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Attrition analysed in five waves of a longitudinal yearly survey of smokers: findings from the ITC Netherlands survey

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Background: Attrition bias can affect the external validity of findings. This article analyses attrition bias and assesses the effectiveness of replenishment samples on demographic and smoking-related characteristics for the International Tobacco Control Netherlands Survey, a longitudinal survey among smokers. **Methods:** Attrition analyses were conducted for the first five survey waves (2008–12). We assessed, including and excluding replenishment samples, whether the demographic composition of the samples changed between the first and fifth waves. Replenishment samples were tailored to ensure the sample remained representative of the smoking population. We also constructed a multivariable survival model of attrition that included all five waves with replenishment samples. **Results:** Of the original 1820 respondents recruited in 2008, 46% participated again in 2012. Demographic differences between waves due to attrition were generally small and replenishment samples tended to minimize them further. The multivariable survival analysis revealed that only two of the 10 variables analysed were significant predictors of attrition: a weak effect for gender (men dropped out more often) and weak to moderate effects for age (respondents aged 15–24 years dropped out more than aged 25–39 years, who dropped out more than those aged 40+ years). **Conclusions:** Weak to moderate attrition effects were found for men and younger age groups. This information could be used to minimize respondent attrition. Our findings suggest that sampling weights and tailored replenishment samples can effectively compensate for attrition effects. This is already being done for the International Tobacco Control Netherlands Survey, including the categories that significantly predicted attrition in this study.

Introduction

Respondent attrition is one of the potential problems in longitudinal survey research. When attrition is random, the smaller sample size will reduce the precision of estimators. But when it is nonrandom, attrition can change the sample composition and result in biased estimators. This undermines the generalizability (i.e. external validity) of research findings.[1–4]

The International Tobacco Control Policy Evaluation Project (ITC Project)[5] was developed to meet the demands for a rigorous evaluation of national tobacco control policies. To date, 22 countries have participated in the ITC Project. This project employs a quasi-experimental pre–post design in which countries that have implemented a particular policy or policies can be compared to other countries that did not implement policies during the same time period. Such countries serve as control groups which allow the ITC Project to assess the psychosocial and behavioural effects of national level tobacco control policies[5] in ways that increase internal validity relative to other evaluation designs (e.g. a single country pre–post design).[6]

The ITC Netherlands Survey uses replenishment samples to maintain a relatively constant sample size over time. These replenishment samples address the problem of reduced precision due to attrition.[7] In spite of this, the original sample may become increasingly unrepresentative of the target population due to long-term attrition.[8] The ITC Netherlands Survey examines discrepancies in four demographics variables (gender, age, geographic region and household size) by comparing the sample composition against the composition of the smoking population. This makes it possible to customize replenishment samples and account for attrition in these demographic groups. This also compensates for disproportionate losses between these categories. However, this may not fully address the problem of nonrandom attrition because other factors may be affected. Thus, nonrandom attrition could still bias the sample and affect the generalizability of findings.

Previous studies of the effects of attrition on generalizability have found mixed results. Most studies examining attrition bias in longitudinal research only found small effects of attrition on generalizability. For example, regardless of large attrition rates (22–35%), Alderman *et al.*[9] found that attrition was not a general or pervasive problem for attaining consistent estimates across data from several different surveys. In spite of a large attrition rate of 74%, Lohse *et al.*[10] only found small, but significant, attrition effects; no effects were found on the primary outcome measures.

Other studies reported only minor problems arising from nonrandom attrition. Dennis and Li[11] found that dropouts and nondropouts had similar attitudes, values and behaviours with respect to areas like politics, health status and lifestyle. The differences they found became smaller after controlling for demographic variables. Another study found that nonrandom attrition had only a minor effect on key study indicators.[7]

Attrition had more substantial effects on sample composition in other studies. For instance, Mirowsky and Reynolds[12] found that suffering from depression predicted attrition. Although Bellón *et al.*[13] did not support this finding, they identified a number of other psychosocial and socio-demographic predictors of attrition. Burkam and Lee[14] reported that attrition resulted in an overestimation of the negative effects of race and ethnicity on academic achievement. We found no clear distinctions between the different analyses methods used in the studies described above and the attrition effects that they found.

