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Polytobacco Use Among Young Adult Smokers: Prospective Association with Cigarette

Consumption

RUNNING HEAD: Polytobacco use in young adult smokers

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Abstract

The risks of polytobacco use among young adults are unclear because we know relatively little about the consistency of multi-product patterns over time and how these patterns impact cigarette smoking. The purpose of this study was to examine changes in multiple tobacco product use over time and associations with cigarette smoking quantity.

Participants ($N = 335$; 55% male) were 18-24 year-old non-daily cigarette smokers living in California. Polytobacco use patterns were assessed quarterly for two years. Transition analyses showed that while the number of products that had been used recently was volatile, the most common pattern was stability between timepoints. A longitudinal negative binomial regression model indicated that those who used more non-cigarette products also reported greater cigarette quantity. The strength of this relationship increased over time. Findings suggest that individuals who use more tobacco products are at greater risk for increased cigarette smoking and maintaining a multiple product use pattern.

Keywords: polytobacco use, non-daily smoking, young adults

What this paper adds:

- The prevalence of polytobacco use has increased substantially in the past decade, particularly among younger populations

- Cross-sectional data suggest polytobacco use may be associated with greater risk of nicotine dependence

- Previous polytobacco studies are generally limited to cross-sectional surveys identifying prevalence and correlates. Little is known about whether polytobacco use predicts tobacco outcomes over time.

- Our findings indicate that, after accounting for baseline use, greater use of multiple tobacco products over time may be associated with increasing consumption of cigarettes and thus with greater risk for negative health outcomes.

Introduction

Polytobacco use (PTU) is increasingly common among US adults [1, 2], particularly among those aged 18-24 [3-5]. Data from the Population Assessment of Tobacco and Health (PATH) study indicate current PTU prevalence of 21.7% among participants aged 18-24, compared with 3.6% of 12-17 year olds and 15.8% of those aged 24-34 [3]. Another study of adults aged 18-34 tracked tobacco use over three waves in 2011-12. They found 57% reported ever using tobacco at baseline, compared with 67% 1 year later, and that those who had tried multiple products were the modal group at wave 3, accounting for 45% of participants [5]. Among young adults, it is increasingly clear that PTU is more common than single product use [6-8], and that this change is a function of escalating use of non-cigarette products, particularly e-cigarettes and hookah tobacco [5-8].

While other tobacco products, such as e-cigarettes and hookah, may not lead to nicotine dependence as readily as regular cigarette consumption, there is substantial evidence that repeated exposure induces dependence [9-12]. In addition, the increasing prevalence of PTU among young adults may signal an impending population level problem. PTU provides exposure to multiple sources of nicotine, potentially increasing risk of dependence [13], and thus of continued or progressive use of multiple products and increased likelihood of cigarette smoking. To date, our understanding is largely limited to the prevalence of multiple product use in a specified time frame, and correlates of current or ever use of multiple products. This is a significant limitation given recent evidence that for young adults, transitions among use states are highly dynamic within a single year [14]. Further, studies have used varying PTU definitions, making it difficult to compare existing findings [2, 15, 16]. It is unclear whether PTU should be defined as use of multiple products within a particular time frame or whether the specific

composition of products matters. As a result, the risk of PTU for development of chronic tobacco use is unknown. However, initial studies suggest other tobacco products are associated with cigarette uptake [17-20], and with cigarette progression among young adults who already smoke [13, 21]. Moreover, preliminary evidence suggests that users of 3 or more products may be more dependent and less motivated to quit cigarettes [22], but whether this predicts cigarette use is unknown. These studies suggest PTU is likely to confer risk for chronic use of multiple products, for cigarette uptake and progression, and therefore for greater likelihood of tobacco-related morbidity and mortality.

The most notable gap in studies of young adults is the lack of longitudinal evaluations of PTU. To date, understanding is largely limited to prevalence of use within a specified time frame, and correlates of current or ever PTU. As a result, the consistency of PTU patterns over time among young adults is not well-understood. Additionally, the extent to which PTU confers risk for the development of nicotine dependence and progression of cigarette smoking is unknown. The present study addresses these gaps by examining the stability of PTU over time and testing the hypotheses that PTU predicts heavier cigarette use over time, and that use of 3 or more products would be more strongly associated with cigarette use than use of 1 or 2 products. Use of Cigarettes was chosen as the primary outcome because of their status as the most dangerous and prevalent combustible tobacco product [23, 24].

