

The stability of baseline-defined categories of alcohol consumption over the adult life course: a 28-year prospective cohort study.

Craig S Knott;^{1,2} Steven Bell;^{1,3} Annie Britton.¹

¹*Research Department of Epidemiology and Public Health, 1-19 Torrington Place, University College London, London, WC1E 7HB.*

²*MRC Epidemiology Unit and Centre for Diet and Activity Research (CEDAR), University of Cambridge School of Clinical Medicine, Cambridge Biomedical Campus, CB2 0QQ.*

³*Department of Public Health and Primary Care, Strangeways Research Laboratory, University of Cambridge, Worts Causeway, Cambridge CB1 8RN, UK.*

Corresponding author: Craig Knott, csk37@medschl.cam.ac.uk.

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Ethics approval

The University College London Medical School Committee on the ethics of human research approved the Whitehall II study.

Availability of data and materials

Whitehall II data are available to bona fide researchers for research purposes. Please refer to the Whitehall II data sharing policy at <http://www.ucl.ac.uk/whitehallII/datasaring>.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CK, SB and AB were co-conceivers of the research question. CK carried out the analysis and completed the first draft of the manuscript. SB and AB provided additional intellectual content and technical assistance. All authors saw and agreed on the final submitted manuscript. CK is the guarantor, having final responsibility for the decision to submit for publication.

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Abstract

Background and aims

Studies that report the relationship between alcohol consumption and disease risk have predominantly operationalised drinking according to a single baseline measure. The resulting assumption of longitudinal stability may be simplistic and complicate interpretation of risk estimates. This study aims to describe changes to the volume of consumption across the adult life course according to baseline categories of drinking.

Design

A prospective observational study.

Setting

A cohort of British civil servants.

Participants

A total of 6,838 men and 3,372 women aged 34-55 years at baseline, followed for a mean 19.1 (SD 9.5) years.

Measurements

The volume of weekly alcohol consumption was estimated from data concerning the frequency and number of drinks consumed. Baseline categories were defined: non-current drinkers, infrequent drinkers, 0.1-50.0 g/week, 50.1-100.0 g/week, 100.1-150.0 g/week and 150.1-250.0 g/week, >250.0 g/week. For women, the highest category was defined as >100.0 g/week. Baseline frequency was derived as 'daily or almost daily' and 'not daily or almost daily'. Trajectories were estimated within baseline categories using growth curve models.

Findings

Trajectories differed between men and women, but were relatively stable within light-to-moderate categories of baseline consumption. Drinking was least stable within the highest categories of baseline consumption (men: >250.0 g/week; women: >100.0 g/week), declining by 47.0 (95% CI [40.7, 53.2]) and 16.8 g/week (95% CI [12.6, 21.0]) respectively per 10-year increase in age. These declines were not a consequence of sudden transitions to complete abstinence. Rates of decline appear greatest in older age, with trajectories converging toward moderate volumes.

Conclusion

Consumption within baseline drinking categories was generally stable across the life course, except among heavier baseline drinkers, for whom intakes declined with increasing age. This shift does not appear to be driven by transitions to non-drinking. Cohorts of older people may be at particular risk of misclassifying former heavy drinkers as moderate consumers of alcohol.

Keywords

Alcohol consumption, drinking, trajectories, longitudinal study, misclassification error

Introduction

An extensive body of research has explored the dose-response association between alcohol consumption and assorted negative health events.^{1,2,3,4} However, the majority of existing studies have operationalised drinking according to a single baseline measure of self-reported alcohol consumption. For instance, of the 38 longitudinal studies analysed as part of a recent meta-analysis into the effect of drinking upon the risk of type 2 diabetes,² only one had utilised data from subsequent phases of follow-up.⁵ In doing so, constituent studies assume that drinking is stable over the period of follow-up, but there is reason to doubt this. As detailed elsewhere,^{6, 7} alcohol consumption appears to vary markedly as a function of age, with disparate trajectories reported across the adult life course. As noted by a meta-analysis of alcohol consumption and cardiovascular disease,¹ the cross-sectional categorisation of participants into drinking categories risks providing a poor operationalization of consumption over the life course, particularly in studies of longer duration.

While the limitations of single alcohol measures have been discussed within the literature, much of the focus has been directed toward the need to reliably disaggregate heterogeneous non-drinkers^{8,9} and infrequent drinkers⁹ owing to their disparate risks of assorted health conditions.^{10,11} Such discussions overlook the risk of misclassification error among current drinkers whose alcohol consumption changes as a function of age.⁷ At least three studies have reported the longitudinal stability of intake within baseline-defined categories of drinking, with each having pooled heterogeneous groups of infrequent and non-drinkers and modelled changes as a function of follow-up time.^{12,13,14} An understanding of how alcohol consumption varies within a broad spectrum of disparate drinking groups is therefore limited, especially within a life course context.

To elaborate upon the issue, this study aimed to (a) quantify the stability of drinking across the adult life course according to baseline categories of consumption, and (b) establish the presence of a sex interaction, given sex-specific differences in the mean trajectory of consumption across the adult life course.⁷ The study also includes two post-hoc analyses. The first reports within-category differences in the trajectory of alcohol consumption according to the frequency of baseline consumption, owing to a greater regularity of drinking with increasing age¹⁵ and the possibility this may be associated with the volume of consumption. The second describes changes to the probability of transition from drinking to non-drinking across the adult life course. This final analysis tackles a limitation of the primary analyses, which estimate mean drinking trajectories and so provide no indication as to how participants transition between drinking categories with increasing age. Such analysis help reveal whether declining trajectories occur as a consequence of a general decrease in consumption, or a sudden transition among some constituent drinkers to complete abstinence.

Methods

Design

The Whitehall II cohort was established in 1985 and enlisted 10,308 (6,895 male and 3,413 female) civil servants aged 34-55 years who worked in the offices of 20 Whitehall departments.¹⁶ Initial measurements were obtained between 1985 and 1988 via a self-administered questionnaire and clinical examination. Participants were then followed up at regular intervals to produce 11 phases of data by 2012–13. The University College London Medical School Committee on the ethics of human research approved the Whitehall II study. Whitehall II data are available to bona fide researchers for research purposes. Please refer to the Whitehall II data sharing policy at <http://www.ucl.ac.uk/whitehallII/datasharing>.

Measures

Drinking data were extracted from all phases at which alcohol consumption questions were incorporated: phases one (1985–88), two (1989–90), three (1991–93), five (1997–99), seven (2003–04), nine (2007–09) and 11 (2012–13). Participants were asked to report the frequency with which they consumed alcohol over the year preceding interview. This information was used to derive a baseline frequency variable: ‘daily or almost daily’ and ‘not daily or almost daily’.

Those who reported drinking alcohol during the preceding year were then asked to declare the number of alcoholic drinks they had consumed in the week prior to interview according to “measures” of spirits, “glasses” of wine, or “pints” of beer or cider. A conservative 8 g of alcohol is assumed per measure of spirits or glass of wine, and 16 g for each pint of beer or cider. Measurements were aggregated to derive the total grams of alcohol consumed in the week prior to interview among current drinkers.

Baseline consumption categories were defined using volume and frequency data reported at phase one: non-current drinkers (no alcohol consumption throughout the year prior to interview), infrequent drinkers (consumed alcohol in the year preceding interview but did not drink in the week prior to measurement), 0.1-50.0 g/week, 50.1-100.0 g/week, 100.1-150.0 g/week, 150.1-250.0 g/week and >250.0 g/week. For women, among whom the volume of alcohol consumption was lower, the top drinking categories were merged (>100.0 g/week).

Statistical analysis

Primary analyses

Age in years was selected as the timescale, scaled to the minimum age at baseline (34.1 years). Sensitivity analyses are also reported that used follow-up in years as the timescale.

