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Original Article

Death, Disability, and Premature Life Years Lost Due to Cigarettes, Bidis, and Smokeless Tobacco in India: A Comparative Assessment

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Abstract

Background: Due to the staggering number of tobacco users in India, it is important to determine the exact mortality and morbidity rates due to tobacco use. This study aimed to estimate deaths, disability-adjusted life years (DALYs), and years of life lost (YLLs) attributable to cigarettes, bidis, and smokeless tobacco (SLT) in India.

Methods: Data pooling and meta-analysis were done using case-control studies available on the three types of tobacco products. Health burden was estimated by applying the population attributable fraction (PAF) value to the total disease burden.

Findings: A total of 33 studies were included. PAF was calculated for oral and lung cancer as well as ischemic heart disease (IHD) due to cigarettes, oral and lung cancer, IHD, and chronic obstructive pulmonary disease due to bidi, and oral and stomach cancer and IHD due to SLT. Cigarettes resulted in 8.4 million DALYs, 8.26 million YLLs, and 341 deaths; bidis led to 11.7 million DALYs, 10.7 million YLLs, and 478 thousand deaths, and SLTs accounted for 4.38 million DALYs, 4.3 million YLLs, and 171 thousand deaths annually.

Conclusion: Evidence of measurable health burden and methodology for calculation for individual states was provided in the study. The generated evidence could be utilized for policy recommendations and revision of the existing taxation norms.

Keywords: Tobacco, Disability-adjusted life years, Morbidity, Mouth neoplasms, Lung diseases, Policy

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Introduction

Tobacco consumption being the single largest cause of preventable deaths, is a globally accepted issue of public health concern.[1] A lot of research work has been conducted on various aspects of tobacco such as its carcinogenic potential as well as direct and indirect effects on health and non-health aspects of consumption. While the World Health Organization (WHO) holds tobacco responsible for 8 million annual deaths globally,[1] several isolated estimates account for mortality due to individual forms of tobacco. The Centers for Disease Control and Prevention (CDC) attributes 480 317 annual deaths to cigarette consumption alone in the United States,[2] while the INTERHEART study (2017) estimates over a quarter of one million deaths globally due to smokeless tobacco (SLT) use in 127 countries.[3] Moreover, due to the shifts in tobacco consumption, where 100 million deaths occurred in the 20th century with 70% from high-income countries, the projected number stands at about one billion for the 21st century, this time, mostly from the low- and middle-income countries.[4]

Incidentally, India is the second largest producer as well as consumer of tobacco in the world.[5] With a prevalence of 28.6% amounting to over 250 million active tobacco users in the country, the burden posed by consumption of such products in terms of cancer, heart diseases, and respiratory diseases is also enormous, which leaves behind a significant disparity of health outcomes.[6]

A high prevalence, coupled with a low mean age of onset (18.9 years), poses a huge threat in the years to come to the Indian population, as health effects due to tobacco usually present themselves after 2 or 3 decades of usage.[6,7] Due to such a staggering number of active tobacco users, it is equally important to determine the exact mortality and morbidity rates that could be used for academic as well as advocacy purposes.

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There are a lot of studies that present evidence in terms of relative risk or odds of disease occurrence; however, there is a paucity of literature quantifying the actual numbers of annual deaths, disability-adjusted life years (DALYs), and years of life lost (YLLs), specifically attributable to the use of tobacco products. For the purpose of this study, health effects due to three major forms of tobacco products, namely cigarettes, bidis, and SLT were analyzed and absolute numbers of deaths, DALYs, and YLLs in India were estimated.

Methods

For the purpose of this study, ethical clearance was taken from the institutional ethical committee of All India Institute of Medical Sciences, Jodhpur, India (Certificate Reference Number: AIIMS/IEC/2022/4208). A meta-analysis was conducted to account the data from all published studies concerning disease occurrence as a result of tobacco consumption. Most common diseases due to all three major forms of tobacco products were searched through a review of available literature. Due to greater availability, case-control studies, done in any part of India, from 2000 to 2022, which contained individual data on odds of disease occurrence due to cigarettes, bidis, and SLT were included in the analysis, while those studies which contained generalized results due to "smoking" or "tobacco" were excluded.

