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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 2008–2011 in the United States.

Methods—We used data from the Pennsylvania Adult Smoking Study to compare the differences in sociodemographic, 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

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Contributors

SJ was responsible for manuscript writing and oversaw data analysis and interpretation. NK was responsible for data collection and research protocols, and manuscript preparation. JZ was responsible for advanced statistical analyses including topography data. YW was responsible for statistical analyses and modeling procedures. RG and SM were responsible for laboratory analysis of tobacco products. DS conducted the analysis of biomarkers. JR contributed to manuscript writing and interpretation of biomarker data results. IN and PC contributed to the writing of the manuscript. JM was responsible for overall design and conception of the study and drafting the manuscript. All authors have approved the final article.

Conflicts of Interest

No conflict declared.

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.

Keywords

Addiction; Dependence; Nicotine; Population Studies; Smoking harm products; Roll-your-own cigarettes

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 2008–2015, 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 preprocessed 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 were identified as outlier puffs, 2.6% (n=193) of all cigarettes were identified as outlier cigarettes, and 4.6% (n=16) of all smokers were identified as outlier smokers. More details are described elsewhere(Krebs et al., 2016). Topography data were entered into regression models.

2.4.3 Regression Models—Linear regression models were used to predict the effect of cigarette type (RYO vs. FM) on cotinine levels, which were log-transformed to account for skewness. The models consisted of the following: model 1 – based on all participants, topography variables not used in the model; model 2 – based on king-size smokers only, topography variables not used in the model; model 3 – based on king-size smokers only, topography variables used in the model. Covariates included in the models were cigarettes per day (CPD and CPD^2), education, sex, and time to the first cigarette.

The cleaned topography data were used to calculate the summary statistics for smoking topography variables on a per-cigarette basis. The dimensions of machine-rolled RYO cigarettes are the same as commercial cigarettes. Cigarette tube sizes vary in length, with "King" (79-88mm) and "Long" (94–101mm) the most common sizes. RYO smokers were compared to smokers of commercial cigarettes. Since 92% of RYO and only 48% of the FM smokers smoked king-size cigarettes, the topography analysis was conducted just in king-size cigarettes smokers to eliminate the effect of cigarette size. The topography dataset of king-sized smokers only included 4034 cigarette records from 189 smokers (58 RYO and 131 FM smokers). Linear mixed effect models were used to compare the selected smoking topography variables between RYO and FM smokers, the multiple cigarette records from the same individual were regarded as repeated measures. The results are shown as the estimated least square mean values, and standard error for both of the cigarette groups and the corresponding p-values are provided.

All statistical analyses were done using SAS version 9.4 software (SAS Institute, Cary, NC, USA). R programming language version 3.3.2 (R Foundation) was used in data cleaning and organization. Python programming language 2.7 (Python Software Foundation) was used in the pre-processing of smoking topography data. All statistical tests were two-sided and the significance level (alpha) usedwas set at 0.05.

3.0 Results

3.1 Demographic Comparisons

Of the RYO smokers, 75% reported using loose tobacco labeled as pipe tobacco. The brands of pipe tobacco used by RYO smokers included The Good Stuff, Criss-Cross Gambler, Roxwell, Golden Harvest, Southern Steel, Smokin' G, and Dark Horse. RYO cigarette smokers were older (P=0.053), were more likely to be white (P=0.013), less likely to have a college education (P=0.007), less likely to be working full-time (P=0.009) and have less

total annual income (P<0.001) than FM cigarette smokers [Table 1]. No statistically significant differences were found by sex.

3.2 Smoking Exposure

The average CPD for RYO smokers was 21.1 (SD 10.0) and 15.4 (SD 7.3) for FM smokers (P<0.001). The Fagerström Test for Cigarette/Nicotine Dependence (Fagerstrom, 2012; Heatherton et al., 1991) and the Penn State Cigarette Dependence Index(Foulds et al., 2015) both showed that RYO smokers were more dependent (P<0.001 and P=0.012, respectively). RYO smokers had a shorter time to the first cigarette (P=0.053) and had a higher urge to smoke after waking (P=0.036). RYO smokers were less likely to have made a quit attempt in the past 12 months (P=0.039). There were no differences in reported awakening at night to smoke (P=0.399). Reasons reported by participants for smoking RYO cigarettes were that they were less expensive (67.6% of all reasons reported), not as bad for your health (12.3%), taste better (9.5%), reduces the amount smoked (6.7%), and are more satisfying (4, 3.8%) [categories not mutually exclusive]. The average cost per pack for RYO cigarettes, comprising of the loose tobacco and cigarette tubes used to make the cigarettes, was approximately $1.13. The average cost of a pack of FM cigarettes was $5.74, a significant difference between the two groups (P <.001).