Materials and Methods

Participants

Participants ($N = 335$) were young adults participating in a longitudinal study of nondaily cigarette smoking. Eligibility criteria included being 18-24 years old, smoking cigarettes at least monthly for the past six months or longer, and never smoking cigarettes daily for one month or

longer. Because study assessments were completed online, consistent internet access was also required. Due to regional and state differences in cigarette prevalence [25] and legal restrictions [26], the parent study was limited to those who lived in California at baseline.

The sample was 45% female, with a racial/ethnic composition of 39% non-Hispanic white, 25% Asian American, 24% Hispanic/Latino, and 11% from other or multiple backgrounds. Participants were on average 20.4 (SD 1.8) years of age and 58% were full time university or community college students.

Procedure

Participants were recruited primarily via paid Facebook posts. Interested individuals completed a brief online screening to determine eligibility. Respondents meeting eligibility criteria provided informed consent and completed an online baseline assessment. Participants subsequently completed online assessments quarterly over the course of two years. They received $25 gift cards for completing assessments at baseline (BL) and one (Y1) and two (Y2) years later. At the other six time-points (3m, 6m, 9m, 15m, 18m, 21m), participants completed daily assessments for 9 consecutive days, and received $4 in gift cards for each day completed, plus an additional $4 if they completed all 9 days. All procedures were approved by the university's Institutional Review Board. Data were collected between 2015 and 2017.

Measures

Demographic characteristics assessed included sex, race/ethnicity, and student status. Race was collapsed into four categories: non-Hispanic white ($n = 132$), Asian American ($n = 85$), Hispanic or Latino ($n = 81$), and other or multiple backgrounds ($n = 37$). Student status was dichotomized as full time students (58%) or part-time and non-students (42%).

Tobacco use. Use of tobacco was assessed at each timepoint for cigarettes, hookah, e-cigarettes, cigars/cigarillos and smokeless tobacco. Tobacco use was assessed for the past 14 days at BL, Y1 and Y2, and for the past 9 days for 3m, 6m, 9m, 15m, 18m and 21m. For BL, Y1 and Y2, participants indicated whether each product was used. Positive responses triggered detailed assessment via the Timeline Followback [27-29], on which participants indicated the number of cigarettes smoked on each day, and whether each of the other products was used on the same days. For 3m, 6m, 9m, 15m, 18m, and 21m, participants reported the number of cigarettes smoked in the past 24 hours, and whether each other product was used during the same period, on each of 9 consecutive days. These measures have been shown to be strongly associated with biological measures of cigarette use, including measures of nicotine, cotinine, and carbon monoxide [30].

Polytobacco Use. Prior to choosing an operational definition for PTU we examined the distribution of baseline use patterns reported for the prior 14 days: 46% of participants reported use of a single tobacco product and 52% used two or more products. Other than PTU consisting only of cigarettes and e-cigarettes (11%) the remainder reflected multiple combinations that precluded a simple classification by types of product used. Thus, consistent with our goal of estimating cumulative nicotine intake, we operationalized PTU in two ways. First, to examine transitions in PTU patterns we created an ordinal variable (*PTUord*) representing the number of products, including cigarettes, reported in the past 9 or 14 days at each assessment interval (0, 1, 2, or 3+ products). Second, to model the cumulative impact of PTU on cigarette outcomes, we created a count variable (*PTUcount*) reflecting the time-varying, cumulative sum of the number of days on which each product was used prior to each assessment point. For example, at 3 months post-baseline, the value of *PTUcount* was the sum of the number of days of use of each

product at baseline. At 6 months post-baseline, the value was the sum of the number of days of use of each product at baseline and 3 months. Two versions of *PTUcount* were generated, one including the sum of days used for all products, and a second excluding cigarettes. To account for differences in the number of days assessed we calculated a *days* variable that reflected the cumulative number of days on which use had been assessed to that point in the study for each participant.

