Original Investigation

Stability of Cigarette Consumption Over Time Among Continuing Smokers: A Latent Growth Curve Analysis

Hua-Hie Yong, Ph.D.,¹ Ron Borland, Ph.D.,¹ James F. Thrasher, Ph.D.,^{2,3} & Mary E. Thompson, Ph.D.⁴

¹ VicHealth Center for Tobacco Control, The Cancer Council Victoria, Carlton, Victoria, Australia

² Department of Health Promotion, Education and Behavior, University of South Carolina, Columbia, SC

³ Centro de Investigaciones en Salud Poblacional, Instituto Nacional de Salud Pública, Cuernavaca, Morelos, Mexico

⁴ Department of Statistics and Actuarial Science, University of Waterloo, Waterloo, Ontario, Canada

Corresponding Author: Hua-Hie Yong, Ph.D., Cancer Control Research Institute, The Cancer Council of Victoria, 100 Drummond Street, Carlton, Victoria 3053, Australia. Telephone: +61-3-9635-5385; Fax: +61-3-9635-5440; E-mail: hua.yong@cancervic.org.au

Received May 6, 2011; accepted September 22, 2011

Abstract

Objectives: This paper examined the stability over time of daily cigarette consumption of continuing smokers and explored factors that might account for the patterns of change in consumption using a latent growth curve (LGC) analytic approach.

Methods: Data come from the first 5 waves of the International Tobacco Control Four-Country Survey, conducted in Canada, the United States, the United Kingdom, and Australia where a cohort of over 2,000 smokers from each country were recruited and followed up annually with replenishment.

Results: Raw data revealed that continuing smokers showed a marked steep decline in cigarettes per day during the first 2 waves followed by a gentler linear decline in consumption over the remaining waves of the study period. This pattern of change in cigarette consumption was best modelled using a piecewise linear LGC model. Baseline consumption level was highest in Australia and lowest in the United Kingdom, although the rate of decline was similar across the 4 countries. Being older than 55 years and having made at least 1 quit attempt were related to greater rate of decline in consumption.

Conclusions: Continuing smokers who are unwilling or unable to quit smoking can and do attempt to reduce their daily cigarette consumption over time. Factors such as making a quit attempt even if unsuccessful and experiencing smoking bans at work and at homes can contribute to reduced smoking among this group, which suggests that interventions focusing in on these factors, along with providing cessation help, may greatly improve their chances of quitting smoking altogether.

Introduction

The number of cigarettes smoked per day is one of the behavioral indications of nicotine dependence among adult smokers. Past research has shown that heavy smokers (>20 cigarettes per

day [CPD]) are less likely to try to quit smoking, and even if they try to quit, they are less likely to succeed than those who are considered low-rate smokers (smoke fewer than 5 cigarettes per day; Borland, Yong, O'Connor, Hyland, & Thompson, 2010; Jarvis, 1997; Zhu, Sun, Hawkins, Pierce, & Cummins, 2003). There is empirical evidence that smokers can indeed initiate and maintain reductions in the number of cigarettes they smoke per day over time (Hughes & Carpenter, 2005; Hughes, Cummings, & Hyland, 1999). Whether reducing daily cigarette consumption will bring health benefits is still somewhat doubtful (see review by Pisinger & Godtfredsen, 2007), although reduced smoking appears to increase the likelihood of future cessation (see review by Hughes & Carpenter, 2006). To date, there are still relatively few studies that have systematically examined the stability of cigarette consumption among adult smokers in the general population, particularly among those who are either unwilling or unable to quit smoking. A better understanding of how daily cigarette consumption might change over time may provide insights into how best to encourage this group of recalcitrant adult smokers to reconsider their continued smoking and move towards smoking cessation.

Nicotine intake is generally expected to be relatively stable over time at least among regular established smokers, and therefore, one would expect that their cigarette consumption would remain fairly stable over time (U.S. Department of Health and Human Services, 1988). Any increase in consumption over time usually indicates those who are still on the uptake trajectory (Chassin, Presson, Pitts, & Sherman, 2000; Costello, Dierker, Jones, & Rose, 2008). On the other hand, with increased awareness of the health consequences of smoking, one might expect that many smokers who are unwilling or unable to quit are likely to be looking for ways to reduce the harms of continual smoking (Hughes, 2000; Shiffman et al., 2002). One such strategy is to cut down the number of cigarettes smoked per day (Hughes & Carpenter, 2005). As smoke-free places become more pervasive following increasing adoption of smoke-free policies in many countries as part of their efforts to protect their population from the harms of secondhand smoke, there are fewer and fewer

doi: 10.1093/ntr/ntr242

Advance Access published on February 6, 2012

© The Author 2012. Published by Oxford University Press on behalf of the Society for Research on Nicotine and Tobacco.

