


BMJ Open Patterns of heavy drinking behaviour over age and birth cohorts among Chinese men: a Markov model

Kyueun Lee , Joshua Salomon, Jeremy Goldhaber-Fiebert

To cite: Lee K, Salomon J, Goldhaber-Fiebert J. Patterns of heavy drinking behaviour over age and birth cohorts among Chinese men: a Markov model. *BMJ Open* 2021;**11**:e043261. doi:10.1136/bmjopen-2020-043261

► Prepublication history and additional materials for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2020-043261>).

Received 29 July 2020
Revised 27 December 2020
Accepted 05 February 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

Center for Health Policy/Primary Care and Outcomes Research, Stanford University School of Medicine, Stanford, California, USA

Correspondence to

Dr Kyueun Lee;
kyueunl@stanford.edu

ABSTRACT

Objectives To estimate the age patterns and cohort trends in heavy drinking among Chinese men from 1993 to 2011 and to project the future burden of heavy drinking through 2027.

Design We constructed a Markov cohort model that simulates age-specific heavy drinking behaviours for a series of cohorts of Chinese men born between 1922 and 1993 and fitted the model to longitudinal data on drinking patterns (1993–2015). We projected male prevalence of heavy drinking from 2015 through 2027 with and without modification of heavy drinking behaviours.

Participants A cohort of Chinese men who were born between 1922 and 1993.

Main outcome measures Outcomes included age-specific and birth cohort-specific rates of initiating, quitting and reinitiating heavy drinking from 1993 through 2011, projected prevalence of heavy drinking from 2015 to 2027, and total reduction in prevalence and total averted deaths with hypothetical elimination of heavy drinking behaviours.

Results Across multiple birth cohorts, middle-aged Chinese men have consistently higher risks of starting and resuming heavy drinking and lower probabilities of quitting their current heavy drinking than men in other age groups. From 1993 to 2011, the risk of starting or resuming heavy drinking continued to decrease over generations. Our model projected that the prevalence of heavy drinking among Chinese men will decrease by 33% (95% CI 11.5% to 54.6%) between 2015 and the end of 2027. Complete elimination of or acceptance of a change in heavy drinking behaviours among Chinese men could accelerate this decrease by 12 percentage points (95% CI 7.8 to 18.2) and avert 377 000 deaths (95% CI 228 000 to 577 000) in total from 2015 to 2027.

Conclusion Heavy drinking prevalence will continue to decrease through 2027 if current age-specific and birth cohort-specific patterns of starting, quitting and resuming heavy drinking continue. Effective mitigation policy should consider age-specific patterns in heavy drinking behaviours to further reduce the burden of heavy drinking.

INTRODUCTION

Drinking alcohol is a prevalent health risk behaviour, with 1.5 billion men and 0.9 billion women current drinkers in the world.¹ Alcohol use causes substantial health loss globally and was the seventh leading risk factor for morbidity and mortality,

Strengths and limitations of this study

- This is the first study to investigate age-specific and birth cohort-specific drivers of changes in heavy drinking prevalence among Chinese men using a mathematical model.
- The constructed model has a potential to improve prediction of alcohol-related disease burden and to optimise potential interventions.
- This study validated its simulation model against two national surveys in China, assuming their consistent sampling procedures and unbiased reporting of drinking behaviours.
- The interpretation of our future projections of heavy drinking prevalence is limited to what is predicted to happen without additional interventions in the future.

accounting for 5.3% of all deaths and 5.1% of all disability-adjusted life years globally in 2016.¹ Over 200 diseases and injuries are caused by or associated with alcohol use. Acute injuries such as self-harm and transportation injuries and chronic diseases such as cancers and cardiovascular diseases are the main causes of alcohol-related burden among those aged 15–49 years and those older than 50 years, respectively.¹ Drinking patterns vary depending on the volume of alcohol consumed per drinking occasion and the frequency of drinking. Moderate drinking is defined as drinking 1–2 drinks per day, whereas heavy drinking indicates excessive drinking patterns of more than 8–15 drinks per week. Alcohol use disorder is the chronic condition characterised by uncontrolled drinking.²

The WHO's global status report on alcohol use and health indicated different temporal trends in drinking alcohol across countries.³ In the European region, where drinking alcohol is more prevalent compared with other countries, the prevalence of drinking has decreased by 14.5% between 2000 and 2016, whereas in the Western Pacific region the prevalence has increased by 2.3% over the

same period. According to the report, China is leading the observed increase in drinking alcohol in the Western Pacific region.

In China, rapid economic and social development since the late 1970s has led to a dramatic change in alcohol production and consumption over time. Between 2004 and 2012, national production of alcohol has increased by 8.5 million tons.⁴ Per capita alcohol consumption in China has increased more than in any other low-income or middle-income country (from 2.5 L in 1978 to 6.7 L in 2010).⁵ There has been a parallel increase in the prevalence of alcohol use disorder (from 0.46% in the mid-1980s to 3.43% in the mid-1990s in Chongqing, Sichuan Province).⁶ A small number of prior studies analysed temporal trends in alcohol consumption in the general population of China. One study reported that the prevalence of current drinkers has increased between 2002 and 2005, whereas a longitudinal study that traced the change in drinking behaviours at the individual level found decreasing prevalence of drinkers who drink at least weekly in 2013–2014 compared with 2004–2008.^{7 8} Only one study examined the temporal trends of drinking over more than two data points (1993–2006), but did not include the most recent surveys in 2011 and 2015.⁹ To our knowledge, no study on trends in harmful drinking behaviours such as heavy drinking in the general population of China exists.

Drinking patterns vary by sociodemographic groups in China. According to the cross-sectional study on chronic disease and risk factor surveillance in 2007, male sex and higher education level were associated with higher drinking prevalence, compared with female sex and lower level of education.¹⁰ In the study, the prevalence of drinking increased by age, being at the highest level in individuals in the mid-30s to 50s. The study's approach to understand age patterns in cross-sectional data does not separate age patterns and cohort-specific trends in observed drinking behaviour over time. For example, China's increasing prevalence of heavy drinking by age in cross-sectional data may actually reflect birth cohort trends.

