

Global Prevalence of Tobacco Use in Adolescents and Its Adverse Oral Health Consequences

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Abstract

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BACKGROUND: Smoking is associated with various systemic conditions and contributes to a huge financial burden to economies around the world.

AIM: The study aimed to evaluate global data about the prevalence of tobacco use among male and female adolescents and to discuss smoking-related oral complications.

METHODS: The prevalence data of tobacco use among adolescents (13-15 years) was retrieved from the World Health Organization (Global Health Observatory). The World Bank's statistics about gross national income (GNI) per capita were used to categorise low-income, lower-middle-income, upper-middle-income, and high-income countries. PubMed, Web of Science, Scopus, and Embase databases were searched to gather updated evidence about the adverse consequences of smoking on oral health among adolescents.

RESULTS: The prevalence of tobacco use was 19.33%, and there were 23.29% of male and 15.35% female smoker adolescents in 133 countries ($p < 0.001$). The highest prevalence of tobacco use in male (24.76%) and female (19.4) adolescents was found in high-income countries. Significantly higher proportions of male adolescents were smokers than female counterparts in low-income, lower-middle-income, and upper-middle-income ($p < 0.001$). However, there were no statistically significant differences in tobacco use between male and female adolescents in high-income countries. Low-income countries had the lowest prevalence (14.95%) of tobacco use, while high-income countries had the highest prevalence estimates (22.08). Gingivitis (72.8%), gingival bleeding (51.2%), oral malodor or halitosis (39.6%) is common oral conditions among smoker adolescents. Smoking habit is significantly associated with dental caries, periodontal disease, hairy tongue, smoking-related melanosis, and hyperkeratosis among adolescents.

CONCLUSION: There was a high prevalence of tobacco use among male and female adolescents around the globe. Available evidence suggests a strong association between smoking and compromised oral health among adolescents. Globally, measures should be taken to prevent and control the menace of tobacco use to reduce systemic and oral complications.

Introduction

Exposure to tobacco is associated with increased morbidity and mortality among children around the world [1]. Smoking contributes to increased risk of asthma, bronchitis, tuberculosis, inflammatory bowel disease, and leukaemia in children [1]. Moreover, children exposed to second-hand smoke may demonstrate structural and functional impairment in arteries that can lead to premature atherosclerosis and adverse long-term effects on the cardiovascular system [2]. Economic burden of smoking is enormous on individuals and healthcare systems. A recent study found that the

economic cost of smoking was US\$ 1436 billion around the globe in 2012 (equal to 1.8% of the annual gross domestic product of the world) which accounted for both direct health care expenditures and loss of productivity [3].

Cigarettes contain about 600 ingredients, they produce 7000 chemicals on combustion, and 69 of these chemicals can cause carcinomas. Nicotine is one of the toxic chemicals found in tobacco smoke [4]. It is documented that nicotine exposure among adolescents can affect the central nervous system and can cause cognitive functional and developmental impairment which can be of great concern considering the long-term use of tobacco [5]. Besides, adolescents

may develop symptoms of dependence sooner and at lower levels of tobacco consumption [6]. There is a reciprocal relationship between diminished autonomy and frequency of smoking, and even the consumption of one cigarette can prompt the loss of autonomy in adolescents [7].

The initiation and establishment of smoking behaviour frequently occur during adolescence, and 9 of 10 children start smoking by the age of 18 years [8]. Globally, about 80,000 to 100,000 children use tobacco per day [9]. Several factors are associated with smoking which includes the influence of smoker peers and smoker parents, genetic factors, and low socioeconomic status [10]. Moreover, there is sufficient evidence about the role of tobacco advertisement in causing the onset and continuation of smoking among adolescents [8]. Smoking initiation in the early age is associated with regular smoking in adulthood [11]. This underscores the importance of controlling the habit of smoking during adolescence so that immediate and long-term complications can be prevented in adolescents and adults, respectively.