All rights reserved. For permissions, please e-mail: journals.permissions@oup.com

public places where people can smoke (Hargreaves et al., 2010; Hopkins et al., 2010). As awareness of the harm of secondhand smoke increases, many smokers are also making efforts to not smoke at homes (Borland et al., 2006) and in private cars when in the presence of children (Hitchman, Fong, Borland, & Hyland, 2010). Thus, cigarette consumption is expected to diminish over time for continuing smokers either because of increasing external pressure to reduce or because of increased knowledge of the harm of smoking and passive smoking (Gilpin & Pierce, 2002). Recent research also shows that smokers who have failed a quit attempt are more likely to return to a lower level of cigarette consumption, but then, the reduction in consumption diminishes over time (Knoke, Anderson, & Burns, 2006; Yong, Borland, Hyland, & Siahpush, 2008). Thus, reduced smoking following a failed quit attempt appears to be more temporary than permanent. Moreover, the pattern of a self-initiated smoking reduction may not necessarily be linear. It is possible that reduction in cigarette consumption is greatest initially but tapers off and reaches a plateau over time. This happens when at the initial stage smokers tend to give up the nonessential cigarettes, which are eliminated quite easily, but over time are left with the essential ones, which become increasingly more difficult to give up (Cheong, Yong, & Borland, 2007).

The present study sought to investigate whether cigarette consumption of continuing adult smokers (those who are either unwilling or unable to quit) remained stable or decreased over time, using the first five waves of data collected from the International Tobacco Control Four-Country (ITC-4) Survey. The ITC-4 is a cohort study of over 2,000 adult smokers from four countries (Canada, United States, United Kingdom, and Australia), designed specifically to understand the psychosocial and behavioral impact of tobacco control policy (Fong et al., 2006). The availability of self-reported daily cigarette consumption at baseline and at each subsequent follow-up for current smokers affords us the opportunity to address the question of whether daily cigarette consumption is stable over time among those who are recalcitrant to quitting. Specifically, we employed multivariate latent growth curve (LGC) modelling (a) to examine the baseline level and rate of change in daily cigarette consumption over time of continuing smokers who reported smoking daily at baseline and (b) to explore the correlates of variability in baseline level and rate of change.

Methods

Sample

Participants for this study were adult smokers from the first five waves (2002–2007) of the ITC-4 Survey conducted in Canada, United States, United Kingdom, and Australia. Those lost to attrition were replenished at each subsequent wave using the same sampling frame. Details of the conceptual model of the ITC-4 study and its methodology have been reported elsewhere (Fong et al., 2006; Thompson et al., 2006). For the purpose of this study, eligible participants were those who provided data for a minimum of at least two consecutive waves (as the primary interest is in change over time and people who contributed only one datapoint could not be used for computing the slope estimates), smoked daily at recruitment, and were aged at least 25 years old (based on the assumption that smoking would be well established by this age). As an indication of being unwilling

or unable to quit smoking over the study period, we included only those who continued to smoke at each subsequent follow-up survey wave and excluded those who had quit smoking for at least one wave. These requirements yielded a total sample of 8,148, of which 3,456 provided only two waves of data, 1,951 provided three waves of data, 1,196 provided four waves of data, and 1,545 provided five waves of data. The characteristics of the sample are presented in Table 1.

Measures

Dependent Variable

Cigarettes per day. Respondents at each wave who reported that they were still smoking either daily, weekly, or monthly were asked, “On average, how many cigarettes do you smoke each [day/week/month], including both factory-made and roll-your-own cigarettes?” From this, a daily cigarette consumption was derived for each respondent.

Covariates

Sociodemographic. Age and gender were collected. Age in years was recoded into three groups, 25–39, 40–54, and 55 or older.

Quit attempts. New recruits at each wave were asked whether they had ever tried to quit smoking and, if so, when their last attempt had ended. A baseline quit attempt variable was computed using responses to the two questions such that those whose quit attempts had ended within the previous 12 months were coded as 1 and others were coded as 0. This variable was then comparable to the quit attempt variable obtained at each follow-up wave, when respondents were asked if they had made a quit attempt since the last survey wave (Yes/No).

Smoking restrictions at both home and workplace at baseline. Smoking restrictions at homes were assessed using the question, “Which of the following best describes smoking in your home?” Response options were “Smoking is allowed anywhere in your home,” “Smoking is never allowed anywhere in your home,” or “Something in between.” Respondents were asked whether they were currently employed outside of home, and those who were employed were asked, “Which of the following best describes the smoking policy where you work?” Response options were “Smoking is not allowed in any indoor area,” “Smoking is allowed only in some indoor areas,” or “Smoking is allowed in all indoor areas.” A new variable to indicate smoking restrictions in both venues reported at the baseline survey was computed based on responses to venue-specific questions. This was done to increase the sensitivity of measurement of the impact of smoke-free policy on smoking behavior as homes and workplaces are the two venues where people tend to spend most of their time. The response options were “Total bans” to indicate those who reported total ban in both venues and also those who reported total bans at home and not working outside of home; “partial bans” to indicate those with a total ban in one venue but a partial ban in the other venue, a partial ban in both venues, or a partial ban in one and no ban in the other; and “no bans at all” to indicate those reporting no bans in both venues.

