Original Article

Breath Carbon Monoxide Concentration in Cigarette and *Bidi* Smokers in India

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ABSTRACT

Objective. To measure and compare the breath carbon monoxide (CO) levels in cigarette and *bidi* smokers in India.

Methods. Breath CO was measured in 389 smokers (241 cigarette smokers,148 *bidi* smokers) using portable breath CO analyser (Bedfont-England, Smokelyzer). Tobacco contents and length of single stick of different brands of cigarette and *bidi* were also measured.

Results. Their mean age was 38.7±13.4 years. The average duration of smoking was 18.2±13.0 years. Average breath CO levels were 15.6±7.0 ppm in smokers and 4.07±1.16 ppm in non-smokers. Average breath CO level was significantly higher in *bidi* smokers (18.9±7.7 ppm) compared to cigarette smokers (13.6±5.8 ppm) when total consumption of cigarette / *bidi* was more than five pack-years (p=0.002). Average tobacco weight of *bidi* (216.8mg) was significantly less than cigarette (696mg).

Conclusions. *Bidi* is equally or more harmful than cigarette smoking. One *bidi* may be considered to one cigarette for calculating "pack-years" of smoking. **[Indian J Chest Dis Allied Sci 2010;52:19-24]**

Key words: Carbon monoxide, *Bidi,* Cigarette, Pack-years.

INTRODUCTION

Smoking is prevalent all over the word. According to World Health Organization (WHO) estimates, there are around 1100 million smokers worldwide. This constitutes about one-third of global population aged over 15 years.[1] Deaths due to tobacco use accounts for around three million globally every year.[2]

Tobacco smoke contains more than 4000 chemicals and around 40 carcinogens, including nicotine, tar, carbon monoxide (CO), methoprene, propylene glycol, benzopyrene, butane, cadmium, acetone, ammonia, lead, benzene, formaldehyde, etc. When inhaled, CO from tobacco smoke is absorbed through lungs and enters into the blood stream and combines with haemoglobin to form carboxy-haemoglobin (COHb), which can be measured in the blood and is a useful marker of tobacco smoke absorption.[3] The CO remains in the blood for about 24 hours after inhalation of tobacco smoke depending on various factors, such as gender, physical activity and ventilation rate.[4] The CO in the blood then re-enters the alveoli because of concentration gradient at the alveoli. The CO present in expired air can be measured using a portable CO analyser. The breath CO concentration has been found to be a reliable indicator of COHb level in the blood.[5] Therefore, indirect measurement of COHb through breath analysis is preferred over direct measurement of blood COHb levels because of its non-invasive nature, easy procedure and better compliance.[6]

Smoking has been considered as a prime cause of CO exposure, though small amount of exposure can also occur due to vehicular smoke emission, occupational exposure among others.[4] However, a small amount of CO is also produced endogeneously as an end product of red blood corpuscles (RBCs) metabolism because of which raised levels are found in acute haemolysis and post-blood transfusion phase.[7] It has also been reported that breath CO levels can be raised due to various inflammatory lung diseases, like bronchiectasis, asthma, etc.[8]

Some studies [9,10] have been done to correlate the number of cigarettes smoked per day and levels of CO in breath. However, not much studies have been done for "*bidi* smoking", which is a very much prevalent form of smoking in India. Therefore, the present study was undertaken to measure breath CO concentration in *bidi* smokers and to compare it with the exhaled breath CO concentration in cigarette smokers.

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MATERIAL AND METHODS

We studied smokers who visited the "Tobacco Cessation Clinic" to quit smoking at our Institute from November 2001 to November 2004. A total of 389 cigarette and *bidi* smokers were included in the study. Forty non-smokers were also included as control subjects.

Smokers were categorised into cigarette and *bidi* smokers. The groups were then further segregated into two sub-groups depending on the consumption of cigarette / *bidi* in a pack-year as, Group 1 (0 to 5 pack-years) and Group 2 (more than 5 pack-years). One pack-year was calculated as 20 *bidis*/cigarettes smoked per day for one year.

Breath CO was measured using portable breath CO analyser (Bedfont-England, Smokerlyzer) using a standard procedure that was followed throughout the study. The subjects were asked to inhale deeply, hold the breath for 15 seconds and then exhale fully into the mouthpiece of the instrument. If the subjects were unable to hold breath for that long, they were asked to hold breath for as long as possible. Single measurement was taken in each case; repeat measurement were done only when the subject failed to do it properly.

