | 5930 | 566555 | 350669 | 893246 |
| | 50-69 | 4469 | 3185 | 5685 | 691566 | 492898 | 880110 |
| | ≥70 | 875 | 637 | 1111 | 141266 | 102846 | 179475 |




Global Burden of Disease 2015 - Superregions and Regions
Pacific Ocean
Atlantic Ocean
Indian Ocean
Pacific Ocean
Coordinate System: World Robinson
Central Meridian: 0°0'0"
North Africa and Middle East
North Africa and Middle East
South Asia
South Asia
Latin America and Caribbean
Andean Latin America
Central Latin America
Latin America and Caribbean
Tropical Latin America
Sub-Saharan Africa
Central Sub-Saharan Africa
Eastern Sub-Saharan Africa
Southern Sub-Saharan Africa
Western Sub-Saharan Africa
High income
High-income Asia Pacific
High-income North America
Southern Latin America
Western Europe
Southeast Asia, East Asia and Oceania
East Asia
Oceania
Southeast Asia
Central Europe, Eastern Europe and Central Asia
Central Asia
Central Europe
Eastern Europe

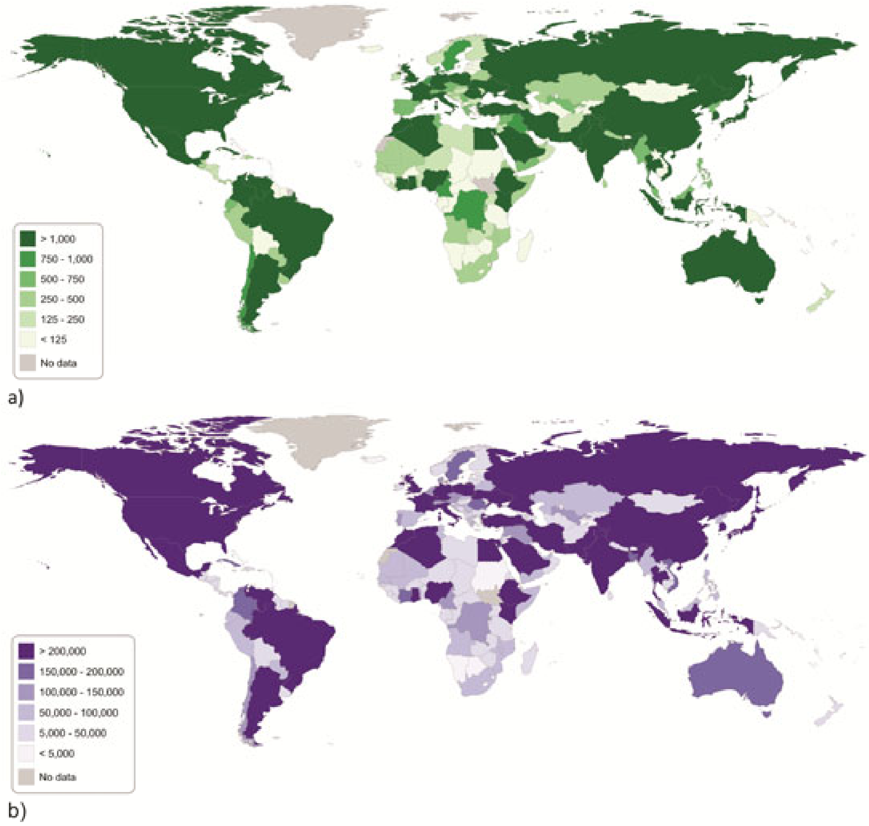
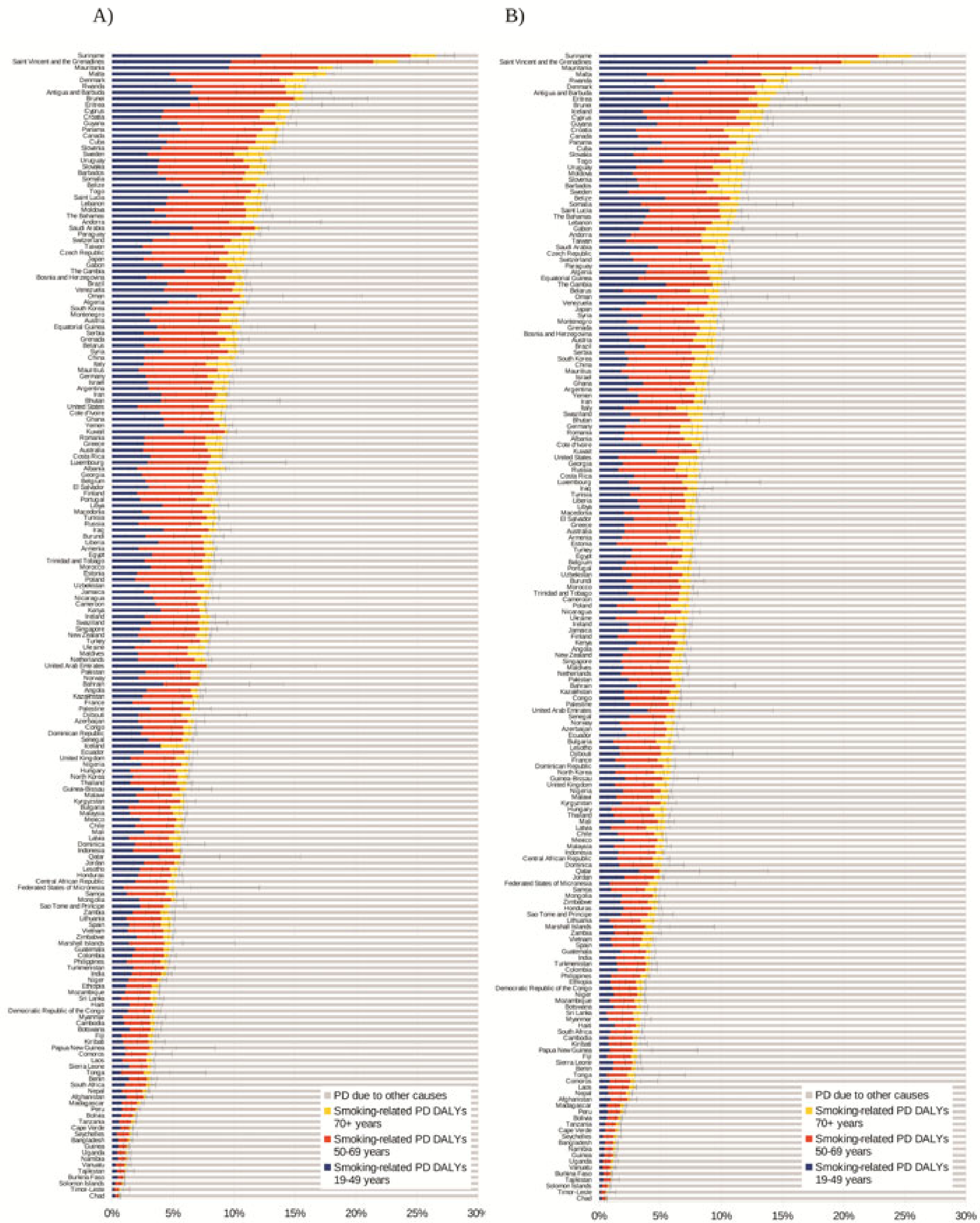



Figure 3: Smoking-attributable DALYs (a) and prevalent cases of periodontal disease (b) in 2015.