Statistical Analyses

LGC models (Willett & Sayer, 1994) were employed to examine the patterns of change in reported cigarette smoked per day over the study period. All cases including those with incomplete

Table 1. Sample Characteristics of Continuing Smokers

	CA N = 2,035	US N = 2,023	UK N = 2,163	AU N = 1,927	Total N = 8,148
Age group (%)					
25–39	32.6	25.5	30.1	38.4	31.5
40–54	44.2	43.0	39.8	43.1	42.5
55+	23.2	31.6	30.2	18.5	26.0
Sex					
Male (%)	43.5	40.8	43.8	44.9	43.2
Made quit attempts between Waves 1 and 2 (%)	36.3	27.6	21.8	26.1	27.6
Made quit attempts at least once over Waves 2–5 (%)	69.1	67.5	67.0	69.3	68.3
Baseline CPD (%)					
1–10	24.1	23.3	22.4	19.9	22.5
11–20	45.6	49.6	59.6	43.3	49.8
21–30	24.9	16.6	12.1	27.3	20.0
31+	5.4	10.4	6.0	9.4	7.8
Smoking restrictions at homes and workplaces reported at baseline (%)					
None	16.2	22.4	18.5	14.3	17.9
Partial bans	63.4	56.7	72.4	54.9	62.1
Total bans	20.3	20.9	9.2	30.8	20.0
Cohort and year of recruitment (n)					
Cohort 1: 2002	1,227	1,011	1,457	1,343	5,038
Cohort 2: 2003	276	318	131	141	866
Cohort 3: 2004	276	371	320	272	1,239
Cohort 4: 2005/2006	256	323	255	171	1,005

Note. Percentages are unweighted. AU = Australia; CA = Canada; UK = United Kingdom; US = United States; CPD = cigarettes per day.

data ($n = 8,148$) were included in analysis, and maximum likelihood parameter estimates for all models were obtained using AMOS 18.0 under the assumption that the data were missing at random. As for the replenishment samples, any missing data are largely due to study design and hence can be assumed to be missing completely at random. For the purposes of analyses, data for CPD underwent a square root transformation before they were employed for LGC modelling because of the highly skewed distribution of the raw data. The square root-transformed CPD has been used successfully in our previous research (Borland et al., 2010).

LGC Models

Four alternate models—no growth, linear, nonlinear (quadratic), and piecewise—were fitted and compared to determine the best way to characterize the patterns of change in the reported CPD (see Figure 1). The piecewise model involved fitting a three-parameter growth curve, with intercept (baseline level) and two linear slopes (see Figure 2), which was decided on following a visual examination of mean reported CPD trajectory for each cohort of participants who entered the study at different survey years (see Figure 3). The first slope was used to model the initial survey participation effect (the marked decline after the first wave that reflects learning and increased awareness of health effects of smoking) and the second slope to model the subsequent linear decline (constant slope, starting from baseline) between assessment Waves 2 and 5. For each of the alternate models, the factor loadings of the level factor to each time-based CPD measure were fixed at 1, while those of the slope factor were fixed to represent the expected pattern of change over the study period as follows: 0, 0, 0, 0, 0 (no growth); 0, 1, 2, 3, 4 (linear); 0, 1, 4, 9, 16 (quadratic); slope 1: 0, 1, 1, 1, 1 and slope

2: 0, 0, 1, 2, 3 (piecewise). To allow us to model the survey participation effect of the different cohorts, data from the different cohorts were realigned based on individual's wave of assessment (rather than based on the actual survey years) before they were used in LGC modelling. This data realignment (see Figure 3) would also allow us to model the pattern of change in cigarette consumption beyond the first two assessments without being confounded by the survey participation effect of subsequent cohorts, something that was problematic when modelling on data based on survey years. Detailed descriptions and examples of LGC modelling using structural equation modelling programs are available elsewhere (Duncan, Duncan, Strycker, Li, & Alpert, 1999; McArdle & Bell, 2000; Stoolmiller, 1995).

Correlates of baseline levels and rate of change of reported CPD were examined by regressing these parameters onto a set of covariates, such as age, sex, country, quit attempts between waves, reported baseline smoking restrictions at both home and workplace, and wave of recruitment. For the purpose of analyses and to increase sensitivity, reported quit attempts between assessment Waves 1 and 2 were used to predict the survey participation effect, while a new variable was derived using the follow-up quit attempt questions to indicate whether the respondents had made at least one quit attempt over the period between assessment Waves 2 and 5. This variable was coded as 1 = Yes and 0 = No to determine its influence on the rate of change in CPD between assessment Waves 2 and 5.

Evaluation of Model Fit

The adequacy of model fit was assessed by the chi-square statistic or discrepancy function. However, it is well known that the chi-square statistic is extremely sensitive to minor deviation

Figure 1. Actual and modelled mean trajectory of daily cigarette consumption by country.

when the sample size is large. Thus, in addition to chi-square tests, overall model fit was evaluated using two relative fit indices, the comparative fit index (CFI; Bentler, 1990) and the root mean squared error of approximation (RMSEA; Browne & Cudeck, 1993). Acceptable model fit is indicated by a value of greater than 0.95 on CFI and a value less than 0.05 on the RMSEA.

Results

Reported Daily Cigarette Consumption by Country, Wave of Assessment, and Cohort

Figure 1 presents the pattern of change in mean reported daily cigarette consumption of continuing smokers by country. The results indicate that overall cigarette consumption declined over the five waves of the study period for continuing smokers in each of the four countries, but the decline appears greater during the first two waves than during the rest of the study period. This pattern of change in consumption is similar across cohorts (see Figure 3).