In this study, we used data from the longitudinal ITC Netherlands Survey to examine attrition bias and whether replenishment samples maintained the representativeness of the cohort. The ITC Netherlands Survey is a web-based survey that has been conducted annually since 2008. Respondents were drawn from a large probability-based database.[15] This study has three main objectives, to assess: (i) whether respondent attrition in the ITC Netherlands Survey biases the composition of the sample, (ii) whether attrition undermines the generalizability of the findings of the ITC Netherlands Survey and (iii) whether replenishment samples compensate for these possible effects.

Methods

The data

The ITC Netherlands Survey employs a probability-based web panel and consists of yearly survey waves with replenishment. The replenishment samples compensate for both the decrease in sample size and bias on demographic characteristics caused by attrition.

Wave 1 was conducted in April 2008 followed by a subwave in November and December 2008. Wave 2 was conducted in April and May 2009, wave 3 in May and June of 2010, wave 4 in May and June of 2011 and wave 5 in May and June 2012. The number of respondents surveyed in each wave and the number successfully followed from each wave is presented in figure 1. The total sample size ranged from 1717 respondents to 2022 respondents in any wave. Overall, 3437 respondents were included in this analysis. For the purpose of this analysis, we defined respondents who skipped a wave but later returned as dropouts once they missed one wave of data collection ($n = 305$).[16] Information obtained from these participants after they returned was not used.

An extra survey wave was conducted after the first wave to evaluate the short-term effects of a media campaign. Only a subset of respondents from the baseline survey was approached and the timing between the first wave and this one did not follow the regular interval of one year. Therefore, we do not examine attrition in this extra wave, but we adjust the analyses for participation in this wave. In this study, this survey wave is called the 'subwave' to ease interpretation for readers, while the actual third wave is called the second wave and so on.

Respondents for the ITC Netherlands Survey were recruited from TNS NIPObase, a large probability-based database.[15] Respondents are recruited into TNS NIPObase by phone or mail. Applying for participation is not permitted, which reduces the proportion of professional and inattentive respondents.[17] A representative sample of Dutch smokers was obtained from TNS NIPObase with quotas on gender, age, geographic region and household size determined from the Dutch Continuous Survey of Smoking Habits,[18] a national surveillance survey on smoking that has weekly measurements and, in 2007, had over 4000 respondents who were smokers.[15] Younger respondents (15–30 years) were oversampled in order to increase estimation precision for this specific subgroup.[15] This procedure was also used for replenishment samples to ensure survey results were representative of the Dutch population of adult smokers. A previous study showed that there were only small differences in sample composition between the first ITC Netherlands survey and the Dutch population of smokers.[15] Respondents were selected on the basis of three inclusion criteria: being 15 years or older, having smoked at least 100 cigarettes in their lifetime and smoking manufactured or roll-your-own cigarettes at least monthly. Respondents received points for questions they answered; points which could be exchanged for 5–7 euros per survey.

Ethics

The ITC Netherlands Surveys received ethics clearance from the University of Waterloo's Office of Research Ethics.

Measurements

The demographic characteristics gender, age, minority status, marital status, education, income, province and frequency of internet use were included in the analyses because previous studies indicated they were correlated with attrition.[7,13,14,19] The smoking-related characteristics heaviness of smoking and ever made a quit attempt were included because they are key smoking-related characteristics within the ITC Project.[20] Descriptive statistics on these characteristics of the original sample are provided in the Supplementary Material (Supplementary Table S1).

Demographic characteristics

- Gender
- Age: categorized as 15–24, 25–39, 40–54 and 55+ years.
- Minority status: both parents born in The Netherlands versus otherwise.
- Marital status: not married, married, widowed and divorced.
- Highest achieved education: low (primary education and lower pre-vocational secondary education), moderate (middle pre-vocational secondary education and secondary vocational education) and high (senior general secondary education, [pre-]university education and higher professional education).
- Gross household income per month: low (less than 2000 Euro), middle (2000–3000 Euro) and high (more than 3000 Euro). An explicit category for nonresponse was also used (27.3%).
- Province of residence: 12 categories representing the provinces of The Netherlands.
- Frequency of internet use: low (<30 min/day), moderate (30–89 min/day) and high (90 min or more per day).