The linear mean trajectory of alcohol consumption was estimated for each baseline drinking category using linear growth curve models via the `-mixed-` command in Stata 13.¹⁷ To determine whether the longitudinal trajectories differed significantly between men and women, a three-way interaction was modelled in the first instance between sex, baseline consumption category and age.

Owing to the degree of variability in alcohol consumption present within and between individuals, both random intercepts and random slopes were permitted and covariance between repeated measures allowed to take any form. Additionally, given that alcohol consumption was positively skewed, robust standard errors were calculated to avoid applying a transformation and thereby aid interpretability.

Non-linear trajectories were explored by subjecting age to a restricted range of fractional polynomial transformations (x^{-2} , x^{-1} , $x^{-0.5}$, $\ln(x)$, $x^{0.5}$, x^1 , x^2 and x^3), which permit the modelling of monotonic and non-monotonic relationships between alcohol consumption and age.¹⁸ The fit of each transformation was assessed according to the Bayesian information criterion (BIC).¹⁹ Owing to a lack of convergence when some non-linear transformations were applied, BICs were calculated for simplified models that constrained to zero any covariance between repeated measures. An improvement in fit relative to a linear model was defined as any reduction in the BIC greater than or equal to a value of 10, which is described as a strong indicator of an improvement to model specification.²⁰ The best-fitting trajectory for each baseline category was then plotted allowing random effects and an unstructured covariance matrix, per the primary linear models.

Given the risk of selection bias in circumstances where underlying missingness mechanisms are informative, a chained equations imputation model was created under the assumption that missing drinking data were predictable from observed covariates.^{21,22} Using the `-mi-` package,²³ missing data for participants who were lost to follow-up or else provided no response to the alcohol consumption questions of interest were predicted from a range of demographic, socio-economic, health and lifestyle characteristics. A total 50 imputations were run to be sure of appropriately capturing the degree of uncertainty surrounding the predicted values, with iterations run for each imputation until predicted values reached convergence. The imputation model excluded missing data for phases of observation on or after any documented date of death. Finally, to ensure that the estimation sample was consistent between imputations, baseline consumption categories were defined using the observed data only, with imputed volumes of alcohol consumption then predicted for all follow-up phases.

Post-hoc analyses

The first post-hoc analysis restricted the primary linear models to current drinkers, then included a three-way interaction between age, baseline consumption category and baseline consumption frequency.

For the second post-hoc analysis, logit models were constructed to estimate the probability of transition to non-drinking across the life course within each baseline category of current drinkers. Sex-specific binary variables were coded for each such category according to whether or not constituent participants had transitioned to non-drinking at a given phase of observation. The `-xtlogit-` command was used to predict the probability of transition to non-drinking within each baseline consumption category, with the predicted probabilities then plotted as a function of age.²⁴

Results

Descriptive statistics

Of the 72,156 potential person-observations captured over seven phases of follow-up, 4.8% (n=3,432) were missing due to mortality and 18.8% (n=13,563) were lost to follow-up. Of the 55,161 valid person-observations, 0.9% (n=481) were missing due to item non-response at baseline, and 3.3% (n=1,823) missing due to missing volume data between phases.

The weekly volume of alcohol consumption was thus measured from baseline across 36,349 person-observations among men and 16,208 person-observations among women, as reported by 6,838 and 3,372 participants respectively. Participants were aged 34.1-56.3 years at baseline and followed for a mean 19.1 (SD 9.5) years, capturing consumption across a period of the adult life course ranging from 34.1-83.6 years of age. Relative to categories of current drinkers, baseline non-drinkers were more likely to be of non-white ethnic background, in fair or poor health, low occupational grade, physically active or current smokers (Appendix 1).

Linear growth curve models

A three-way interaction between sex, baseline consumption category and age revealed differences between men and women in both the volume of consumption within each category at baseline ($p < 0.001$) and the category-specific rates of change with increasing age ($p < 0.001$). Accordingly, sex-specific results are hereafter reported.

Among men and women, a total 12.2% and 10.0% of variability in alcohol intake was explained by within-subject changes with increasing age. Consumption changed within a number of baseline consumption categories over the adult life course, with slopes appearing to converge toward moderate levels (Table 1, Figure 1).

<Insert Figure 1 here>

The magnitude of these changes was most pronounced among participants within the highest baseline categories (men: >250.0 g/week; women: >100.0 g/week), where the volume of consumption fell by an average 47.0 g/week (95% CI [40.7, 53.2]) among men and 16.8 g/week (95% CI [12.6, 21.0]) among women per 10-year increase in age (each calculated as the coefficient for the average rate of change per decade increase in age within the referent category, plus the group specific change per decade increase in age). Changes within most other categories were comparatively small, indicating that light and moderate categories of baseline alcohol consumption were largely stable during the period of the life course captured by the Whitehall II study. Longitudinal trends between baseline categories were comparable when follow-up time was adopted as the timescale, with adjustment for date of birth (Appendix 2).

<Insert Table 1 here>

Results based upon the imputed dataset are reported in Appendix 3. Relative to the complete-case model (Table 1), baseline volumes of alcohol consumption were slightly higher within each drinking category, with rates of change shifted consistently toward the negative.

Non-linear growth curve models

Non-linear slopes provided an improvement in fit for all but male and female baseline non-drinkers, for whom drinking remained stable with age. In addition to the gradual convergence toward moderate volumes of consumption evident in Figure 1, the non-linear trajectories show that consumption within all baseline categories of current drinking declined from around 60-65 years of age onwards (Figure 2).

<Insert Figure 2 here>

Consumption frequency

Appendix 4 reports results from analyses that included a three-way interaction between age, baseline category of drinking volume, and baseline consumption frequency. Despite within-category differences in the volume of consumption at baseline according to whether or not participants reported drinking on a 'daily' or 'almost daily' basis, there was no difference in the rate of change across the adult life course by frequency.

Transitions to non-drinking

As shown in Figure 3, the likelihood of transition to abstinence increased as a function of age among all baseline categories except infrequent drinkers, indicating that current drinkers were most likely to stop drinking in older age. Interestingly, despite participants within the heaviest baseline drinking categories (men: >250.0 g/week; women: >100.0 g/week) exhibiting the greatest rates of decline in mean consumption with increasing age (Figure 1), the probability of transition to non-drinking remained consistently low across the adult life course.

<Insert Figure 3 here>

Discussion

This study investigated the stability of alcohol consumption categories across the adult life course, when defined according to a single measure recorded at baseline. Over a period of 50 years, intakes within baseline-defined consumption categories were found to vary in a manner concordant with results from at least two other studies, whereby less longitudinal stability present within higher categories of baseline consumption as a function of follow-up time.^{13,14} This was in contrast to a study of five-year changes to alcohol consumption among post-menopausal women, where the proportion of transitions between categories of current drinkers were roughly equivalent regardless of the volume consumed at baseline.¹³

Results from the post-hoc logit models indicate that downward trajectories observed among heavier baseline drinkers (men: >150.0 g/week; women: >100.0 g/week) were unlikely to have been a consequence of sudden transitions to complete abstinence, but of a general reduction in drinking with increasing age. Reasons for this attenuation are likely to be complex, including a response to declining health or a proactive health precaution.^{25,26} This longitudinal convergence of drinking trajectories with increasing age suggests that the categorisation of drinkers using a single baseline measure may be especially problematic when applied to cohorts of older populations. Specifically, with higher volumes of alcohol consumption associated elsewhere with an increased risk of adverse health conditions,^{27,28} the misclassification of former heavy drinkers as moderate consumers may lead to an overestimation of risk among older moderate drinkers. This convergence may explain why reductions in the risk of coronary heart disease²⁹ or all-cause mortality³⁰ at moderate volumes of consumption appear less pronounced within adults who were older at baseline.