Wherever case-control studies and odds ratio were not available for the analysis of a specific disease, cohort studies and relative risk were used. It is well documented in the literature that when the outcome occurs in less than 10% of the unexposed population, odds ratio (OR) approximately equals relative risk (RR), hence they may be used interchangeably.[8]

To estimate the proportion of health burden due to risk factors of cigarette, bidi, and SLT consumption, meta-analysis was done and pooled OR/RR values were calculated to determine population attributable fraction (PAF). In cases where multiple studies were not available, PAF was calculated using OR or RR values from the available studies with representative sample sizes. PAF is the proportion of cases for an outcome that can be attributed to a certain risk factor among the entire population. In other words, the number of deaths or DALYs attributable to tobacco consumption in the population could be estimated by applying the PAF due to cigarette, bidi, and SLT consumption respectively, to the total number of deaths or DALYs due to a particular disease.

PAF was calculated using the following formula:

$$PAF = Pe \cdot \frac{(OR-1)}{OR}$$

Where 'Pe' is the proportion of cases amongst the exposed and 'OR' is the pooled odds ratio (pooled relative risk (RR) in instances, where case-control studies were not found for the specific disease).[8]

After calculating the value of PAF, the same was applied to the total number of deaths, DALYs, and YLLs, as obtained from the global burden of disease data for India,[9] to estimate morbidity and mortality specifically attributable to the three forms of tobacco. The statistical analysis was carried out using MetaXL v4.0 add-in for MS Excel (2019) and SPSS v23.

Results

The review of the literature showed that the most common diseases that occur due to the use of smoked tobacco products are lung cancer (Lung Ca) and oral cancer (Oral Ca), chronic obstructive pulmonary disorder (COPD), ischemic heart disease (IHD), and ischemic stroke, while those due to use of SLT are Oral Ca, stomach cancer (St Ca), IHD, and ischemic stroke.[10,11]

Considering the inclusion criteria, a total of six studies were included for Lung Ca, nine for Oral Ca, two for IHD, and one for ischemic stroke due to cigarettes; six studies for Lung Ca, 10 for Oral Ca, two for IHD, one for COPD, and two for stroke due to bidi; and 17 studies were included for Oral Ca, six for Stomach Ca, three for stroke, and one for IHD due to SLTs. Detailed characteristics of the studies are provided in Table 1.

Pooled OR values with 95% lower- and upper-confidence intervals (OR; 95% LCI, 95% UCI) obtained for oral cancer ranged from 3.66 (2.39, 5.61) from SLTs, 3.32 (2.67, 4.12) from bidis, and 1.15 (0.77, 1.71) from cigarettes; for lung cancer, 4.45 (3.25, 6.34) from bidis and 2.73 (2.08, 3.58) from cigarettes; for IHD, 2.85 (2.27, 3.57) from cigarettes and 2.68 (2.11, 3.4) from bidis; for ischemic stroke, 2.58 (1.32, 5.03) from SLTs and 1.60 (0.45, 5.72) from bidi; and for stomach cancer, 1.84 (1.16, 2.91) from SLTs. A high level of heterogeneity amongst the included studies was observed in all the groups except for IHD due to bidi and cigarettes (Figures 1 and 2; Tables 1 and 2).

The fraction of disease occurrence in the population that could be attributed to cigarette, bidi, and SLT consumption (or the PAF) was calculated to be (in descending order): oral cancer – 0.45 by SLTs, 0.32 by bidis, and 0.03 by cigarettes; lung cancer – 0.39 by bidis and 0.28 by cigarettes; ischemic stroke – 0.24 by SLTs, 0.13 by bidis, and 0.10 by cigarettes; IHD – 0.21 by cigarettes, 0.17 by bidis, and 0.08 by SLTs; COPD – 0.19 by bidis and 0.16 by SLTs (Tables 1 and 2).