Oral conditions pose significant public health problems and can negatively affect systemic health and quality of life of individuals [12]. Globally, untreated oral conditions affected 2.5 billion people in 1990 which rose to 3.5 in 2015 [13]. According to the Global Burden of Disease Study (2017), oral conditions accounted for 1.83 million disability-adjusted life-years, an increase of 21.4 % during the past decade (2007-2017) [14]. It was estimated that the cost of dental treatment was \$102 billion and 1.6 million school days were missed because of acute dental conditions in 2009 in the U.S. [8].

There is widespread use of tobacco among adolescents which enormously contributes to a high burden of oral and systemic diseases. Therefore, the present review aimed to evaluate global data about the prevalence of tobacco use during adolescence and to discuss oral complications commonly seen among smoker adolescents. The review utilised most updated evidence about the adverse effects of smoking on oral health among adolescents. The information presented in the review is expected to benefit healthcare professionals and other stakeholders so that they familiarise with the global smoking trends and its negative impacts on oral health. Their contribution in raising awareness is critical to preventing smoking-related oral and systemic complications during adolescence and long-term adverse effects in adulthood.

Methods

Data about the prevalence of tobacco use (including smoking cigarettes, oral tobacco, and snuff)

among adolescents (13-15 years) were retrieved from the Global Health Observatory, the World Health Organization [15]. Data were collected from 133 countries since 2007. Many of these countries have data collected in multiple years (more than one data), however latest data were used. The countries with data collected in 2006 and beyond were excluded from the study. To evaluate the ecological impact of the income of countries (Gross national income (GNI) per capita) on the prevalence of tobacco use, we compared data among low-income, lower-middle-income, upper-middle-income, and high-income countries. According to the World Bank (2017), the countries with a GNI per capita of \leq \$1,025 are defined as low-income countries; those with a GNI per capita between \$1,026 and \$4,035 as lower-middle-income countries, those with a GNI per capita between \$4,036 and \$12,475 as upper-middle-income countries, and those with a GNI per capita of \geq \$12,476 as high-income countries.

For this review, PubMed (Medline) was searched to retrieve studies about tobacco use and its impact on oral tissues. Using the library resources of Imam Abdulrahman Bin Faisal University, Scopus and Web of Science databases were searched. Search through Embase was also carried out to ensure a comprehensive search of related studies. Further, the reference lists of retrieved studies were searched to obtain more information regarding the topic of the review. The literature review gathered recent studies, mostly published during the last ten years, to provide updated information. Data from animal studies, case series, and case reports were excluded. Medical Subject Headings (MeSH)/keywords such as "smoking", "tobacco", "nicotine", "caries", "decay", "cavities", "gingival", "periodontal", "halitosis", "oral malodor", "cancers", "carcinoma", "oral health", and "oral conditions," were used to retrieve relevant studies.

Statistical analyses of the data were performed using SPSS Version 22.0 (IBM Corp. Armonk, NY, USA). Mann Whitney U test was conducted to make comparisons between the prevalence of tobacco use in male and female adolescents. Kruskal Wallis test compared the prevalence data among low-income, lower-middle-income, upper-middle-income, and high-income-countries. A significance level of $p < 0.05$ was used.

Results

There were 28 low-income, 76 lower-middle-income, 48 upper-middle-income, and 33 high-income countries included in the present review. The prevalence of tobacco use in adolescents in low-income countries is presented in Figure 1.

