ADDICTION

RESEARCH REPORT

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Cross-country differences in age trends in alcohol consumption among older adults: a cross-sectional study of individuals aged 50 years and older in 22 countries

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ABSTRACT

Background and Aims Age-related changes in physiological, metabolic and medication profiles make alcohol consumption likely to be more harmful among older than younger adults. This study aimed to estimate cross-national variation in the quantity and patterns of drinking throughout older age, and to investigate country-level variables explaining cross-national variation in consumption for individuals aged 50 years and older. **Design** Cross-sectional observational study using previously harmonized survey data. **Setting** Twenty-two countries surveyed in 2010 or the closest available year. **Participants** A total of 106 180 adults aged 50 years and over. **Measurements** Cross-national variation in age trends were estimated for two outcomes: weekly number of standard drink units (SDUs) and patterns of alcohol consumption (never, ever, occasional, moderate and heavy drinking). Human Development Index and average prices of vodka were used as country-level variables moderating age-related declines in drinking. **Findings** Alcohol consumption was negatively associated with age (risk ratio = 0.98; 95% confidence interval = 0.97, 0.99; P-value < 0.001), but there was substantial cross-country variation in the age-related differences in alcohol consumption [likelihood ratio (LR) test P-value < 0.001], even after adjusting for the composition of populations. Countries' development level and alcohol prices explained 31% of cross-country variability in SDUs (LR test P-value < 0.001) but did not explain cross-country variability in the prevalence of heavy drinkers. **Conclusions** Use and harmful use of alcohol among older adults appears to vary widely across age and countries. This variation can be partly explained both by the country-specific composition of populations and country-level contextual factors such as development level and alcohol prices.

Keywords Aging, alcohol, cross-cultural, development, drink, global, mixed model, multi-level, price, old age.

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INTRODUCTION

The world population is rapidly aging [1] and cohorts entering old age are now, on average, living longer and healthier lives than previous cohorts [2,3]. Recent evidence, however, suggests that these unprecedented demographic and epidemiological changes have been coupled with increased prevalence of alcohol use and heavy use among older adults in many countries [4–8]. In the United States, China, Korea, Mexico, Chile and 16 European countries, approximately 52% of adults aged 50 years and older drink alcohol within a given year, and 12% of those drinkers are heavy drinkers (men have more than three drinks per day or binge more than five drinks in a single occasion, and women have more than two drinks per day or binge more than four in a single occasion) [6]. In the United States, an estimated 60% of adults aged more than 60 years drink alcohol regularly and 22% drink heavily [7]. Alcohol use disorders among adults aged 65 and older have increased by 106% in the last 10 years [5]. These trends are a cause for concern, and suggest that more cross-national research on later-life alcohol consumption is needed.

This research is especially relevant because the majority of alcohol-related deaths occur among older adults [9–11]. Although this is partly explained by the cumulative consequences of life-time alcohol consumption [12], evidence-based interventions in older adults have been validated to reduce consumption even after years of continued use [13,14], and reducing consumption in older age is associated with reduced harm [15]. Alcohol consumption is probably more harmful as individuals age because liver function decreases causing a slower metabolism of alcohol [16,17]. Biological aging is also associated with changes in body composition towards decreased lean muscle mass [18] and decreased volume of body water available for alcohol to distribute [16,19]. These age-related changes result in more intoxications and potential harm among older adults, especially if they interact and interfere with their treatments and medications [20–22]. Heavy drinking is thus particularly detrimental to older adults' health, including cognition [23–25], depression [26], falls [23] and survival [27]. Although many studies show a beneficial association between drinking and health in old age, these findings are probably due to selection effects as older drinkers tend to remain drinking if they are healthy, while recent abstainers (as opposed to life-time abstainers) may be 'sick quitters' [28].

In summary, alcohol consumption among older adults is increasing over historical time among numerous countries. However, alcohol consumption tends to decrease with chronological age partly due to physiological, metabolic and medication profile changes that make drinking at older ages more detrimental than drinking at younger ages. Cross-country research on alcohol consumption, however, is relatively limited due to the scarcity of comparable micro-data across countries [29–33]. It is well established that patterns of alcohol consumption vary throughout countries [9,32,34]. The country-level Human Development Index (HDI is a summary measure of country development understood as the capability to have a decent standard of living, a long and healthy life and being knowledgeable) is key to explaining cross-national variation, as it predicts not only psychosocial risk factors associated with drinking (e.g. depression and unemployment), but also price [35,36]. Indeed, higher alcohol prices both within and across countries predict higher per capita consumption patterns [35,37–39]. However, the extent to which such cross-national factors predict alcohol use among older adults, who have different levels of purchasing power and health risks for use, remains largely unknown.