Analytic plan

Data were tabulated to describe quarterly transitions in total number of products used from BL to Y2 follow-up (see Figure 2) using the ordinal definition of PTU. The hypothesis that PTU predicts greater cigarette use was tested by fitting separate longitudinal models for each time-varying predictor (i.e., *PTUcount* with and without cigarettes) with final models selected to examine overall strength of predictors. Additionally, to test whether use of 3 or more products was more predictive of cigarette use, we fit a third longitudinal model that utilized *PTUord* as an ordinal predictor and total cigarettes over time as the outcome. For all models, the outcome variable was total cigarettes at each of 8 assessments (3m, 6m, 9m, Y1, 15m, 18m, 21m and Y2 post-baseline) from 3 months to 2 years post-baseline. To account for potential pre-existing differences in cigarette consumption, all models included total cigarettes at baseline, sex, racial/ethnic background, and student status. The *days* variable was also included as a covariate. Because the outcome variables were over-dispersed, negative binomial models were a better fit compared to alternative choices (e.g., multi-level or Poisson models) [31]. No assumptions or imputations were made for missing data. Models initially included terms for time, time^2, sex, race/ethnicity, and student status and their interactions with PTU. Nonsignificant interactions

were removed and the model was re-fit. All analyses were conducted using Stata IC 15.1

(StataCorp LP, College Station, TX), with α = .05.

<div align="center">Results</div>

Preliminary Analyses. Eighteen participants (5.1%) did not complete any assessments

after baseline and were excluded from analyses. Dropouts did not differ significantly from

responders with regard to age, race/ethnicity, sex, student status, education, or polytobacco use.

Overall, the 335 participants included in the analyses below completed 94% of possible

assessments. Preliminary analyses indicated that male participants and those who were not full-

time students reported higher levels of PTU ($ps < .05$).

<div align="center"><Insert Figure 1 about here></div>

Transitions in Use Over Time. Initial analyses examined transitions across PTU

categories over two years. Results indicated substantial instability across product use categories,

but as seen in Figure 1 stability was the modal state from one timepoint to the next. The

proportion of the sample that reported stability from one timepoint to the next gradually

increased from 32% between BL and 3m to 55% between 21m and Y2. Additionally, Figure 2

shows the proportion of the sample using 0, 1, 2, or 3+ products at each timepoint. This plot

indicates that recent use of one product was most common over time, and that non-use increased

from 2% at BL to approximately 30% at Y2. Across timepoints, 92.8% of single-product users

smoked cigarettes, compared with 95.2% of users of 2 products and 99.5% of users of 3+

products.

<div align="center"><Insert Figure 2 about here></div>

PTU Predicting Cigarettes Smoked. The initial model examined PTU including

cigarettes (Table 1). Some demographic categories predicted smoking fewer cigarettes, including

being a full-time student ($z = -2.82$, $p < .001$), being female ($z = 3.34$, $p < .001$), and reporting

Asian American ethnicity ($z = 2.55$, $p = .011$). PTU x demographics interaction terms were not

significant and were not retained. In terms of the impact of PTU on cigarette consumption, we

found significant linear ($z = 3.46$, $p = .001$) and quadratic ($z = -4.37$, $p < .001$) interactions

between PTU and time. To better understand this interaction, we plotted pairwise correlations

between PTU and total cigarettes at each timepoint, as seen in Figure 3. The pattern of

correlations indicates that greater PTU frequency was associated with more cigarettes smoked,

and that the strength of this association increased over time during the two years of the study.

More specifically, correlations ranged from $r = .02$ at 3m to $r > .43$ from Y1 onward.

<Insert Table 1 about here>

Next we examined the association between *PTUcount* excluding cigarettes and cigarettes

smoked over time. This model (Table 2) produced similar results. In particular, this model

yielded linear ($z = 2.11$, $p = .035$) and quadratic ($z = -2.35$, $p = .019$) PTU x time interactions that

were similar to the original model. We again plotted correlations between non-cigarette PTU

and cigarettes smoked at each timepoint. Correlations over time indicated a pattern in which the

association between frequency of use of non-cigarette products and quantity of cigarettes

consumed grew stronger over time. Removing cigarettes from the PTU calculation weakened

these associations, which ranged from near-zero at 3m and 6m to $r = .16$ at 9m and Y1, and $r >$

.22 for each of the last four assessments. From 9m onward all correlations were significant at p

$< .05$.

<Insert Figure 3 about here>

<Insert Table 2 about here>

Finally, we used *PTUord* as an ordinal predictor to examine whether the number of products used at each timepoint was associated with cigarettes smoked over time. Because previous research suggested use of 3+ products may be particularly predictive, we coded this as the reference category. Differences between number of products used did not vary over time. We found that participants who used 3+ products reported significantly more cigarettes over time compared with those who used 2 products ($z = -4.57$, $p < .001$), 1 product ($z = -8.40$, $p < .001$), and no products ($z = 21.74$, $p < .001$). Over each 9-14 day period, 3+ product users reported 0.27 more cigarettes than 2 product users and 0.51 more than single product users. Refitting the model with 2 products as the reference indicated that this group smoked significantly more than single product users ($z = -5.26$, $p < .001$). After accounting for covariates the average difference between these groups was 0.24 cigarettes per assessment period.