The increasing burden of alcohol-related harms and an ageing population at higher risk of alcohol-related chronic diseases have motivated calls to action in China.¹¹ Appropriately addressing these challenges requires an examination of age-specific and birth cohort-specific drivers of changes in heavy drinking prevalence in order to make accurate predictions of alcohol-related disease burden and to consider how best to target potential interventions. Therefore, we estimated age patterns in heavy drinking behaviours and their trends across birth cohorts among men in China, projecting their implied trends in terms of future prevalence of heavy drinking through 2027. We gauged the importance of these trends by quantifying the potential health benefit of changing heavy drinking behaviours in different age groups.

METHODS

Analysis overview

We constructed a Markov model that simulates change in drinking behaviour and heavy drinking-related deaths over time among men in each birth cohort. Using empirical calibration, we determined probabilities of heavy drinking behaviour that generate age-specific prevalence estimates consistent with the observed birth cohort-specific age trends in drinking from 1993 to 2011.^{12 13} We validated our calibration and extrapolation methods by comparing the model's prediction on the prevalence of heavy drinking in 2015 with the prevalence observed in 2015 in China. We then projected future heavy drinking prevalence in China through 2027 and estimated the maximum possible benefits of changing drinking behaviour in different age group-specific subpopulations from 2015 through 2027.

Patient and public involvement

By nature of the design of this study, which draws on secondary data collected as part of two large survey programmes and made available for academic research, patients and the public were not directly involved.

Data sources

Prevalence of drinking behaviours

We used two national surveys: the China Health and Nutrition Survey (CHNS) and the China Health and Retirement Longitudinal Survey (CHARLS). In total, we used data from nine waves of CHNS (1993–2015) and two waves of CHARLS (2011, 2015) every 3–4 years to establish our calibration and validation targets. Our study focused on heavy drinking behaviour among men. The details of data management to harmonise the two data sets are provided in online supplemental appendix 1.

Briefly, CHNS is a household panel survey that has monitored the socioeconomic and health changes of the general population every 3–4 years.¹⁴ CHARLS surveys a nationally representative sample of Chinese residents aged 45 or older on their sociodemographics, family structure, health status and healthcare utilisations every other year since 2011.¹⁵ We compared sample regions and survey populations of the two data sets in online supplemental appendix 1.

Both surveys asked respondents about their drinking frequency and quantity as well as the types of alcohol consumed in the year before the survey. Among those aged 15 and above, CHNS recorded individuals' total amount of alcohol intake per week for each type of drink (beer, grape and red wine, spirits), whereas CHARLS documented both drinking amount per occasion and frequency. In addition to current drinking behaviour, CHARLS respondents were asked about their history of drinking (have never drank more than once a month, used to drink more than once a month but currently do not drink more than once a month).

Mortality and excess mortality due to heavy drinking

In the model, current heavy drinkers have higher all-cause mortality than non-heavy drinkers. We first obtained age-specific and sex-specific overall all-cause mortality for China from the United Nations (UN) World Population Prospects.¹⁶ We then estimated excess mortality due to heavy drinking from the US National Health and Nutrition Examination Survey III follow-up study (1984–1993) using Cox proportional hazard model because there are no sufficient Chinese-specific data.^{17 18} We assumed that the overall all-cause mortality is the weighted average of all-cause mortality among non-heavy drinkers and all-cause mortality among heavy drinkers with heavy drinking prevalence in China as a weight. Based on this assumption, we decomposed the observed overall all-cause mortality in China to all-cause mortalities by heavy drinking status. We described the HR estimation and mortality decomposition in online supplemental appendix 2.

Calibration

Model structure

We constructed a Markov cohort model with four states: (1) current heavy drinker, (2) never heavy drinker, (3) former heavy drinker and (4) dead. Heavy drinking was defined as drinking an equivalent of ≥ 210 g of pure alcohol per week.² Never heavy drinkers are those who never have had any experience of heavy drinking before. Former heavy drinkers are those who currently do not drink heavily but have previously done so. Transitions from one state to another can occur annually in the model. Everyone enters the model at age 0 as never heavy drinkers and faces the risk of initiating heavy drinking from the age of 16 years onwards. Heavy drinkers have a chance of stopping their heavy drinking and becoming former heavy drinkers. Former drinkers can resume heavy drinking at different rates than the rates of initiating heavy drinking among never heavy drinkers. Mortality rates depend on age and heavy drinking status. We assumed that all transition probabilities can vary over time at age-specific and birth-cohort specific rates.

Model parameterisation

Calibration identified age-specific and birth cohort-specific probabilities of initiating or resuming heavy drinking and probabilities of quitting heavy drinking that could generate drinking prevalence consistent with the observed prevalence among Chinese men (calibration targets). Instead of directly estimating these probabilities, we estimated parameters that determine the age patterns in these probabilities.

We first identified age patterns in starting, quitting and resuming probabilities by implementing calibration where age-specific parameters were calibrated independently and the risks of initiating and resuming heavy drinking were assumed to be the same (online supplemental appendix 3). We then used four shape parameters to implement the identified age patterns: the age where a change in the direction of curve occurs,

and the probabilities at age 16 and 90, and the age at the inflection point. We also added a set of parameters to implement age patterns in the rate ratio of starting heavy drinking between former and never heavy drinkers ('alpha'). In total, we calibrated 11 parameters in each birth cohort. Further details on how shape parameters form age patterns in model parameters are described in online supplemental appendix 4.