3.3 Biomarker Analysis

In regression analyses, RYO smokers had significantly lower levels of cotinine than FM smokers (Table 2) and at most levels of CPD (Figure 1). Significant predictors of increased cotinine levels include age, cigarettes per day, male sex, earlier time to the first cigarette and lower mean interpuff duration. In an alternative model substituting mean interpuff duration with total smoking duration (total puff duration plus total interpuff duration), longer smoking duration was associated with a significant decrease in cotinine (results not shown). Similar findings were found modeling the effect of cigarette type on 3HC and COT + 3HC (results not shown).

3.4 Smoking Topography

Smoking topography measures (on a per-cigarette basis) among the two cigarette groups who smoked king-sized cigarettes only were measured. RYO smokers had a significantly greater mean interpuff duration (P=0.018) and total smoking duration (P=0.001) than FM smokers. There were no differences in number of puffs, puff flow, or puff volume measures. Among smokers of all cigarette sizes, the findings were similar.

3.5 Laboratory Measurements of Cigarettes

The weights of the RYO cigarettes made by the laboratory staff ranged between 0.67–1.11 grams (mean, 0.91 grams; SD, 0.1). In addition, the weights of the nine different combinations of tobacco and cigarette tube brands are shown in Figure 2. The figure shows the weight of the cigarettes varied by about 20% depending on both the tobacco and tube brands. The Good Stuff is pipe tobacco, which has higher moisture content than cigarette tobacco (Morris and Tynan, 2012), but weighed about the same as Natural American Spirit cigarette tobacco. Both weighed more than Rave cigarette tobacco.

4.0 Discussion

The major reason reported for using RYO in our study was lower price, which is consistent with other reports (Agaku et al., 2016; Fu et al., 2014; Healey et al., 2016; Leatherdale et al., 2009) . RYO smokers in our study had lower levels of education and income and were less likely to be employed full time. Similarly, smoking RYO cigarettes is associated with lower SES in the United States and abroad (Ayo-Yusuf and Olutola, 2013; Brown et al., 2015; Leatherdale et al., 2009). RYO smokers in our study smoked predominantly king-size cigarettes.

The prevalence of RYO smoking in the United States has not been systematically investigated, except for the longitudinal International Tobacco Control Survey which documented a proportional increase in RYO smoking from 7.3% among all cigarette smokers to 10.9% in 2008. The seemingly high prevalence of RYO smokers in our sample (20%) is likely due to the tax differences of tobacco products imposed by state and federal governments. For 2016, the Pennsylvania state government increased taxes ($0.55/ounce) for the first time on smokeless, pipe, and roll-your-own tobacco products, making Pennsylvania the last state to do so (Pennsylvania Department of Revenue, 2016). This still leaves pipe tobacco for RYO cigarettes being federally taxed at a much lower per-cigarette rate than FM cigarettes. It only takes roughly 0.65 ounces to make 20 cigarettes (Campaign for Tobacco-Free Kids, 2017), so the benefit of recent state tax increase on RYO will likely not substantially reducing smoking in RYO smokers.

The abuse liability of RYO compared to other tobacco products is not known. RYO smokers smoked more cigarettes per day, had an earlier time to first cigarette, and had higher scores on multiple measures of cigarette/nicotine dependence. RYO cigarettes in international surveys were also found to be associated with higher levels of dependence according to the Heaviness of Smoking Index and quit rates (Leatherdale et al., 2009; Young et al., 2006). The reasons for these differences are not well understood. In an animal model that compared the self-administration of pure nicotine to tobacco particulate matter (TPM) from RYO tobacco having the same nicotine concentration, RYO TPM was found to be more reinforcing and resulted in more reward-seeking behavior than both nicotine and FM cigarette TPM. The findings indicate that non-nicotinic components from RYO tobacco increased tobacco dependence regardless of nicotine levels (Brennan et al., 2015). It should be noted that if non-nicotinic components in tobacco smoke affect the level of dependence between RYO and FM smokers, then it might be expected that non-nicotinic components are also important in the level of addiction for other tobacco products. Further, the appeal of RYO cigarettes may be affected by their relative perceived safety. In the 2005–2006 International Tobacco Control Survey among adult smokers, RYO cigarettes were perceived as being safer than FM cigarettes despite that the predominant form of RYO in some of these countries are hand-rolled cigarettes without a filter (Young et al., 2006). In more recent data among U.S. college students, the perceived risk of RYO cigarettes is about the same for FM cigarettes in both smokers and nonsmokers (Latimer et al., 2014). In the current study, 12% of adult RYO smokers reported that they perceived their cigarettes were better for their health.