Smoking-related characteristics

- The Heaviness of Smoking Index had three categories indicative of nicotine dependence: low, moderate and high.[21] It was calculated by summing two categorized measurements: number of cigarettes per day and time till first cigarette of the day, reverse scored.[22] It had a fourth category indicating nonsmoking (quitter).
- Ever made a quit attempt: 'Yes' and 'No'.

Analyses

The effect of attrition on demographic and smoking-related characteristics of respondents was assessed using attrition ratios (ARs). ARs were calculated as:

$$AR = P_{fi}/P_{ri}$$

where P_{fi} is a proportion of a subgroup in the wave 1 sample and P_{ri} is the proportion of the same subgroup in the sample in wave 5. For example, if 20% of the wave 1 sample was married and 19% of this

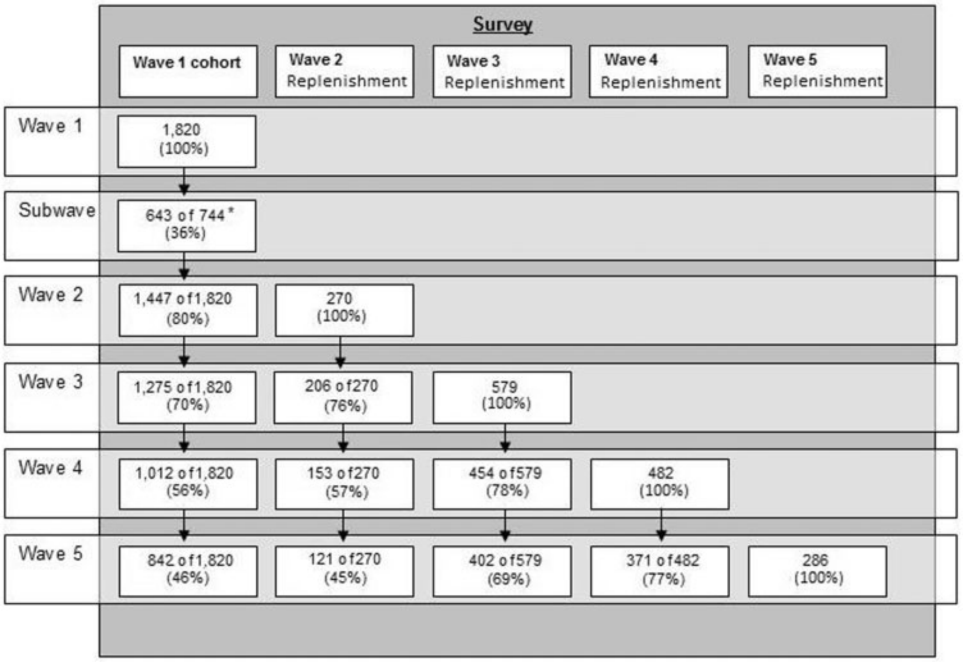

Figure 1 Number of respondents of the ITC Netherlands Survey per wave and their retention rates. *In the subwave, 643 responded from 744 randomly selected participants from wave 1

sample retained in wave 5 was married, the AR would be 0.20/0.19 = 1.05. This AR could be interpreted as a measure of change in the distribution of marital status between survey waves. The AR was calculated twice for every subgroup; once excluding the replenishment samples at wave 5 and once including them.

The ARs reported here represent the weight sizes needed to compensate for the effects of attrition on specific categories in the final wave.[7] Although these ARs are similar to weight sizes, they are not the actual sampling weights used in the ITC Netherlands surveys. Those weights only account for gender, age, geographic region and household size.[23]

A multivariable survival analysis was then conducted on the original unweighted data using a discrete-time proportional hazards regression model.[24] This specific multivariable survival analysis method can be performed with standard logistic regression[25,26] and allowed us to disentangle the effects of correlated characteristics on attrition.[7] The analysis was conducted in SPSS and examined participants that started in any wave and assessed which factors predicted whether they participated in all subsequent waves. The logit link was chosen over the complementary log–log link because it is easier to interpret, allowed us to report odds ratios and was used in similar previous studies.[7,13,27] The main advantage of the complementary log–log link, that it is preferable for models of continuous time,[24] has no bearing on this analysis because our underlying metric of time was discrete: respondents were approached at the same period every year.