To fill these gaps in the literature, the primary aim of this study is to estimate the quantity and patterns of drinking throughout older age and countries. We focus upon both quantity (number of standard drink units per week) and patterns of drinking (never, ever, occasional, moderate and heavy drinking) to make a comprehensive characterization, considering that drinking heavily is especially harmful to health. Following previous studies [40–42], we model non-linear age trends. A secondary aim is to investigate countries' development level and alcohol prices as potential contextual variables explaining cross-country variability in alcohol consumption across age. We asked whether age trends in alcohol consumption vary among countries and, if so, whether a higher HDI [36] and lower average alcohol prices [43] are associated with smaller age declines in drinking.

METHODS

Design, data and sample

To address the study aims, we used recently harmonized cross-sectional survey data for 106 180 individuals aged 50 years and older, observed in 2010 or the closest available year in 22 countries (see Supporting information, Table S1) [6]. These observational multi-level data allow for simultaneous modeling of age trends and cross-country variation. Data were drawn from eight ongoing cohort surveys, including: the Survey of Health, Ageing and Retirement in Europe (SHARE; Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Israel, Italy, Netherlands, Poland, Slovenia, Spain, Sweden, Switzerland) [44], Social Protection Survey (in Spanish, EPS; Chile) [45], China Health and Retirement Longitudinal Study (CHARLS; China) [46], English Longitudinal Study of Aging (ELSA; England) [47], The Irish Longitudinal Study on Ageing (TILDA; Ireland) [48], Korean Longitudinal Study of Aging (KLOSA; Korea) [49], Mexican Health and Aging Study (MHAS; Mexico) [50] and Health and Retirement Study (HRS; United States) [51].

The harmonization process aimed at achieving data comparability by following well-established steps [30,52–54]. First, we defined overarching research objectives and identified eligible studies. Secondly, for each survey we documented study design aspects and variables that were relevant to our research objectives. Thirdly, we evaluated the feasibility of harmonizing each variable across countries. Fourthly, we employed three approaches to transform individual data points to common data elements: (1) we used existing codes provided by the Gateway to Global Aging Data platform (G2AGING) [55] to harmonize some of the variables for seven of the surveys that we used in this study, (2) we modified existing G2AGING codes to improve the harmonization results and (3) created our own codes for the harmonization of EPS data and alcohol consumption variables across all surveys, as they were not available in G2AGING. In the final step we evaluated the harmonized data quality through internal consistency checks and triangulation with similar measures obtained from different sources. The harmonization of alcohol measures [6] and other variables is described in Supporting information, B.

Alcohol consumption outcome measures

Our main outcomes included the number of standard drink units (SDUs) per week and the prevalence of alcohol consumption categories to determine the most harmful drinking patterns. An SDU is equivalent to a 333-ml bottle or can of beer, a 120-ml glass of table wine, an 80-ml glass of fortified wine or a 40-ml glass of spirits [56,57]. Alcohol consumption categories follow National Institutes of Alcohol Abuse and Alcoholism (NIAAA) guidelines on moderate and binge drinking [58]: (i) life-time abstainers (never drank alcohol, had fewer than 12 drinks in their entire life-time or have not drunk for at least 4 years and do not report evidence of ever drinking in the past), (ii) current abstainers (do not drink now, but drank in the past or we cannot rule out that they drank in the past), (iii) occasional drinkers (frequency $<$ 1 day per week, three or fewer drinks per day men or two or fewer for women, and no binging in a single occasion more than five for men or more than four for women), (iv) moderate drinkers (frequency one or more drink $\geq$ 1 day per week, three or fewer drinks per day for men or fewer than two for women, and no binging in a single occasion more than five for men or more than four for women) and (v) heavy drinkers (men have more than three drinks per day or binge more than five drinks in a single occasion, and women have more than two drinks per day or binge more than four drinks in a single occasion).

Exposure of interest

The main exposure was current age in years and mean-centered. The age-squared term was included to model non-linear associations (other polynomials were neither supported by running-mean smoothed bivariate graphs nor by multi-level models).

Country-level moderating variables

Publicly available HDI [36] and alcohol prices [43] data (see Supporting information, Table S1) were used to test for cross-level interactions with individual-level age terms. HDI is a summary measure of national income, health and education, measured in 2010 in 100 units, and mean-centered (see Supporting information, C). Alcohol prices were measured in 2017 $US (the only year available) as the average price of a bottle of red label Smirnoff vodka and logarithmically transformed to improve normality and linearity.