In the International Tobacco Control Four-Country Survey from 2002–2008, RYO use increased in all countries including the United States (Young et al., 2012). RYO cigarette users are more likely to be of lower socioeconomic status than FM users (Licht et al., 2011; Young et al., 2006; Young et al., 2012). Reasons for smoking RYO cigarettes have been mainly cited as being lower in cost, but other reasons such as being healthier and better in taste have also been reported (Rosenberry et al., 2013; Young et al., 2006; Young et al., 2012). RYO cigarette smokers were 1.8–2.9 times more likely to rate RYO cigarettes the least harmful out of all other tobacco products (O'Connor et al., 2007). In these studies, it is likely that some of the RYO smokers used rolling machines, although the distinction was not made.

The differences in exposure to tobacco constituents in RYO compared to FM cigarettes are not well known. Levels of the tobacco smoke carcinogen metabolites 1-hydroxypyrene (1-HOP) and total 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL) measured in 127 FM smokers and 28 smokers who used filtered RYO cigarettes were similar (Shahab et al., 2009). Nicotine and tar yields from RYO cigarettes vary widely depending on their physical characteristics including the use of a filter and may be higher than FM cigarettes on the market (Darrall and Figgins, 1998; Kaiserman and Rickert, 1992). In Norway, where smokers primarily smoke unfiltered hand-rolled cigarettes, RYO cigarettes were associated with a higher lung cancer risk than FM cigarettes (Engeland et al., 1996; Rolke et al., 2009). Loose tobacco may contain more humectants to prevent drying that occurs when the pouch is unsealed. Glycerol is a humectant additive in tobacco and a potential source of acrolein formation.

In our topography analysis for RYO and FM smokers, there was a greater interpuff duration and total smoke duration in RYO smokers. There were no differences in puff parameters. Smokers of RYO cigarettes tend to take longer to smoke their cigarettes, perhaps indicating a slightly greater enhancement of mood or reduction in stress. However, only a small percent of RYO smokers indicated that RYO cigarettes were more satisfying. In a previous study of hand-rolled RYO, machine-rolled RYO, and FM cigarettes, there were little differences in topography parameters between the cigarette types (Koszowski et al., 2014). Although the levels of cigarette dependence are higher in RYO smokers than in FM smokers in the current study, this did not affect the total volume of smoke inhaled per cigarette in RYO smokers. In FM cigarettes, level of dependence is correlated with puffing measures (Ahijevych and Gillespie, 1997; Zielinska-Danch et al., 2010).

Among king-size cigarettes, the filter length of the RYO is slightly shorter than the filter of FM, and the tube length is slightly longer, suggesting that more tobacco can be packed into machine-rolled RYO cigarettes. The average weight of the RYO cigarettes made in this study was 0.9 g/cigarette compared to 0.7 g/cigarette in FM cigarettes reported in other studies (Connolly et al., 2007; Karter et al., 1994; Malson et al., 2001). The heavier weight of the MYO cigarettes is not unexpected and suggests that despite expected human variability in packing the rolling machine hopper and that our RYO weight studies were conducted by nonsmokers, RYO cigarettes will weigh more on average than FM cigarettes. Further, the weight depends on the brand of both the tobacco and the tube used to manufacture the RYO cigarette. While direct comparisons of weights of RYO and FM have

not been previously conducted, another study of RYO cigarettes prepared by RYO smokers found that the weights were comparable to that reported here (Rosenberry et al., 2013). The variability in the physical characteristics of RYO cigarettes, even when limited to king-size cigarettes, introduces some uncertainty when making direct comparisons of tobacco smoke constituent delivery and exposure to FM cigarettes. The higher weight of the RYO cigarette and shorter filter length doesn't necessarily indicate that RYO smokers consume more tobacco per cigarette or are exposed to more tobacco smoke since smokers don't usually smoke the cigarettes all the way down to the level of the filter. Typically, smokers leave a portion of the cigarette tube unburnt.