Definition of prior distribution

We employed uniform distributions as a prior distribution on the shape parameters. The search range for the probabilities ranged from 0 to the maximum of those identified in estimating age patterns in the first step (online supplemental appendix 3). The hazard rate ratio of initiating heavy drinking was bounded between 1 and 10. We sampled the age at the inflection point between ages 20 and 50. Prior distributions on the shape parameters are summarised in online supplemental appendix 4.

Calibration target data and data likelihood

We employed two sets of calibration targets: (1) age-specific and birth cohort-specific prevalence of heavy drinkers over 18 years (1993–2011) from CHNS and CHARLS; and (2) prevalence of never heavy drinkers and former heavy drinkers in 2011 from CHARLS. We included birth cohorts who were born between 1922 and 1993.

For our first set of calibration targets, we constructed longitudinal observations of heavy drinking prevalence in each birth cohort from 1993 to 2011 (figure 1A). We combined the estimates in 2006 and 2009 from CHNS to follow up prevalence in a 4-year interval the estimates in 2011 when both CHNS and CHARLS are available (online supplemental appendix 1). In order to smooth the fluctuations in our birth cohort-specific targets, we fit polynomial curves to them (online supplemental appendix 5).

For our second set of calibration targets, we estimated the prevalence of never heavy drinkers and former heavy drinkers in 2011 from CHARLS. We counted those who have never drunk more than once a month and those who currently drink less than once a month but used to drink more than once a month in the past as never heavy drinkers and former heavy drinkers, respectively. Because drinking history data are available only for individuals aged 45 years and older, we imputed these calibration targets in birth cohorts younger than 45 years in 2011. We applied the proportion of never (former) heavy drinkers among non-heavy (never and former) drinkers in the reference birth cohort 1962–1965 (equivalent to 48–51 in 2011) to the prevalence of non-heavy drinkers in other birth cohorts whose drinking history data are not missing. Our imputation method is described in online supplemental appendix 6.

The likelihood of the observed data, given the model outcomes, was taken to be beta-distributed and centred on the model outcomes. By assuming that the likelihood of prevalence is independent across ages and different

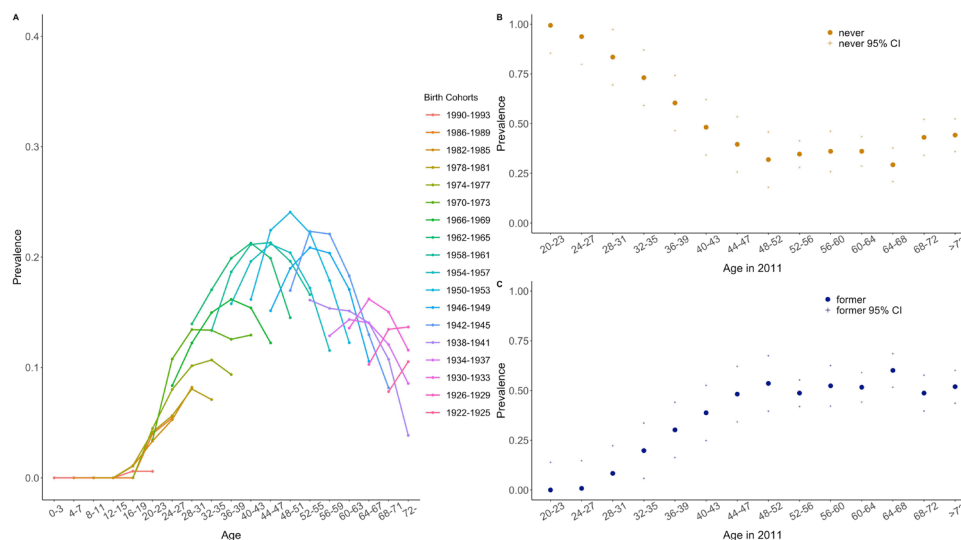


Figure 1 Age-specific and birth cohort-specific prevalence of (A) heavy drinking from 1993 to 2011, (B) never heavy drinkers in 2011 and (C) former heavy drinkers in 2011.

targets, we calculated overall likelihood of target data given a sampled parameter set by multiplying individual likelihoods.

Sampling from posterior distribution

In order to approximate the joint posterior distribution, we implemented sampling-importance resampling (SIR) in Python.^{12 13 19} After drawing 500 000 sets of parameters from the prior distributions and then calculating the likelihood of the target data given sampled parameters, we resampled parameters with replacement using the normalised likelihood as a sampling weight. We described further details of our SIR calibration in online supplemental appendix 7.

Predictive validity

We validated our calibration results and method for extrapolating them to future projections by comparing the model's projections of the age-specific prevalence of current, never and former heavy drinkers in 2015 against the observed prevalence in 2015. We fit an exponential function to the historical time trend in the calibrated age-specific rates of initiating, resuming and quitting heavy drinking between 1993 and 2011 and used the function to extrapolate the birth cohort's rates after 2011. The extrapolated rates were transformed back to probabilities before employing them in the model (online supplemental appendix 8).

Future projections

We projected overall and age-specific prevalence of heavy drinking through 2027. We extrapolated the rates of heavy drinking using the same method as in the validation step. In the simulations, we used the UN's projections of future mortality rates.¹⁶ Once completing simulation of prevalence in each birth cohort, we calculated overall prevalence of heavy drinking by weighting the modelled

age-specific prevalence by the size of the age group projected by the UN's World Population Prospects.¹⁶

Potential benefits of changing heavy drinking behaviours in age-specific subpopulations

To estimate the maximum potential benefits of mitigating heavy drinking, we made counterfactual projections where we drastically changed the heavy drinking behaviours including initiating, resuming or quitting heavy drinking for individuals in broad age categories (16–35 years; 36–55 years; or 56 years or older) from 2015 through 2027. For example, under one such hypothetical scenario, current or former heavy drinkers aged 36–55 years in any year between 2015 and 2027 will not start or resume heavy drinking. Another hypothetical scenario would involve all current heavy drinkers in a given age range immediately quitting heavy drinking. For each heavy drinking behaviour and age group, we computed changes in the projected prevalence of heavy drinking and the number of deaths from 2015 through 2027.