Discussion

Use of multiple tobacco products is increasingly common among youth and young adults, but little is known regarding the potential consequences of this behavior. The present study examined PTU over time in a sample of young adult nondaily cigarette smokers. Examination of self-reported use revealed considerable instability over time, both within and across categories reflecting the number of tobacco products used. In addition, we found that greater PTU significantly predicted greater cigarette use, and that this relationship grew stronger over time. The pattern held whether or not cigarettes were included in the PTU predictor. We also found incremental effects, whereby users of 3+ products reported significantly more cigarettes smoked versus users of 1 or 2 products, and that 2-product users smoked more cigarettes than those who only used a single product. These findings are consistent with initial studies and suggest PTU confers a significant risk for progression of cigarette use and therefore may increase long-term

risk for negative health effects from tobacco use. Findings also suggest that risk for chronic cigarette smoking increases in tandem with the number of products used.

Findings in the present sample mirror prior work [14, 32]., identifying frequent transitions among different categories of tobacco product use. Changes occurred both across the number of products used and in the proportion of the sample within a given category over time. Despite this instability, the most common transition pattern was to remain in the same category of number of products used from one timepoint to the next, and the likelihood of stability increased over time. The proportion of those reporting recent use of two or more products declined over time, and the number reporting no recent use increased. These reductions in use could reflect that recent cigarette smoking was a study entry criterion, and potentially captured a period of heightened use for all participants. The fluctuations in tobacco use patterns observed here also indicate that these behaviors have not yet become routinized , suggesting that these natural transitions may represent opportunities for disruptive interventions to prevent progression to long term tobacco use.

Findings from the present study were consistent with our hypothesis that higher levels of PTU would predict greater cigarette smoking. Importantly, the finding of a positive association between PTU frequency and cigarette quantity that grew stronger over time was consistent regardless of whether cigarette frequency was included in the PTU predictor. Thus, while the likelihood of PTU across the sample was unstable and declined over time, those who did use multiple products also reported increasing cigarette consumption across 2 years. This finding adds to a growing body of evidence that PTU presents a risk for progression to nicotine dependence and chronic cigarette use. This is a concern given that PTU now appears to be the most common pattern of tobacco use in younger populations [6-8], and suggests that without

intervention this pattern could lead to an increase in the prevalence of adult use of tobacco products generally and cigarettes particularly. Beyond concerns related to tobacco related health consequences, PTU is also associated with problem use of alcohol, marijuana, and other drugs [6, 33] and may also increase risk for chronic use of these substances. This suggests that young adult PTU may reflect a higher risk of negative consequences from tobacco as well as other drugs of abuse.

The finding of a dose-response relationship between the number of products used and quantity of cigarettes is consistent with prior work in younger samples [22]. This relationship suggests that using more products is associated with greater likelihood of chronic cigarette smoking and attendant negative consequences. It is notable that users of 2 products smoked significantly more than participants who used a single product. This suggests that use of non-cigarette products was not primarily motivated by cigarette harm reduction or to aid in cessation. This is consistent with previous studies which suggest that PTU among young adults is associated with recreation and experimentation [34, 35]. We also found that participants who were female, full-time students, and identified as Asian American tended to smoke fewer cigarettes, and that women and full-time students were less likely to use multiple products. However, none of these moderated associations between PTU and cigarette smoking, indicating that PTU predicted increased cigarette use across demographic categories.

The present findings must be interpreted in light of a number of limitations. The parent study from which this sample was drawn recruited current non-daily cigarette smokers residing in California and may not generalize to other populations of young adults in the US or elsewhere. In addition, assessment of non-cigarette products was limited to number of days used but did not capture quantity used. It may be that more detailed assessment of product types and nicotine

content would yield different results. However, it is noteworthy that this relatively gross assessment of tobacco product use during brief assessment periods significantly predicted increased cigarette use.

