

## Brief Report

# Nicotine delivery from smoking bidis and an additive-free cigarette

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The present study was conducted to determine whether smoking bidis, an additive-free cigarette, and conventional cigarettes caused similar biochemical, physiological and subjective effects. This was an open-label, within-subject design. In each session, subjects ( $n = 10$ ) smoked a single cigarette: an unfiltered Natural American Spirit, an unfiltered Irie bidi, an unfiltered Sher bidi, or one of the participant's own brand. The presentation of the cigarettes was randomized. Before and up to 1 h after smoking, biochemical markers [plasma nicotine levels and exhaled carbon monoxide (CO)] and physiological effects of nicotine (heart rate and blood pressure) were measured. After smoking, subjects completed two standardized tests of cigarette liking and cigarette sensations. American Spirit (32.1 ng/ml) and Irie bidi (26.0 ng/ml) cigarettes increased plasma nicotine more than the participant's own brand (18.5 ng/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 cigarette delivered nicotine, CO and (presumably) other toxic components of tobacco smoke in equal or greater amounts than conventional cigarettes. These results do not support an emerging belief that bidi cigarettes are safer than conventional brands.

## Introduction

Despite ongoing public health efforts to reduce smoking among adolescents, approximately 4.5 million US teenagers continue to smoke (American Lung Association, 1999). While the cigarettes most often used by young people are the most heavily advertised brands (i.e. Marlboro, Camel and Newport), cigarettes sold by small manufacturers or importers have become increasingly popular. These niche brands are often distributed in health food stores, ethnic groceries and 'head' shops (Fisher, 2000; Kexwer, 1998). Recently, there has been an increase in the use of alternative cigarettes (such as bidis, cloves and additive-free cigarettes) by adolescents (CDC, 1999; Fisher, 2000).

Bidis are hand-rolled cigarettes from India that have been imported into the US for years. However, in the early 1990s, bidi use among adolescents increased (CDC, 1999). In the Boston area, for example, 40% of teenagers had smoked bidis at least once in their lifetime and 16% were current bidi smokers (CDC, 1999); about 13% of the sample thought bidis were safer than conventional cigarettes. In a national survey, 5% of high school students and 2.4% of middle school students reported bidi smoking in the past month (CDC, 2000). Bidis appeal to adolescent smokers because they are available in a wide variety of flavors (fruit, chocolate, root beer, etc.), taste better, are less expensive and easier to buy than conventional cigarettes (CDC, 1999).

Bidis contain much less tobacco (215.3 mg) than conventional cigarettes (738.6 mg); however, nicotine concentrations in the tobacco of bidis were greater (21.2 mg/g), than unfiltered (12.0 mg/g) and filtered conventional cigarettes (16.3 mg/g) (Malson, Sims, Murty, & Pickworth, 2001). Although there are recognized differences in the physical characteristics of bidis and the way they are smoked, the delivery of nicotine

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and other components of tobacco smoke from bidis is unknown. Thus, a major objective of the present study was to determine participants' plasma nicotine levels after smoking bidis.

Recently, additive-free cigarettes, made with whole leaf natural tobacco containing no chemical additives, preservatives, or reconstituted tobacco have been marketed. A majority of adolescents and approximately 25% of adults surveyed believed that such advertisements implied that additive-free cigarettes are healthier and/or less addictive than conventional cigarettes (Arnett, 1999). The Federal Trade Commission (FTC, 1998) ruled that such advertisements are deceptive. There is no evidence that additive-free cigarettes are safer than conventional cigarettes. Natural American Spirit Non-Filter, a popular additive-free cigarette, has a higher nicotine content per rod and higher concentrations of nicotine (17.7 mg; 16.6 mg/g, respectively) than unfiltered conventional cigarettes (11.8 mg; 12.0 mg/g respectively) (Malson *et al.*, 2001). American Spirit cigarettes deliver substantial amounts of nicotine (2.90 mg) and tar (29.0 mg) as determined by FTC methods (Pillsbury, 1996; Federal Registry, 1967). Because there have been no reports of effects from smoking additive-free cigarettes, another objective of this study was to determine their biochemical, physiological and subjective effects.