The same measures used in the analysis of ARs were included as covariates in the survival model. Because these variables were measured in every wave, they allowed the model to control for time varying characteristics. 'Presence in subwave' was added to control for whether participants were interviewed in the subwave. An interaction between 'recruitment wave' and 'duration' was also included. This was done in place of the intercept and allowed us to control for time.[24] 'Recruitment wave' indicated the wave in which a participant was first interviewed. 'Duration' indicated the number of interviews a respondent had completed including the current wave. An interaction between 'recruitment wave' and 'duration' controlled for the different time paths participants followed. In other words, participants in their second wave ('duration' = 2) who were recruited for the cohort at wave 2 ('recruitment wave' = 2) were interviewed in 2010 (wave 3). Participants who were also in their second wave ('duration' = 2) but were recruited for the cohort at wave 1 ('recruitment wave' = 1) were interviewed in 2009 (wave 2).

The model was estimated with and without the three-way interactions of 'recruitment wave', 'duration' and each of the predictor variables using the deviance statistic.[24] None of the three-way interactions significantly improved model fit and they are therefore not reported here.

Results

Attrition ratios

Figures 2 and 3 illustrate the change in the proportion of respondents in each category, expressed as ARs. This is displayed in the figures for the original first wave sample present in wave 5 compared to the original first wave sample present in wave 1 (triangles) and for the total sample (i.e. with all replenishment samples) present in wave 5 compared to the first wave sample present in wave 1 (dots).

Figure 2 shows a relatively high AR of the original sample in wave 5 for the 15–24-year age group (AR = 1.46). The replenishment samples decreased the size of the ARs for the total sample in wave 5, from 1.46 to 1.12 in the 15–24-year age group and from 1.11 to 1.04 in ethnic minorities. However, the total sample also shows some small increases in the AR in a few demographic groups, most notably the low education group (AR increased from 1.00 to 1.23).

Figure 3 shows a large AR for participants who reported never having made a quit attempt in the original sample (AR = 1.94). Relatively high ARs were found for unmarried participants (1.29) and participants with low and medium nicotine dependence (1.38 and 1.29, respectively). ARs decreased towards 1.00 in these same categories when the total sample in wave 5 was used to calculate ARs. The largest difference in the AR occurred in the group of respondents who reported never having made a quit attempt (from 1.94 to 1.07). Other notable changes in the AR were seen for participants