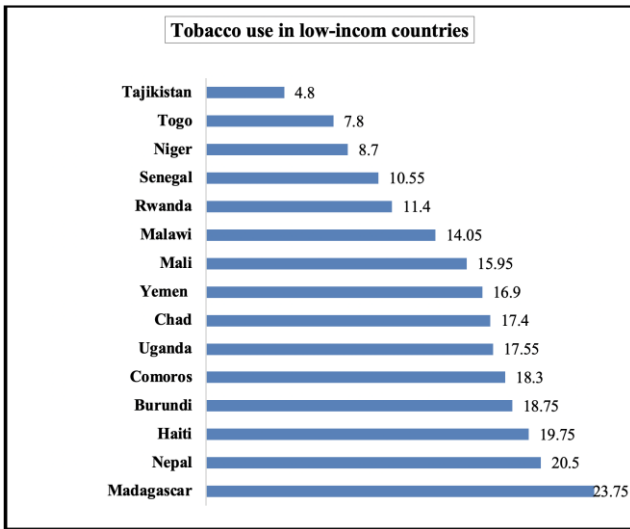


Figure 1: The prevalence of tobacco use in adolescents in low-income countries

Among low-income countries, tobacco use was most frequent in Madagascar (23.75%), followed by Nepal (20.5%), and Haiti (19.75%) whereas 4.8% of adolescents in Tajikistan used tobacco. About half the adolescents (47.85%) in Papua New Guinea consumed tobacco which was highest among lower-middle-income countries. On the other hand, tobacco use was the least common in Vietnam (4%), Bangladesh (6%) and Cambodia (6.45%) (Figure 2).

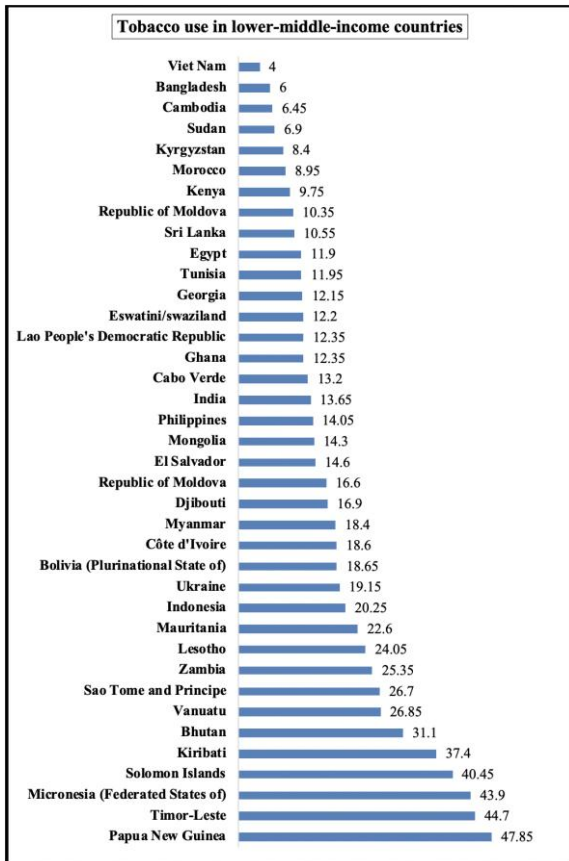


Figure 2: The prevalence of tobacco use in adolescents in lower-middle-income countries

Approximately one-quarter of adolescents in Tuvalu (37.15%), Lebanon (36.65%), and Tonga (36.45%) consumed tobacco in upper-middle-income countries. Montenegro (6.25), China (6.7%), and Azerbaijan (6.75%) had the lowest consumption of tobacco in upper-middle-income countries (Figure 3).

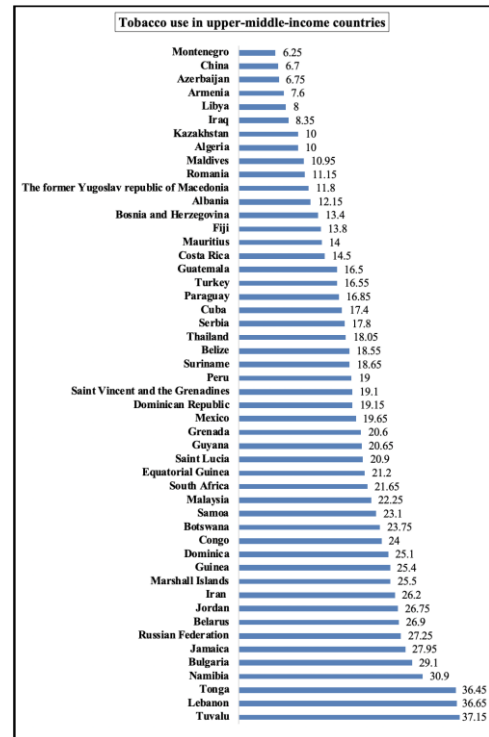


Figure 3: The prevalence of tobacco use in adolescents in upper-middle-income countries

Oman had the lowest prevalence of tobacco use (3.3%), whereas Palau demonstrated the highest distribution of tobacco use in adolescents in high-income countries (Figure 4).