Inclusion criteria adopted in the present study were as follows: smokers who have not changed their smoking habits (abrupt increase or decrease in the number of cigarettes / *bidis* smoked per day) in the immediate past one month; smokers who were smoking either cigarette or *bidi*; and smokers who inhale the smoke into their lungs, as absorption of CO through mouth and pharynx does not occur.[9] Persons smoking both cigarette and *bidi* were excluded from the study.

We also recorded the tobacco weight and length of a single stick for different brands of cigarettes and *bidis* available in the market for an account of the average tobacco content.

Statistical Analysis

The statistical analysis was performed on (Statistical Package for Social Sciences [SPSS]) statistical software. The groups were compared for all the variables using the Student's t-test to compare eqyality for means, Levene's test for equality of variance and the χ^2 (Chi-square) test to compare category value. The differences were considered to be statistically significant at the $p < 0.05$ (two-tailed test) level. Results are presented as percentage and mean ± SD.

RESULTS

Three hundred and eighty-nine smokers (241 cigarette smokers and 148 *bidi* smokers) with an average age of 38±13.4 years were studied. Only two percent of the subjects were females. The demographic details of cigarette and *bidi* smokers are summarised in table 1. Most of the smokers belong to Hindu community. Seventy-three percent of the smokers were married and most of them were residing in urban areas. Thirty-five percent smokers had family history of smoking, while 13.6% smokers were alcoholics. Most of the smokers belong to service class (30.1%) followed by businessmen (24.7%), students (21.3%) and others (23.9%).

Table 1. Demographic profile of cigarette and *bidi* smokers (n=389)

Demographic Profile		Cigarette Smokers % (n=241)	*Bidi* Smokers % (n=148)
Gender (%)	Male	61.4	36.5
Religion (%)	Hindu	56.6	34.7
	Muslim	3.9	2.6
	Others	1.5	0.8
Education (%)	Illiterate	1.5	5.4
	Class 1 to 4	0.5	1.5
	Class 5 to 8	3.1	7.5
	Class 9 to 12	13.6	18.8
	Class >12	43.2	4.9
Marital status (%)	Married	36.8	36.2
	Unmarried	25.2	1.8
Area of residence (%)	Rural	3.1	9.8
	Urban	58.9	28.3
Occupation (%)	Business	17.0	7.7
	Service	14.7	15.4
	Student	20.8	0.5
	Others	9.5	14.4
Alcohol consumption (%)	Yes	9.0	4.6
	No	53.0	33.4
Previous quit attempt (%)	NA	15.2	1.6
	MUA	9.8	8.5
	1-3 SA	34.2	15.4
	>3 SA	2.8	2.6
Family history (%)	Present	20.1	13.9
	Absent	41.9	24.2
Co-morbidity (%)	Present	15.4	16.2
	Absent	46.5	21.9
Breath CO (Zone) (%)	Light	23.9	7.2
	Heavy	28.8	17.7
	Dangerous	9.3	13.1
No. of cigarette / *bidi* per day (%)	1-10	24.4	5.7
	>10	37.5	32.4
Total Fagarstrom score (%)	1-6	40.1	13.6
	>6	21.9	24.4
Total		**62**	**38**

Breath CO levels=7-10 ppm (light zone); 11-20 ppm (heavy zone); >20 ppm (dangerous zone)
NA=No attempt, MUA=Multiple unsuccessful attempts, SA=Successful attempts (quit for at least one month); CO=Carbon monoxide

Approximately two-thirds (69.9%) of smokers consumed more than 10 cigarette / *bidis* per day; sixty-eight percent of smokers were without co-morbid conditions. Average duration of smoking was 18.2±13.0 years [14.4±11.6 years in cigarette smokers and 24.3±12.9 years in *bidi* smokers; ($p<0.001$)]. Average

Table 2. Descriptive statistics of cigarette and *bidi* smokers (n=389)