Possible explanations for the lower cotinine levels in RYO smokers could be due to lower nicotine content of pipe tobacco, lower exposure to nicotine if RYO smokers are smoking more for non-nicotinic reasons as indicated above, or lower bioavailability of nicotine from pipe tobacco. Seventy-five percent of RYO smokers in PASS used loose tobacco labeled as pipe tobacco. The level of nicotine in modern formulations of loose tobacco for RYO/MYO cigarettes is not known and may differ by blends and blend mixtures. Based on the FTC machine-smoked protocols, nicotine yields of tobacco prepared from fine-cut tobaccos for RYO cigarettes were found to be higher than in commercial cigarettes (Kaiserman and Rickert, 1992). However, these results were obtained in 1989, and it is uncertain if they can be extrapolated to today's loose tobacco and FM cigarette formulations. In addition to possible nicotine content variability, nicotine delivery to the smoker varies by the degree of ventilation of the filters and the paper porosity for both FM and RYO cigarette filters and paper (Kaiserman and Rickert, 1992). The differences in cotinine were not due to the weight of the tobacco in the cigarettes, which were similar in RYO and FM. However, studies from several decades ago found mouth-level absorption from pipe tobacco due to its higher alkaline pH content whereas cigarette tobacco smoke absorption occurs entirely in the lungs (Elson and Betts, 1972; Gori et al., 1986). Further work is needed to determine whether this might explain the lower cotinine in RYO smokers.

Limitations of the current study include its self-selected participants and that the remuneration might have had greater appeal to lower-income smokers, who were more likely to be RYO smokers. The study was conducted primarily in white smokers, reflecting the racial distribution of central Pennsylvania. The topography measurements were obtained longitudinally and, in the smokers', natural environment. The portable smoking device may affect smoking patterns and enjoyment (Blank et al., 2009), and it is reasonable to anticipate that smokers may change their smoking patterns while on the device. However, a previous report showed no significant changes in self-reported puffing before and after using a topography device (Shahab et al., 2008). The findings of the higher use of RYO among men and in lower-incomes are consistent with international population-based surveys (Young et al., 2006).

5.0 Conclusions

Smokers who use machine-rolled equipment to manufacture their cigarettes from pipe tobacco are an emerging subgroup of smokers. Little is known about these smokers; their patterns of tobacco use and exposure to tobacco smoke. From a population health

perspective, these cheaper cigarettes may have a relatively high appeal by making smoking affordable to smokers who might otherwise reduce their cigarette consumption or quit altogether. In 2018, the U.S. Food and Drug Administration will require warning labels on nicotine addictiveness for RYO and pipe tobacco.

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Highlights

- Most roll your own smokers used pipe tobacco and rolling machines.
- Roll your own smokers had lower levels of income.
- There were little differences in smoking topography.
- Roll your own smokers had lower levels of nicotine exposure.