Socio-demographic and health covariates

Socio-demographic covariates included gender, educational attainment (no education or primary uncompleted, primary completed but high school uncompleted, high school completed, some college and college completed or more) and marital status (married or partnered, divorced or separated, widowed and single never married). Health covariates included a dichotomy indicating limitations to perform at least one of three activities of daily living (bath, dress and eat), body mass index (underweight, healthy weight, overweight and obese), self-reported health (very bad, bad, normal, good and very good) and five dichotomous indicators of whether the respondent reported being diagnosed by a physician with high blood pressure, diabetes, heart disease, stroke and arthritis.

Statistical analyses

We report results based on multi-level models that analyzed cross-country variation in both alcohol consumption (random intercept) and age trends in alcohol consumption (random slope) [59]. An important advantage of this modeling approach is that the results can be regarded as applying to all similar countries, not just the specific countries included.

Considering the distribution of outcome variables (see Fig. 1) and computational burden of mixed models for categorical outcomes, we estimated negative binomial multi-level models using generalized linear mixed-effects for the number of SDUs per week [60,61] and multinomial multi-level regressions using generalized structural equation modeling for alcohol consumption categories [62]. Supporting information, A for country fixed-effects models that yielded similar results.

For each outcome, we report four sequential models. Model 1 did not include covariates, as the goal was partitioning the unexplained variance in alcohol consumption throughout individuals and countries, as well as determining whether linear and quadratic age trends in alcohol consumption varied across countries. Model 2 included individual-level covariates to adjust estimates for differences in the composition of the populations across countries. Model 3 attempted to explain cross-country variation in alcohol consumption and age trends in alcohol consumption by further adding country-level HDI and a cross-level interaction with age terms. Model 4 used alcohol prices (logged) as a country-level covariate instead of HDI. For each model we examined variance components and conducted likelihood ratio tests indicating if it was

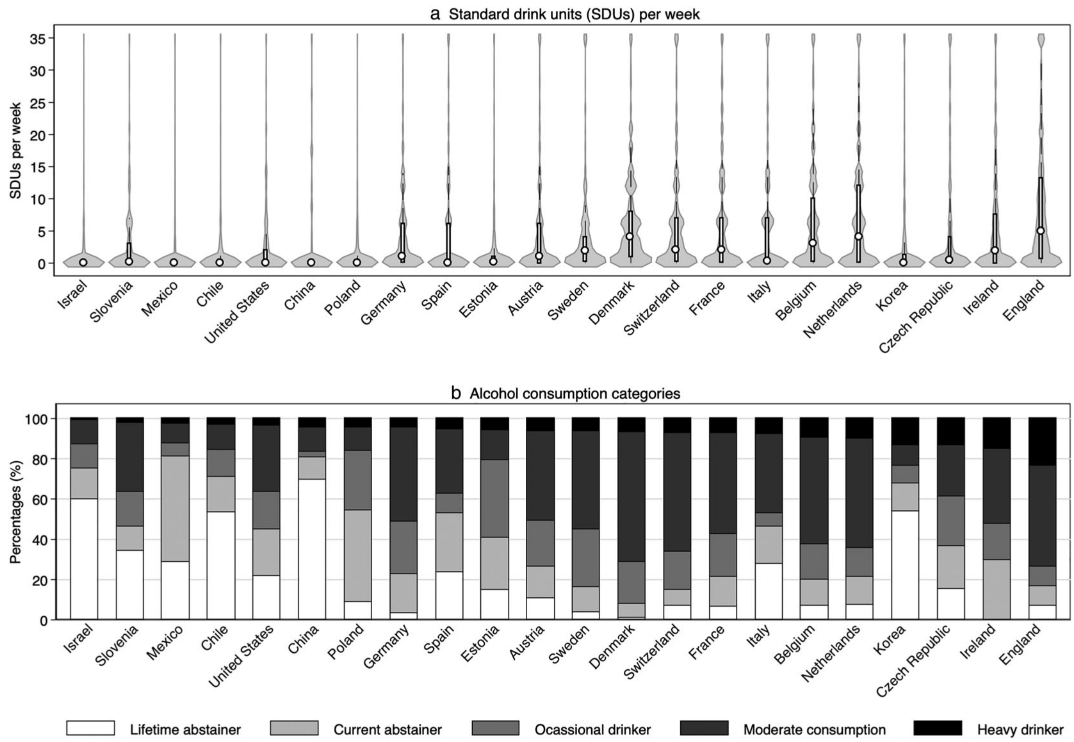


Figure 1 Distribution of alcohol consumption at age 50 and older by country (n = 106 180)

appropriate to model age trends as random-effects across countries.