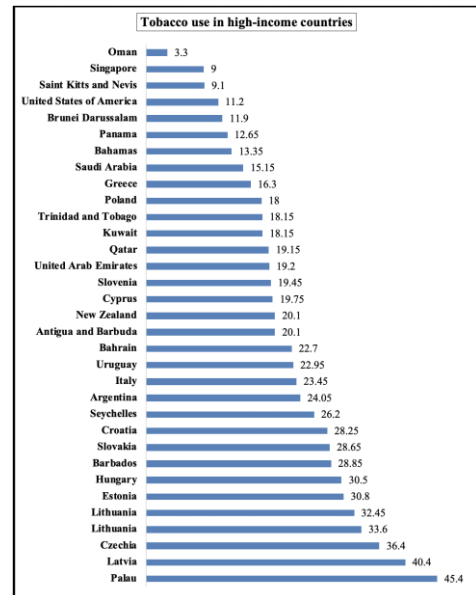


Figure 4: The prevalence of tobacco use in adolescents in high-income countries

The prevalence of tobacco use in adolescents in 133 countries was 19.33%, and it ranged from 1.5% to 65.5%. There were 23.29% male and 15.35% female smoker adolescents in these countries ($p < 0.001$). In low-income countries, 18.48% of male and 11.41% of female adolescents consumed tobacco ($p < 0.006$). The prevalence of tobacco use was higher in males (24.18%) than females (13.37%) in lower-middle-income countries ($p < 0.001$). Upper-middle-income countries had prevalence estimates tobacco use in 22.97% of male and 15.29% of female adolescents ($p < 0.001$). Adolescents in high-income countries showed no statistically significant differences in the prevalence of tobacco use ($p < 0.052$) (Table 1).

Table 1: Tobacco use among male and female adolescents (13-15 years) in 133 countries

Countries based on GNI	Number of countries	Prevalence of tobacco use in male adolescents (Percentages)	Prevalence of tobacco use in female adolescents (Percentages)	p-value
Low-Income Countries	28	18.48 Min = 6.8 Max = 33.2	11.41 Min = 2.8 Max = 19.2	0.006
Lower-Middle-Income Countries	76	24.18 Min = 6.5 Max = 65.5	13.37 Min = 1.5 Max = 40.3	< 0.001
Upper-Middle-Income Countries	48	22.97 Min = 6.6 Max = 44.9	15.29 Min = 2.1 Max = 32.7	< 0.001
High-Income Countries	33	24.76 Min = 4.9 Max = 54.1	19.4 Min = 1.7 Max = 41.4	0.052
Total	133	23.29	15.35	< 0.001

Discussion

The comparison of tobacco use among different countries is shown in Figure 5. Low-income countries had the lowest prevalence (14.95%) of tobacco use, while high-income countries had the highest prevalence estimates (22.08). There were statistically significant differences in the prevalence of tobacco use among low-income, lower-middle-income, upper-middle-income, and high-income countries ($p < 0.008$).

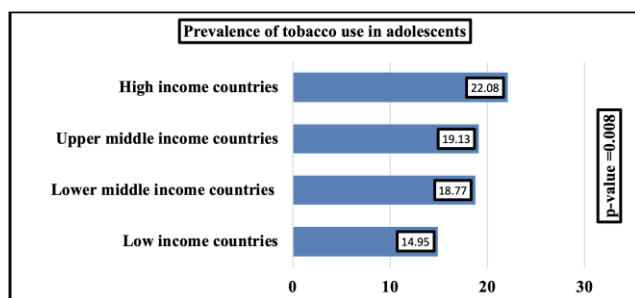


Figure 5: Differences in the prevalence of tobacco use in 133 countries according to their income