RESULTS

Age patterns and birth cohort trends in the observed prevalence of heavy drinking

Between 1993 and 2011, for most birth cohorts of Chinese men observed in their 30s–50s, the prevalence declined in later calendar years (figure 1A). This led to the age of peak prevalence being at earlier ages for the more recent birth cohorts (eg, born in 1966–1969) relative to older birth cohorts (eg, born in 1942–1945). At similar ages, younger birth cohorts had lower prevalence in their 20s–40s than older birth cohorts; this pattern was opposite for birth cohorts observed in their 50s–60s.

For birth cohorts who were born before 1965 (ie, aged 48 years and older in 2011) in CHARLS, the prevalence of never heavy drinkers and former heavy drinkers was

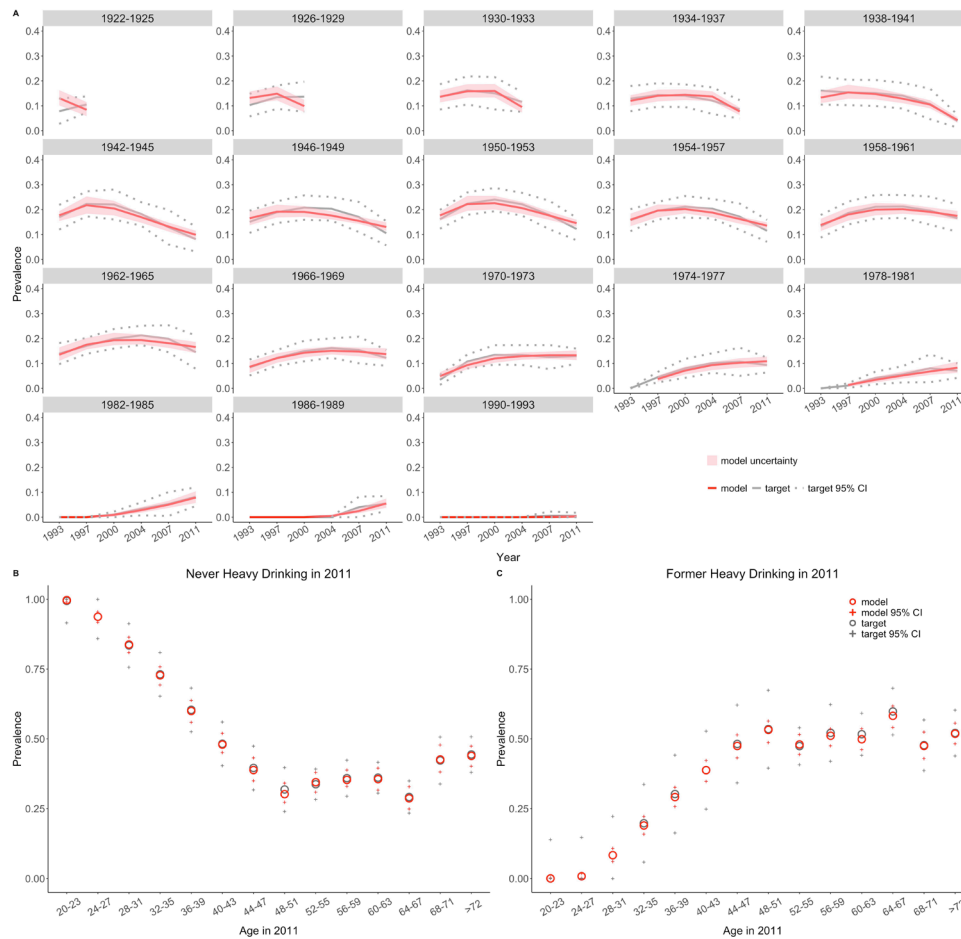


Figure 2 Calibration fit to the observed prevalence of (A) heavy drinking from 1993 to 2011 by birth cohort, (B) never heavy drinkers in 2011 and (C) former heavy drinkers in 2011.

approximately 40% and 50%, respectively (figure 1B,C). Across the age groups, there was no statistically significant difference. The extrapolated prevalence of never heavy drinkers and former heavy drinkers among men younger than 48 years monotonically decreased and increased by age, respectively.

Calibration and validation

By calibrating age-specific and birth cohort-specific probabilities of initiating and quitting heavy drinking, we reproduced the prevalence of heavy drinkers, never heavy drinkers and former heavy drinkers consistent with the observed prevalence in the past 18 years for all birth cohorts (figure 2). The calibrated models and extrapolated model parameters validated well in comparison with the observed prevalence of current, never and former heavy drinkers in 2015 (figure 3).

Age patterns and temporal trend in calibrated drinking probabilities

The probability of initiating heavy drinking rose up to ages 32–56 and fell afterwards within each of the birth cohorts (figure 4). The age with the highest risk of initiating heavy drinking varied by birth cohorts. For example, the risk was highest at the age of 28–31 years in the 1962–1965 birth cohort, whereas the 1974–1977

birth cohort had its peak at the age of 24–27 years. The probability of quitting heavy drinking was lowest in that age group and had more birth cohort variation than in initiating probabilities. The probabilities of resuming had similar age patterns with those who had probabilities of initiating heavy drinking. We presented the uncertainty in the estimated probabilities of heavy drinking in online supplemental appendix 9.

In general, all age groups had decreasing probabilities of starting and resuming heavy drinking from 1993 through 2011, especially among men younger than 28 years old (figure 5A,B). This trend resulted in a projected decline in the probabilities of starting and resuming heavy drinking in the future. The probabilities of quitting heavy drinking among middle-aged men (32–35 years) increased over this period (figure 5C). Future trend in quitting heavy drinking probabilities varied by age.