## Methods

### Subjects

Ten research volunteers participated in the study, including nine men and one woman. Participants were recruited from the local community by advertisements in newspapers, radio and coffee shops, and in tobacco shops where bidis were sold. The average age of the participants was 24.5 years (range = 20–37 years) and their average weight was 91.8 kg (range = 56.8–120.5 kg). All subjects were healthy cigarette smokers with a history of bidi use. Participants had smoked, on average, for 8.7 years (range = 3–20 years) and smoked an average of 25 cigarettes a day (range = 20–40). Dependence was determined by the Fagerström Test for Nicotine Dependence, where the average was 6.0 (range = 5–9) (Heatherton, Kozlowski, Frecker & Fagerström, 1991). All subjects regularly smoked filtered, conventional cigarettes with an average FTC yield of 0.9 mg nicotine (range = 0.7–1.1 mg) and 12.8 mg of tar (range = 10–18 mg) (Federal Registry, 1967; Pillsbury, 1996).

Prior to participation in the study, subjects signed an informed consent document approved by the NIDA Institutional Review Board. The consent form met guidelines established by the US Department of Health and Human Services. Volunteers were paid for their participation in the study.

### Design

This was an open-label, within-subject study with four cigarette conditions: an unfiltered American Spirit, a flavored bidi (Irie bidi – Strawberry), a non-flavored bidi (Sher bidi), and the participant's own brand. The alternative cigarettes were unfiltered; the subject's own brand was filtered. All cigarettes were obtained from a local tobacco outlet. Subjects smoked a single cigarette in each session; presentation of the conditions was randomized.

### Dependent measures

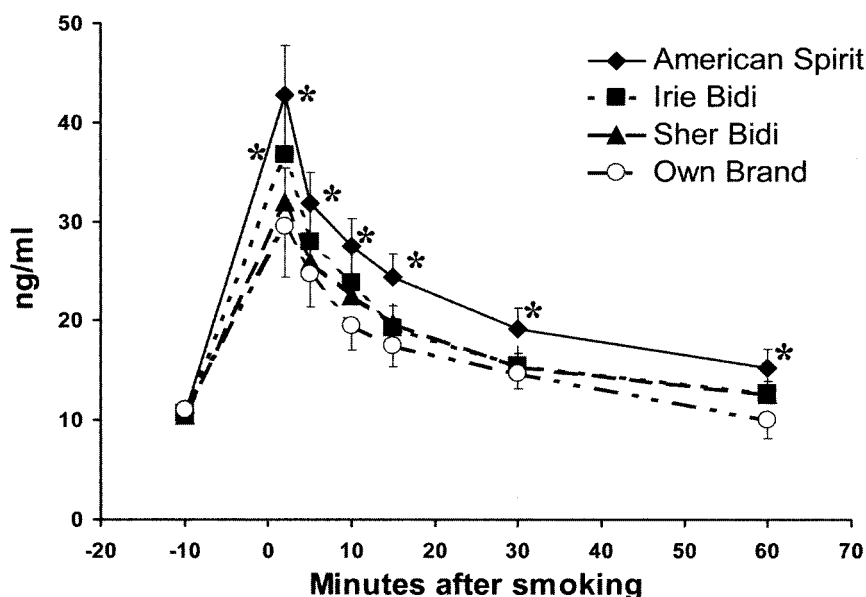
**Biochemical markers.** Plasma nicotine and exhaled carbon monoxide (CO) were measured as biochemical markers of smoke exposure. Plasma nicotine was measured using a high-performance liquid-chromatography method (Hariharan, Van Noord & Greden, 1988). The lower limit of quantification was 1 ng/ml. Blood samples were collected before smoking and 2, 5, 10, 15, 30 and 60 min after smoking. Blood samples were kept on ice until centrifugation and separation of plasma. Plasma was frozen (–20°C) until the time of analysis. Exhaled CO was measured in parts per million (ppm) with a CO sensor (Vitalograph, Lenexa, KS). Exhaled CO was measured before smoking, and 15, 30 and 60 min after smoking.