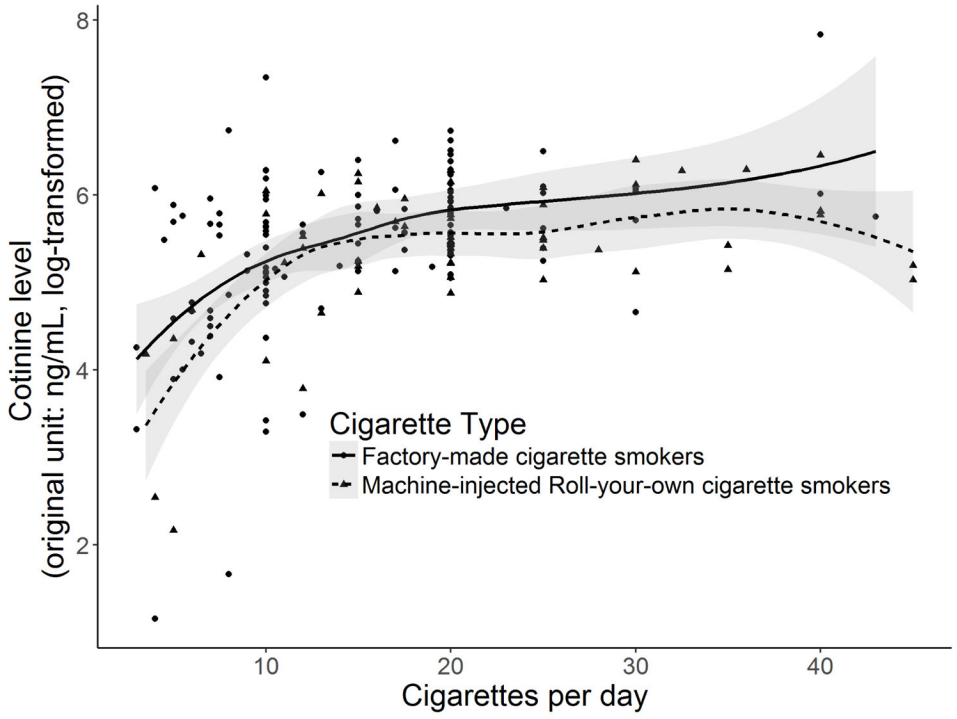

Figure 1.

Relationship between cotinine and self-reported cigarettes per day by roll-your-own (n=68) and factory made (n=280) cigarette smokers

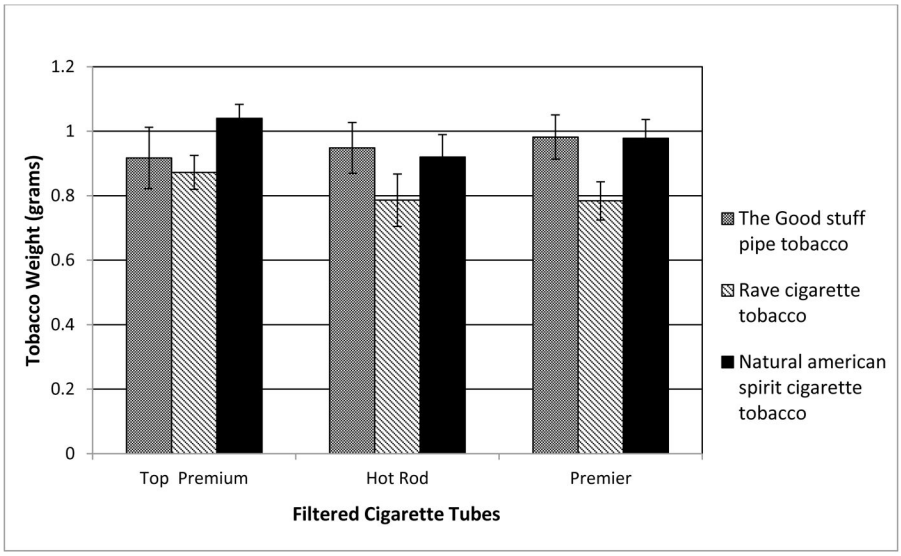

Figure 2.
Tobacco weights by tobacco and cigarette tube brands

Table 1

Socio-demographic characteristics and nicotine dependence measures of roll-your-own and factory-made cigarette smokers, Pennsylvania Adult Smoking Study 2012–2014