Future projection

Our model projected that the overall prevalence of heavy drinking among men will continue to decrease through 2027 (figure 6A). Historically, heavy drinking prevalence increased from 1993 through 2000 and started to decrease through 2015. From 2015 when the model assumed continuation of past trends in starting,

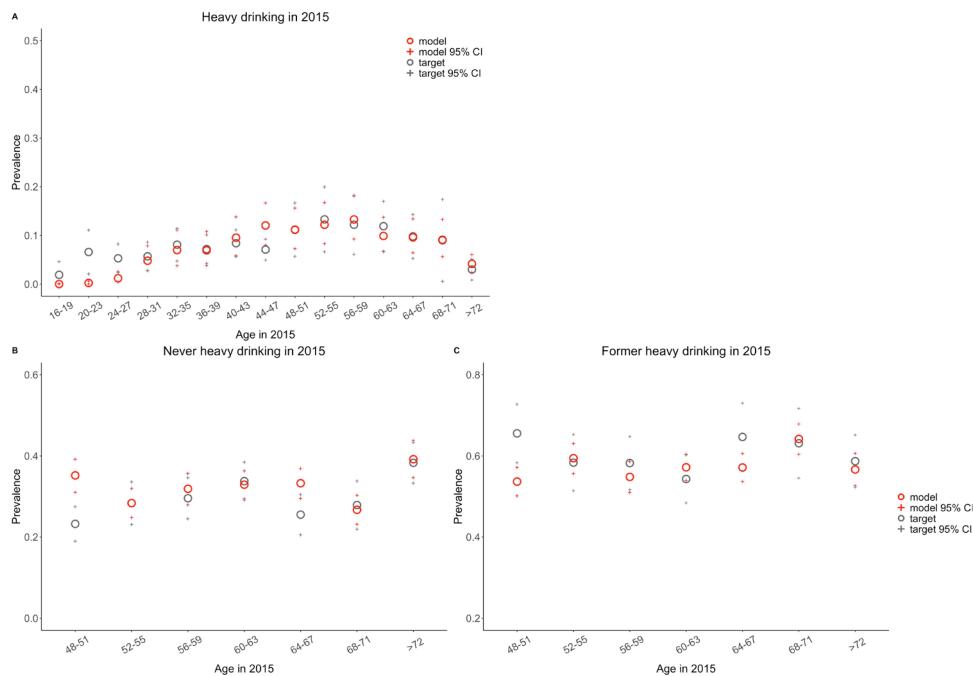


Figure 3 Validation fit to the observed prevalence of (A) heavy drinking, (B) never heavy drinkers and (C) former heavy drinkers in 2015.

quitting and resuming heavy drinking, the prevalence was projected to decrease by 33% through 2027 (from 5.8% to 3.8%). Uncertainty in the projected prevalence in 2027 ranged from 2.9% to 5.0%, implying a high likelihood of decline but a wide uncertainty range over the magnitude of decline. Uncertainty in the future projection carried out both uncertainty in estimates of heavy

drinking prevalence in the past due to limited sample size and uncertainty in the extrapolated trends among them.

Given birth cohort trends in age-specific probabilities of initiating, resuming and quitting heavy drinking, the model predicted different time trends in age-specific prevalence (figure 6B). The prevalence of heavy drinking is expected to decrease in all age groups except for the

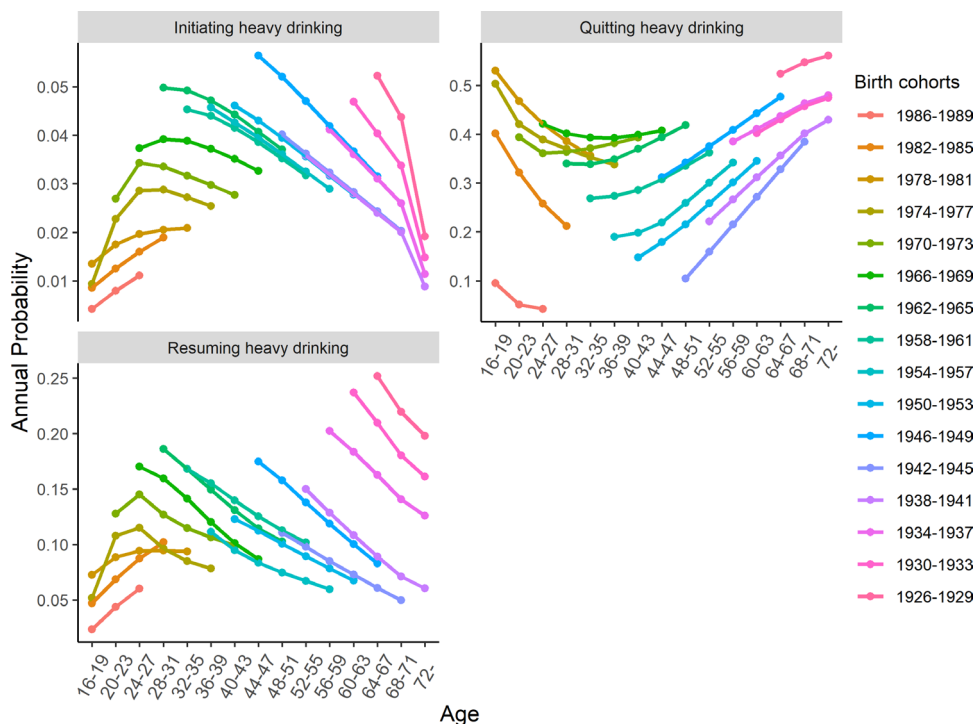


Figure 4 Age patterns in the calibrated probabilities of three heavy drinking behaviours; initiating, resuming and quitting heavy drinking.