A)
B)
PD due to other causes
Smoking-related PD DALYs 70+ years
Smoking-related PD DALYs 50-69 years
Smoking-related PD DALYs 19-49 years
0%
5%
10%
15%
20%
25%
30%

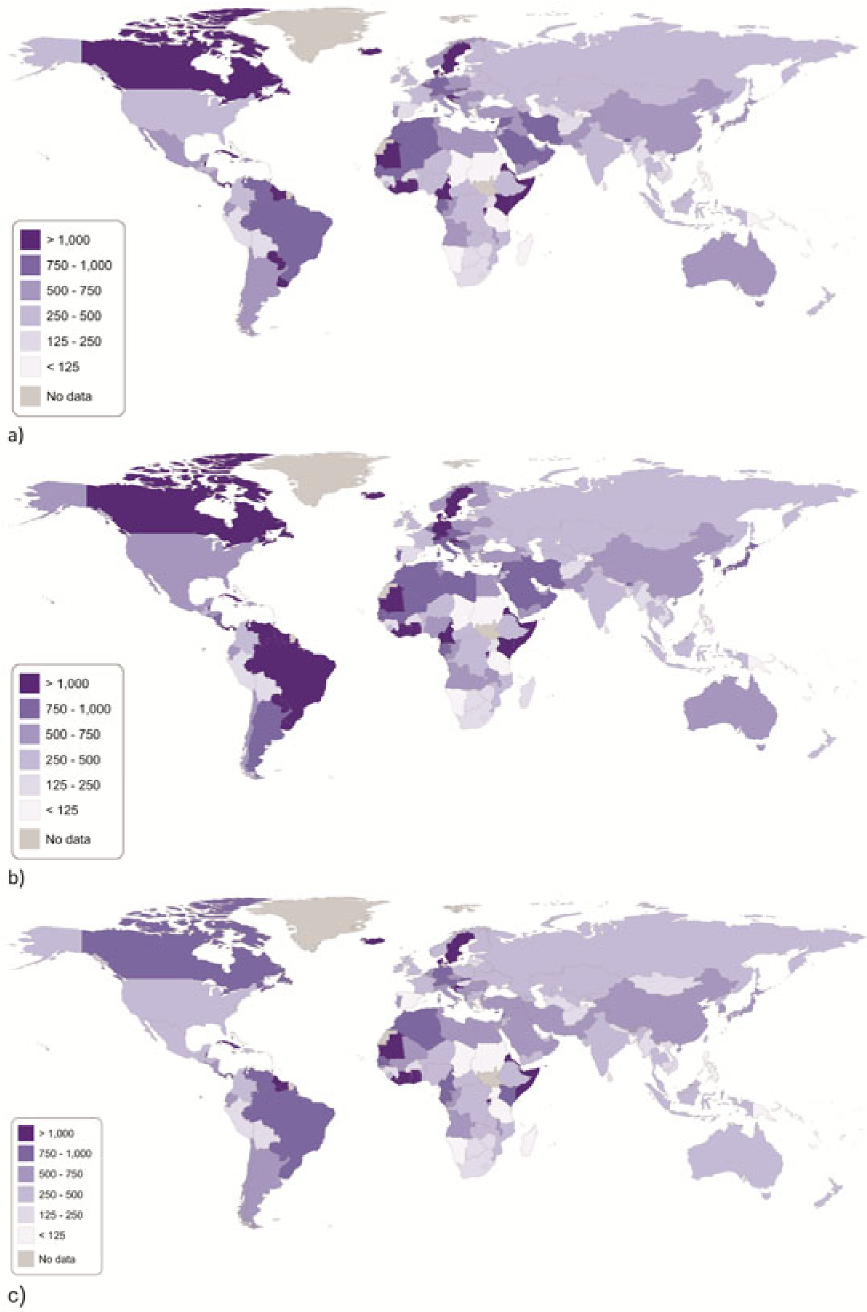



Figure 5: Age-standardized smoking-attributable prevalent cases of periodontal disease per 100,000 in 2015. (a) Both sexes pooled, (b) male, (c) female.