The tendency of observational studies to model drinking according to only a single measure of exposure thus ignores changes to alcohol intake across the life course and the possible effect of such variation on disease risk. For example, in an analysis of type 2 diabetes risk, a significant interaction is reported between the volume of consumption at baseline and changes to exposure over time,¹⁴ whereby reductions in risk are only apparent among moderate drinkers (<15 g/day) who increased their consumption over time. A similar finding has been reported for coronary heart disease.³¹ Elsewhere, study participants who drank heavily during early adulthood exhibit a greater risk of metabolic syndrome and common cardiovascular risk factors relative to participants with stable trajectories of consumption,³² with less stable drinking trajectories having been associated with a higher risk of mortality irrespective of average consumption.³³

Such papers illustrate how the direction and timing of longitudinal changes to drinking behaviour across the adult life course may represent important modifiers of disease risk that are largely overlooked by contemporary research. Although the number and frequency of repeated measures reported by existing studies are variable, and no study is yet to capture drinking behaviours across the whole adult life course,^{7,34} the use of repeated measures is important if differences in risk between heterogeneous consumption trajectories are to be better understood and sensitive periods identified during which particular alcohol consumption behaviours may be most harmful, aiding the targeting of alcohol reduction interventions.³⁵ To date, however, there is no consistent approach to handling such data, with some opting to restrict analyses to participant whose consumption was stable within pre-defined limits,³⁶ or else categorising participants according to whether their drinking increased,

decreased or remained stable over a given period of time.¹⁴ In addition, there is no clear agreement concerning the appropriate means of classifying drinkers who cease consumption prior to baseline measurement. A number of proposals have been put forward, including an intention-to-treat approach, which assigns former drinkers with a current drinking value predicted to be most representative of their prior consumption,³⁷ or the use of a retrospective life grid as a means of soliciting participants to estimate their past consumption.³⁸ Although the best approach for dealing with both issues will differ to some extent according to the aim of the study and the data available, the incorporation and treatment of longitudinal data for the analysis of alcohol-related risks represents an important area for future debate.

Strengths and limitations

Although other studies have reported the stability of consumption according to baseline categories of drinking,^{12,13,14} this is the first study of which we are aware to describe changes from a life course perspective as opposed to shifts during follow-up. Analyses benefitted from seven phases of observation covering almost 50 years of the adult life course. Though representing a geographically-concentrated and occupationally-narrow cohort, trajectories derived from Whitehall II data are consistent with those reported from nationally representative, UK-based cohorts.⁷ This increases our confidence that trajectories stratified by baseline consumption should be generalisable to other cohorts.

Despite these benefits, the dataset lacks prospective alcohol consumption data during early adulthood and advanced old age. Based on existing research,⁷ it is hypothesised that the latter is likely marked by a continued convergence toward lower volumes of consumption. This is intimated by the non-linear trajectories presented in Figure 2. As such, longitudinal transitions between baseline categories may be even more pronounced during periods of the life course not captured by the Whitehall II study. However, while correlations between intercepts and rates of change were negative, there is a possibility that the convergence of drinking trajectories was a result of regression to the mean and not a consequence of age-related factors.

Analyses were dependent upon self-reported measures of alcohol consumption and so potentially subject to a degree of inaccuracy owing to reporting and recall biases³⁹ and measurement error.⁴⁰ Furthermore, current drinking was derived from questions that concern consumption during the week prior to interview. It is possible that these provide a poor surrogate for true average weekly consumption, with quantity-frequency questionnaires tending to produce lower drinking estimates than graduated frequency questionnaires,³⁹ which may be more effective at capturing episodic heavy drinking.⁴¹ Drinking diaries also show promise as a more accurate means of estimating consumption.⁴² Regardless, observed issues of longitudinal stability will apply to data obtained using any means of self-reported questionnaire, with implications for all studies of alcohol, whether cross-sectional or longitudinal in design. Finally, reported analyses show just one of many different dimensions of drinking behaviour, such as differences by drink type and episodic heavy consumption.

In summary, baseline-defined categories of alcohol consumption appear largely stable across the life course among both sexes, except for heavier drinkers, where intake declined markedly with increasing age. These downward trajectories do not seem to be driven by transitions to non-drinking, indicating that attenuations to the volume of consumption may be gradual. Owing to unstable trajectories among heavier baseline drinkers, there is an indication that cohorts of older people are at particular

risk of misclassifying former heavy drinkers as moderate consumers of alcohol. This may have implications for risk estimates derived in studies of predominantly older adults.

Figures and tables**Table 1 Mean weekly volume of alcohol consumption according to a two-way interaction between the baseline category of alcohol consumption and age, stratified by sex**

Linear growth curve models	Sample (n)	Mean g/week (95% CI)	p-value
Men			
Consumption volume			
Intercept		1.4 (-0.3, 3.1)	0.110
Change per 10-year increase in age		1.1 (0.3, 2.0)	0.010
Difference in baseline consumption			
Non-drinker	220	Reference	
Infrequent drinker	669	6.8 (3.0, 10.6)	<0.001
0.1-50.0 g/week	2,073	30.3 (27.9, 32.7)	<0.001
50.1-100.0 g/week	1,432	75.1 (71.4, 78.9)	<0.001
100.1-150.0 g/week	881	127.7 (123.4, 132.0)	<0.001
150.1-250.0 g/week	915	194.7 (189.5, 199.8)	<0.001
>250.0 g/week	648	389.3 (376.0, 402.5)	<0.001
Difference in the decennial rate of change			
Non-drinker		Reference	
Infrequent drinker		6.6 (4.6, 8.6)	<0.001
0.1-50.0 g/week		6.0 (4.8, 7.3)	<0.001
50.1-100.0 g/week		5.0 (2.8, 7.2)	<0.001
100.1-150.0 g/week		-1.6 (-3.9, 0.7)	0.177
150.1-250.0 g/week		-10.7 (-13.6, -7.8)	<0.001
>250.0 g/week		-48.1 (-53.5, -42.7)	<0.001
Women			
Consumption volume			
Intercept		-0.1 (-1.2, 1.0)	0.810
Change per 10-year increase in age		0.6 (-0.2, 1.3)	0.150
Difference in baseline consumption			
Non-drinker	216	Reference	
Infrequent drinker	764	2.5 (0.7, 4.3)	0.006
0.1-50.0 g/week	1,428	28.7 (26.8, 30.5)	<0.001
50.1-100.0 g/week	542	71.4 (67.9, 74.9)	<0.001
>100.0 g/week	422	167.9 (159.2, 176.5)	<0.001
Difference in the decennial rate of change			
Non-drinker		Reference	
Infrequent drinker		2.6 (1.5, 3.7)	<0.001
0.1-50.0 g/week		0.2 (-1.0, 1.3)	0.771
50.1-100.0 g/week		-1.0 (-3.2, 1.1)	0.356
>100.0 g/week		-17.4 (-20.8, -13.9)	<0.001