In sum, these findings suggest that use of multiple nicotine-containing products is associated with increasing cigarette consumption over time. This is alarming considering that PTU appears more common than use of any individual product among younger US populations [6-8], and in conjunction with evidence that multiple product users are more receptive to tobacco company marketing [15, 36] raises the possibility of causing increased tobacco-related illness and death. The possibility that high PTU prevalence could lead to higher rates of chronic cigarette smoking over time highlights the need to address this issue and counter factors driving PTU use, particularly because public health education efforts designed to reduce tobacco prevalence have been effective [37]. For example, anti-smoking campaigns on college campuses have been successful in reducing cigarette consumption [38]; broadening such campaigns to include content about other products and about PTU, and to reach young adults who are not students, could reduce the long-term impact of PTU on nicotine dependence and its health consequences. Additionally, new regulatory policies may be an effective way to mitigate PTU growth among youth and young adults [39]. For example, current restrictions on tobacco advertising are of limited effectiveness in preventing young people's exposure to such advertisements [40]. Additional restrictions may reduce exposure and thus long-term risk for PTU and cigarette smoking.

Figure 1. Proportion of participants whose number of tobacco products increased, decreased, or remained the same between timepoints.
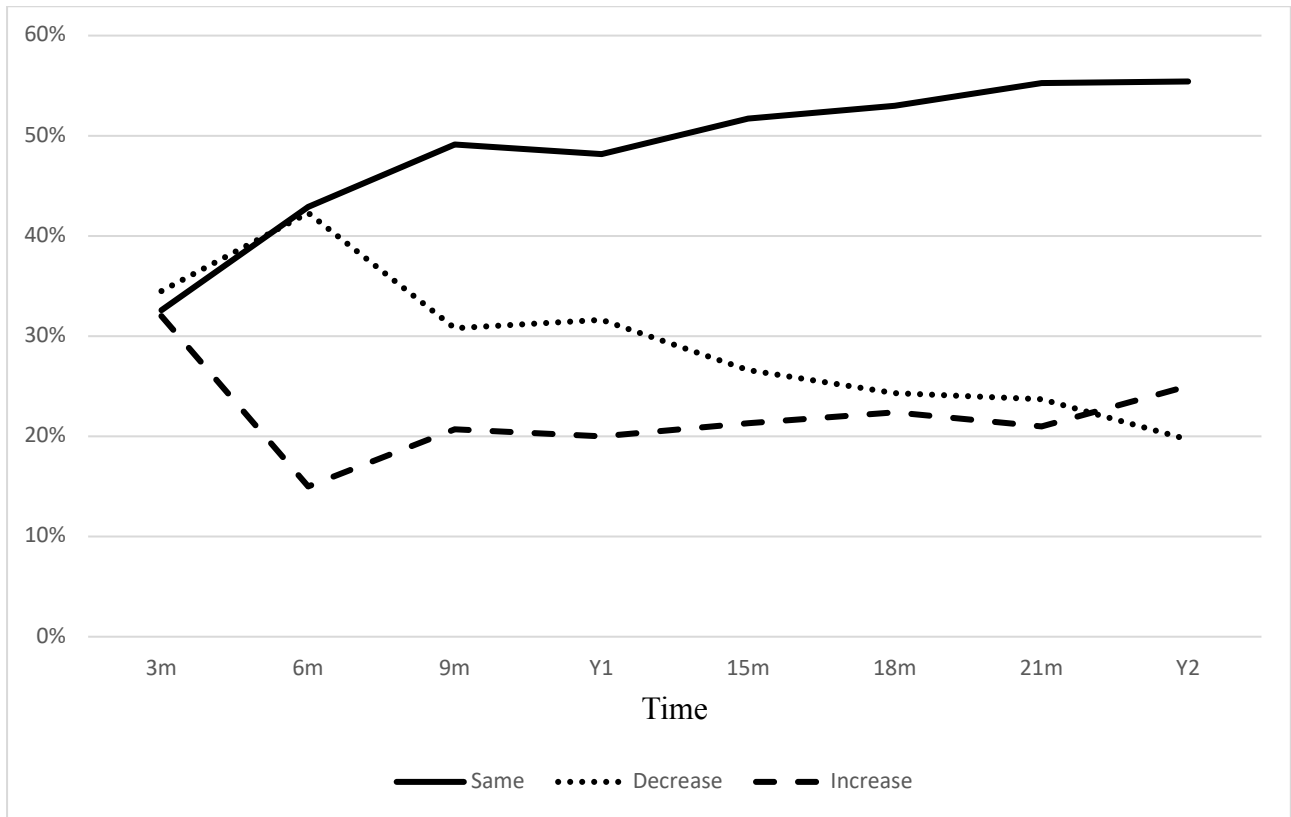
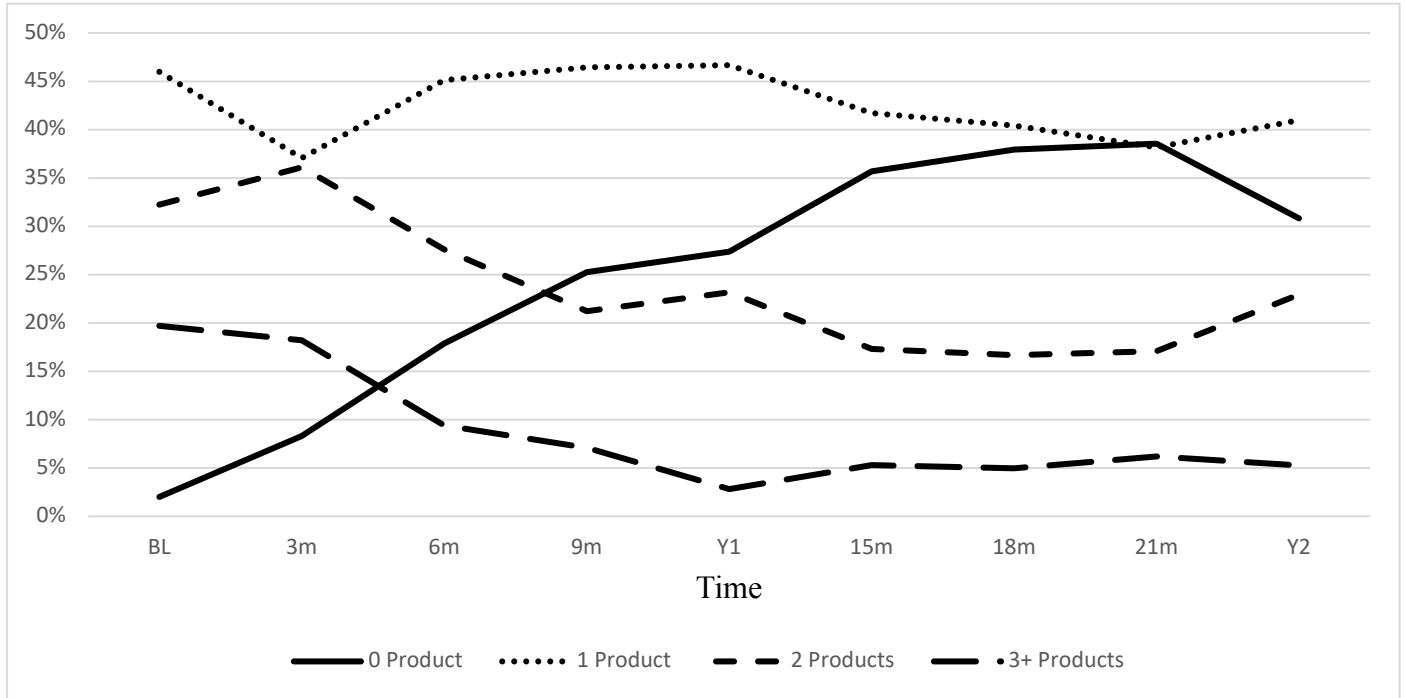Figure 2. Proportion of sample using different numbers of products over time.