These PAF values were then applied to the disease burden (GBD – 2019) due to the corresponding diseases to obtain the final values of Deaths, DALYs, and YLLs that could be specifically attributed to tobacco product consumption by type. An estimated 8 391 843 annual DALYs could be attributable to cigarette smoking nationally (56 038 DALYs of oral cancer, 633 891 DALYs

Table 1. Pooled odds ratio and population attributable fraction for smoked tobacco products (cigarettes and bidis) obtained by meta-analysis

Study	Exposed Cases	Unexposed Cases	Exposed Controls	Unexposed Controls	OR (LCI, UCI)	Pooled OR (LCI, UCI); I^2	PAF
Tobacco Product Type: Cigarettes Disease: Oral Cancer							
Gholap et al (2022)[12]	296	387	266	810	2.33 (1.90, 2.86)	1.15 (0.77, 1.71); $I^2=88.31$	0.03
Chatterjee et al (2021)[13]	64	205	33	127	1.20 (0.75, 1.93)		
Mahapatra et al (2015)[14]	24	110	43	225	1.14 (0.66, 1.98)		
Madani et al (2012)[15]	59	291	39	311	1.62 (1.05, 2.50)		
Muwonge et al (2007)[16]	63	100	324	491	0.95 (0.68, 1.35)		
Subapriya et al (2007)[17]	36	352	21	367	1.79 (1.02, 3.12)		
Buch et al (2002)[18]	23	262	88	338	0.34 (0.21, 0.55)		
Balaram et al (2002)[19]	36	273	41	251	0.81 (0.50, 1.30)		
Dikshit et al (2000)[20]	64	331	33	227	1.33 (0.85, 2.09)		
Tobacco Product Type: Cigarettes Disease: Lung Cancer							
Chatterjee et al (2021)[13]	46	117	33	127	1.51 (0.91, 2.53)	2.73 (2.08, 3.58); $I^2=67.76$	0.28
Dikshit et al (2000)[20]	46	117	33	227	2.70 (1.64, 4.46)		
Ganesh et al (2011)[21]	219	189	412	971	2.73 (2.18, 3.42)		
Gajalakshmi et al (2003)[22]	113	87	564	1717	3.95 (2.94, 5.31)		
Gupta et al (2001)[23]	209	56	263	262	3.72 (2.64, 5.23)		
Prasad et al (2010)[24]	19	265	33	819	1.78 (1.00, 3.18)		
Tobacco Product Type: Cigarettes Disease: Ischemic Stroke							
Agashe and Gawde (2013)[25]	15	65	8	72	2.08 (0.83, 5.22)	-	0.10
Tobacco Product Type: Cigarettes Disease: Ischemic Heart Disease							
Rastogi et al (2005)[26]	105	204	93	525	2.91 (2.10, 4.01)	2.85 (2.27, 3.57)	0.21
Rastogi et al (2004)[27]	105	245	93	607	2.79 (2.04, 3.83)		
Tobacco Product Type: Bidi Disease: Oral Cancer							
Balaram et al (2002)[19]	128	181	74	218	2.08 (1.47, 2.95)	3.32 (2.67, 4.12); $I^2=81.09$	**0.32**
Madani et al (2014)[28]	70	280	20	330	4.13 (2.45, 6.95)		
Rahman et al (2005)[29]	2347	2431	1247	5024	3.89 (3.58, 4.23)		
Gholap et al (2022)[12]	318	409	129	673	4.06 (3.20, 5.15)		
Chatterjee et al (2021)[13]	254	141	94	166	3.18 (2.30, 4.41)		
Mahapatra et al (2015)[14]	48	86	20	248	6.92 (3.89, 12.32)		
Muwonge et al (2007)[16]	84	79	340	475	1.49 (1.06, 2.08)		
Subapriya et al (2007)[17]	84	304	22	366	4.60 (2.81, 7.53)		
Buch et al (2002)[18]	74	211	41	385	3.29 (2.17, 5.00)		
Dikshit et al (2000)[20]	254	141	94	166	3.18 (2.30, 4.41)		
Tobacco Product Type: Bidi Disease: Lung Cancer							
Ganesh et al (2011)[21]	153	255	145	1238	5.12 (3.93, 6.67)	4.54 (3.25, 6.34); $I^2=85.92$	**0.39**
Gajalakshmi et al (2003)[22]	204	574	413	3017	2.60 (2.15, 3.14)		
Gupta et al (2001)[23]	209	56	263	262	3.72 (2.64, 5.23)		
Prasad et al (2010)[24]	195	89	297	555	4.09 (3.07, 5.46)		
Chatterjee et al (2021)[13]	131	32	94	166	7.23 (4.56, 11.47)		
Dikshit et al (2000)[20]	131	32	94	166	7.23 (4.56, 11.47)		
Tobacco Product Type: Bidi Disease: Ischemic Heart Disease							
Rastogi et al (2005)[26]	87	222	78	540	2.71 (1.92, 3.82)	2.68 (2.11, 3.40)	0.17
Rastogi et al (2004)[27]	89	261	80	620	2.65 (1.89, 3.70)		