Baseline LGC Model of Reported CPD

Of the various alternate models tested, the piecewise linear model was considered the best model for describing the pattern of change in daily cigarette consumption over time for continuing smokers (see Table 2). The parameter estimates of the piecewise linear change model are presented in Table 3. As can be

Figure 2. Latent growth curve model of reported cigarettes per day among continuing adult smokers. Note: CPD1-5, square root-transformed cigarette per day for assessment Waves 1-5; E1-E5, measurement errors at each assessment wave; d_INT, d_S1, and d_S2 are residual terms for intercept, slope 1, and slope 2, respectively.

seen, the square root-transformed CPD for the group was characterized by a starting baseline mean level of 4.236 (i.e., 18.35 CPD) and the pattern of change characterized by an initial mean decline of 0.158 units per year associated with survey participation followed by a subsequent mean linear decline at a rate of 0.038 units per year. The results also indicate that there was significant individual variability in baseline level (0.979 *SD* units), survey effect (0.315 *SD* units), and subsequent rate of change (0.177 *SD* units) in daily cigarette consumption. There is some evidence of heteroscedasticity as indicated by the increasing error variances across waves except for the last wave.

We explored whether the piecewise linear change model was similar across the different cohorts using multigroup analyses to test for invariance of parameter estimates (results not shown) and found no evidence of differences in baseline levels and rates of change in cigarette consumption across cohorts.

Predictors of the Variability in Baseline Level and Pattern of Change in the LGC Model

A set of potential predictors of the variability in the baseline levels and pattern of change were added to the LGC model to

Figure 3. Actual mean trajectory of daily cigarette consumption by cohort (top panel) and actual and modelled mean trajectory of daily cigarette consumption overall (bottom panel).

examine their effects, and the results are presented in Table 4. The conditional model yielded a chi-square value of 72.76 with 30 degrees of freedom ($p < .001$), and the fit indices showed that the model was a good fit to the data (CFI = .999 and RMSEA = .013). Compared with those in the 25–39 years age group, those in the two older age groups had significantly higher baseline levels of daily cigarette consumption (both $ps < .001$), and also those aged 55+ years showed a much greater rate of decline in consumption over time ($p < .01$), but the survey effect did not differ across the age groups. Male smokers had both higher baseline levels of consumption ($p < .001$) and greater survey effect ($p < .05$) than female smokers, but they did not differ in rate of change over time. Smokers from Australia had significantly higher baseline levels of consumption than those from Canada ($p < .001$), the United Kingdom ($p < .001$), and the

Table 2. Evaluating Best Fitting Model to Describe the Pattern of Change in Reported Daily Cigarette Consumption

Alternative models	χ^2	<i>df</i>	<i>p</i> Value	CFI	RMSEA
No growth	740.70	13	<.001	0.950	0.083
Linear	194.14	10	<.001	0.987	0.048
Quadratic	275.48	10	<.001	0.982	0.057
Piecewise linear	31.66	8	<.001	0.998	0.019

Note. CFI = comparative fit index; RMSEA = root mean squared error of approximation.

Table 3. Unconditional Latent Growth Curve Model of SRT-CPD of Continuing Smokers

Parameters	Estimate (SE)
Group mean in initial level of SRT-CPD (intercept)	4.236 (0.012)
Individual variability in initial level (SD units)	0.979 (0.009)
Group mean in survey effect on SRT-CPD (slope 1)	−0.158 (0.009)
Individual variability in survey effect (SD units)	0.315 (0.018)
Group mean in rate of change in SRT-CPD (slope 2)	−0.038 (0.006)
Individual variability in rate of change (SD units)	0.177 (0.008)
Error variance in Wave 1 SRT-CPD (SD units)	0.550 (0.010)
Error variance in Wave 2 SRT-CPD (SD units)	0.563 (0.008)
Error variance in Wave 3 SRT-CPD (SD units)	0.564 (0.008)
Error variance in Wave 4 SRT-CPD (SD units)	0.599 (0.011)
Error variance in Wave 5 SRT-CPD (SD units)	0.546 (0.018)

Note. All estimates were significant at $p < .001$. SRT-CPD = square root–transformed cigarettes per day.

United States ($p < .01$). The initial decline due to survey effect was greater among Australian smokers than those from Canada ($p < .001$) and the United Kingdom ($p < .01$). The subsequent rate of decline, however, did not differ across the four countries. Smokers who had made a quit attempt between assessment Waves 1 and 2 had lower baseline level of daily cigarette consumption ($p < .05$) but showed a stronger survey effect than those who did not make any quit attempts ($p < .001$). The rate of decline over time, however, was slower for those who had made a quit attempt ($p < .001$). Those who had made at least one quit attempt over the remaining study period showed a greater rate of decline than those who did not make any attempts at all ($p < .001$), although the initial levels of consumption were lower ($p < .001$). The baseline levels of consumption were significantly lower among those who reported at baseline survey being subjected to partial or total bans in home and workplace (both $ps < .001$) than those not subjected to any ban in these venues; and these two subgroups also showed a much weaker survey effect ($p < .01$ and $p < .001$, respectively). However, compared with those who did not experience any restriction in these venues, the rate of decline in consumption over time was slower only among those reporting experiencing a total smoking ban in both home and workplace ($p < .05$).