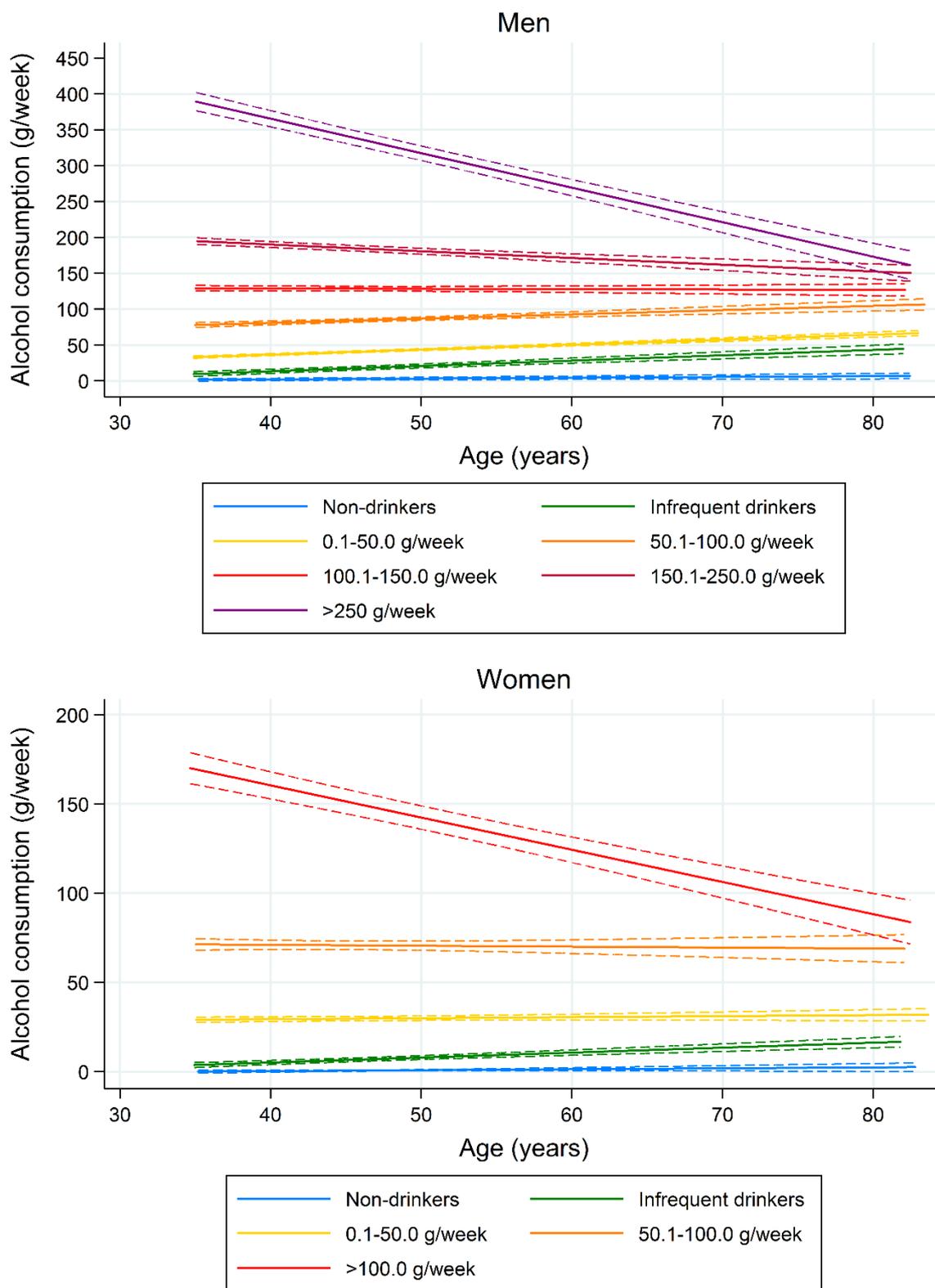
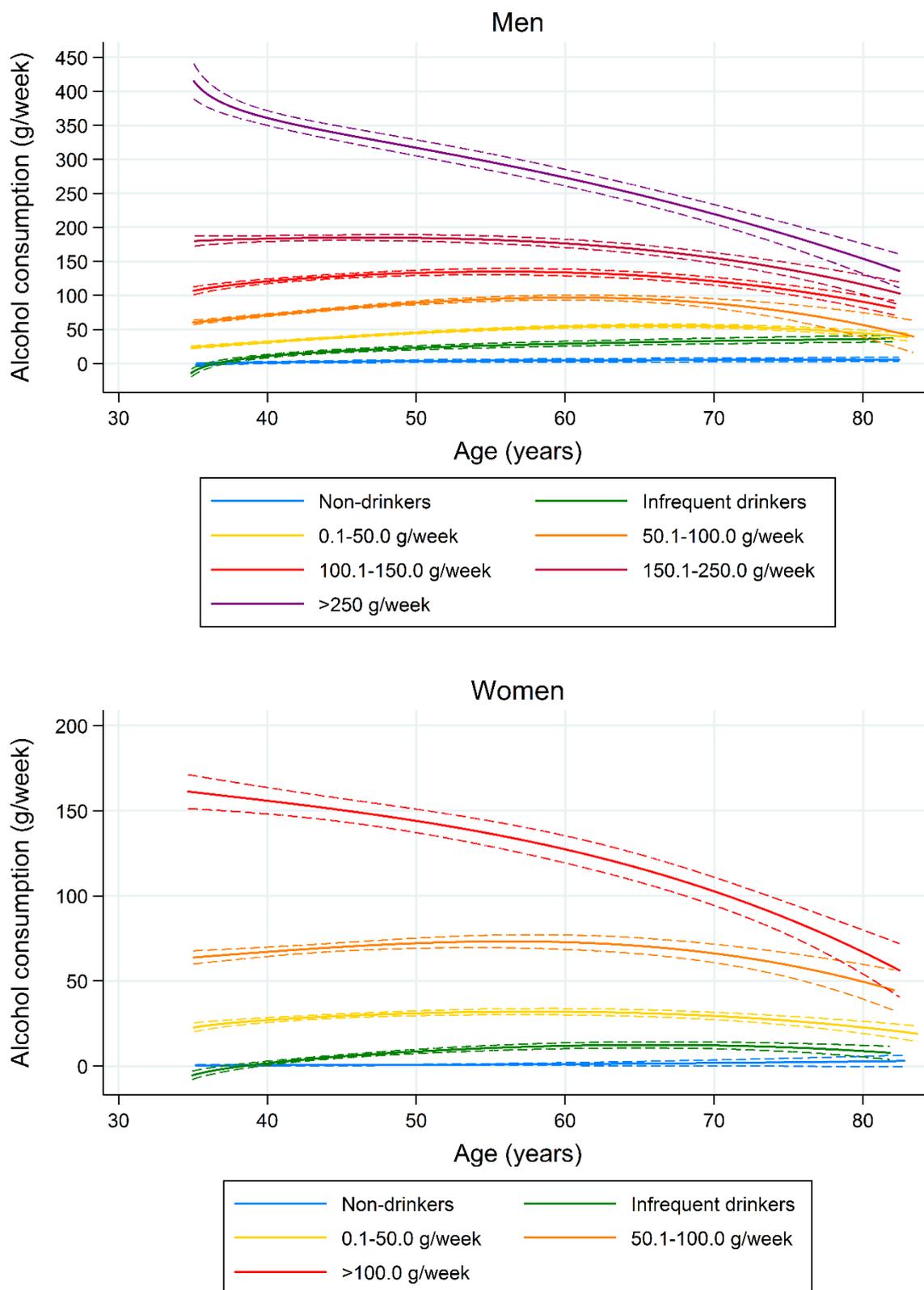


Figure 1 Linear trajectories of mean weekly volume of alcohol consumption between the ages of 34-84 years, stratified by sex and baseline alcohol consumption category



Dashed lines represent 95% pointwise confidence bands

Figure 2 Non-linear trajectories of mean weekly volume of alcohol consumption between the ages of 34-84 years, stratified by sex and baseline alcohol consumption category