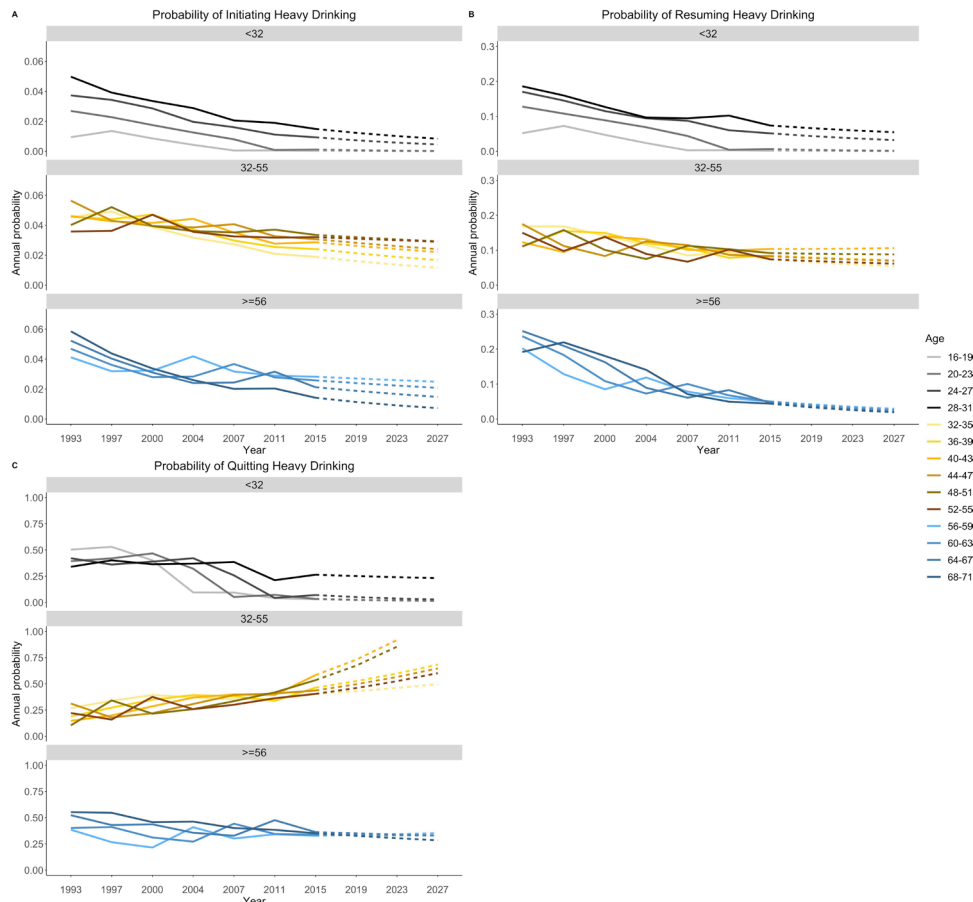


Figure 5 Time trends in the calibrated probabilities of three heavy drinking behaviours: (A) initiating heavy drinking, (B) resuming heavy drinking and (C) quitting heavy drinking.

16–19 years old group. The decline was smallest in the oldest ages (18%) and largest in the 20–23 years old group (67%).

Reduced burden of heavy drinking due to hypothetical changes in the risks of heavy drinking in age-specific subpopulations

Mitigating heavy drinking behaviours has substantial potential to accelerate declines in heavy drinking prevalence, especially when it changes the behaviours that the considered age groups are unlikely to otherwise change.

For example, compared with no change in behaviours, the overall prevalence of heavy drinking decreased by 12 percentage points in total from 2015 through 2027 (average annual reduction: 3 percentage point) in the hypothetical scenario where men in their mid-30s to mid-50s halt resuming heavy drinking (figure 7). On the other hand, halting resuming heavy drinking did not yield substantial reduction in prevalence in the younger age group (16–35 years) whose former heavy drinking is less prevalent than other age groups. In this age group,

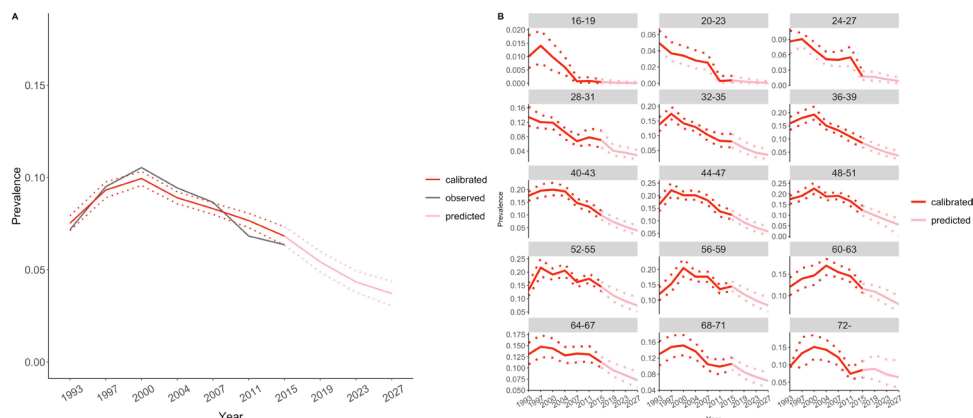


Figure 6 Prediction of future heavy drinking prevalence: (A) overall and (B) age-specific prevalence of heavy drinking.