Mechanisms of Adverse Effects of Tobacco Use on Oral Health

Several mechanisms are responsible for the adverse effects of tobacco use on oral health. Tobacco smoke is a mixture of thousands of complex chemicals, many of which are poisonous and are responsible for the chemically mediated disease, including cancers [16]. Cigarette smoking is associated with alterations in oral microbial profile. A recent study showed that oral microbiome was significantly different in smokers compared with non-smokers. The smokers demonstrated the depletion of *Actinobacillus*, *Neisseria*, *Aggregatibacter*, *Eikenella*, *Haemophilus*, *Lautropia*, *Fusobacterium*, *Leptotrichia*, and *Cyanobacteria* and abundance of *Treponema*, and *Mycoplasma* [17]. Oral microorganisms accumulate to form biofilm on the tooth surface and subgingival sulcus, and smokers have been shown to demonstrate diverse microbial colonisation of biofilms than non-smokers, thus suggesting the role of smoking in promoting bacterial acquisition and colonisation in the biofilm [18].

Compared with non-smokers, smokers exhibit increased pathogenic species in marginal and subgingival biofilms and greater pro-inflammatory response [19]. It is well recognised that increased susceptibility of smokers to oral infections is because smoking promotes virulence of microorganisms and increases antibiotic resistance [20]. Besides, the adverse health effects of smoking can be related to potential microbial pathogens present in cigarettes. A variety of cigarette brands contain microorganisms which include *Acinetobacter*, *Bacillus*, *Staphylococcus* species, *Clostridium*, *Serratia*, and *Pseudomonas* [20].

Health consequences of tobacco consumption are related to its suppressive effects on the immune system. Exposure to tobacco smoke plays an important role in the production of immune and inflammatory mediators [21]. Similarly, provocation of oxidative stress because of smoke can result in dysregulation of the immune system to cause autoimmunity. Smoke can also produce autoantibodies and contribute to autoreactivity in some autoimmune diseases [22]. Smoking is also known to cause temperature variations and alterations in the pH in the oral cavity, which can be attributed to increased incidence of oral cancers. High intraoral temperature variations are associated with certain oral conditions and act as co-carcinogens. Also, chemicals present in tobacco are responsible for high alkaline pH which promotes the absorption of nicotine in the oral mucosal membrane [23]. Tobacco use compromises wound healing by inducing changes in connective and vascular tissues, reducing the supply of oxygen and nutrient to tissues, and decreasing collagen synthesis [24].

Common Oral Conditions among Smoker Adolescents

Smoker adolescents are predisposed to increased risk of oral conditions which include gingivitis and gingival bleeding, oral malodor, staining, dental caries, oral mucosal lesions, periodontal disease, dryness of mouth, and sensitivity.

Gingivitis and bleeding gums

Common adverse oral health consequences among adolescents include gingivitis, including bleeding gums and tooth staining [25]. Gingivitis is dental plaque-induced inflammation of gingiva without periodontal attachment loss or alveolar bone loss. However, persistent gingivitis is a risk factor for attachment loss and tooth loss later in life [26]. A recent study showed a high prevalence rate of gingivitis (72.8%) among adolescents, and male gender, poor oral hygiene, and smoking were significantly associated with gingivitis. It was also found that the smokers were 2.26 times more likely to have gingivitis than non-smokers [27]. A previous study also showed that 51.2% of adolescent smokers exhibited gingival bleeding than 33.1% of non-smokers ($p < 0.02$) [25]. It is documented that poor oral hygiene results in plaque accumulation which causes gingival inflammation and bleeding gums [27].

Oral Malodor

Oral malodor, also known as halitosis has negative effects on self-confidence, self-esteem, professional life, and social interaction. There is a high prevalence of oral malodor among school children. Yokoyama et al. detected oral malodor in 39.6% of senior high school children [28]. Oral malodor prevalence of 23.6% in adolescents was observed by Kim et al., [29]. Tobacco use is considered an extrinsic cause of oral malodor and smoking habit is known to correlate with the presence of oral malodor in youth [30]. Nevertheless, some studies did not find a significant association between smoking and oral malodor in adolescents and youth [29], [31].