**Substance delivery factors.** The time to smoke and the number of puffs were recorded as the subject smoked *ad lib*.

**Physiological markers.** Systolic and diastolic blood pressure and resting heart rate were measured using an automated cardiovascular monitor (Datascope, Paramus, NJ).

**Subjective measures.** Twenty minutes after smoking, subjects completed two tests of cigarette liking and cigarette sensation, the Duke Sensory Questionnaire (Behm & Rose, 1994) and the Duke Cigarette Evaluation Scale (Rose, Behm, Westman & Johnson, 2000; Westman, Levin & Rose, 1992). Both questionnaires are based on an anchored, seven-point Likert scale, with 1 = 'not at all' and 7 = 'extremely'. The Duke Sensory Questionnaire (DSQ) has nine items, including puff liking; puff satisfaction; nicotine in puffs; similarity to own brand; and puff strength on the tongue, nose, mouth and throat, windpipe, and chest. For statistical analyses, ratings for puff strength on tongue, nose, mouth and throat, windpipe, and chest were collapsed to determine an overall measure of strength (maximum score = 35; range 7–35).

The Cigarette Evaluation Scale (CES) is an 11-item questionnaire that evaluates the cigarette smoking experience in terms of satisfaction, good taste and effects of smoking on: dizziness, ability to calm, concentration, wakefulness, reduction of hunger, nausea, irritability, enjoyment of sensations of smoke in one's throat and chest, and reduction of craving. The enjoyment of



**Figure 1.** Mean ( $n = 10$ ) venous plasma nicotine levels before ( $-10$  min) and after smoking a single cigarette. \*Indicates significant difference from own brand at that time point. Own brand was the subjects preferred and usually smoked cigarette.

sensation (sensations in throat and chest) and craving reduction items were analyzed separately. Composites of several items were created to measure satisfaction (satisfaction, good taste), psychological reward (calm, concentration, wakefulness, reduction of hunger, irritability), and aversion (dizziness, nausea), using techniques described by Brauer, Behm, Westman, Patel, and Rose (1999).

#### Procedure

This study was conducted at the National Institute on Drug Abuse, Intramural Research Program, on an outpatient basis. The experimental sessions were at least 24 h apart, with each session lasting approximately 90 min. A 45-min abstinence period was imposed before the experimental cigarette was smoked.

At the beginning of each session, an indwelling catheter was inserted into a forearm vein. Baseline biochemical markers and physiological measures were collected. Subjects were then instructed to smoke *ad lib* to a line 40 mm (bidis) or 50 mm (own brand, American Spirit) from the tip of the cigarette rod. The number of puffs and the time to smoke for each cigarette were recorded. At 2, 5, 10, 15, 30 and 60 min after the cigarette was extinguished, measures were collected in the following order: blood draw, heart rate, blood pressure, exhaled CO (before smoking, and 15, 30, 60 min after smoking only). Subjective ratings were completed 20 min after the cigarette was extinguished.

#### Data analyses

Statistical analyses were conducted on the difference scores between baseline and post-smoking measure-

ments. Repeated-measures analysis of variance (ANOVA) was used to compare variables (Winer, Brown & Michels, 1991). The within-subject factors were cigarette condition (four levels) and time (six levels: 2, 5, 10, 15, 30, 60 min). The Greenhouse-Geisser epsilon was used in the ANOVA to adjust for degrees of freedom in within-subject analyses. Comparisons were made with Dunnett's post-hoc test if the ANOVA indicated a significant main effect of cigarette or time, or a cigarette-by-time interaction (Winer *et al.*, 1991). Data are presented as mean $\pm$ SD unless otherwise indicated.