Profile	Total	Cigarette Smokers (n=241)	*Bidi* Smokers (n=148)	p value*	p value†
Age (Years)	38.7±13.4 (16-70)	35.1±13.2 (17-68)	44.5±11.8 (16-70)	<0.001	0.041
No. of cigarette / *bidi*	17.8±12.8 (1-125)	14.5±8.5 (1-50)	23.3±16.4 (2-125)	<0.001	<0.001
Duration of smoking (years)	18.2±13.0 (1-57)	14.4±11.6 (1-48)	24.3±12.9 (1-57)	<0.001	0.183
Breath CO (ppm)	15.6±7.1 (7-35)	13.6±5.8 (7-35)	18.9±7.7 (7-35)	<0.001	<0.001
Fagarstrom score	6.1±2.6 (1-11)	5.4±2.6 (1-11)	7.1±2.3 (2-11)	<0.001	0.030
Age at start (years)	20.5±6.3 (8-55)	20.7±5.7 (8-55)	20.2±7.1 (8-50)	0.407	0.002
Pack-years	17.7±20.1 (0.10-175)	11.4±13.1 (0.15-84)	28.1±24.8 (0.10-175)	<0.001	<0.001

Figures in parantheses indicate range; Data is expressed as mean±SD; CO=Carbon monoxide
*=Using Student's t-test for equality of means; †=Levene's test for equality of variance;

Table 3. Comparison of breath CO levels in cigarette and *bidi* smokers

Pack-years	Type of Smoking	Total No. of Subjects	Average CO±SD (ppm)	No. of Subjects in Light Zone	No. of Subjects in Heavy Zone	No. of Subjects in Dangerous Zone	p Value
≤5	Cigarette	103	11.8±4.7	53	41	9	0.908
	Bidi	13	12.5±4.9	6	6	1	
>5	Cigarette	138	15.0±6.1	40	71	27	0.002
	Bidi	135	19.5±7.6	22	63	50	

CO=Carbon monoxide; SD=Standard deviation

breath CO was observed to be 15.6± 7.1 ppm in smokers, and 4.1±1 ppm in non-smokers. However, average CO concentration separately for cigarette and *bidi* smokers was found to be 13.6±5.8 ppm and 18.9±7.7 ppm, respectively (p<0.001). The details are summarised in table 2.

As had been followed by majority of the Centers,[10] we also took 6 ppm cut-off value for exhaled breath CO concentration. All non-smokers had breath CO levels of 6 ppm or less. All the smokers had breath CO levels of greater than 6 ppm. Breath CO levels 7-10 ppm, 11-20 ppm and >20 ppm are categorised as light zone, heavy zone, and dangerous zone of smoking, respectively (Table 3). Comparative study of breath CO levels (Group 1) of cigarette and *bidi* smokers (Table 3) in subjects who consumed 0 to 5 pack-year (Group 1) was not significant (p=0.908), i.e. there is no difference between breath CO levels of cigarette and *bidi* smokers if they consumed less than five pack-years. However, in Group 2 who consumed more than five pack-years of cigarette / *bidi*, the breath CO level was significantly high in *bidi* smokers (p=0.002) compared to cigarette smokers.

Tobacco weight and length of a single stick of different brands of cigarettes and *bidis* available in the Indian market were measured and presented in table 4.

Table 4. Measurement of tobacco weight and length of a single stick of different brands of cigarettes and *bidis* available in the market

Cigarette/ *Bidi* Brands	Total Length (mm)	Filter Length (mm)	Average Weight of Single Stick (mg)	Average Tobacco Weight in a Single Stick (mg)
Cigarette				
Brand A*	100	30	556.8	392.8
Brand B	84	20	964.0	751.7
Brand C	84	20	1024.3	807.6
Brand D	70	11	865.4	722.1
Brand E	74	10	879.9	781.4
Brand F	70	10	843.4	714.6
Bidi†				
Brand P	65		411.0	221.3
Brand Q	65		448.0	244.9
Brand R	65		491.4	282.8
Brand S	62		441.4	150.3
Brand T	62		435.7	184.7

*=Brand A was an extra slim brand because of which tobacco weight in it was lowest in spite of being the longest of all brands
†=*Bidi* is an alternative variety of tobacco stick made by rolling tobacco in *tendu* leaves (*Diospyrus melanoxylum* or *Diopyrus ebemum*). Except for few exported brands, all brands that are locally available are without filter

Tobacco weight of single stick varied from 392.8 mg to 807.6 mg for a cigarette and 150.3 mg to 282.8 mg for a *bidi*. The total content of tobacco was less in *bidi*. Mean tobacco weight in a single stick for brands B, C, D, E and F was 755.5 mg. Mean tobacco weight in a single stick of *bidi* for brands P, Q, R, S and T was 216.8 mg (Table 4).