Dental caries

The literature consistently shows an association between smoking and increased risk of caries during adolescence [32], [33], [34]. Tobacco consumption (tobacco and smokeless tobacco) is a significant risk factor for caries development. A population-based longitudinal study of 10,068 adolescents (2006-2012) found that tobacco users had significantly higher mean value of decay, missing, and filled surface (DMFS = 1.8) than never tobacco users (mean DMFS = 1.2), and tobacco use was significantly associated with increased caries incidence [32]. Another epidemiological study of

20,703 schoolchildren reported an association between household smoking and increased risk of dental caries. The study also demonstrated a significant dose-response relationship between household smoking and prevalence of decayed and or filled teeth [33]. Passive tobacco exposure also contributes to the development of caries in adolescents. A recent meta-analysis of 21 studies found a moderate association between passive smoking and dental caries in children and adolescents [34].

Periodontal Disease

According to the American Academy of Periodontology, several periodontal diseases affect adolescents, although their prevalence is higher in adults than adolescents [35]. Smoking negatively affects periodontal health by causing degradation of periodontal tissues. A study of adolescents found that smoker participants had significantly more periodontal pockets of ≥ 4 mm than non-smokers. Also, the study identified significantly higher root calculus in smokers than non-smoker adolescents [36]. Available evidence suggests that tobacco consumption can affect inflammatory biomarkers in saliva which have been successfully used as an alternative to evaluating periodontal health. It was reported that smoking increased the risk of periodontal disease among adolescents by lowering salivary biomarkers like matrix metalloproteinase (MMP)-8 and male adolescents demonstrated more susceptibility to periodontitis than female teenagers [37].

Oral Mucosal Lesions

The studies documented high prevalence (26.2%-28%) of oral mucosal lesions in adolescents [38], [39]. Male adolescents were found to have a high prevalence of oral mucosal lesions than females [39]. Aphthous ulcers, traumatic ulcerations, herpes stomatitis, angular cheilitis, geographic tongue, and candidiasis are the most common types of oral mucosal lesions during adolescence [38], [40]. A recent study of adolescents observed a significant association between smoking habit and hairy tongue, smoking-related melanosis, and hyperkeratosis. The authors suggested that smoking can induce alterations in oral microbial profile, thickening of oral mucous membrane, and extravasation of melanocytic pigment which may lead to oral mucosal lesions [41]. A study of 17,027 schoolchildren showed that about 1.5% had smokeless tobacco lesions which were more common in male than female students. The study also demonstrated a dose-response relationship between tobacco use and smokeless tobacco lesions, and snuff use was strongly associated with increased odds (odds ratio 18.4) of these lesions [42].

Dryness and hypersensitivity

A significantly higher proportion of smokers were shown to have tooth sensitivity and dryness of the mouth than non-smokers [43]. Evidence suggests that smoking reduces salivary flow which predisposes individuals to dryness of the mouth or xerostomia [44]. A previous study also showed a significant difference in the prevalence of xerostomia among smokers (39%) and non-smokers (12%) [45]. Similarly, it was reported that 37% of smokers had xerostomia compared with 13% of non-smokers [44]. It is well-known that dryness of the mouth can cause inflammation of oral tissues including salivary glands, and can promote caries development, oral malodor, calculus formation, and fungal infection [45], [46].

Oral pre-cancerous lesions and cancers

Tobacco smoking contributes to the formation of oral pre-cancerous lesions, such as leukoplakia and erythroplakia [24]. Oral cancers involve carcinomas of lip, tongue, mouth, and pharynx, and are considered the sixth most prevalent cancers around the world [47]. Globally, 128,000 patients with oral cancer die annually [48]. Men have a higher incidence of oral cancer than women, and tobacco use is a major contributor to oral cancer [49]. The incidence of lip, oral cavity, and pharyngeal cancers was 3.8% (529,500 cases) of all cancers in 2012, and it was predicted that the number of these cancers would increase to 856,000 cases in 2035 representing 62% increase in 23 years [48].