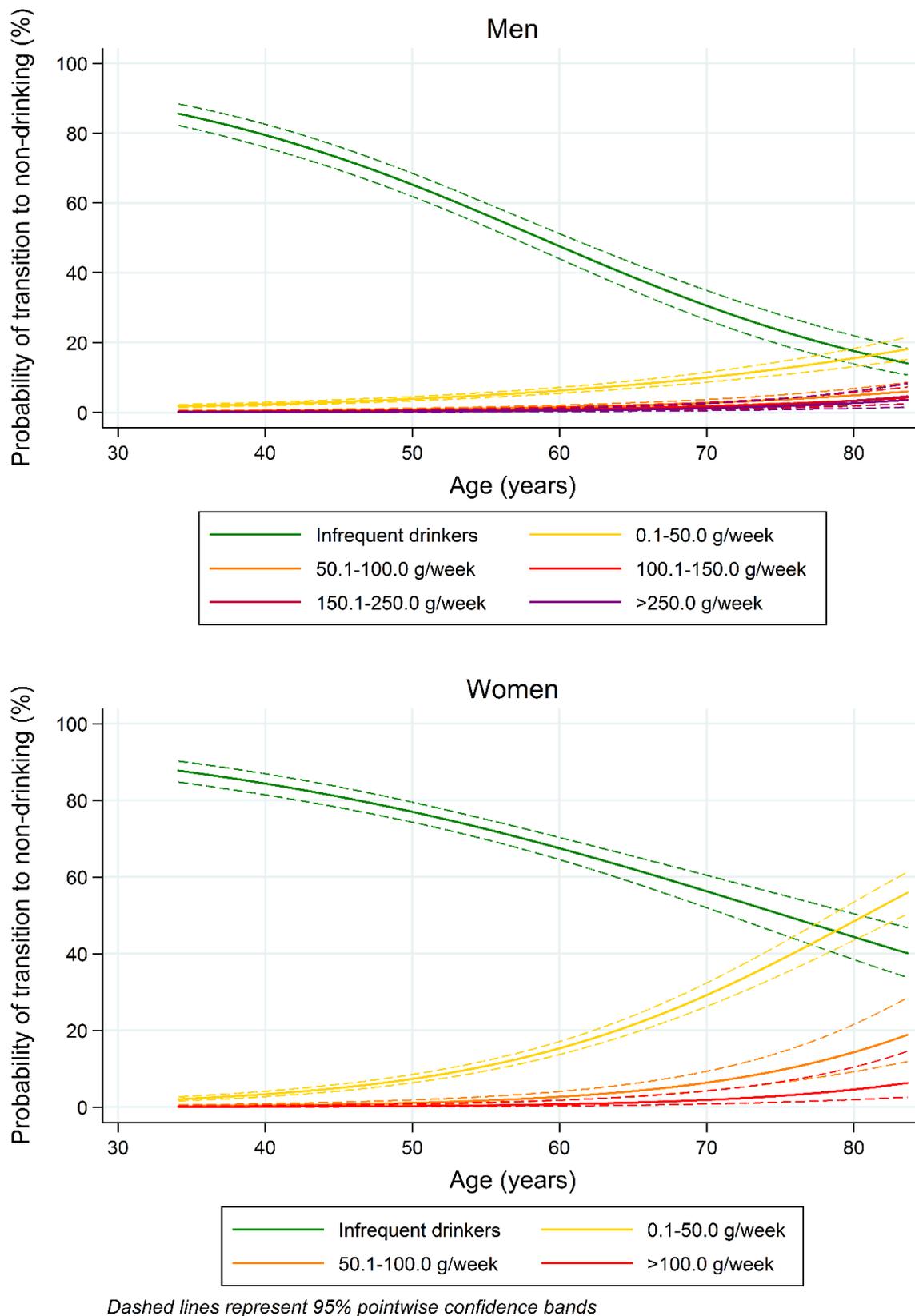


Figure 3 Probability of transition to non-drinking across the adult life course, stratified by baseline alcohol consumption category

Supporting information**Appendix 1 Descriptive statistics as reported at baseline**

Variable	Non-drinkers		Infrequent drinkers		0.1-50.0g/week		50.1-100.0g/week		>100.0g/week	
	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n
Age										
Mean (years)	45.87 (45.29, 46.46)	436	45.89 (45.58, 46.20)	1,433	45.46 (45.26, 45.66)	3,501	44.47 (44.21, 44.74)	1,974	43.98 (43.77, 44.20)	2,866
Body mass index										
Mean (kg/m ²)	24.97 (24.58, 25.36)	436	24.93 (24.71, 25.14)	1,431	24.54 (24.42, 24.67)	3,497	24.35 (24.21, 24.50)	1,971	24.76 (24.65, 24.88)	2,861
Ethnicity^a										
White	53.4 (48.6, 58.1)	229	82.6 (80.5, 84.4)	1,169	89.4 (88.3, 90.4)	3,100	95.3 (94.3, 96.2)	1,871	96.0 (95.2, 96.7)	2,732
South Asian	33.6 (29.2, 38.2)	144	10.0 (8.5, 11.6)	141	5.0 (4.3, 5.8)	174	2.6 (2.0, 3.5)	52	2.6 (2.0, 3.2)	73
Other	13.1 (10.2, 16.6)	56	7.5 (6.2, 9.0)	106	5.6 (4.9, 6.4)	194	2.0 (1.5, 2.8)	40	1.4 (1.1, 2.0)	41
General health										
Excellent/very good	62.3 (57.6, 66.8)	271	64.1 (61.6, 66.6)	917	71.6 (70.0, 73.0)	2,496	77.4 (75.5, 79.2)	1,520	77.9 (76.3, 79.4)	2,227
Good	28.7 (24.7, 33.2)	125	28.7 (26.5, 31.1)	411	23.0 (21.6, 24.4)	801	18.8 (17.1, 20.6)	369	18.4 (17.0, 19.8)	525
Fair/poor	9.0 (6.6, 12.1)	39	7.1 (5.9, 8.6)	102	5.5 (4.8, 6.3)	191	3.8 (3.1, 4.8)	75	3.7 (3.1, 4.5)	107
Marital status										
Married or cohabiting	71.0 (66.5, 75.1)	308	67.1 (64.7, 69.5)	960	73.7 (72.2, 75.2)	2,568	78.0 (76.1, 79.8)	1,535	75.9 (74.3, 77.4)	2,169
Single	19.8 (16.3, 23.9)	86	20.8 (18.8, 23.0)	298	16.8 (15.6, 18.1)	586	14.0 (12.5, 15.6)	275	15.0 (13.7, 16.4)	429
Divorced	7.6 (5.4, 10.5)	33	9.5 (8.1, 11.1)	136	7.9 (7.0, 8.8)	275	7.1 (6.1, 8.3)	140	8.3 (7.4, 9.4)	238
Widowed	1.6 (0.8, 3.4)	7	2.5 (1.8, 3.5)	36	1.6 (1.2, 2.0)	54	0.9 (0.6, 1.4)	18	0.8 (0.5, 1.2)	23
Occupational grade^b										
High	13.3 (10.4, 16.8)	58	12.2 (10.6, 14.0)	175	26.1 (24.6, 27.6)	913	36.1 (34.0, 38.2)	712	40.0 (38.2, 41.8)	1,147

Middle	38.1 (33.6, 42.7)	166	43.5 (40.9, 46.1)	623	47.7 (46.0, 49.3)	1,669	49.2 (47.0, 51.4)	971	51.3 (49.5, 53.1)	1,470
Low	48.6 (43.9, 53.3)	212	44.3 (41.8, 46.9)	635	26.2 (24.8, 27.7)	919	14.7 (13.2, 16.4)	291	8.7 (7.7, 9.8)	249
Physical activity^c										
Active	33.1 (28.8, 37.7)	140	23.6 (21.4, 25.9)	328	15.4 (14.2, 16.6)	531	10.7 (9.4, 12.2)	209	9.7 (8.6, 10.8)	275
Moderately active	31.9 (27.6, 36.5)	135	35.3 (32.8, 37.8)	491	38.8 (37.2, 40.5)	1,339	39.7 (37.6, 41.9)	776	37.3 (35.5, 39.1)	1,060
Inactive	35.0 (30.6, 39.7)	148	41.2 (38.6, 43.8)	573	45.8 (44.1, 47.4)	1,578	49.6 (47.3, 51.8)	968	53.1 (51.2, 54.9)	1,509
Sex										
Male	50.5 (45.8, 55.2)	220	46.7 (44.1, 49.3)	669	59.2 (57.6, 60.8)	2,073	72.5 (70.5, 74.5)	1,432	85.3 (83.9, 86.5)	2,444
Female	49.5 (44.8, 54.2)	216	53.3 (50.7, 55.9)	764	40.8 (39.2, 42.4)	1,428	27.5 (25.5, 29.5)	542	14.7 (13.5, 16.1)	422
Smoking status										
Current smoker	72.1 (67.6, 76.1)	312	54.4 (51.8, 57.0)	775	56.5 (54.8, 58.1)	1,964	48.0 (45.8, 50.3)	941	36.1 (34.4, 37.9)	1,029
Former smoker	15.0 (11.9, 18.7)	65	24.6 (22.4, 26.9)	350	27.4 (25.9, 28.9)	952	35.4 (33.3, 37.6)	694	41.9 (40.1, 43.8)	1,195
Never smoker	12.9 (10.1, 16.5)	56	21.0 (19.0, 23.2)	299	16.2 (15.0, 17.4)	562	16.5 (15.0, 18.3)	324	21.9 (20.5, 23.5)	625