Table 1. Continued

Study	Exposed Cases	Unexposed Cases	Exposed Controls	Unexposed Controls	OR (LCI, UCI)	Pooled OR (LCI, UCI); I^2	PAF
Tobacco Product Type: Bidi Disease: Ischemic Stroke							
Ram et al (2012)[30]	65	70	33	102	2.87 (1.71, 4.82)	1.60 (0.45, 5.72)	0.13
Agashe and Gawde (2013)[25]	8	72	10	70	0.78 (0.29, 2.09)		
Tobacco Product Type: Bidi Disease: COPD*							
Duong et al (2017)[31]	82	187	1843	11152	2.58 (2.00, 3.33)**	-	0.19

Abbreviations: OR, odds ratio; LCI, 95% lower class interval; UCIL, 95% upper class interval; I^2, statistic representing heterogeneity of studies included; PAF, population attributable fraction; COPD, chronic obstructive pulmonary disease.
*For COPD, cohort study was considered as per the study methodology. In the table, exposed cases may be referred to as event occurrence amongst exposed, unexposed cases as event occurrence amongst unexposed, exposed controls as event not occurred amongst exposed, and unexposed controls as event not occurred amongst unexposed.
**Relative risk value with 95% confidence interval was calculated for the cohort study.

Table 2. Pooled odds ratio and population attributable fraction for smokeless tobacco products obtained by meta-analysis

Study	Exposed Cases	Unexposed Cases	Exposed Controls	Unexposed Controls	OR (LCI, UCI)	Pooled OR (LCI, UCI); I^2	PAF
Tobacco Product Type: SLT Disease: Oral Cancer							
Gholap et al (2022)[12]	892	81	457	543	13.08 (10.10, 16.96)	3.66 (2.39, 5.61); $I^2=97.25$	0.45
Chatterjee et al (2021)[13]	220	175	108	152	1.77 (1.29, 2.43)		
Gajalakshmi et al (2015)[32]	171	285	51027	378279	4.45 (3.68, 5.38)		
Mahapatra et al (2015)[14]	27	107	9	259	7.26 (3.30, 15.96)		
Kadashetti et al (2015)[33]	90	10	10	22	19.8 (7.34, 53.43)		
Krishna et al (2014)[34]	404	67	491	65	0.80 (0.55, 1.15)		
Lakhanpal et al (2014)[35]	100	25	152	55	1.45 (0.85, 2.47)		
Ray et al (2013)[36]	171	313	154	794	2.82 (2.18, 3.63)		
Madani et al (2012)[15]	175	175	55	295	5.36 (3.76, 7.66)		
Muwonge et al (2007)[16]	202	80	495	915	4.67 (3.52, 6.18)		
Anantharaman et al (2007)[37]	301	157	428	301	1.35 (1.06, 1.72)		
Subapriya et al (2007)[17]	259	129	167	221	2.66 (1.99, 3.56)		
Znaor et al (2003)[38]	757	799	374	3260	8.26 (7.14, 9.56)		
Buch et al (2002)[18]	105	180	161	265	0.96 (0.70, 1.31)		
Balaram et al (2002)[19]	435	156	99	483	13.60 (10.25, 18.06)		
Dikshit et al (2000)[20]	220	175	108	152	1.77 (1.29, 2.43)		
Gupta et al (2017)[39]	163	24	119	121	6.91 (4.20, 11.36)		
Tobacco Product Type: SLT Disease: Stomach Cancer							
Gajalakshmi et al (2015)[32]	113	235	51027	378279	3.56 (2.85, 4.46)	1.84 (1.16, 2.91); $I^2=87.81$	0.16
Lakhanpal et al (2014)[35]	95	31	152	55	1.11 (0.67, 1.85)		
Malakar et al (2014)[40]	24	81	33	177	1.59 (0.88, 2.86)		
Phukan et al (2005)[41]	93	236	101	557	2.17 (1.58, 2.99)		
Shetty et al (2017)[42]	15	85	14	186	2.34 (1.08, 5.07)		
Rao et al (2002)[43]	61	109	714	1470	1.15 (0.83, 1.60)		
Tobacco Product Type: SLT Disease: Ischemic Heart Disease							
Gajalakshmi et al (2015)[32]	1423	5918	51027	378279	1.78 (1.68, 1.89)	-	0.08
Tobacco Product Type: SLT Disease: Ischemic Stroke							
Ram et al (2012)[30]	65	70	42	93	2.06 (1.25, 3.38)	2.58 (1.32, 5.03); $I^2=87.52$	0.24
Agashe and Gawde (2013)[25]	50	30	40	40	1.67 (0.89, 3.13)		
Gajalakshmi et al (2015)[32]	475	815	51027	378279	4.32 (3.86, 4.84)		