## Results

### Biochemical markers

Maximal plasma nicotine concentrations occurred 2 min after smoking. As shown in Figure 1, venous plasma nicotine increased by 32.1, 26.0, 21.4 and 18.5 ng/ml after the participants smoked the American Spirit, Irie bidi, Sher bidi and their own brand, respectively. Plasma nicotine levels varied significantly as a function of cigarette ( $F[15,135] = 17.15$ ,  $p < 0.001$ ), time ( $F[15,135] = 12.40$ ,  $p < 0.001$ ) and the interaction of cigarette and time ( $F[15,135] = 16.24$ ,  $p < 0.001$ ). In post-hoc tests, plasma nicotine levels were significantly higher after the American Spirit cigarette than the subject's own brand ( $p < 0.05$ ) at all time points. At the 2-min time point, the Irie bidi was significantly higher ( $p < 0.05$ ).

Analysis of exhaled CO showed a significant interaction of time by cigarette ( $F[6,54] = 18.87$ ,  $p < 0.001$ ). Exhaled CO, measured 15 min after smoking, increased

**Table 1.** Subjective ratings of puffs (DSQ) and cigarette characteristics (CES)

Duke Sensory Questionnaire	American Spirit®	Irie Bidi	Sher Bidi	Own brand
Liking	3.1 ± 2.2 <sup>a</sup>	4.8 ± 0.9 <sup>a</sup>	3.9 ± 1.6	6.3 ± 0.7
Satisfaction	3.1 ± 2.2 <sup>a</sup>	4.8 ± 1.3 <sup>a</sup>	3.7 ± 1.7 <sup>a</sup>	6.3 ± 0.7
High in nicotine	5.2 ± 1.7	4.7 ± 1.8	4.2 ± 1.9	5.2 ± 1.1
Similar	2.1 ± 1.3 <sup>a</sup>	1.9 ± 1.1 <sup>a</sup>	1.6 ± 1.0 <sup>a</sup>	7.0 ± 0.0
Strength (maximum = 35) <sup>b</sup>	22.3 ± 9.3	21.4 ± 5.4	18.6 ± 5.9 <sup>a</sup>	24.6 ± 7.4
Cigarette Evaluation Scale				
Satisfaction (maximum = 14) <sup>b</sup>	6.1 ± 4.3 <sup>a</sup>	9.2 ± 2.4 <sup>a</sup>	8.4 ± 3.4 <sup>a</sup>	12.6 ± 1.2
Enjoyment of sensations in throat and chest	2.8 ± 1.8 <sup>a</sup>	4.7 ± 1.1	3.7 ± 1.8 <sup>a</sup>	5.7 ± 0.1
Aversion (maximum = 14) <sup>b</sup>	6.0 ± 2.5	6.1 ± 3.5	4.3 ± 2.1	3.5 ± 1.8
Psychological reward (maximum = 35) <sup>b</sup>	13.2 ± 6.5	17.5 ± 5.4	14.3 ± 7.3	19.3 ± 6.5
Craving relief	5.4 ± 2.0	4.7 ± 1.8 <sup>a</sup>	4.1 ± 2.0 <sup>a</sup>	6.0 ± 0.9

Values are mean ± SD on ratings of cigarette characteristics on the Duke Sensory Questionnaire (Behm & Rose, 1994) and the Cigarette Evaluation Scale (Westman *et al.*, 1992).

<sup>a</sup> Indicates significant difference from own brand ( $p < 0.05$ , Dunnett's test).

<sup>b</sup> Indicates collapsed values.

by  $3 \pm 2.7$ ,  $5 \pm 3.1$ ,  $3.4 \pm 1.3$  and  $4.6 \pm 1.8$  ppm for the American Spirit, Irie Bidi, Sher Bidi and own brand, respectively. After the American Spirit cigarettes, CO was significantly lower at 15 and 30 min compared to own brand, whereas CO following the Irie bidi was significantly higher than the subject's own brand at 60 min ( $p < 0.05$ ).