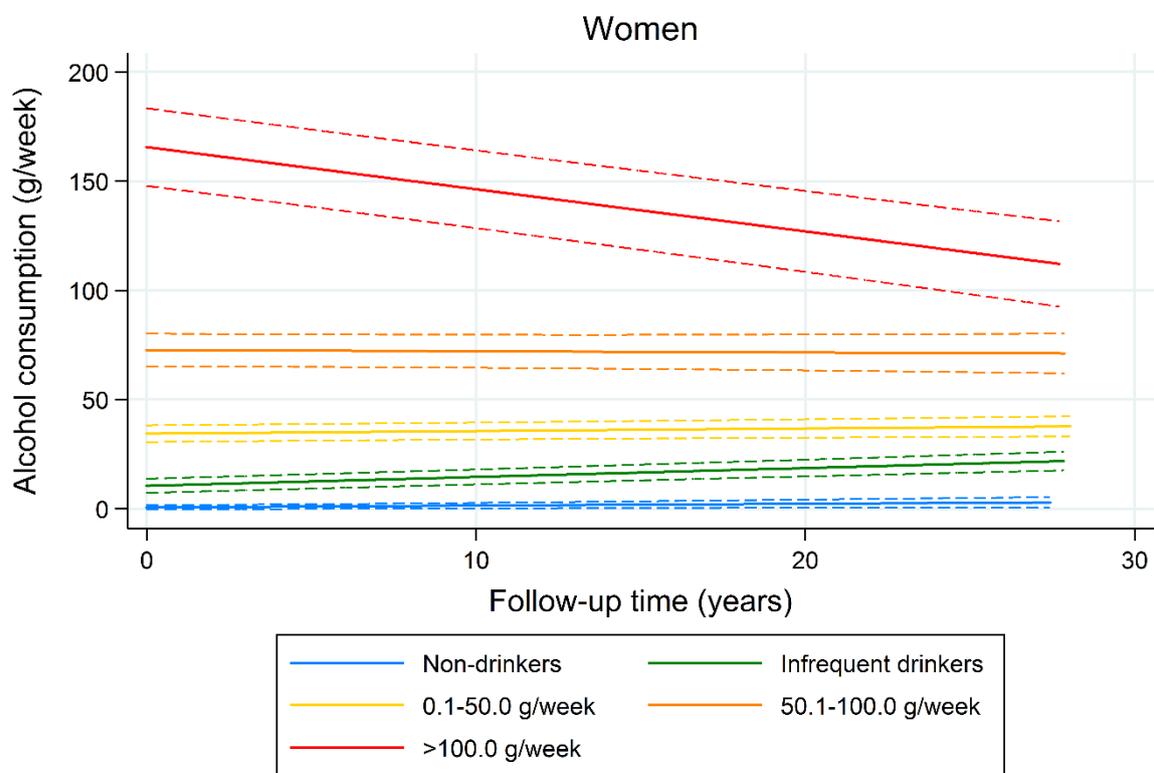
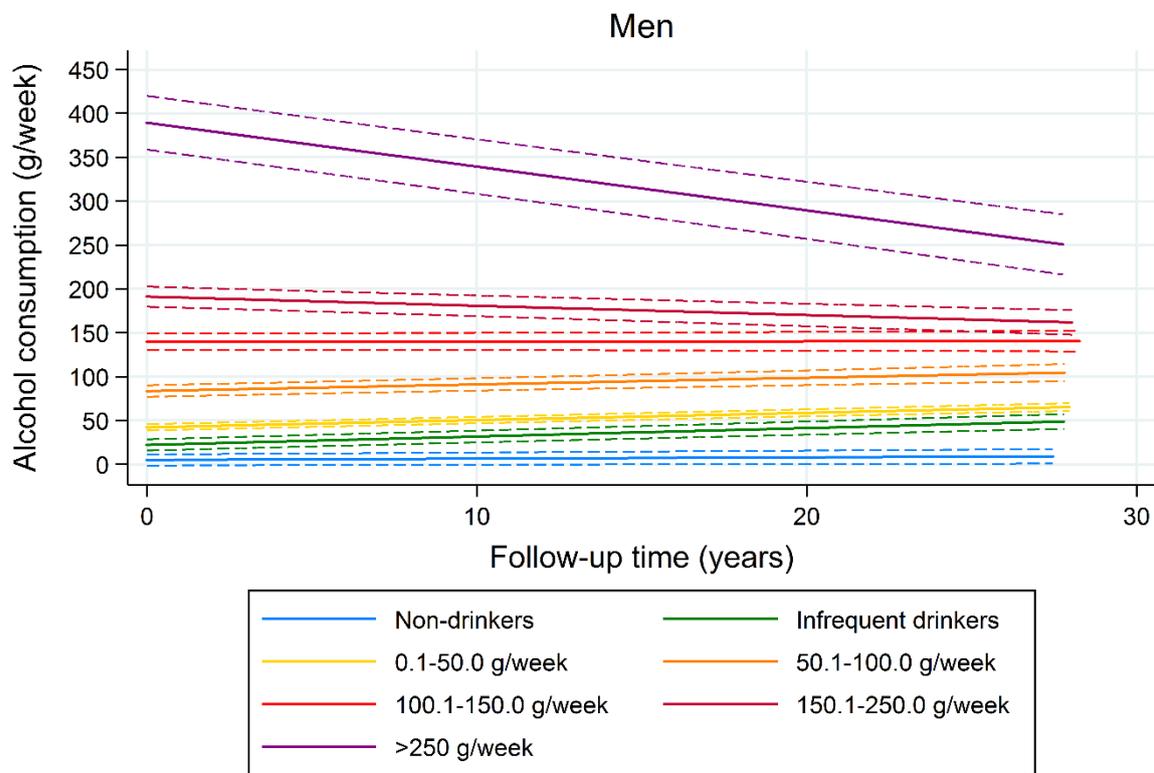
^aOther: includes participants of black ethnic background, Chinese origin or mixed race.

^bHigh: administrative; Middle: professional or executive; Low: Clerical or support.

^cActive: ≥ 150 minutes of moderate-intensity exercise per week, or ≥ 75 minutes of vigorous-intensity activity; Inactive: < 60 minutes of moderate physical activity and < 60 minutes of vigorous physical activity; Moderately active: not inactive or active.

Sample sizes differ according to item non-response at baseline. Differences between alcohol consumption categories were statistically significant ($p < 0.001$) in all instances, as determined using Wald tests.

Appendix 2 Linear trajectories of mean weekly volume of alcohol consumption over the period of follow-up, adjusted for date of birth and stratified by sex and baseline consumption category



Dashed lines represent 95% pointwise confidence bands

Appendix 3 Mean weekly volume of alcohol consumption according to a linear two-way interaction between the baseline category of alcohol consumption and age, stratified by sex. Multiply imputed data.