All estimations used independent covariance and robust standard errors to relax the assumptions of independency among error-terms and homoscedasticity [63]. Population weights were used to represent each country age and sex distribution and make every country sample size equivalent to 4826 individuals (106 180 individuals divided by 22 countries approximates to 4826), thus avoiding over-representation of countries with bigger sample sizes. The research question and analysis plan were not pre-registered, and thus the results should be considered exploratory. All analyses were performed using STATA-MP version 15.1.

RESULTS

Descriptive statistics of study variables averaged among individuals and countries, respectively, are reported in Table 1. Respondents drank an average of 3.8 SDUs per week [95% confidence interval (CI) = 3.8–3.9]. Of all respondents, 7.3% were classified as heavy drinkers (95% CI = 7.2–7.5). Due to skewness, country medians and interquartile ranges (IQR or difference between the 75th and 25th percentiles of the distribution) are arguably better indicators of centrality in alcohol consumption variation (SDUs median = 3.8 and IQR = 2.9; heavy drinker median = 6.3 and IQR = 6.0), age (median = 66.2, IQR = 1.5), HDI (median = 88.0, IQR = 4.7), alcohol prices (median = 14.6, IQR = 7.1) and other variables. See Supporting information, Table S1 for country-specific information.

The unadjusted cross-sectional age trends in the weekly number of SDUs and prevalence of heavy drinkers also varied substantially across countries (see Figs S1 and S2), sometimes displaying sharp decreases (e.g. England) and others remaining fairly low and flat (e.g. Israel). Cross-country variations in these unadjusted age trends, however, may be driven by differences in the composition of the populations across countries.

Table 2 reports cross-sectional negative binomial multi-level modeling regression results for the weekly number of SDUs. The quadratic association between age and weekly SDUs in model 1 indicates that drinking peaks at age 60 and then declines with age, with faster decreases in drinking at older ages [age risk ratio (RR) = 0.988, 95% CI = 0.97–0.99; age squared RR = 0.999, 95% CI = 0.99–1.00]. However, the slope and shape of the age-related decline in alcohol consumption varies across countries (LR test P-value < 0.001). The quadratic age decline in drinking held after including individual-level covariates in model 2, suggesting that they cannot be fully attributed to the composition of the countries' population and that they may be at least partly attributed to contextual influences. Model 3 suggests that country-level HDI is one relevant contextual factor explaining 30.71% of the variance in the weekly number of SDUs after accounting for compositional effects. Higher

Table 1 Descriptive statistics of study variables (n = 106 180)

	Individuals			Countries	
Variable	Mean	95% CI		Median	IQR
Standard drink units per week	3.8	3.8	3.9	3.8	2.9
Alcohol consumption categories (%)					
Life-time abstainer	26.0	25.7	26.2	21.6	22.6
Current abstainer	20.6	20.4	20.8	17.5	8.9
Occasional drinker	15.8	15.6	16.0	18.1	11.7
Moderate drinker	30.3	30.1	30.6	33.7	29.8
Heavy drinker	7.3	7.2	7.5	6.3	6.0
Age (years)	66.3	66.2	66.4	66.2	1.5
Human Development Index (HDI)	–	–	–	88.0	4.7
Alcohol prices (in $US)	–	–	–	14.6	7.1
Female (%)	55.6	55.3	55.8	55.4	3.7
Limitations to perform ADLs (%)	17.7	17.4	18.1	16.3	9.1
Weight categories (%)					
Under weight	2.1	2.0	2.2	1.5	0.9
Normal weight	38.1	37.8	38.3	34.3	14.0
Overweight	37.9	37.6	38.2	39.7	6.8
Obese	21.9	21.7	22.2	23.0	11.9
Chronic diseases (%)					
High blood pressure	45.9	45.6	46.2	45.2	16.9
Diabetes	15.4	15.2	15.6	14.8	12.1
Heart disease	16.8	16.6	17.0	15.4	10.8
Stroke	5.0	4.9	5.1	5.0	3.2
Arthritis	34.3	34.0	34.5	33.0	15.9
Self-reported health (%)					
Very bad	12.6	12.4	12.8	8.4	9.4
Bad	28.5	28.3	28.8	24.8	12.2
Regular	32.5	32.2	32.7	32.4	7.3
Good	19.3	19.1	19.6	17.5	22.1
Very good	7.1	6.9	7.2	6.6	7.7
Educational status (%)					
Primary uncompleted	15.1	15.0	15.4	10.7	19.1
High school uncompleted	35.2	34.9	35.5	38.8	26.4
High school completed	28.0	27.7	28.2	26.4	29.6
College uncompleted	5.7	5.5	5.8	3.6	5.8
College completed or more	16.0	15.8	16.2	20.6	13.3
Marital status (%)					
Married	71.6	71.3	71.8	71.2	13.6
Divorced or separated	7.8	7.7	8.0	8.7	4.8
Widowed	15.9	15.7	16.2	15.5	4.6
Single	4.7	4.5	4.8	4.8	2.2