Abbreviations: OR, odds ratio; LCI, 95% lower class interval; UCIL, 95% upper class interval; I^2, statistic representing heterogeneity of studies included; PAF, population attributable fraction.

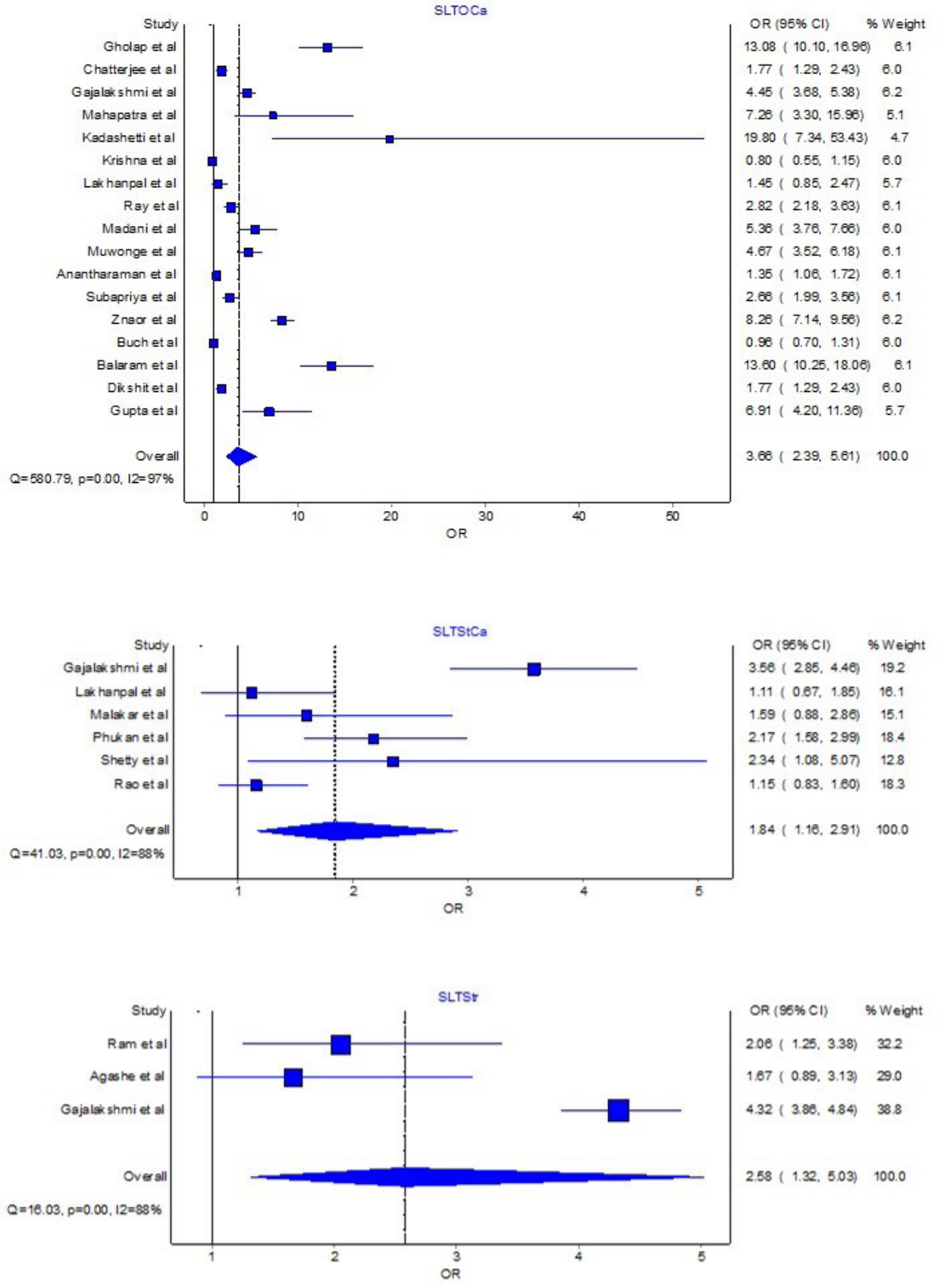

Figure 1. Forest plot of pooled odds ratio for smokeless tobacco consumption (From top to bottom: oral cancer attributable to smokeless tobacco, stomach cancer attributable to smokeless tobacco, ischemic stroke attributable to smokeless tobacco)