DISCUSSION

Measurement of breath CO level is said to enhance the efficacy of doctor's advice to stop smoking. We measured breath CO concentration in cigarette and *bidi* smokers and attempted to observe if any significant difference existed in the levels of breath CO concentration between the two groups of smokers.

The 'pack year' is calculated on the basis of the quantity of cigarettes a person smokes (one pack each containing 20 cigarettes smoked per day for one year is one pack year). This has been made for the convenience of calculation and to have standardisation of all smokers for different duration and quantity. Net weight of tobacco in a *bidi* (150-250 mg) is considered to be about one-fourth of that in a cigarette. In literature[11-13] 'cigarette-equivalent' had been calculated by assigning a weight of 1 for a cigarette and 0.25 for a *bidi*, based on number of grams of tobacco content. Consumption of tobacco has, therefore, been calculated in terms of "pack years" based on tobacco weight. Logically, "pack-years" cannot be calculated on the basis of the weight of tobacco; otherwise, "pack-years" would vary according to brand of cigarettes as different brands have different weights. Thus, there appears to be no scientific basis for equating cigarette and *bidi* on the basis of tobacco weight.

Bidis are independent entities. Even if the tobacco content is less than that in cigarettes, their harmful effects may be more as: *(i)* nicotine content is more in *bidi*; *(ii)* nature of inhalation is different in *bidi* smoking; and *(iii)* puff content is more in *bidi* smoking. Nicotine content in a *bidi* (21.2 mg / g) is significantly higher than that of a cigarette (13.3-16.5 mg / g).[12,14] They have to inhale more deeply leading to increased level of exposure to CO and other harmful constituents.[12,14] A study [15] indicates higher level of tar, CO in *bidi* than in cigarette. The CO level and other constitutents have been found to be higher in *bidi* smoke than cigarette smoke.[16]

Lung cancer has also been reported to be higher in *bidi* smokers than the cigarette smokers.[17] There is strong evidence that *bidi* smoking is more hazardous than cigarette smoking in the development of lung or oesophageal cancers.[18] Thus, there is no justification to compare cigarette and *bidi* on the basis of weight to calculate "pack-year".

Further, in our study the aim was to compare the breath CO level of *bidi* smokers with that of cigarette smokers. Hence, we have to equate "pack years" of *bidis* with "pack-years" of cigarettes to facilitate comparison.

In a study Malson *et at*[12] have compared the nicotine content of 12 unfiltered brand of *bidi* cigarettes (hand rolled cigarettes imported from India) with eight popular brands of filtered and unfiltered cigarettes from the United States of America (USA) and conventional cigarettes from India. The concentration of the tobacco of *bidi* cigarettes (21.2 mg / g) was significantly greater than the commercial filtered (16.3 mg / g) and unfiltered cigarettes (13.5 mg / g). They[12] concluded that *bidi* cigarettes contain higher concentration of nicotine than conventional cigarettes. Therefore, it is logical to presume that *bidi* smokers have a high risk of becoming nicotine dependent. Although we did not measure the nicotine content, the tobacco content in *bidi* (216.8 mg) was less than in the cigarette (695 mg).

Benowitz and Henningfield[19] have theorised that a minimum threshold level of nicotine delivery is necessary to initiate and sustain dependence. The cigarette smokers can titrate the amount of nicotine they obtain from a cigarette by changing their smoking behaviour.[16] But *bidi* smokers may not titrate the amount of nicotine delivery from *bidis*, just as they adjust the nicotine delivery from commercial cigarettes. *Bidi* cigarettes are smoked differently than commercial cigarettes. *Bidis* must be re-lit several times because they self-extinguish.[20] To continue lighted they have to be puffed at least two times a minute. There is less air dilution through the *tendu* leaf than conventional cigarette.[21]