Median and interquartile range (IQR) calculated as the country-level subtraction between the 75th and 25th percentiles for 22 countries observed in the available year closest to 2010; more details in Supporting information, Table S1. CI = confidence interval; ADL = activities of daily living.

HDI was associated with a higher weekly number of SDUs (RR = 1.080, 95% CI = 1.02–1.14) and with a slower age-related decline in the weekly number of SDUs (RR = 1.001, 95% CI = 1.000–1.002). Model 4 suggests that alcohol prices are another relevant contextual factor explaining 30.65% of the variance in the weekly number of SDUs after accounting for compositional effects. Higher country-level alcohol prices were associated with weekly number of SDUs in a non-linear fashion (prices RR = 2.562, 95% CI = 1.26–5.20; prices × age squared RR = 0.999, 95% CI = 0.99–1.00). Country-level factors included both in models 3 and 4 fully explained the random slope in age squared. Across models, individual-level characteristics behaved largely as expected: being female, having chronic conditions, extremely bad self-reported health, obese and with uncompleted primary education were associated with lower SDUs (see Supporting information, Table S2).

To illustrate cross-country variability in age trends in alcohol consumption, in Fig. 2 we plotted the predicted

Table 2 Negative binomial multi-level model regression for the number of standard drink units per week (n = 106 180)

	Model 1	*Model 2*	*Model 3*	*Model 4*
	RR (95% CI)	*RR (95% CI)*	*RR (95% CI)*	*RR (95% CI)*
Age (centered)	0.988*** (0.97, 0.99)	0.983*** (0.97, 0.99)	0.981* (0.97, 0.99)	0.973 (0.91, 1.04)
Age^2 (centered)	0.999*** (0.99, 1.00)	0.999*** (0.99, 1.00)	0.999 (0.99, 1.00)	1.002 (1.00, 1.00)
HDI (centered)	–	–	1.080*** (1.02, 1.14)	–
HDI × age	–	–	1.001* (1.00, 1.00)	–
HDI × age^2	–	–	1.000 (1.00, 1.00)	–
Alcohol prices (logged)	–	–	–	2.562** (1.26, 5.20)
Alcohol prices × age	–	–	–	1.004 (0.98, 1.03)
Alcohol prices × age^2	–	–	–	0.999** (0.99, 1.00)
Constant	3.56*** (2.60, 4.88)	9.72*** (7.40, 12.77)	8.71*** (6.22, 12.19)	0.76 (0.11, 5.41)
Individual-level covariates	No	Yes	Yes	Yes
Variance partitioning				
Total variance	3.82 (100%)	3.51 (100%)	2.43 (100%)	2.43 (100%)
Individual-level residual	3.25 (85.1%)	2.89 (82.31%)	2.00 (82.32%)	1.91 (78.64%)
Random country intercept	0.57 (14.9%)	0.62 (17.69%)	0.43 (17.68%)	0.52 (21.36%)
Random age slope	0.0003	0.0003	0.0002	0.0002
Random age^2 slope	1.31e-07	1.34e-07	–	–
Explained variance	–	–	30.71%	30.65%
Likelihood-ratio test for random slopes	P-value < 0.001	P-value < 0.001	P-value < 0.001	P-value < 0.001
Ln (alpha)	5.02*** (3.55, 7.09)	3.95*** (3.12, 5.00)	1.37*** (1.13, 1.60)	1.37*** (1.13, 1.60)