Although childhood cancers are rare, however, there is a rise in the number of new cancer cases of oral cavity and pharynx in adolescents which are associated with human papillomavirus (HPV) infection in addition to tobacco use [50]. Since smoking is widely prevalent among adolescents, and adverse health consequences of oral cancers are huge and far-reaching. Therefore, health professionals should be aware of the signs and symptoms of oral cancers so that early detection and treatment should be started as early as possible to reduce morbidity and mortality later in life. It is the responsibility of healthcare providers to provide counselling to adolescents and their patients about the hazardous consequences of smoking on oral and systemic health in daily practice. A previous study found that the adolescents who were aware of the adverse effects of smoking on oral health had 22% – 47% lesser chances of smoking than those who were unaware of negative smoking consequences [51].

Prevention of smoking

The WHO suggested the 5 A's model that helps individuals avoid exposure to secondhand smoke and prepares individuals to quit smoking, and the 5R's model that increases the motivation of quitting [52]. More than 80% of smokers approach primary health care providers each year, which place

them in a central position to advise smokers to quit tobacco use. The 5 A's model (Ask, Advise, Assess, Assist, Arrange) involves using actions and strategies to provide advice to tobacco users [52].

Table 2: Description of 5 A's Model

5 A's	Description
Ask	Health care providers should "ASK" their patients about using tobacco and identify and document tobacco users in each visit.
Advise	They should strongly "ADVISE" tobacco users to quit smoking.
Assess	Smoker's readiness to quitting should be "ASSESSED" health care professionals.
Assist	The tobacco users should be "ASSISTED" by providing them with a smoking quit plan.
Arrange	A follow-up visit or a referral to a specialist should be "ARRANGED" to identify problems and challenges and provide support.

The 5 R's model (Relevance, Risks, Rewards, Roadblocks, and Repetition) provides strategies that can be used in motivational counselling for those individuals who are not ready to quit tobacco use.[52]

Table 3: Description of 5 R's Model

5 R's	Description
Relevance	When using "RELEVANCE", health care providers should describe that quitting smoking is personally relevant to tobacco users concerning diseases, health risks, and family or social concerns.
Risks	Health care providers should help individuals identify negative consequences (RISKS) associated with the use of tobacco, such as acute risks, long-term risks, and environmental risks.
Rewards	The "REWARDS" are potentially relevant advantages of quitting, such as better health outcomes, improved social interactions, and economic benefits. Health care providers should encourage tobacco users to recognize the benefits of quitting.
Road Blocks	They should explain barriers (ROADBLOCKS) to quitting to their patients which may include dependence, fear of failure, and lack of support.
Repetition	"REPETITION" involves repeating motivational counselling intervention if the patient does not demonstrate readiness to quit smoking.

Conclusion and recommendations

The study found a high prevalence of tobacco use among male and female adolescents in 133 countries. High-income countries had the highest prevalence of smoker adolescents, while low-income countries had the lowest prevalence of tobacco use. A significantly higher proportion of male than female adolescents used tobacco in low-income, lower-middle-income, and upper-middle-income countries. However, male and female smoker adolescents in high-income countries showed no significant differences, suggesting that both male and female adolescents were almost equally exposed to tobacco in high-income countries.

The smoker adolescents exhibit a high burden of gingivitis, gingival bleeding, malodor (halitosis), and tooth staining. There is a significant association between smoking and increased incidence of caries, calculus, periodontal pockets, oral mucosal lesions among adolescents. Healthcare professionals, decision-makers in healthcare agencies, and other stakeholders should be aware of the epidemic of smoking and associated systemic and oral health complications among adolescents. They should play

their roles at the individual level and through collaborations in the prevention and control of smoking.

Medical and dental curricula should include strategies on smoking cessation in addition to the epidemiology of tobacco use and pathology of tobacco-related conditions. The health care professionals should use 5A's and 5R's models in their clinical practice to encourage quitting, and they should act as clinicians, educators, opinion makers, role models, researchers, and collaborators to help control tobacco epidemic and to improve the quality of life of adolescents.

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