Discussion

Several key findings emerge from this study. First, rather than being stable, daily cigarette consumption of continuing adult smokers (those who are either unwilling or unable to quit smoking) from the United States, Canada, United Kingdom, and Australia showed a linear decline over time with surprisingly similar rate in all countries, even though their baseline mean levels of consumption differed. Second, there is evidence of a survey participation effect contributing to the decline in cigarette consumption, which was especially marked in the wave immediately following the first assessment wave. Third, there is evidence of interindividual differences in baseline levels and rate of change in cigarette consumption. Fourth, factors that could explain the individual differences in baseline levels of cigarette consumption were not necessarily the same as those

Table 4. Multivariate Regression of Covariates on Latent Growth Curve Model of Reported Square Root–Transformed Cigarettes Per Day

Predictors	Intercept (baseline levels), estimate (SE)	Slope 1 (survey effect), estimate (SE)	Slope 2 (rate of change), estimate (SE)
Age group			
40–54 vs. 25–39	0.278 (0.028)***	0.029 (0.021)	–0.022 (0.014)
55+ vs. 25–39	0.197 (0.032)***	0.001 (0.025)	–0.042 (0.016)**
Sex (male vs. female)	0.320 (0.024)***	–0.049 (0.018)**	0.013 (0.012)
Country			
Canada vs. Australia	–0.298 (0.034)***	0.101 (0.026)***	0.004 (0.017)
United States vs. Australia	–0.124 (0.034)***	0.029 (.026)	–0.023 (0.017)
United Kingdom vs. Australia	–0.372 (0.034)***	0.079 (0.026)**	–0.002 (0.017)
Tried to quit between Waves 1–2	–0.083 (0.033)*	–0.370 (0.025)***	0.112 (0.013)***
Made quit attempts between Waves 2–5			
At least once vs. none at all	–0.144 (0.034)***	–	–0.080 (0.013)***
Smoking restrictions at home and at workplace (baseline)			
Partial vs. none	–0.370 (0.033)***	0.077 (0.025)**	0.013 (0.016)
Total vs. none	–0.858 (0.040)***	0.105 (0.030)***	0.039 (0.019)*
Interpretations	Showing higher baseline levels of cigarette consumption: older age groups; male; from Australia; not made any attempts to quit during study period; no smoking restriction at home and at work at baseline	Showing greater survey effect: male, from Australia and United States, tried to quit between assessment Waves 1 and 2; no smoking restriction at home and at work at baseline	Showing greater rate of decline in consumption: aged 55 years or older; not tried to quit between assessment Waves 1–2; tried to quit at least once over assessment Waves 2–5; reported no smoking bans at home and workplace at baseline

Note. Model also controlled for cohort (not shown).

* $p < .05$. ** $p < .01$. *** $p < .001$.

for explaining the individual differences in rate of change over time. These findings are discussed below.

Survey Participation Effect

Meaningful interpretation of the findings may benefit from some discussion of the role of survey participation effect evident in this paper. Consistent with other studies showing that being surveyed can induce practice/learning effect on subsequent reports (Duncan & Kalton, 1987; Karlamangla et al., 2009; Thompson, Boudreau, & Driezen, 2005), this study clearly demonstrates that participation in a survey is acting as an intervention in itself producing a marked initial downward effect on reported cigarette consumption. One would expect that the longer the participation in the study, the greater the influence of the surveying effect, but we found no such evidence as the rate of decline was similar across the various cohorts with different lengths of participation in the study suggesting that the survey participation effect was limited to the initial period of participation and not beyond. The survey effect appears largely to be due to increased attempts to quit between assessment Waves 1 and 2, presumably stimulated by increased awareness of the harms of smoking following participation in the ITC Survey. The effect of quitting activity on consumption is consistent with our previous findings that a failed quit attempt can help keep cigarette

consumption at a low level upon resumption (Yong et al., 2008). The decline could also reflect an attempt by continuing smokers (not interested in quitting) to reduce their consumption after being stimulated by the survey to think more about the harm of smoking. Regardless of the actual mechanism, survey participation appears to have a positive immediate incidental effect on continuing smokers' daily cigarette consumption.

Linear Decline in CPD

The finding of a linear decline over the study period (2002–2007) in reported daily cigarette consumption of continuing smokers suggests that in all four countries studied here, there is a secular trend toward reduced smoking among those who are unwilling or unable to quit smoking. The trend toward reduced smoking could either be due to external coercion resulting from comprehensive tobacco control policies and programs, such as increased smoke-free places (Pierce, Messer, White, Cowling, & Thomas, 2011), or an intentional act on the part of the smokers for the purpose of harm reduction (Gilpin & Pierce, 2002; Hughes & Carpenter, 2005). The former explanation seems less plausible, given that the cohort of daily smokers newly recruited at each survey wave did not show any evidence of differences in baseline CPD and also there was no known extensive implementation of smoke-free policies in the four studied countries

during the study period. Regardless of the reasons for reduction from a population perspective, a key benefit from the decline in smoking behavior will be a corresponding continued reduction in the prevalence of adverse health consequences of smoking in the years to come. At the individual level, however, the health benefits of reduced smoking will be modest at best (see review by [Pisinger & Godtfredsen, 2007](#)), given the fact that reduced smoking will not eliminate the increased health risk associated with even low-rate smoking (1–4 CPD; [Bjartveit & Tverdal, 2005](#)).