Linear growth curve models	Sample (n)	Mean g/week (95% CI)	p-value
Men			
Consumption volume			
Intercept		1.4 (-0.3, 3.1)	0.110
Change per 10-year increase in age		4.8 (3.3, 6.4)	<0.001
Difference in baseline consumption			
Non-drinker	220	Reference	
Infrequent drinker	669	9.9 (5.6, 14.2)	<0.001
0.1-50.0 g/week	2,073	35.3 (31.9, 38.8)	<0.001
50.1-100.0 g/week	1,432	81.7 (77.4, 86.0)	<0.001
100.1-150.0 g/week	881	132.3 (126.7, 138.0)	<0.001
150.1-250.0 g/week	915	196.4 (189.9, 202.9)	<0.001
>250.0 g/week	648	377.1 (362.9, 391.2)	<0.001
Difference in the decennial rate of change			
Non-drinker		Reference	
Infrequent drinker		3.6 (1.5, 5.7)	0.001
0.1-50.0 g/week		3.6 (1.8, 5.4)	<0.001
50.1-100.0 g/week		1.0 (-1.4, 3.3)	0.421
100.1-150.0 g/week		-6.0 (-8.8, -3.2)	<0.001
150.1-250.0 g/week		-15.0 (-18.4, -11.7)	<0.001
>250.0 g/week		-53.9 (-59.5, -48.3)	<0.001
Women			
Consumption volume			
Intercept		-1.2 (-3.0, 0.7)	0.207
Change per 10-year increase in age		3.9 (2.8, 5.1)	<0.001
Difference in baseline consumption			
Non-drinker	216	Reference	
Infrequent drinker	764	3.3 (1.0, 5.7)	0.005
0.1-50.0 g/week	1,428	31.4 (28.7, 34.2)	<0.001
50.1-100.0 g/week	542	74.9 (70.4, 79.3)	<0.001
>100.0 g/week	422	166.0 (155.6, 176.3)	<0.001
Difference in the decennial rate of change			
Non-drinker		Reference	
Infrequent drinker		2.1 (0.7, 3.5)	0.004
0.1-50.0 g/week		-0.5 (-2.0, 1.0)	0.502
50.1-100.0 g/week		-3.5 (-5.9, -1.1)	0.005
>100.0 g/week		-21.2 (-25.1, -17.2)	<0.001

Appendix 4 The mean weekly volume of alcohol consumption according to a linear three-way interaction between the baseline category of alcohol consumption, baseline frequency of alcohol consumption and age, stratified by sex

Linear growth curve models	Sample (n)	g/week (95% CI)	p-value
<u>Men</u>			
Consumption volume			
Baseline consumption		30.5 (28.8, 32.1)	<0.001
Change to consumption per 10-year increase in age		7.2 (6.2, 8.1)	<0.001
Difference in baseline consumption, by baseline consumption frequency ^a		27.7 (17.6, 37.7)	<0.001
Difference in change to consumption per 10-year increase in age, by baseline consumption frequency ^a		-0.6 (-5.7, 4.6)	0.830
Difference in baseline consumption between baseline categories			
0.1-50.0 g/week	2,068	Reference	
50.1-100.0 g/week	1,424	42.6 (38.2, 47.1)	<0.001
100.1-150.0 g/week	880	90.6 (84.5, 96.7)	<0.001
150.1-250.0 g/week	913	144.7 (136.1, 153.4)	<0.001
>250.0 g/week	648	245.5 (212.7, 278.3)	<0.001
Difference in baseline consumption between baseline categories, by baseline consumption frequency^a			
0.1-50.0 g/week	2,068	Reference	
50.1-100.0 g/week	1,424	-14.5 (-26.6, -2.4)	0.019
100.1-150.0 g/week	880	-12.5 (-25.2, 0.3)	0.056
150.1-250.0 g/week	913	0.1 (-14.2, 14.5)	0.985
>250.0 g/week	648	97.0 (60.1, 133.8)	<0.001
Difference in the decennial rate of change between baseline categories			
0.1-50.0 g/week	2,068	Reference	
50.1-100.0 g/week	1,424	-1.8 (-4.6, 1.0)	0.207
100.1-150.0 g/week	880	-10.0 (-13.2, -6.8)	<0.001
150.1-250.0 g/week	913	-20.6 (-25.4, -15.9)	<0.001
>250.0 g/week	648	-52.9 (-69.0, -36.8)	<0.001
Difference in the decennial rate of change between baseline categories, by baseline consumption frequency^a			
0.1-50.0 g/week	2,068	Reference	
50.1-100.0 g/week	1,424	3.0 (-3.5, 9.4)	0.370
100.1-150.0 g/week	880	4.5 (-2.2, 11.2)	0.186
150.1-250.0 g/week	913	5.6 (-2.1, 13.3)	0.152
>250.0 g/week	648	-0.9 (-18.6, 16.9)	0.924
<u>Women</u>			
Consumption volume			

Baseline consumption		27.6 (26.0, 29.1)	<0.001
Change to consumption per 10-year increase in age		0.2 (-0.6, 1.0)	0.608
Difference in baseline consumption, by baseline consumption frequency ^a		17.2 (9.4, 25.0)	0.000
Difference in change to consumption per 10-year increase in age, by baseline consumption frequency ^a		6.5 (1.5, 11.5)	0.011
Difference in baseline consumption between baseline categories			
0.1-50.0 g/week	1,425	Reference	
50.1-100.0 g/week	541	36.9 (32.6, 41.2)	<0.001
>100.0 g/week	420	102.3 (88.7, 115.8)	<0.001
Difference in baseline consumption between baseline categories, by baseline consumption frequency^a			
0.1-50.0 g/week	1,425	Reference	
50.1-100.0 g/week	541	-0.9 (-11.1, 9.3)	0.860
>100.0 g/week	420	30.4 (11.9, 48.9)	0.001
Difference in the decennial rate of change between baseline categories			
0.1-50.0 g/week	1,425	Reference	
50.1-100.0 g/week	541	-2.6 (-5.3, 0.1)	0.060
>100.0 g/week	420	-20.5 (-27.1, -13.9)	<0.001
Difference in the decennial rate of change between baseline categories, by baseline consumption frequency^a			
0.1-50.0 g/week	1,425	Reference	
50.1-100.0 g/week	541	-1.9 (-8.3, 4.6)	0.565
>100.0 g/week	420	-2.4 (-11.5, 6.7)	0.605

Baseline consumption frequency coded as a binary variable: 0 less than 'daily' or 'almost daily'; 1 'daily' or 'almost daily'. Reported coefficients are relative to participants who consumed alcohol less than 'daily' or 'almost daily'.