#### Substance delivery factors

Time to smoke differed significantly as a function of cigarette ( $F[3,27] = 14.19$ ,  $p < 0.001$ ). Time to smoke averaged  $452.8 \pm 74.7$  s for the American Spirit cigarettes and  $354.4 \pm 110.6$  s for the Sher bidis, which was significantly longer than  $297.4 \pm 72.0$  s, the subject's own brand ( $p < 0.05$ ). Time to smoke did not differ between the Irie bidi ( $322.1 \pm 107.9$  s) and the subject's own brand.

The average number of puffs per cigarette were  $14 \pm 4.5$ ,  $13.6 \pm 3.9$ ,  $14.1 \pm 4.25$  and  $10.4 \pm 3.9$  for the American Spirit®, Irie bidis, Sher bidis and own brand, respectively. There was a nearly significant effect of cigarette condition ( $F[3,27] = 2.80$ ,  $p = 0.059$ ). Post-hoc tests revealed significantly more puffs were taken to consume the American Spirit and Sher bidi than the own brand ( $p < 0.05$ ).

#### Physiological markers

Changes in heart rate were significantly related to time after smoking ( $F[15,135] = 3.31$ ,  $p < 0.05$ ) and there was a significant cigarette by time interaction ( $F[15,135] = 4.65$ ,  $p < 0.01$ ). Heart rate significantly increased 2 min after smoking the American Spirit ( $8.5 \pm 6.1$  bpm), the Irie bidi ( $6.7 \pm 7.7$  bpm), the Sher bidi ( $7.1 \pm 7.5$  bpm) and own brand ( $2.5 \pm 6.4$  bpm). All cigarettes increased diastolic and systolic blood pressure; however, blood pressure did not differ between the conditions.

#### Subjective measures

Responses on the Duke Sensory Questionnaire characterized the puff quality of the cigarette (Table 1). There were significant differences in liking ( $F[3,27] = 11.23$ ,  $p < 0.001$ ), satisfaction ( $F[3,27] = 10.68$ ,  $p < 0.001$ ), and similarity to own brand ( $F[3,27] = 84.84$ ,  $p < 0.001$ ). Subjects rated the American Spirit and Irie bidis lower than their own brand in liking and satisfaction. The alternative cigarettes were rated as significantly dissimilar from their own brand. In addition, subjects felt that the Sher bidi was significantly weaker and less satisfying than their own brand ( $p < 0.05$ ). Subjective evaluation of nicotine levels did not differ significantly between cigarette conditions.

Responses on the Cigarette Evaluation Scale characterized the cigarette smoking experience (Table 1). There were significant differences in satisfaction ( $F[3,27] = 9.11$ ,  $p < 0.001$ ), enjoyment of sensations in throat and chest ( $F[3,27] = 7.16$ ,  $p < 0.001$ ), and craving relief ( $F[3,27] = 3.88$ ,  $p < 0.05$ ). The subject's own brand was rated significantly more satisfying than the alternative cigarettes. In comparison to their own brand, subjects rated both brands of bidis significantly lower in reduction of cravings. The American Spirit and Sher bidi were rated lower than the subject's own brand in enjoyment of sensations in the throat and chest. There were no differences in the composite of aversive effects. Differences in the composite of psychological reward approached significance ( $F[3,27] = 2.86$ ,  $p = 0.056$ ). Post-hoc analyses revealed a trend that the American Spirit was rated less rewarding than the subject's own brand in the psychological composite.

#### Discussion

The effects of two popular types of alternative cigarettes, bidis and an additive-free cigarette (American Spirit), were studied. Previous studies have documented the use

of these cigarettes among US adolescents (CDC, 1999, 2000; Kexwer, 1998). Adolescent smokers regard bidis as less harmful than conventional cigarettes, and both adolescents and adults judged the advertisements of additive-free cigarettes as implying a relative health benefit from smoking such cigarettes (Arnett, 1999). In the present study, bidis delivered nicotine and CO (and presumably, other toxic components of tobacco smoke) in equal or larger amounts than the own brand. In this and other studies, bidi smoking produced concentrations of exhaled CO equal to or greater than conventional cigarette smoking (CDC, 1999; Fisher, 2000; Hoffmann, Sanghvi & Wynder, 1974). The additive-free cigarette delivered more nicotine than own brand. These findings do not support the conclusion that bidis or the additive-free cigarettes are a safer or less addictive form of tobacco consumption.