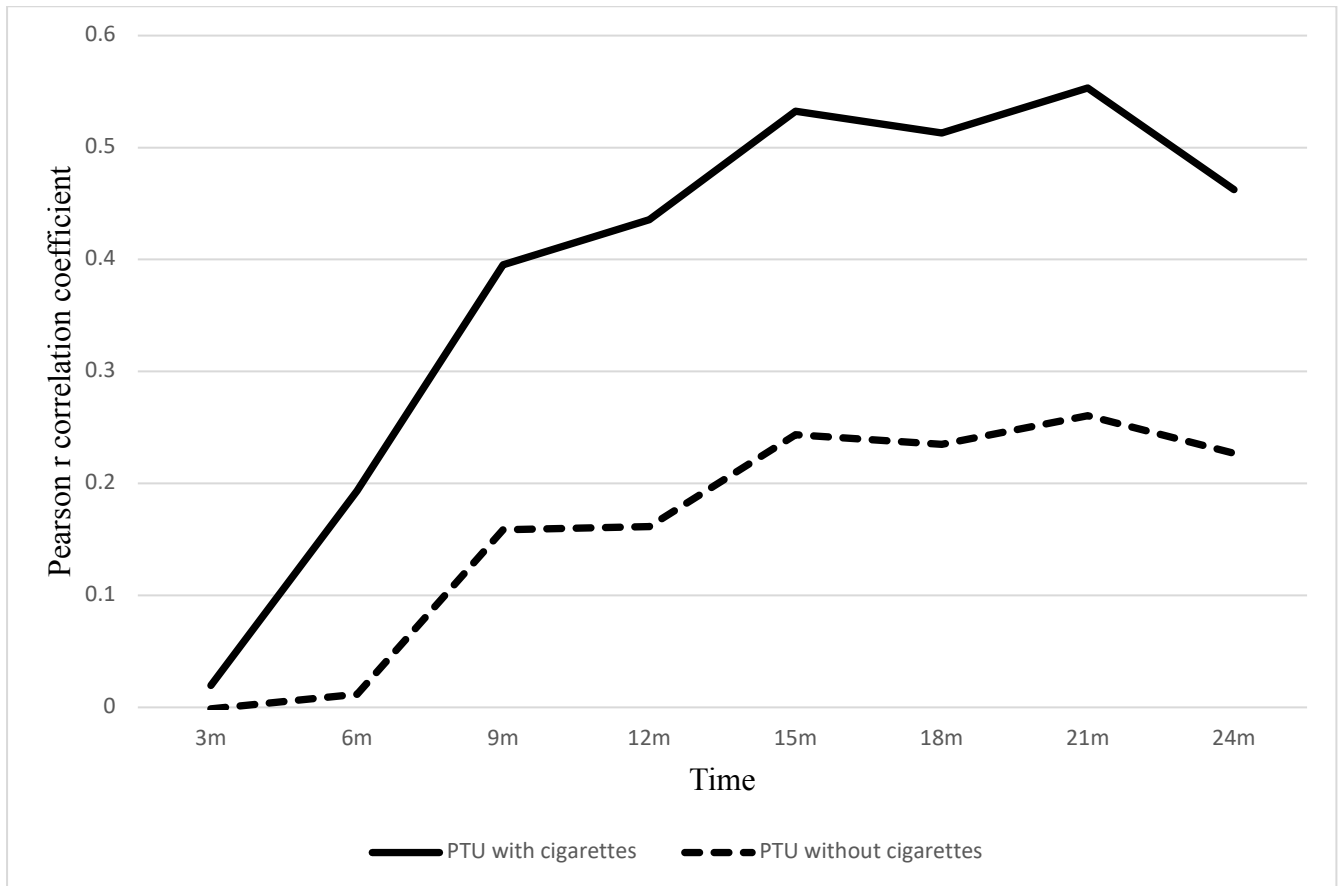Figure 3. Correlations between PTU and cigarettes smoked over time.