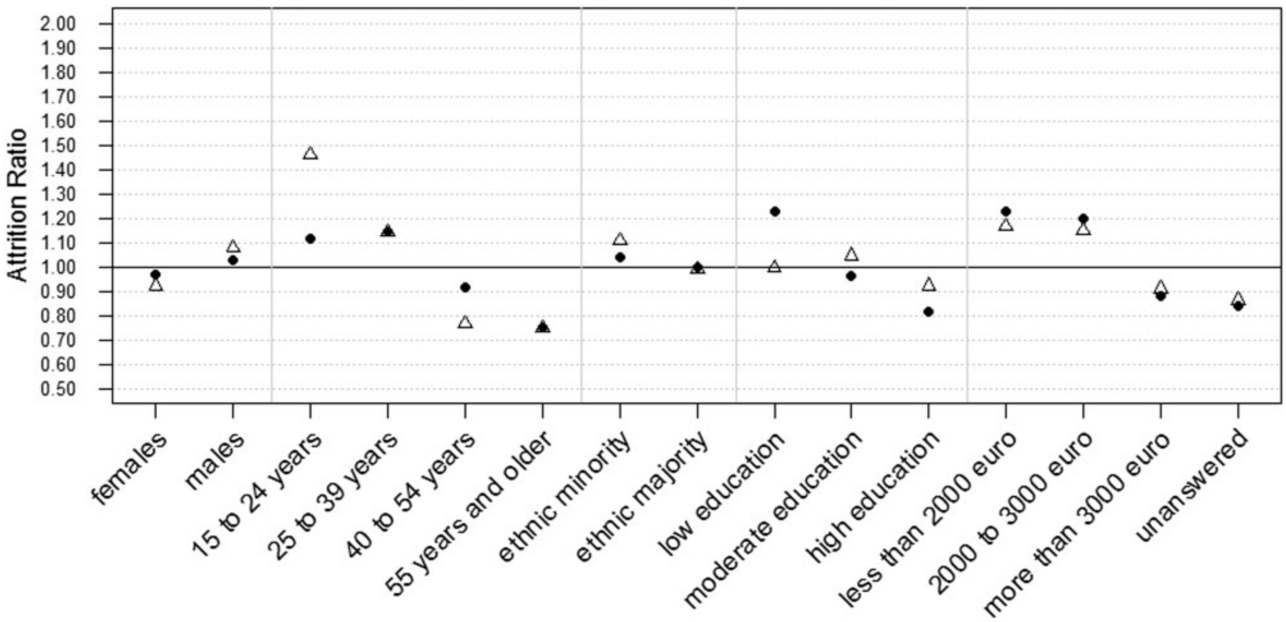

Figure 2 ARs (weight sizes) for demographic characteristics of the original sample and the total sample. Legend: △ Original sample • Total sample

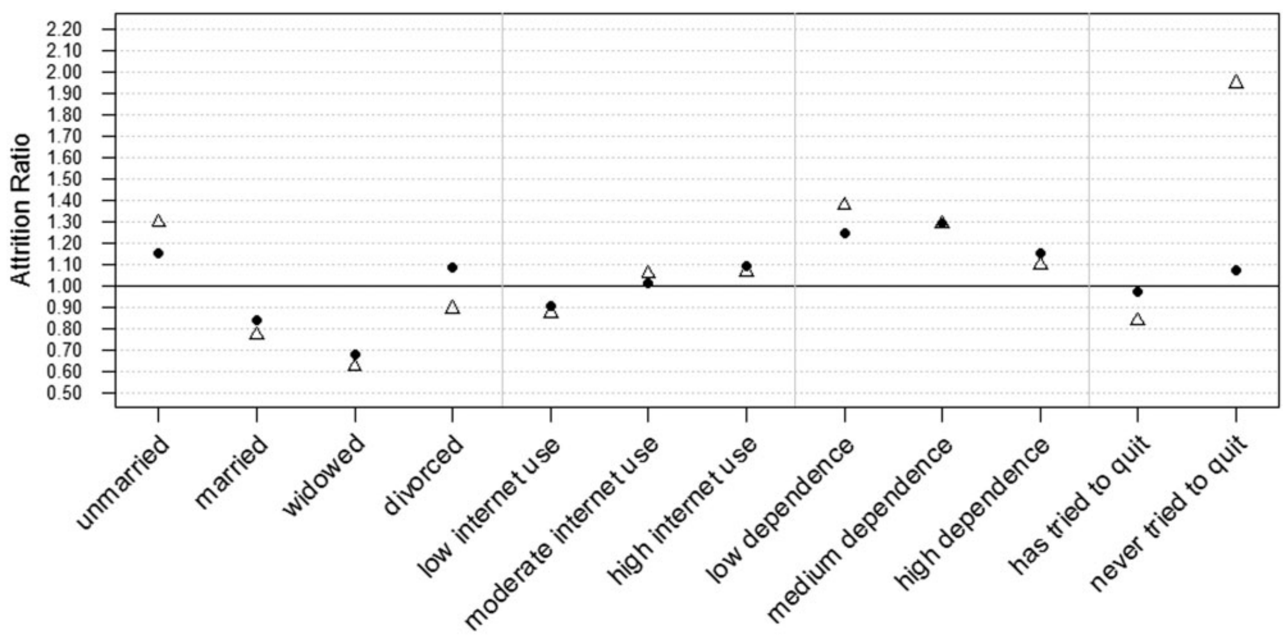

Figure 3 ARs (weight sizes) for demographic and smoking-related characteristics of the original sample and the total sample. Legend: △ Original sample • Total sample

with low nicotine dependence (from 1.38 to 1.25) and who were not married (from 1.29 to 1.15).