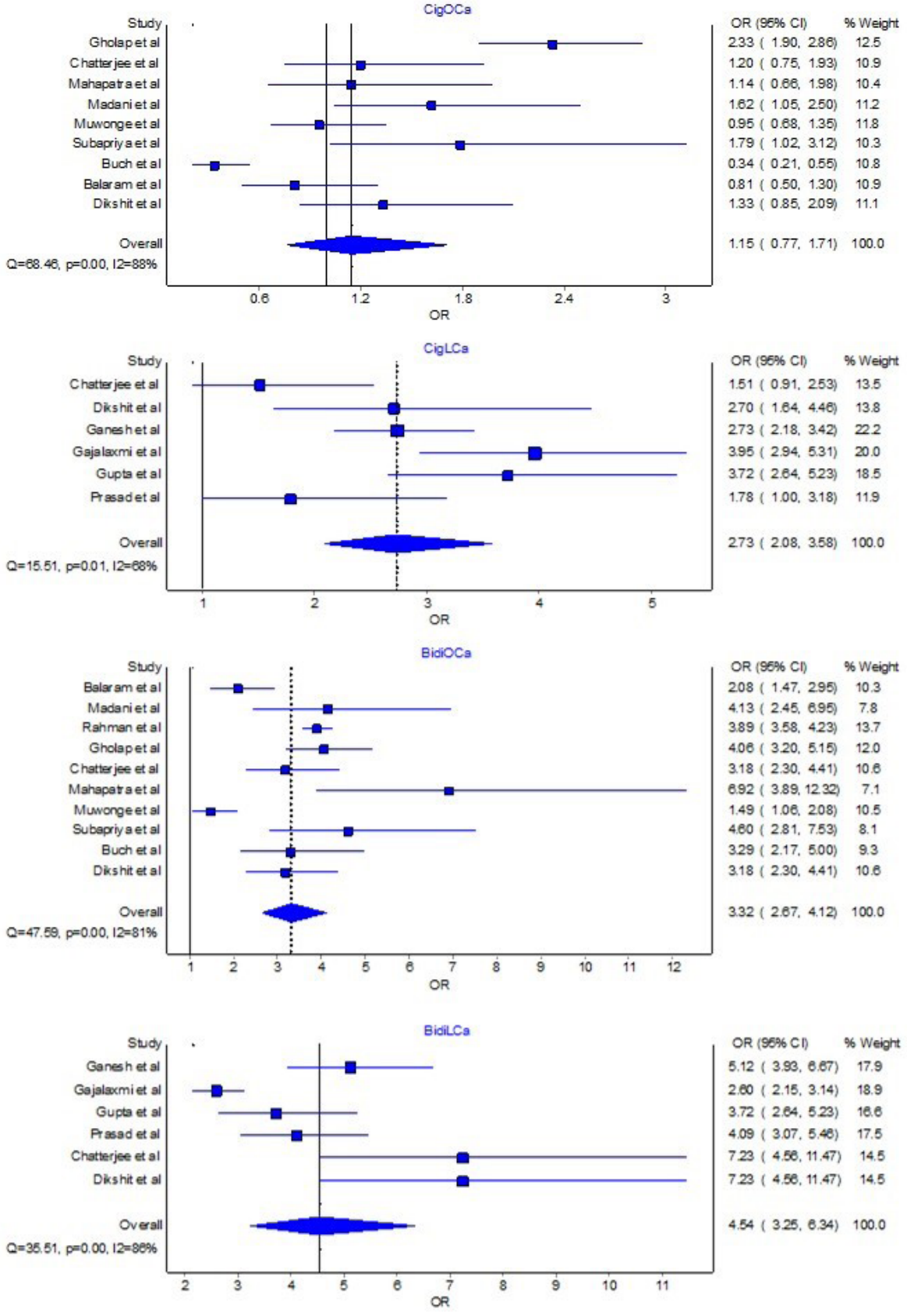

Figure 2. Forest plot of pooled odds ratio for smoked tobacco products (From top to bottom: oral cancer attributable to cigarettes, lung cancer attributable to cigarettes, oral cancer attributable to bidis and lung cancer attributable to bidis)

of lung cancer, and 7 701 914 DALYs of IHD) in 2019. Similarly, cigarettes were responsible for over 8.26 million premature life years lost and 341 thousand annual deaths in India in 2019, due to oral and lung cancer and IHD (Table 3).

For bidi consumption, the estimated values were even greater, with 11.7 million national DALYs, 10.7 million YLLs, and 478 thousand deaths due to oral and lung cancer, IHD, and COPD in 2019 (Table 3).

For SLT consumption, the disease burden was estimated to be over 4.38 million annual national DALYs, 4.3 million YLLs, and over 171 thousand deaths due to oral and stomach cancer and IHD in 2019 (Table 3).

Discussion

The present study followed an approach to determine the direct health burden that is attributable to various forms of tobacco product consumption in the general population through the calculation of PAF. Similar approaches have been suggested as valid methodologies by numerous researchers, such as Mansournia and Altman, describing PAF as a valid epidemiologic measure to assess the impact of exposures in populations; Lin and Chen stating it to be an effective measure of disease burden attributable to specific risk factors; and description of PAF by the WHO.