Of note is the finding that the rate of decline in cigarette consumption was similar across the four countries even though mean baseline levels of cigarette consumption were not all the same across the countries, with Australian and the U.S. smokers smoking approximately two cigarettes more than that of the U.K. and Canadian smokers. The country differences in mean consumption may reflect the larger pack sizes available in Australia and the United States rather than any differences in the history and/or intensity of tobacco control efforts across these countries. Cigarette packs come in larger sizes in Australia (pack sizes of 20, 25, 30, 35, 40, and 50) than in the other countries (United Kingdom: pack sizes of 10 and 20; Canada and United States: sizes of 20 and 25), and it is possible that smokers regulate their nicotine intake based on pack sizes available. Previous research conducted in the United States and Canada has noted that as the market share of packs of 25 increases in North America, reports of smoking 25 CPD increase, suggesting that reported cigarette smoking rate can be influenced by pack size ([Kozlowski, 1986](#)).

Individual Differences in Baseline Level and Rate of Linear Decline

The results from this study also show evidence of heterogeneity in both the baseline levels and rates of change in cigarette consumption among continuing smokers, suggesting the need to consider individual-level factors when designing programs to help these smokers to quit their habits. Consistent with previous studies ([Gilpin & Pierce, 2002](#); [Knocke et al., 2006](#)), individual differences in baseline levels of consumption can be explained by age and gender with older smokers and also male smokers generally smoking more CPD. However, only age but not gender could account for the different rates of change in consumption over time with those aged 55 and older having a higher rate of decline compared with the 25–39 year olds, presumably because of greater health concerns among the older group ([Sachs-Ericsson et al., 2009](#)).

The greater rate of decline in consumption among those who had made at least one quit attempt is also consistent with our earlier study on the impact of failed quit attempts on cigarette consumption ([Yong et al., 2008](#)) and strengthens the case for encouraging continuing smokers to persevere and to try and quit again as this will help to keep their consumption down to a low level.

The finding that greater smoking restrictions reported at baseline in places where people spent most of their waking hours, such as at workplace and at home, were associated with lower baseline mean levels of consumption is consistent with the findings of previous studies ([Borland et al., 2006](#); [Chapman et al., 1999](#); [Gilpin & Pierce, 2002](#); [Zhu et al., 2003](#)). The greater rate of decline in cigarette consumption among those who reported no smoking restriction in either of these venues at

baseline as compared with those who reported being subject to total bans at both venues is somewhat counterintuitive. This may be an artifact of the floor effect experienced by those who were already smoking at a low rate following smoking bans as reported for these venues at baseline; those who had not been subject to any smoking restriction at baseline may have experienced the uptake of smoke-free policy after baseline, which thereby contributed to the more rapid decline in their consumption over the study period. The measure we used for our analysis does not capture the temporal changes in smoking restriction in these two venues, something that we acknowledge as a limitation of the study.

Strengths and Limitations

The large sample size and availability of multicountry data for comparison are strengths of this study. In addition, the use of LGC models for analyses provides not only better estimates of initial levels of cigarette consumption and its rate of change over time but also yields additional insights about the interindividual differences in findings not possible with population average models (e.g., generalized estimating equation models).

Several limitations warrant a mention. First, while efforts have been made to control for measurement errors in our self-report data, we are not able, without biomarker validation, to ascertain if the observed decline in consumption reflects a real change in nicotine dependence as smokers who reduce their CPD could still maintain their nicotine intake by compensatory behaviour ([Adda & Cornaglia, 2006](#); [Hughes & Carpenter, 2005](#)). Second, the findings may reflect only that of smokers from largely English-speaking developed countries with fairly similar histories of tobacco control efforts. Hence, these results may not generalize to developing countries and/or countries with more recent efforts in tobacco control. Third, patterns of change in consumption were examined only among daily smokers, and no effort was made to tease out the methods used to reduce their consumption over time. Future research should examine the relative efficacy of these methods, which may include cutting back the total number of cigarettes smoked per day, switching to nondaily smoking, and using nicotine replacement medications either alone or in combination with these strategies. Emerging evidence suggests that many smokers are using nicotine replacement therapy for reasons other than quitting ([Hammond et al., 2008](#)).

Funding

The ITC Project is supported by grants R01 CA 100362 and P50 CA111236 (Roswell Park Transdisciplinary Tobacco Use Research Center) from the National Cancer Institute of the United States, Robert Wood Johnson Foundation (045734), Canadian Institutes of Health Research (57897, 79551), National Health and Medical Research Council of Australia (265903, 450110), Cancer Research UK (C312/A3726), Canadian Tobacco Control Research Initiative (014578); Centre for Behavioural Research and Program Evaluation, National Cancer Institute of Canada/Canadian Cancer Society.