References

- ¹ Ronksley PE, Brien SE, Turner BJ, Mukamal KJ, Ghali WA. Association of alcohol consumption with selected cardiovascular disease outcomes: a systematic review and meta-analysis. *BMJ* 2011; **342**: d671.
- ² Knott C, Bell S, Britton A. Alcohol Consumption and the Risk of Type 2 Diabetes: A Systematic Review and Dose-Response Meta-analysis of More Than 1.9 Million Individuals From 38 Observational Studies. *Diabetes Care* 2015; **38**: 1804–12.
- ³ Bagnardi V, Rota M, Botteri E, Tramacere I, Islami F, Fedirko V, et al. Alcohol consumption and site-specific cancer risk: a comprehensive dose-response meta-analysis. *Br J Cancer*. 2015; **112**: 580–93.
- ⁴ Stockwell T, Zhao J, Panwar S, Roemer A, Naimi T, Chikritzhs T. Do "Moderate" Drinkers Have Reduced Mortality Risk? A Systematic Review and Meta-Analysis of Alcohol Consumption and All-Cause Mortality. *J Stud Alcohol Drugs* 2016; **77**: 185–98.
- ⁵ Djoussé L, Biggs ML, Mukamal KJ, Siscovick DS. Alcohol Consumption and Type 2 Diabetes among Older Adults: The Cardiovascular Health Study. *Obesity*. 2007; **15**: 1758–65.
- ⁶ Sher KJ, Jackson KM, Steinley D. Alcohol Use Trajectories and the Ubiquitous Cat's Cradle: Cause for Concern? *J Abnorm Psychol*. 2011; **120**: 322–35.
- ⁷ Britton A, Ben-Shlomo Y, Benzeval M, Kuh D, Bell S. Life course trajectories of alcohol consumption in the United Kingdom using longitudinal data from nine cohort studies. *BMC Med*. 2015; **13**: 47.
- ⁸ Rehm J, Irving H, Ye Y, Kerr WC, Bond J, Greenfield TK. Are Lifetime Abstainers the Best Control Group in Alcohol Epidemiology? On the Stability and Validity of Reported Lifetime Abstention. *Am J Epidemiol*. 2008; **168**: 866–871
- ⁹ Zeisser C, Stockwell TR, Chikritzhs T. Methodological biases in estimating the relationship between alcohol consumption and breast cancer: The role of drinker misclassification errors in meta-analytic results. *Alcohol Clin Exp Res*. 2014; **38**: 2297–2306.
- ¹⁰ Fillmore KM, Stockwell T, Chikritzhs T, Bostrom A, Kerr W. Moderate alcohol use and reduced mortality risk: systematic error in prospective studies and new hypotheses. *Ann Epidemiol*. 2007; **17**: S16–23.
- ¹¹ Stockwell T, Zhao J, Panwar S, Roemer A, Naimi T, Chikritzhs T. Do "Moderate" Drinkers Have Reduced Mortality Risk? A Systematic Review and Meta-Analysis of Alcohol Consumption and All-Cause Mortality. *J Stud Alcohol Drugs*. 2016; **77**: 185–98.
- ¹² Kerr WC, Fillmore KM, Bostrom A. Stability of alcohol consumption over time: evidence from three longitudinal surveys from the United States. *J Stud Alcohol*. 2002; **63**: 325–33.
- ¹³ Dam MK, Hvidtfeldt UA, Tjønneland A, Overvad K, Grønbaek M, Tolstrup JS. Five year change in alcohol intake and risk of breast cancer and coronary heart disease among postmenopausal women: prospective cohort study. *BMJ*. 2016; **353**: i2314
- ¹⁴ Joosten MM, Chiuve SE, Mukamal KJ, Hu FB, Hendriks HF, Rimm EB. Changes in alcohol consumption and subsequent risk of type 2 diabetes in men. *Diabetes*. 2011; **60**: 74–9.
- ¹⁵ Brown L. Adult alcohol consumption. In: Fuller E, Mindell J, Prior G (eds). *Health Survey for England 2015: Health, social care and lifestyle*. NHS Digital; 2016.
- ¹⁶ Marmot M, Brunner E. Cohort Profile: the Whitehall II study. *Int J Epidemiol* 2005; **34**: 251–6.
- ¹⁷ StataCorp LP. *Stata multilevel mixed-effects reference manual: release 13*. College Station, TX: StataCorp LP; 2013.
- ¹⁸ Royston P, Altman DG. Regression using fractional polynomials of continuous covariates: parsimonious parametric modelling (with discussion). *Appl Stat*. 1994; **43**: 425–467.
- ¹⁹ Jones RH. Bayesian information criterion for longitudinal and clustered data. *Stat Med*. 2011; **30**: 3050–6.
- ²⁰ Raftery AE. Bayesian Model Selection in Social Research. *Sociological Methodology* 1995; **25**: 111–163.
- ²¹ StataCorp LP. *Stata multiple-imputation reference manual: release 13*. College Station, TX: StataCorp LP; 2013.
- ²² Royston P, White IR. Multiple imputation by chained equations (MICE): implementation in Stata. *J Stat Softw* 2011; **45**: 1–20.

- ²³ Lee KJ, Carlin JB. Multiple imputation for missing data: fully conditional specification versus multivariate normal imputation. *Am J Epidemiol*. 2010; **171**: 624–32.
- ²⁴ StataCorp LP. *Stata longitudinal-data/panel-data reference manual: release 13*. College Station, TX: StataCorp LP; 2013.
- ²⁵ Britton A, Bell S. Reasons why people change their alcohol consumption in later life: findings from the Whitehall II Cohort Study. *PLoS One*. 2015; **10**: e0119421.
- ²⁶ Liang W, Chikritzhs T. Reduction in alcohol consumption and health status. *Addiction*. 2011; **106**: 75–81.
- ²⁷ Bell S, Daskalopoulou M, Rapsomaniki E, George J, Britton A, Bobak M, et al. Association between clinically recorded alcohol consumption and initial presentation of 12 cardiovascular diseases: population based cohort study using linked health records. *BMJ*. 2017; **356**: j90..
- ²⁸ Bagnardi V, Rota M, Botteri E, Tramacere I, Islami F, Fedirko V, et al. Alcohol consumption and site-specific cancer risk: a comprehensive dose–response meta-analysis. *British Journal of Cancer*. 2015; **112**: 580–593. doi:10.1038/bjc.2014.579.
- ²⁹ Hvidtfeldt UA, Tolstrup JS, Jakobsen MU, Heitmann BL, Grønbaek M, O'Reilly E, et al. Alcohol intake and risk of coronary heart disease in younger, middle-aged, and older adults. *Circulation*. 2010; **121**: 1589–97.
- ³⁰ Knott CS, Coombs N, Stamatakis E, Biddulph JP. All cause mortality and the case for age specific alcohol consumption guidelines: pooled analyses of up to 10 population based cohorts. *BMJ*. 2015; **350**: h384.
- ³¹ Mukamal KJ, Conigrave KM, Mittleman MA, Camargo CA Jr, Stampfer MJ, Willett WC, et al. Roles of drinking pattern and type of alcohol consumed in coronary heart disease in men. *N Engl J Med*. 2003; **348**: 109–18.
- ³² Fan AZ, Russell M, Stranges S, Dorn J, Trevisan M. Association of Lifetime Alcohol Drinking Trajectories with Cardiometabolic Risk. *J Clin Endocrinol Metab*. 2008; **93**: 154–161.
- ³³ Britton A, Marmot MG, Shipley MJ. How does variability in alcohol consumption over time affect the relationship with mortality and coronary heart disease? *Addiction*. 2010; **105**: 639–45.
- ³⁴ Johnstone BM, Leino EV, Ager CR, Ferrer H, Fillmore KM. Determinants of life-course variation in the frequency of alcohol consumption: meta-analysis of studies from the collaborative alcohol-related longitudinal project. *J Stud Alcohol Drugs*. 1996; **57**: 494.
- ³⁵ Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. *J Epidemiol Community Health*. 2003; **57**: 778–83.
- ³⁶ O'Neill D, Britton A, Brunner EJ, Bell S. Twenty-Five-Year Alcohol Consumption Trajectories and Their Association With Arterial Aging: A Prospective Cohort Study. *J Am Heart Assoc*. 2017; **6**: e005288.
- ³⁷ Liang W, Chikritzhs T. Observational Research on Alcohol Use and Chronic Disease Outcome: New Approaches to Counter Biases. *The Scientific World Journal*. 2013; 1–14.
- ³⁸ Bell S, Britton A. Reliability of a retrospective decade-based life-course alcohol consumption questionnaire administered in later life. *Addiction*. 2015; **110**: 1563–73.
- ³⁹ Del Boca FK, Darkes J. The validity of self-reports of alcohol consumption: state of the science and challenges for research. *Addiction*. 2003; **98**: 1–12.
- ⁴⁰ Stockwell T, Donath S, Cooper-Stanbury M, Chikritzhs T, Catalano P, Mateo C. Under-reporting of alcohol consumption in household surveys: a comparison of quantity-frequency, graduated-frequency and recent recall. *Addiction*. 2004; **99**: 1024–33.
- ⁴¹ Stahre M, Naimi T, Brewer R, Holt J. Measuring average alcohol consumption: the impact of including binge drinks in quantity-frequency calculations. *Addiction*. 2006; **101**: 1711–8.
- ⁴² Greenfield TK, Kerr WC. Alcohol measurement methodology in epidemiology: recent advances and opportunities. *Addiction*. 2008; **103**: 1082–99.