The additive-free cigarette increased plasma nicotine concentrations above the levels of the participant's own brand. The American Spirit® has a higher FTC average (2.9 mg per cigarette rod) of nicotine delivery (Federal Registry, 1967; Pillsbury, 1996) compared with the subject's own brand (0.9 mg). However, the FTC has not published yields for bidi cigarettes. Although Sher bidis and Irie bidis were smaller (370 and 450 mg, respectively) and contained less tobacco (170 and 220 mg, respectively) than conventional cigarettes (940 and 740 mg, respectively) (Malson *et al.*, 2001), the bidis raised plasma levels of nicotine to values equal or larger than the subject's own brand. The non-porous tendu leaf wrapping, the smaller cigarette diameter, and packing density are all factors that may be associated with increased exposure to nicotine (Fisher, 2000). The non-porous wrapping of the bidi limits air dilution, whereas conventional cigarettes use techniques to aid in air dilution (i.e. vent holes in filter, porous paper). If bidis were smoked daily, they could deliver enough nicotine to initiate and sustain tobacco dependence, as estimated by Benowitz and Henningfield (1994).

Evidence increasingly indicates that teenagers might be more sensitive to the effects of smoking than are adults. DiFranza *et al.* (2000) reported that nicotine withdrawal symptoms in a subgroup of adolescent smokers can be identified before they become daily smokers, which suggests that even smaller doses of nicotine that are spread out over a longer period of time can create and sustain nicotine dependence. Similarly, Kandel and Chen (2000) reported that adolescents develop symptoms of tobacco dependence at lower daily smoking rates than adults. In laboratory studies, cigarette smoking increased heart rate in teenagers more than in adults (Corrigall, Zack, Eissenberg, Belsito & Scher, 2001; Zack, Belsito, Scher, Eissenberg & Corrigall, 2001). This heightened sensitivity puts adolescents who smoke any cigarette at risk for becoming tobacco dependent.

Toxicological and epidemiological reports indicate that the smoke of additive-free cigarettes and bidis contain considerable quantities of carcinogenic com-

pounds (Behera, Dash & Dinakar, 1991; Federal Trade Commission, 1998; Nair, Pakhale & Bhide, 1989; Yadav & Thakur, 2000). For example, compared to that of an unfiltered conventional cigarette, bidi smoke contained more CO, ammonia, hydrogen cyanide, phenol, volatile phenols, benz(a)anthracene and benzo(a)pyrene (Madsen, Bush & Gay, 1985; Rahman & Fukui, 2000; Severson, McDuffie, Arrendale, Gwynn & Chaplin, 1981). Furthermore, the delivery of nicotine in sufficient quantities to initiate and sustain dependence perpetuates the delivery of toxic components of smoke to the user. The present study confirms and extends the results that bidis deliver high concentrations of nicotine and CO.

Although bidis and American Spirit delivered equal or more nicotine than subjects' own brand, subjects could not distinguish differences in nicotine delivery between the cigarettes, nor did they reduce craving more than the own brand. This dissociation between nicotine boost and cigarette craving has been reported in studies using denicotinized cigarettes (Butschky, Bailey, Henningfield & Pickworth, 1995; Pickworth, Fant, Nelson, Rohrer, Henningfield, 1999; Rose *et al.*, 2000), supporting the notion that subjective effects of smoking are only partially explained by the delivery of nicotine.

Data from this study were collected in a single exposure to alternative cigarettes in a laboratory environment. The sample size was small, predominately male, and restricted to those over 18 years of age, and included only occasional bidi smokers. These characteristics may have influenced smoking patterns and subjective estimates and may limit the generalizability of the results. Nevertheless, the results indicate that, contrary to the belief of many consumers, bidi and additive-free cigarettes deliver substantial amounts of nicotine and other toxic components of tobacco smoke.

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