In our study, those who smoked cigarette / *bidi* more than five pack-years showed a higher breath CO level which is significantly higher in *bidi* smokers compared to cigarette smokers. This was despite the fact that average tobacco weight in a *bidi* is almost one-third of average tobacco content of a cigarette. This probably may be due to the fact that *bidi* has no filter and hence, all the noxious contents of tobacco smoke enter the lung unhindered. One more factor responsible for the above result could be, because of low combustibility of *bidi* and its self extinguishing nature, more puffs per minute are required and the smoker has to inhale more frequently and more deeply to increased level of exposure to CO and other harmful constituents of tobacco smoke. The low combustibility forces a smoker to inhale deeply resulting in greater delivery of CO, nicotine and other components of tobacco smoke. Hence, these factors may exaggerate the health risks associated with nicotine and other components of *bidi* smoke. The dependence potential of *bidis* is evident in India where *bidi* smoking accounts for 40% of tobacco consumption.[1]

A survey[16] of the nicotine, tar, and CO levels in mainstream smoke from 21 brands of *bidi* cigarettes and

five brands of traditional cigarettes was conducted using a variation of the Federal Trade Commission (FTC) standardised cigarette smoking machine method. The shorter puff interval was required to prevent the *bidi* cigarettes from self-extingushing and may represent a closer approximation to human usage. The goal of this study[16] was to evaluate the smoke-delivery potential for tar, nicotine and CO in mainstream smoke from *bidi* cigarettes compared with traditional domestic cigarettes smoked under identical conditions. Unlike traditional cigarettes, the filtered and unfiltered *bidi* brands yielded comparable smoke deliveries. The findings indicate that *bidi* cigarettes can deliver high levels of tar (77.9±9.5 mg / *bidi*), nicotine (2.7±0.4 mg / *bidi*) and CO (39.2±5.7 mg / *bidi*).[16]

The results of our study correlates well with few other studies[14, 16, 17, 22] on *bidi* which showed the levels of CO and several other constituents to be higher in *bidi* smoke compared to unfiltered cigarette smoke. Nicotine content in tobacco used in *bidis* is also said to be higher compared to cigarettes.[14] It has also been reported that risk of lung cancer is higher in *bidi* smokers compared to cigarette smokers.[17, 22]

American Spirit (32.1 µg / mL) and Irie *bidi* (26.0 mg / mL) cigarettes increased plasma nicotine more than the participant's own brand (18.5 µg / mL). Subjects smoked longer and took more puffs to consume the American Spirit (452.8 s, 14 puffs) and Sher *bidi* (354.4 s, 14 puffs) than the participant's own brand (297.4 s, 10 puffs). In spite of differences in nicotine delivery, participants rated all cigarettes as similar in nicotine content. Overall, the results indicate that *bidis* and the additive-free cigarettes delivered nicotine, CO and (presumably) other toxic components of tobacco smoke in equal or grater amounts than conventional cigarettes.

These data provide strong evidence that *bidi* smoking is even more hazardous than cigarette smoking in the development of lung and oropharyngeal cancer. An interventional study to prevent the use of tobacco will be useful in this population as it also underwent gas exposure due to a chemical accident in 1984.[23]

The above data and findings from the present study suggest that *bidi* is more harmful or at least equally harmful as cigarette. Further, this hypothesis is concluded by calculating pack-year for *bidi*, equating one *bidi* with one cigarette. It is observed that there is a definite need to educate smokers that *bidis* are not the safe alternatives to cigarettes, and switching from cigarette to *bidi* will not reduce the harm of smoking. Moreover, the safest way is to quit all forms of smoking.

CONCLUSIONS

The general perception among the people, especially smokers, is that *bidi* is less harmful compared to cigarette because the tobacco content in a *bidi* is less compared to a cigarette. However, results of the present study prove that inspite of having lower tobacco content compared to cigarette, *bidi* is more harmful. Our conclusion is based on a single parameter of CO level in breath, therefore, it has its limitations in comparing the hazards of cigarette and *bidi*, but our study provides a platform for further research involving multiple parameters for comparing the hazards of cigarette and *bidi*. As of now we can, to a certain extent, negate the popular assumption that *bidi* is less harmful and a safe alternative to cigarette and one *bidi* is equal to one cigarette for calculating pack-year smoking.

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