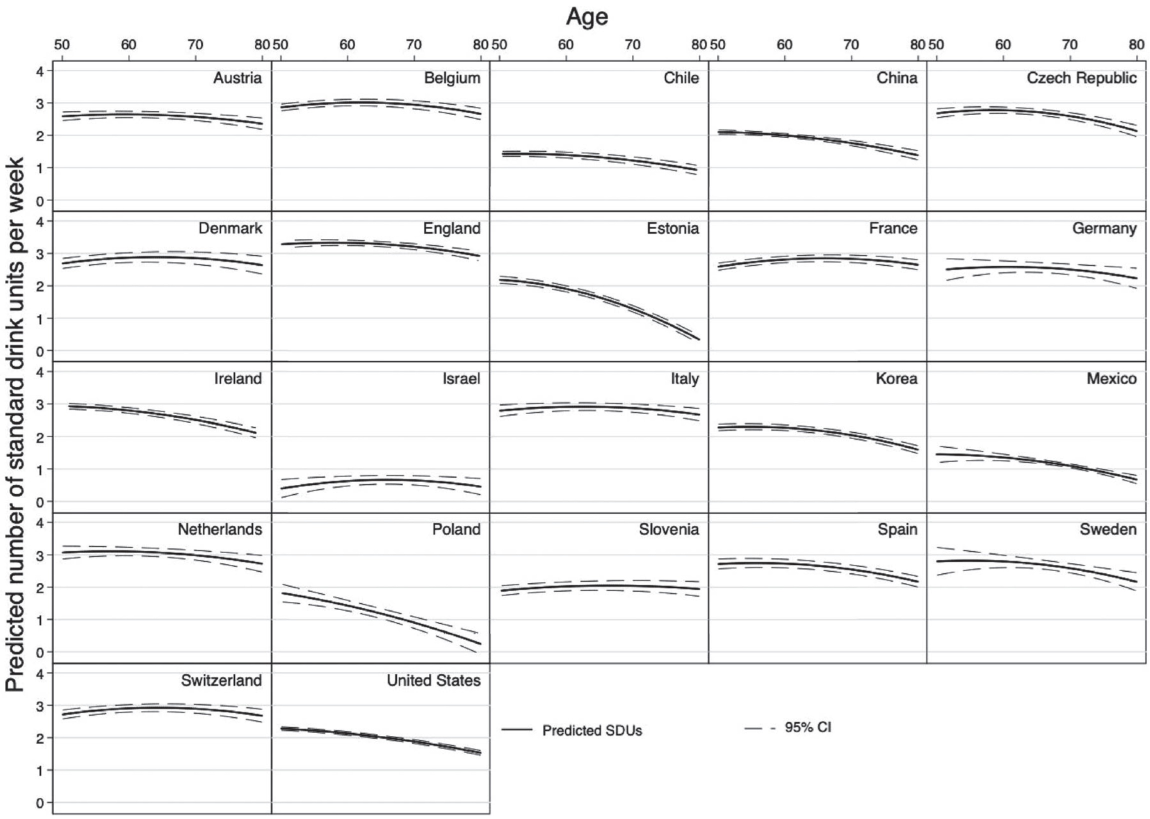
RR = risk ratio; CI = confidence interval. Full results for covariates are presented in Supporting information, Table S2. The random slope for age^2 was dropped from models 2 and 3 (likelihood ratio P-value > 0.05). Total variance was calculated as: $e^{(random\ intercept)*}(1 + e^{(Ln(alpha))})$-1. Explained variance was calculated using the total variance from model 2 as the denominator. *P < 0.05; **P < 0.01; ***P < 0.001.

values for the number of weekly SDUs against age, based on model 2 from Table 2. The adjusted cross-sectional age trend in the number of weekly SDUs varies substantially among countries: most countries display a moderate age-related decline (e.g. China and the United States), but some display sharper decreases (e.g. Estonia and Poland) and others are fairly stable, sometimes following a brief increase after age 50 (e.g. Denmark and France).

To illustrate contextual factors shaping cross-country age trends in alcohol consumption, we plotted predictions based on models 3 and 4 from Table 2. Figure 3 plots overall cross-sectional age trends in weekly number of SDUs for the maximum and minimum observed values in HDI and alcohol prices (see Supporting information, C). Figure 3a shows that countries with high HDI tend to consume more SDUs than countries with low HDI and that this is true regardless of age, although the age-related decrease is steeper in countries with higher than lower HDI. Figure 3b shows that adults aged 50 tend to consume more SDUs in countries with lower alcohol prices than in countries with higher alcohol prices. However, the age decline in alcohol consumption is linear for countries with low alcohol prices and non-linear for countries with high alcohol prices, so that individuals in their 60s and 70s drink more in countries with higher prices.