	Machine-injected RYO cigarette smokers n=68	Factory-made cigarette smokers n=280	Test Statistic[1]	Degrees of Freedom	P-Value
Socio-demographic characteristics					
Age, mean (SD)	40.5 (12.4)	37.2 (11.3)	-1.96	96	0.053
Male, no. (%)	32 (47.1)	115 (41.1)	0.58	1	0.447
White, no. (%)	66 (97.1)	237 (84.6)	8.74	2	0.013
Education, no. (%)			10	2	0.007
High school graduate or less	41 (60.3)	113 (40.4)			
Some college/Associate degree	25 (36.8)	139 (49.6)			
Bachelor degree of higher	2 (2.9)	28 (10.0)			
Employment Status, no. (%)			11.5	3	0.009
Working (full-time and part-time)	37 (54.4)	205 (73.3)			
Not working (temporary laid off, unemployed, retired)	15 (22.0)	29 (10.4)			
Disabled	10 (14.7)	22 (7.9)			
Other	6 (8.8)	24 (8.6)			
Total annual income ($),mean (median)	$41,316 ($34,000)	$57,328 ($50,000)	3.66	128	<0.001
Nicotine Dependence Measures					
Cigarettes per day, mean (SD)	21.1 (10.0)	15.4 (7.3)	-4.38	85	<0.001
Baseline Cotinine (ng/mL), mean (SD)	274.2 (144.9)	311.8 (241.2)	1.65	170	0.10
Fagerström Test for Cigarette/Nicotine Dependence, mean (SD)	5.2 (2.3)	4.1 (2.2)	−3.89	101	<0.001
Penn State Cigarette Dependence Index, mean (SD)	11.8 (3.5)	10.4 (3.7)	−2.56	82	0.012
Time to first cigarette within 5 minutes, no. (%)	32 (47.1)	94 (33.6)	3.74	1	0.053
Urge to smoke after awakening (1–10 rating), mean (SD)	6.5 (2.4)	5.8 (2.7)	−2.12	110	0.036
Quit smoking for at least 1 day in the past 12 months, no. (%)	18 (35.3)	111 (52.6)	4.26	1	0.039

[1]Test statistic represents t-statistic for the comparison between continuous variables and chi-square statistic for comparison between categorical variables. Abbreviations: SD=standard deviation.

Table 2

Multiple linear regression models for predictors of cotinine levels, Pennsylvania Adult Smoking Study 2012–2014

		Parameter estimate (SE), p-value		
Effect	**Levels**	**Model1**	**model2**	**model3**
Roll-your-own	Yes	−0.3066(0.1013), p=0.0027	−0.3536(0.1152), p=0.0025	−0.3119(0.1131), p=0.0064
	No	(reference)	(reference)	(reference)
CPD (self-reported)		0.0613(0.0163), p=0.0002	0.1009(0.0215), p<0.0001	0.1(0.0207), p<0.0001
CPD^2		−0.0009(0.0004), p=0.013	−0.0016(0.0005), p=0.0006	−0.0017(0.0005), p=0.0004
Education (years)		0.0154(0.0183), p=0.4021	0.0194(0.0261), p=0.4575	−0.0312(0.026), p=0.2317
Sex	Male	0.2706(0.0742), p=0.0003	0.3858(0.1035), p=0.0003	0.2799(0.1026), p=0.007
	Female	(reference)	(reference)	(reference)
Age (years)		0.0112(0.0033), p=0.0007	0.01(0.0047), p=0.0342	0.0102(0.0046), p=0.0284
TTFC	≤30 min	0.475(0.0937), p<0.0001	0.436(0.1308), p=0.001	0.3611(0.1257), p=0.0046
	>30 min	(reference)	(reference)	(reference)
Cigarette size	King-size	−0.0267(0.08), p=0.7391	NA	NA
	Others	(reference)		
Average inter-puff duration (s)		NA	NA	−0.0021(0.0006), p=0.0009

Note: The outcome variable for the linear regression models was cotinine (log-transformed). Three separate regression models were set up: model 1 – based on all participants, topography variable not used in the model; model 2 based on king-size smokers only, topography variable not used in the model; model 3 based on king-size smokers only, topography variable used in the model. Abbreviations: CPD; cigarettes per day, TTFC; time to first cigarette

Table 3

Comparison of smoking topography measures (on a per-cigarette basis) between smokers of “King” sized machine-injected roll-your-own and factory made cigarettes, Pennsylvania Adult Smoking Study 2012–2014

	Make-your own- cigarette smokers n=58	Factory made cigarette smokers n=131	P-Value
Total number of cigarette puffs	12.1 (0.3)	12.1 (0.2)	0.867
Mean puff volume (mL)	49.5 (1.0)	49.0 (0.7)	0.684
Total puff volume (mL)	595.9 (13.3)	580.4 (10.1)	0.354
Mean interpuff interval (s)	26.6 (0.6)	24.8 (0.5)	0.018
Mean puff duration (s)	1.6 (0.03)	1.6 (0.02)	0.110
Mean puff flow (mL/s)	33.4 (0.6)	34.5 (0.5)	0.146
Total smoking duration (s)	311.4 (5.3)	289.3 (4.1)	0.001

All values are mean (standard deviation).