Multivariable attrition model

Table 1 reports the results of the multivariable survival analysis. It assesses the participant characteristics associated with dropout and includes the odds ratios for the independent variables. Respondents not participating in the subwave had slightly higher odds of attrition (OR = 1.755). There was a weak but significant effect of gender such that males had greater odds of dropping out than females (OR = 1.251). Younger respondents dropped out more often than the oldest respondents (aged 55+ years) with a weak effect among respondents aged 25–39 years (OR = 1.770) and moderate effects for respondents aged 15–24 years (OR = 2.377).

Discussion

More than half of the ITC Netherlands sample that was recruited in 2008 was lost to follow-up by 2012. Despite this, only small (unweighted) ARs were found, suggesting the total sample present in wave 5 might not be biased by attrition. The survival analysis showed that the odds of attrition were somewhat higher for males, moderately higher for the youngest age group and moderately lower for those who participated in the subwave. This concurs with findings from the European Community Household Panel for 14

Table 1 Multivariable survival analysis: logistic regression of attrition between waves 1 and 5

Variables	Factors	OR[a]	95% CI[b] Lower	Higher	Significance	Likelihood ratio test
Present in subwave	Yes	Ref.				$\chi_{(1)}$=52.73, **P < 0.001**
	No	1.755	1.504	2.051	***	
Gender	Female	Ref.				$\chi_{(1)}$=12.65, **P < 0.001**
	Male	1.251	1.107	1.416	***	
Age (years)	55 and older	Ref.				$\chi_{(3)}$=68.30, **P < 0.001**
	40–54	1.065	0.855	1.330		
	25–39	1.770	1.420	2.214	***	
	15–24	2.377	1.844	3.075	***	
Ethnicity	Dutch	Ref.				$\chi_{(1)}$=0.35, P = 0.552
	Not Dutch	1.066	0.862	1.311		
Marital status	Married	Ref.				$\chi_{(3)}$=4.98, P = 0.173
	Divorced	0.987	0.696	1.373		
	Widowed	1.365	0.798	2.233		
	Not married	1.167	0.996	1.367	†	
Highest education	High education	Ref.				$\chi_{(2)}$=1.25, P = 0.535
	Moderate education	1.009	0.864	1.179		
	Low education	0.929	0.778	1.111		
Household income	3.000 euros and higher	Ref.				$\chi_{(3)}$=1.20, P = 0.752
	Between 2.000 and 3.000 euros	0.985	0.828	1.172		
	Less than 2.000 euros	0.926	0.775	1.106		
	Unanswered	0.926	0.783	1.095		
Province	Limburg	Ref.				$\chi_{(11)}$=12.55, P = 0.324
	Groningen	1.039	0.724	1.483		
	Friesland	0.912	0.630	1.312		
	Drenthe	0.829	0.545	1.242		
	Overijssel	1.050	0.768	1.435		
	Gelderland	0.975	0.731	1.305		
	Flevoland	0.983	0.606	1.557		
	Utrecht	0.906	0.640	1.278		
	Noord-Holland	1.135	0.871	1.486		
	Zuid-Holland	0.987	0.765	1.179		
	Zeeland	1.431	0.904	2.232		
	Noord-Brabant	0.844	0.644	1.109		
Frequency of internet use	90 min or more per day	Ref.				$\chi_{(2)}$=3.40, P = 0.183
	30–89 min/day	0.969	0.837	1.123		
	<30 min/day	1.110	0.945	1.303		
Heaviness of smoking	High nicotine dependence	Ref.				$\chi_{(3)}$=1.50, P = 0.683
	Moderate nicotine dependence	0.933	0.719	1.224		
	Low nicotine dependence	1.016	0.770	1.352		
	Quit smoking	0.941	0.691	1.290		
Ever made a quit attempt	No	Ref.				$\chi_{(1)}$=.74, P = 0.390
	Yes	1.068	0.920	1.242		
		Odds				
Interaction of recruitment wave and duration	1st wave, 1 wave	0.091	0.057	0.145	***	$\chi_{(3)}$=38.86, **P< 0.001**
	1st wave, 2 waves	0.083	0.052	0.133	***	
	1st wave, 3 waves	0.118	0.073	0.189	***	
	1st wave, 4 waves	0.077	0.047	0.124	***	
	2nd wave, 1 wave	0.079	0.045	0.138	***	
	2nd wave, 2 waves	0.090	0.050	0.159	***	
	2nd wave, 3 waves	0.069	0.037	0.128	***	
	3rd wave, 1 wave	0.116	0.070	0.189	***	
	3rd wave, 2 waves	0.056	0.032	0.094	***	
	4th wave, 1 wave	0.070	0.041	0.118	***	