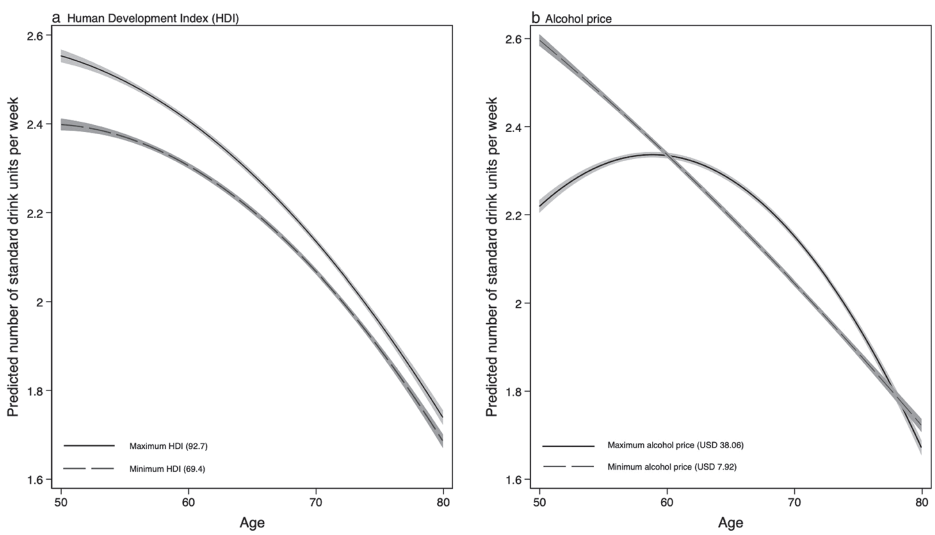
Table 3 reports multinomial multi-level logistic regression results for alcohol consumption categories. Consistent with our previous results for SDUs, model 1 suggests a quadratic decrease in drinking with age, but these age trends vary across countries. Although these cross-sectional age trends have a similar non-linear shape across countries (LR test for random age-squared slope P-value > 0.05), the age-related decline in alcohol consumption is more pronounced in some countries rather than in others (LR test for random age-squared slope P-value < 0.001). Model 2 suggests that after controlling for individual-level characteristics, age is associated with increased relative risk ratio (RRR) of life-time abstaining (Table 3a), currently abstaining (Table 3b), drinking occasionally (Table 3c) and drinking moderately (Table 3d), compared with heavy drinking (reference). These age-related declines in alcohol consumption become stronger with age, except for current abstainers compared with heavy drinkers. In contrast to what we found for SDUs, models 3 and 4 suggest that HDI and alcohol prices contribute little to explaining cross-country variation in mean levels or age trends in alcohol consumption categories. Individual-level covariates behaved as expected (see Supporting information, Tables S3, S4 and S5).

Figure 4 plots the predicted prevalence of heavy drinking against age, based on model 2 reported in Table 3. Most countries display a moderate cross-sectional age-related decline (e.g. Korea and Mexico), but some display sharper decreases (e.g. England and Ireland) and others are fairly stable (e.g. Israel and Slovenia).



Notes: Marginal predictions based on the negative binomial multilevel model 2 from Table 2; model-estimated SDUs were calculated setting covariates to the following reference groups: male, no limitations to perform activities of daily living, normal weight, no chronic diseases, very good health, college completed or more, and married.

Figure 2 Adjusted age trends in the number of standard drink units per week, by country.



Notes: Marginal predictions based on the negative binomial multilevel model 3 (panel A) and model 4 (panel B) from Table 2; model-estimated SDUs were calculated setting covariates to the following reference groups: male, no limitations to perform activities of daily living, normal weight, no chronic diseases, very good health, college completed or more, and married. Shadowed areas around solid lines display 95% CI.

Figure 3 Adjusted age trends in the number of standard drink units per week, by country-level human development index and alcohol prices.

Table 3 Multinomial multi-level regression for alcohol consumption categories (n = 106 180)