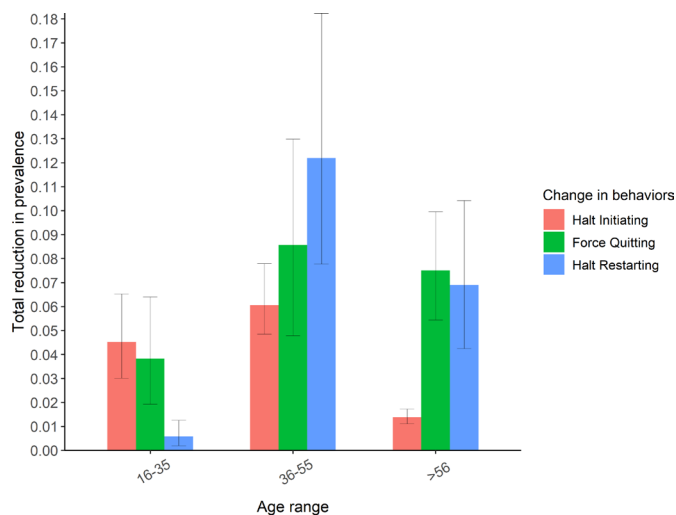


Figure 7 Change in prevalence of heavy drinking with hypothetical changes in heavy drinking behaviours for various age groups from 2015 through 2027.

halting initiating and quitting heavy drinking resulted in larger reductions in prevalence (0.045 and 0.038, respectively) than halting resuming heavy drinking (0.005).

We also found that modifying current heavy drinking behaviours or preventing future heavy drinking behaviours can avert substantial number of deaths through 2027 (figure 8). If men who are older than 56 years old quit their heavy drinking or halt resuming heavy drinking, 373 000 and 377 000 deaths can be averted over this period. Halting initiating heavy drinking in this age group was not effective in averting deaths as most in this subpopulation already have had the prior experience of heavy drinking or else have not but are not likely to initiate heavy drinking at more advanced ages. The mortality benefit in the younger age group (16–35 years) was smaller than the other two age groups, although we note life expectancy gains for each death

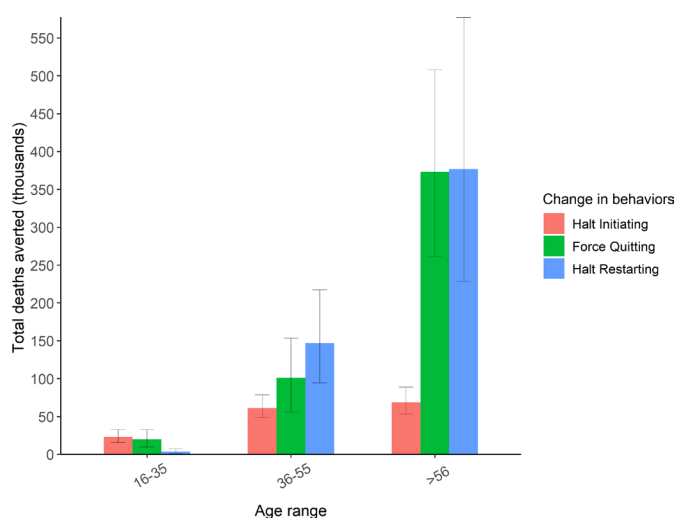


Figure 8 Change in deaths from all causes with hypothetical changes in heavy drinking behaviours for various age groups from 2015 through 2027.

averted would be larger for younger individuals relative to older individuals.

DISCUSSION

Our study found that Chinese men in recent years are less likely to engage in heavy drinking because they are initiating or resuming heavy drinking less frequently and are more likely to quit heavy drinking than equivalently aged men in previous years. Increased access to primary care after the healthcare reform and enhanced education level among the general population may have led to avoiding high-risk health behaviours and seeking healthier lifestyles compared with the past.^{10 20}

We also found that middle-aged men are more likely to engage in high-risk drinking compared with other ages. Such age patterns in the calibrated probabilities of heavy drinking behaviours resulted from the equivalent age pattern in the observed heavy drinking prevalence. Similar age patterns were observed in an external data set according to a study that estimated binge drinking prevalence among Chinese men using 2007 risk factor surveillance data.¹⁰ Increase and decrease in frequency and/or intensity of drinking around the mid-40s could be explained by a unique culture in China: teenagers and young adults focus on their education, whereas middle-aged men encounter social and work-related occasions that encourage excessive drinking.^{10 21}

The decreasing trend in the projected heavy drinking prevalence through 2027 is consistent with the decline in the prevalence of male heavy drinking in China which began in 2000. Of note, the CHNS data set and other studies have shown recent upward trends in current drinkers among men, which implies that more Chinese men who had never drank before are starting to drink in recent years but at lower intensity levels (online supplemental appendix 10).³ However, recent increase in total alcohol per capita consumption in China may imply that heavy drinkers in the future consume even larger amounts of alcohol, further increasing their risks for alcohol-related harms.^{5 8}

Given its predictive validity, the model has the capacity to gauge potential effects of age-based targeting interventions. There are several alcohol policies to regulate production and advertisement of alcohol products in China, but they are not currently targeted to age groups based on their risks and potential to benefit.⁴ In order to effectively reduce the burden of alcohol-related harm, it is important to understand in which groups high-risk drinking behaviours are concentrated and how they change over time. Our model showed that changing current heavy drinking among men had a high potential to reduce heavy drinking prevalence and avert alcohol-related deaths. The optimal age groups to target can vary depending on the choice of intervention effect measures (life expectancy, quality-adjusted life years), cost of implementation and resistance to change drinking behaviour in the target group. Our model can be expanded to

consider these factors when optimising the targeting of more realistic alcohol policies in China.

This study has several limitations. First, we assumed complete follow-up and consistent replacement for lost-to-follow-up in the longitudinal CHNS data. Although attrition in CHNS was substantial, crude heavy drinking prevalence is close between the remaining individuals in the sample and those sampled to replace those lost to follow-up in most years (online supplemental appendix 11). Because drinking frequency and amount were self-reported, there is a possibility of under-reporting. Although it is feasible to model change in reporting patterns over time, it requires detailed data on cause-specific deaths in order to identify the true state of drinking. However, in China, social drinking is generally acceptable among men, implying a low risk of under-reporting in the data set.²¹ Our analysis made a simplifying assumption that former heavy drinkers have the same all-cause mortality as never heavy drinkers. Underestimation of mortality in former heavy drinkers can affect the level of rates of heavy drinking estimated in the model: higher rate of resuming heavy drinking and lower rate of quitting heavy drinking than when excess mortality with the history of heavy drinking is considered. It is also important to interpret our future projections in terms of what is predicted to happen without additional interventions. For example, a policy to reduce tax on alcoholic beverages can bring a sharp increase in heavy drinking prevalence in the future.