Declaration of Interests

None declared.

Acknowledgments

We would like to acknowledge the assistance provided by the ITC project data management core team in the preparation of the data used for this paper.

References

- Adda, J., & Cornaglia, F. (2006). Taxes, cigarette consumption, and smoking intensity. *American Economic Review*, 96, 1013–1028. doi:10.1257/aer.96.4.1013
- Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, 107, 238–246. doi:10.1037/0033-2909.107.2.238
- Bjartveit, K., & Tverdal, A. (2005). Health consequences of smoking 1–4 cigarettes per day. *Tobacco Control*, 14, 315–320. doi:10.1136/tc.2005.011932
- Borland, R., Yong, H. H., Cummings, K. M., Hyland, A., Anderson, S., & Fong, G. T. (2006). Determinants and consequences of smoke-free homes: Findings from the International Tobacco control Policy Evaluation Survey. *Tobacco Control*, 15(Suppl. 3), iii42–iii50. doi:10.1136/tc.2005.012492
- Borland, R., Yong, H. H., O'Connor, R. J., Hyland, A., & Thompson, M. E. (2010). The reliability and predictive validity of the Heaviness of Smoking Index and its two components: Findings from the international Tobacco Control (ITC) Four-country study. *Nicotine & Tobacco Research*, 12(Suppl. 1), S45–S50. doi:10.1093/ntr/ntq038
- Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 445–455). Newbury Park, CA: Sage.
- Chapman, S., Borland, R., Scollo, M., Brownson, R. C., Dominello, A., & Woodward, S. (1999). The impact of smoke-free workplaces on declining cigarette consumption in Australia and the United States. *American Journal of Public Health*, 89, 1018–1023. doi:10.2105/AJPH.89.7.1018
- Chassin, L., Presson, C. C., Pitts, S. C., & Sherman, S. J. (2000). The natural history of cigarette smoking from adolescence to adulthood in a Midwestern community sample: Multiple trajectories and their psychosocial correlates. *Health Psychology*, 19, 223–231. doi:10.1037/0278-6133.19.3.223
- Cheong, Y. S., Yong, H. H., & Borland, R. (2007). Does how you quit affect success? A comparison between abrupt and gradual methods using data from the International Tobacco Control Policy Evaluation Study (ITC). *Nicotine & Tobacco Research*, 9, 801–810. doi:10.1080/14622200701484961
- Costello, D. M., Dierker, L. C., Jones, B. L., & Rose, J. S. (2008). Trajectories of smoking from adolescence to early adulthood and their psychosocial risk factors. *Health Psychology*, 27, 811–818. doi:10.1037/0278-6133.27.6.811
- Duncan, G., & Kalton, G. (1987). Issues of design and analysis of surveys across time. *International Statistical Review*, 55, 97–117. Retrieved from <http://www.jstor.org/stable/1403273>
- Duncan, T. E., Duncan, S. C., Strycker, L. A., Li, F., & Alpert, A. (1999). *An introduction to latent variable growth curve modeling: Concepts, issues, and applications*. Mahwah, NJ: Lawrence Erlbaum.
- Fong, G. T., Cummings, K. M., Borland, R., Hastings, G., Hyland, A., Giovino, G. A., et al. (2006). The conceptual framework of the International tobacco Control (ITC) Policy Evaluation Project. *Tobacco Control*, 15(Suppl. 3), iii3–iii11. doi:10.1136/tc.2005.015438
- Gilpin, E. A., & Pierce, J. P. (2002). The California Tobacco Control Program and potential harm reduction through reduced cigarette consumption in continuing smokers. *Nicotine & Tobacco Research*, 4(Suppl. 2), S157–S166. doi:10.1080/1462220021000032708
- Hammond, D., Reid, J. L., Driezen, P., Cummings, K. M., Borland, R., Fong, G. T., et al. (2008). Smokers' use of nicotine replacement therapy for reasons other than stopping smoking: Findings from the ITC 4-country survey. *Addiction*, 103, 1696–1703. doi:10.1111/j.1360-0443.2008.02320.x
- Hargreaves, K., Amos, A., Highet, G., Martin, C., Platt, S., Ritchie, D., et al. (2010). The social context of change in tobacco consumption following the introduction of 'smokefree' England legislation: A qualitative, longitudinal study. *Social Science & Medicine*, 71, 459–466. doi:10.1016/j.socscimed.2010.04.025
- Hitchman, S. C., Fong, G. T., Borland, R., & Hyland, A. (2010). Predictors of smoking in cars with nonsmokers: Findings from the 2007 Wave of the International Tobacco Control Four Country Survey. *Nicotine & Tobacco Research*, 12, 374–380. doi:10.1093/ntr/ntq008
- Hopkins, D. P., Razi, S., Leeks, K. D., Kalra, G. P., Chattopadhyay, S. K., & Soler, R. E. (2010). Smokefree policies to reduce tobacco use. A systematic review. *American Journal of Preventive Medicine*, 38(Suppl. 2), S275–S289. doi:10.1016/j.amepre.2009.10.029
- Hughes, J. R. (2000). Reduced smoking: An introduction and review of the evidence. *Addiction*, 95(Suppl. 1), S3–S7. doi:10.1080/09652140032008
- Hughes, J. R., & Carpenter, M. J. (2005). The feasibility of smoking reduction: An update. *Addiction*, 100, 1074–1089. doi:10.1111/j.1360-0443.2005.01174.x
- Hughes, J. R., & Carpenter, M. J. (2006). Does smoking reduction increase future cessation and decrease disease risk? A qualitative review. *Nicotine & Tobacco Research*, 8, 739–749. doi:10.1080/14622200600789726
- Hughes, J. R., Cummings, K. M., & Hyland, A. (1999). Ability of smokers to reduce their smoking and its association with future smoking cessation. *Addiction*, 94, 109–114. doi:10.1046/j.1360-0443.1999.9411097.x
- Jarvis, M. J. (1997). Smoking cessation. *European Respiratory Review*, 7, 230–234. Retrieved from <http://err.ersjournals.com/>
- Karlamangla, A. S., Miller-Martinez, D., Aneshensel, C. S., Seeman, T. E., Wight, R. G., & Chodosh, J. (2009). Trajectories