a: Ref., reference level.
b: CI, confidence interval.
*P < 0.05.
**P < 0.01.
***P < 0.001.
†P < 0.10.

countries, which found higher ARs for lower age groups[7] and with findings from other ITC Europe Surveys.[28,29] Other studies also found attrition effects for both gender and age,[13,27] including ITC surveys conducted in other countries.[30]

The lower risk of attrition for participants present in the subwave may indicate a greater probability of remaining in the survey for seven months (i.e. presence in the subwave) which would then predict remaining in the survey for one year (i.e. presence in the second wave). However, loyalty to the survey may also be a factor: respondents who participated more often in the past are more likely to participate in subsequent waves. Survey loyalty may be due to the financial incentives provided for participation[31] or because subwave participation encouraged respondent rapport, making them more devoted to future participation.

The tailored replenishment samples used in the ITC Netherlands Survey were designed to compensate for sample attrition and to ensure the cohort of smokers included remained representative of the population of Dutch smokers on specific variables (gender, age, geographic region and household size). In doing so, the replenishment samples alleviated attrition bias on some other variables also (e.g. low nicotine dependence and never made a quit attempt). Additionally, the use of sampling weights increases the extent to which attrition effects are taken into account. It is therefore likely that the results from the ITC Netherlands survey are robust against deviations in sample compositions that result from respondent attrition.

Limitations and strengths

The analytic approach used in this study provides insight into the representativeness of the ITC Netherlands Survey and respondent attrition. ARs do not establish definitively whether a characteristic is significantly related to attrition or even whether participants dropped out of the cohort at all; the characteristics of a participant may just have changed (e.g. from never having made a quit attempt to having made a quit attempt). The sample is constantly changing and some of the observed changes in composition may be due to population changes. These changing characteristics may have inflated the ARs and they may also have an informing role on patterns of attrition.[13] The survival model provides more insight into factors associated with attrition because it accounts for changing characteristics by way of time varying covariates. The model also makes it possible to account for the effects of correlated characteristics on attrition[7] and includes replenishment samples in the analysis as potential sources of dropout, thus utilizing an extra source of information on attrition. However, our model does not contain data about characteristics of participants that changed since their last wave of participation before dropping out. Therefore, the model cannot account for such changes.[7]

Conclusion

Less than half of the ITC Netherlands sample that was recruited in 2008 remained in the cohort in 2012. However, the ARs calculated to measure attrition bias were small. Larger deviations, where participants with specific characteristics dropped out more often, were alleviated by replenishment samples, thus improving the sample structure. Our study revealed that only two variables out of ten were significant predictors of attrition: gender and age. Men and younger respondents dropped out more often. The replenishment samples in the ITC Netherlands Survey account for this because they are tailored to gender and age. These results support that sampling weights and tailored replenishment samples can compensate for attrition effects on the sample composition. Attrition prevention methods could also be aimed at participants who fall in categories that predict attrition.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- Replenishment samples tailored to keep the cohort representative of the population do compensate for attrition bias, even for variables other than the ones used to tailor the replenishment samples.
- Male gender and younger age were found to be the only characteristics that predicted attrition.
- Multivariable survival analyses across waves give a more exhaustive and therefore different picture of attrition than sampling weights do.
- Results suggest large dropout rates (>50%) in longitudinal surveys do not necessarily create problems with attrition bias.

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