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Differences in nicotine dependence, smoke exposure and consumer characteristics between smokers of machine-injected roll-your-own cigarettes and factory-made cigarettes

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ABSTRACT

Background: Consumption of machine-injected roll-your-own (RYO) filtered cigarettes made from pipe tobacco increased almost 7-fold from 2008 to 2011 in the United States.
Methods: We used data from the Pennsylvania Adult Smoking Study to compare the differences in socio-demographic, smoking topography, nicotine dependence, and cotinine levels between 280 smokers using factory made (FM) cigarettes and 68 smokers using RYO cigarettes.
Results: RYO smokers were older (41 vs. 37, P = 0.053), had significantly lower levels of income (P < 0.001) and education (P = 0.007), and were less likely to be fully employed (P = 0.009). RYO smokers consumed more cigarettes per day [CPD] (21 vs. 15, P < 0.001), and had a higher mean score on the Fagerström Test for Cigarette/Nicotine Dependence (5.2 vs. 4.1, P < 0.001). The main reasons for choosing RYO cigarettes were the lower cost (68%) and believed they are less harmful (12%). The average cost per pack of FM cigarettes was $5.74 vs. $1.13 for RYO. In multiple regression analyses, RYO smokers had significantly lower cotinine levels across all levels of CPD. Among smokers of king-size cigarettes, mean interpuff interval (P < 0.05) and total smoke duration (P < 0.01) per cigarette was significantly greater in RYO smokers. In laboratory measurements, RYO cigarettes contained more tobacco by weight than FM cigarettes, but weight varied by both tobacco and cigarette tube brands.
Conclusions: Machine-injected RYO cigarettes made from pipe tobacco are cheaper than FM cigarettes but may have higher abuse liability. Smokers who might otherwise reduce their cigarette consumption or quit altogether may continue to smoke RYO cigarettes due to their affordability.

1. Introduction

In the United States, an estimated 42.1 million adults currently smoke cigarettes (Jamal et al., 2014). Tobacco control prevention and regulatory strategies including higher cigarette taxes have been implemented to reduce the prevalence of tobacco use, especially to prevent youth smoking initiation (DeCicca et al., 2013; DeCicca and McLeod, 2008; Frieden et al., 2005). To alleviate the tax burden imposed on commercial cigarettes, price-sensitive smokers have shifted either to cheaper discount brands or other forms of tobacco that are sold at lower price points (Hanewinkel et al., 2008; Hyland et al., 2005; Kengganpanich et al., 2009). It has been estimated that large price

increases (10%) reduce overall cigarette consumption by 3–5% (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012). The 2009 Children's Health Insurance Program Reauthorization (CHIPR) Act increased the federal factory made (FM) cigarette excise tax rate from $0.39 to $1.01 per pack causing a market shift away from FM cigarettes. One of the most striking examples of changes in tobacco product choice that resulted from the CHIPR Act was a decline in roll-your-own (RYO) cigarette tobacco and an increase in pipe tobacco use. Both products were previously taxed at the same rate, but a $22 per pound tax disparity was created by the larger increase in RYO cigarette tobacco (Tynan et al., 2015). RYO cigarette tobacco and pipe tobacco are both forms of loose

tobacco and traditionally differ in curing methods, flavor, moisture content, and width of tobacco cut. As there were no product standards associated with the cigarette tax increases, tobacco manufacturers started marketing the cheaper pipe tobacco as "dual purpose" tobacco to RYO cigarette users to inform them that the product is suitable for making cigarettes (Morris and Tynan, 2012). Concurrently, the cigarette-equivalent sales of RYO cigarette tobacco, after increasing from 2000 to 2008, declined by about 85% from 2008 to 2015, whereas pipe tobacco consumption increased by almost 7-fold from 2008 to 2011 (Agaku and Alpert, 2016; Centers for Disease Control and Prevention, 2012; Wang et al., 2016). The similar characteristics of loose pipe tobacco effectively served to substitute for loose cigarette tobacco in making RYO cigarettes. The Federal Tobacco Tax Parity Act of 2010 was proposed to make the excise tax equal for pipe tobacco and RYO tobacco but was not voted on.

In addition to these changes, the 2012 Federal Transportation Reauthorization Bill on State and Local Regulation of RYO Tobacco Retailers taxed tobacco retail outlets that used tobacco rolling machines to manufacture cigarettes. This law was intended to reduce the tax disparity in pipe tobacco although its effects are thought to be minor (Tynan et al., 2015). With many retailers no longer using rolling machines, consumers of RYO tobacco now buy their own cigarette rolling machines. The term Make Your Own (MYO) has been used interchangeably with RYO, with subcategories of MYO including machine-rolled RYO cigarettes and hand-rolled RYO cigarettes. Hand-rolled RYO contains about 60% less tobacco than machine-rolled cigarettes in one study (Rosenberry et al., 2013), and are often made without filters although they can be rolled with a filter inserted into the paper. RYO using loose tobacco inserted into cigarette tubes equipped with a filter can be made with electric or hand-cranked table-top rolling machines. Equipment for rolling cigarettes can be purchased in tobacco retail shops or on the internet at affordable prices. In a recent online survey of FM cigarette smokers, a remarkable 88% reported ever having used a machine-injected RYO (Casseus et al., 2016). The recent and rapid growth of an emerging tobacco product is a public health concern as little is known about these smokers or their dependence on these products. The purpose of our study was to explore the characteristics, levels of nicotine dependence, nicotine exposure, and smoking topography differences between RYO and FM cigarette users in a sample of adult smokers.