of cognitive function in late life in the United States: Demographic and socioeconomic predictors. *American Journal of Epidemiology*, 170, 331–342. doi:10.1093/aje/kwp154

Knoke, J. D., Anderson, C. M., & Burns, D. M. (2006). Does a failed quit attempt reduce cigarette consumption following resumption of smoking? The effects of time and quit attempts on the longitudinal analysis of self-reported cigarette smoking intensity. *Nicotine & Tobacco Research*, 8, 415–423. doi:10.1080/14622200600672740

Kozlowski, L. T. (1986). Pack size, reported cigarette smoking rates, and public health. *American Journal of Public Health*, 76, 1337–1338. Retrieved from <http://ajph.aphapublications.org/>

McArdle, J. J., & Bell, R. Q. (2000). An introduction to latent growth models for developmental data analysis. In T. D. Little, K. U. Schnabel & J. Baumert (Eds.), *Modeling longitudinal and multilevel data* (pp. 69–107), Mahwah, NJ: Lawrence Erlbaum.

Pierce, J. P., Messer, K., White, M. M., Cowling, D. W., & Thomas, D. P. (2011). Prevalence of heavy smoking in California and the United States, 1965–2007. *Journal of American Medical Association*, 305, 1106–1112. doi:10.1001/jama.2011.334

Pisinger, C., & Godtfredsen, N. S. (2007). Is there a health benefit of reduced tobacco consumption: A systematic review. *Nicotine & Tobacco Research*, 9, 631–646. doi:10.1080/14622200701365327

Sachs-Ericsson, N., Schmidt, N. B., Zvolensky, M. J., Mitchell, M., Collins, N., & Blazer, D. G. (2009). Smoking cessation behaviour in older adults by race and gender: The role of health problems and psychological distress. *Nicotine & Tobacco Research*, 11, 433–443. doi:10.1093/ntr/ntp002

Shiffman, S., Gitchell, J. G., Warner, K. E., Slade, J., Henningfield, J. E., & Pinney, J. M. (2002). Tobacco harm reduction: Conceptual structure and nomenclature for analysis

and research. *Nicotine & Tobacco Research*, 4(Suppl. 2), S113–S129. doi:10.1080/1462220021000032717

Stoolmiller, M. (1995). Using latent growth curve models to study developmental processes. In J. M. Gottman (Ed.), *The analysis of change* (pp. 103–108), Mahwah, NJ: Lawrence Erlbaum Associates.

Thompson, M. E., Boudreau, C., & Driezen, P. (2005). *Incorporating time-in-sample in longitudinal survey models*. Proceedings: methodological challenges for future information needs. Session 12: Challenges in using data from longitudinal surveys. Statistics Canada Symposium, October 2005.

Thompson, M. E., Fong, G. T., Hammond, D., Boudreau, C., Driezen, P. R., Hyland, A., et al. (2006). Methods of the International Tobacco Control Four-Country Survey. *Tobacco Control*, 15(Suppl. 3), iii12–iii18. doi:10.1136/tc.2005.013870

U.S. Department of Health and Human Services. (1988). *The health consequences of smoking. Nicotine addiction. A report of the Surgeon General*. Rockville, MD: U.S. Department of Health and Human Services, Office on Smoking and Health. Retrieved from <http://profiles.nlm.nih.gov/NN/B/B/Z/D/segments.html>

Willett, J. B., & Sayer, A. G. (1994). Using covariance structure analysis to detect correlations and predictors of individual change over time. *Psychological Bulletin*, 116, 363–381. doi:10.1037/0033-2909.116.2.363

Yong, H. H., Borland, R., Hyland, A., & Siahpush, M. (2008). How does a failed quit attempt among regular smokers affect their cigarette consumption? Findings from the International Tobacco Control Four Country Survey (ITC-4). *Nicotine & Tobacco Research*, 10, 897–905. doi:10.1080/14622200802023841

Zhu, S. H., Sun, J., Hawkins, S., Pierce, J., & Cummins, S. (2003). A population study of low-rate smokers: Quitting history and instability over time. *Health Psychology*, 22, 245–252. doi:10.1037/0278-6133.22.3.245