[44-47] PAF has also been adopted in a number of studies including the computation of smoking attributable mortality in the United States by CDC,[48] Deubner and colleagues' study for death and hypertension amongst 40- to 69-year-old population of Evans County, Georgia; the study by Rahman et al for risk of oral cancer due to bidi smoking in three South Asian countries namely, India, Pakistan, and Sri-Lanka; Grundy and colleagues' study for evaluation of cancers attributable to lifestyle and environment in Alberta; and the study by Khosravi and Mansournia for pulmonary tuberculosis in China.[26,49-51]

Table 3. Disease burden directly attributable to cigarette, bidi, and SLT consumption in India (2019)

	Death	DALY	YLL
Cigarettes			
Oral cancer	1911.15	56 038.37	54 975.92
Lung cancer	24 863.27	633 890.57	628 216.06
Ischemic heart disease	314 234.55	7 701 913.81	7 579 730.84
Ischemic stroke*	26 288.71	551 405.10	463 497.06
Total	341 008.97	8 391 842.75	8 262 922.83
Bidi			
Oral cancer	21 169.83	620 738.25	608 969.49
Lung cancer	34 539.30	880 581.26	872 698.41
Ischemic heart disease	254 183.93	6 230 068.45	6 131 234.80
Ischemic stroke*	34 535.85	724 388.83	608 902.77
COPD	167 843.41	3 966 196.80	3 062 973.06
Total	477 736.47	11 697 584.77	10 675 875.77
SLT			
Oral cancer	29 305.30	859 285.26	842 993.82
Stomach cancer	12 707.49	358 524.89	355 371.70
Ischemic heart disease	129 037.95	3 162 730.47	3 112 556.99
Ischemic stroke*	65 118.95	1 365 868.75	1 148 114.42
Total	171 050.74	4 380 540.62	4 310 922.51

Abbreviations: DALY, disability-adjusted life years; YLL, years of life lost; COPD, chronic obstructive pulmonary disease; SLT, smokeless tobacco
*Death, DALY, and YLL values of "Ischemic stroke" have not been added in the "Total" as values of "ischemic heart disease" are inclusive of values of ischemic stroke as obtained from the Global Burden of Disease database.