2. Material and methods

2.1. The Pennsylvania Adult Smoking Study (PASS)

PASS was conducted to determine the role of social and demographic factors on measures of nicotine dependence and smoke exposure in adult cigarette smokers in central Pennsylvania from June 2012 to April 2014. Non-probability sampling methods were employed to recruit cigarette smokers including local radio advertisements, flyers, social media, word-of-mouth, and internet resources. Inclusion criteria included at least 18 years of age, smoking at least 1 cigarette daily for the past year, and not currently pregnant. A total of 353 eligible participants signed the consent. The Institutional Review Board at Penn State College of Medicine (Hershey, Pennsylvania) approved the study.

2.2. Procedures

All participants were screened with a telephone interview for eligibility, and those who were eligible were scheduled for two home visits. At the first visit, written consent was obtained, and participants completed an interviewer-administered questionnaire. Questions covered socio-demographic measures, tobacco use history, nicotine dependence, medical history, and stress measures. Participants were asked "Do you usually buy cigarettes by the carton, pack, or roll-your-own?" to capture their predominant cigarette purchasing behavior. If participants

indicated, they bought cigarettes by the pack or carton they were placed into the FM cigarette group. If they indicated they made their cigarettes, they were placed in the RYO cigarette group. Cigarette group placement was confirmed by the reported brand of their usual cigarettes or brand of loose leaf tobacco used for rolling. Participants were asked to show the tobacco product to the research coordinator for verification, and for RYO smokers whether they used a rolling machine. Two smokers were excluded because their predominant cigarette use status could not be confirmed. Three smokers were excluded from the RYO cigarette group because they smoked hand-rolled RYO cigarettes without filters and did not use a cigarette injector machine. The final sample size included 280 FM and 68 RYO smokers.

Saliva samples were taken with SalivaBio Oral Swabs (Salimetrics, State College, Pennsylvania) for biochemical analysis of nicotine metabolites. Participants were provided with a smoking topography device, Smoking Puff Analyzer-Mobile (SPA-M, SODIM SAS, Fleury-les-Aubrais, France), to use for the next two days. At the second visit, the smoking topography device was collected, and participants were given compensation for study completion.

2.3. Laboratory studies

The levels of the major nicotine metabolites including cotinine (COT) and 3- hydroxycotinine (3HC) were determined by mass spectrometry. The nicotine metabolite ratio was calculated as 3HC:COT. Details of the methods are provided elsewhere (Chen et al., 2010; Krebs et al., 2016). Laboratory weight measurements of RYO cigarettes were determined. Research staff (n = 5) each made 10 RYO cigarettes using the same brand of tobacco and cigarette tubes (The Good Stuff pipe tobacco and Hot Rod cigarette tubes) and cigarette injector machine (Powermatic 2 PLUS Electric Cigarette Injector Machine). The measurements were further extended by comparing the weights between nine different cigarettes types (n = 5 each) comprised of three different brands of non-menthol tobacco (The Good Stuff pipe tobacco, Rave cigarette tobacco, Natural American Spirit cigarette tobacco) and three different brands of RYO cigarette tubes (Top Premium, Premier, Hot Rod). Each cigarette was weighed using an analytical balance.

2.4. Statistical methods

2.4.1. Survey data

For descriptive socio-demographic and smoking behavior variables, frequencies and proportions were computed for categorical variables. Mean and standard deviations were calculated for continuous descriptive variables. Independent two-sample *t*-tests and chi-squared tests were conducted to look for differences in continuous and categorical variables respectively between the two cigarette groups.

2.4.2. Smoking topography

The smoking topography data (obtained from the SPA-M) contains mechanically-recorded measures such as the puff volume, puff flow, interpuff interval, puff duration and the puff count for each cigarette smoked. The smoking topography measurements were collected in the smokers' daily living environment. Data were initially pre-processed and checked for outliers. Outliers are puff parameters that are beyond physiological limits. Outliers were excluded based on the following parameters: (1) puff level: any puff with puff volume greater than 150 mL, or the average flow rate less than 10 mL/second (2) cigarette level: any cigarette with more than 3 outlier puffs or more than 25% of the puffs marked as outliers, and (3) person level: if more than 25% of cigarettes of an individual smoker contained outlier puffs then that smoker is regarded as an outlier. Person-level outlier data (3) were deleted. For (1) and (2), we tried two different methods: either delete them directly or impute their values by the average of the non-outlier puffs' values. The final results were similar between these two methods, so we deleted all puff level outliers. In all, 2.2% (n = 1977) of all puffs