Table 1. Longitudinal model of association between PTU and total cigarettes

Predictor	Coefficient (S.E.)	z	p-value
Baseline cigarettes	0.01 (0.01)	2.43	.015
Sex	3.22 (0.89)	3.60	<.001
Race/ethnicity	0.08 (0.03)	2.55	.011
Student status	-0.21 (0.07)	-2.82	.005
Days assessed	0.09 (0.01)	11.50	<.001
Time	-0.63 (0.06)	-10.80	<.001
Time^2	0.04 (0.01)	6.55	<.001
PTU	0.01 (0.01)	0.80	.421
PTU x Time	0.01 (0.01)	3.46	.001
PTU x Time^2	-0.01 (0.01)	-4.37	<.001

Table 2. Longitudinal model of association between PTU (excluding cigarettes) and total cigarettes

Predictor	Coefficient (S.E.)	z	p-value
Baseline cigarettes	0.01 (0.01)	4.30	<.001
Sex	3.11 (0.99)	3.13	.002
Race/ethnicity	0.09 (0.03)	2.66	.008
Student status	-0.26 (0.08)	-3.42	.001
Days assessed	0.08 (0.01)	11.11	<.001
Time	-0.42 (0.05)	-8.62	<.001
Time^2	0.03 (0.01)	4.61	<.001
PTU	0.01 (0.01)	0.19	.848
PTU x Time	0.01 (0.01)	2.11	.035
PTU x Time^2	-0.01 (0.01)	-2.35	.019

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