The PAF of tobacco-attributable cancers in the present study was estimated in the range of 0.45 (SLT use – oral cancer) to 0.03 (cigarette smoking – oral cancer). Such values indicate a high predilection of oral cancer amongst tobacco users. Similar findings were also inferred from the review of Global Cancer Observatory data by Asthana et al in which the upper and lower respiratory tract, mouth, and esophagus were described to be the leading sites for cancers. The study stated a high cancer incidence, in tobacco users, ranging from 1-in-27 to 1-in-143 for men and 1-in-63 to 1-in-333 for women.[52]

In this study, tobacco was estimated to be responsible for a staggering 1 million deaths and 24 million DALYs in India in 2019, from major diseases such as oral and lung cancer, IHD, and COPD. These figures, however, coincide with the global estimates generated by He et al using the Global Burden of Disease data revealing 8.71 annual deaths and 229.77 million DALYs globally in 2019, solely attributable to tobacco use.[53]

Furthermore, the current study estimated over 23 million premature life years lost due to tobacco use nationally. Similar estimations for Middle East and North African countries by Nagi et al in 2015 showed a loss of over 7 million premature life years while Østbye and Taylor showed 4.7 million premature life years lost in the US population.[54,55] This again reinforces the argument that a greater share of tobacco-related morbidity and mortality is contributed by low- and middle-income countries, and tobacco smoking reduces the life expectancy of an individual by an average of 10 years.[2]

This study also provided comparative evidence of health burden due to different tobacco products. Upon comparing burden due to three major diseases attributable to all three forms of tobacco, it is evident that bidi consumption is equally, if not more, responsible for a tremendous health burden in the form of deaths, DALYs, and YLLs. This in turn further raises the need for an urgent review of existing regulation of the bidi industry as a cottage industry, with minimal taxation and regulatory norms.

This study had the limitation of being conducted only considering certain study types for the purpose of pooling and only a limited number of diseases. Thus, it is to be highlighted that though the numbers described are already staggering, the actual figures may yet be

substantially greater if every disease documented to occur due to the consumption is considered.

Conclusion

This study provided empirical evidence regarding measurable health burden due to the consumption of cigarettes, bidis, and SLT in India. The study also provided a methodology that could be adopted to calculate the overall burden due to all documented diseases caused by tobacco consumption in India and individual states. This paves the way for further scaling up of the study to gain a holistic estimate of the health burden. Moreover, the evidence of burden due to individual product types could be utilized for policy recommendations and revision in existing taxation norms.

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Authors' Contribution

Conceptualization: Pankaj Bhardwaj, Yogesh Kumar Jain, Nitin Kumar Joshi.
Data Curation: Pankaj Bhardwaj, Nitin Kumar Joshi.
Formal Analysis: Yogesh Kumar Jain, Akhil Dhanesh Goel.
Investigation: Nitin Kumar Joshi, Manoj Kumar Gupta.
Methodology: Yogesh Kumar Jain, Nitin Kumar Joshi, Prem Prakash Sharma.
Resources: Pankaj Bhardwaj, Nitin Kumar Joshi.
Use Of Statistical Software: Yogesh Kumar Jain, Prem Prakash Sharma.
Supervision: Pankaj Bhardwaj.
Validation: Prem Prakash Sharma, Pankaj Bhardwaj.
Visualization: Yogesh Kumar Jain, Nitin Kumar Joshi.
Writing–Original Draft: Yogesh Kumar Jain, Pankaj Bhardwaj.
Writing–Review & Editing: Yogesh Kumar Jain, Nitin Kumar Joshi, Pankaj Bhardwaj.

Competing Interests

The authors declare no conflict of interest in this study.

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