CONCLUSION

By applying calibration technique to longitudinal data, we identified unique patterns in heavy drinking behaviours over age and generations among Chinese men. Future policies to mitigate harmful alcohol use should consider age-based risk of engaging in harmful drinking, specifically focusing on preventing initiation of heavy drinking in young men and encouraging quitting heavy drinking in middle-aged and elderly men in order to accelerate reducing the burden of alcohol use.

Twitter Kyueun Lee @KyuQLee

Contributors KL and JG-F were involved in initial conceptualisation and methodology development. KL cleaned and analysed the data. KL constructed a mathematical model. KL and JG-F contributed to the first draft of the manuscript. KL, JG-F and JS contributed to study design, interpretation of results, development of visualisations, writing and editing. JG-F and JS were involved in validation of results and conclusions. All authors have read and approved the final draft of the manuscript. All authors had access to all data in the study and had final responsibility for the decision to submit for publication. The corresponding author attests that all listed authors meet the authorship criteria and that no others meeting the criteria have been omitted.

Funding The authors received no funding specifically for this work and have declared that no competing interests exist. KL receives support for her PhD research as a Society of Medical Decision Making Fellow that is funded by the Gordon and Betty Moore Foundation (<https://smdm.org>) and Graduate Student Fellow from Stanford King Center on Global Development (<https://kingcenter.stanford.edu/>). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funders.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. All data used in the analysis are available to academic researchers through China Health and Nutrition Survey (CHNS) and China Health and Retirement Survey (CHARLS) websites.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID ID

Kyueun Lee <http://orcid.org/0000-0002-0013-4733>

REFERENCES

- Griswold MG, Fullman N, Hawley C, *et al*. Alcohol use and burden for 195 countries and territories, 1990–2016: a systematic analysis for the global burden of disease study 2016. *Lancet* 2018;392:1015–35.
- Center for Disease Control and Prevention. Fact sheets - alcohol use and your health [online]. Available: <https://www.cdc.gov/alcohol/fact-sheets/alcohol-use.htm>
- World Health Organisation. Global status report on alcohol and health 2018 [online], 2018. Available: <http://apps.who.int/iris/bitstream/handle/10665/274603/9789241565639-eng.pdf?ua=1>
- Guo X, Huang Y-G, Huang YG. The development of alcohol policy in contemporary China. *J Food Drug Anal* 2015;23:19–29.
- Jiang H, Room R, Hao W. Alcohol and related health issues in China: action needed. *Lancet Global Health* 2015;3:e190–1.
- Tang Y-lang, Xiang X-jun, Wang X-yi, *et al*. Alcohol and alcohol-related harm in China: policy changes needed. *Bull World Health Organ* 2013;91:270–6.
- Zhang J, Casswell S, Cai H. Increased drinking in a metropolitan City in China: a study of alcohol consumption patterns and changes. *Addiction* 2008;103:416–23.
- PK I, Millwood IY, Guo Y. Patterns and trends of alcohol consumption in rural and urban areas of China: findings from the China Kadoorie Biobank 11 medical and health sciences 1117 public health and health services. *BMC Public Health* 2019;19:1–13.
- Ma Y, Zhang B, Wang H. Status and trend in alcohol consumption among adults in nine provinces (autonomous region) of China from 1993 to 2006. *Zhonghua Yu Fang Yi Xue Za Zhi* 2011;45:323–9.
- Li Y, Jiang Y, Zhang M, *et al*. Drinking behaviour among men and women in China: the 2007 China chronic disease and risk factor surveillance. *Addiction* 2011;106:1946–56.
- Wang L, Kong L, Wu F, *et al*. Preventing chronic diseases in China. *Lancet* 2005;366:1821–4.
- Kennedy MC, O'Hagan A, O'Hagan A. Bayesian calibration of computer models. *J R Stat Soc Ser B* 2001;63:425–64.
- Menzies NA, Soeteman DI, Pandya A, *et al*. Bayesian methods for calibrating health policy models: a tutorial. *Pharmacoeconomics* 2017;35:613–24.
- Popkin BM, Du S, Zhai F, *et al*. Cohort profile: The China Health and Nutrition Survey-monitoring and understanding socio-economic and health change in China, 1989–2011. *Int J Epidemiol* 2010;39:1435–40.
- Zhao Y, Hu Y, Smith JP, *et al*. Cohort profile: the China health and retirement longitudinal study (CHARLS). *Int J Epidemiol* 2014;43:61–8.
- United Nations, Department of Economic and Social Affairs PD. World Population Prospects 2019 [online], 2019. Available: <https://population.un.org/wpp/>



- 17 Liu S, Cipriano LE, Holodny M. *New protease inhibitors for the treatment of chronic hepatitis C: a cost-effectiveness analysis*, 2016.
- 18 Yang L, Zhou M, Sherliker P, *et al*. Alcohol drinking and overall and cause-specific mortality in China: nationally representative prospective study of 220 000 men with 15 years of follow-up. *Int J Epidemiol* 2012;41:1101–13.
- 19 Rubin DB, Bernardo JM, DeGroot MH. Using the SIR algorithm to simulate posterior distributions. In: *Bayesian statistics*. 3rd edn. Oxford: Oxford University Press, 1988: 395–402.
- 20 FB H, Liu Y, Willett WC. Preventing chronic diseases by promoting healthy diet and lifestyle: public policy implications for China. *Obes Rev* 2011;12:552–9.
- 21 Hao W, Young D. Drinking patterns and problems in China. *J Subst Use* 2000;5:71–8.