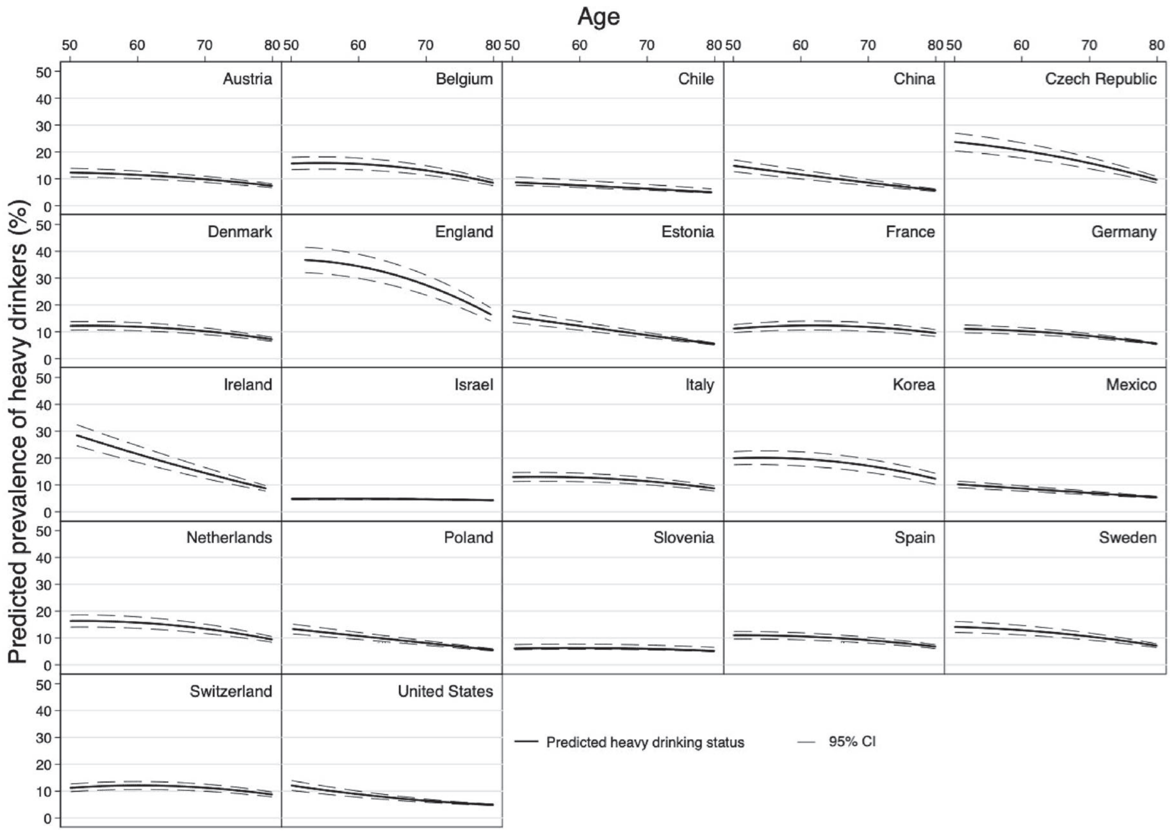
		Model 1	*Model 2*	*Model 3*	*Model 4*
Outcome	*Exposure*	*RRR (95% CI)*	*RRR (95% CI)*	*RRR (95% CI)*	*RRR (95% CI)*
(a) Life-time abstainer	Age (centered)	1.048*** (1.02, 1.07)	1.043*** (1.02, 1.07)	1.050*** (1.03, 1.07)	0.960 (0.84, 1.10)
	Age^2	1.001*** (1.00, 1.00)	1.001*** (1.00, 1.00)	1.001*** (1.00, 1.00)	1.006** (1.00, 1.01)
	Constant	4.460*** (2.38, 8.33)	0.536 (0.20, 1.44)	0.678 (0.25, 1.86)	62.554** (3.201221.54)
	HDI	–	–	0.910*** (0.86, 0.96)	–
	HDI × age			1.001 (1.00, 1.00)	
	HDI × age^2			1.000 (1.00, 1.00)	
	Prices (log)			–	0.172*** (0.06, 0.49)
	Prices × age				1.033 (0.98, 1.09)
	Prices × age^2				0.998* (1.00, 1.00)
(b) Current abstainer	Age (centered)	1.071*** (1.06, 1.08)	1.062*** (1.02, 1.07)	1.064*** (1.05, 1.08)	1.109 (0.98, 1.26)
	Age^2	1.001 (1.00, 1.00)	1.000 (1.00, 1.00)	1.000 (0.99, 1.00)	0.998 (0.99, 1.00)
	Constant	3.92*** (2.37, 6.46)	1.17 (0.59, 2.32)	1.316 (0.66, 2.64)	61.279* (2.04, 1839.59)
	HDI	–	–	0.922* (0.86, 0.99)	–
	HDI × age			0.998 (1.00, 1.00)	
	HDI × age^2			1.000 (1.00, 1.00)	
	Prices (log)			–	0.229* (0.06, 0.82)
	Prices × age				0.984 (0.94, 1.03)
	Prices × age^2				1.001 (1.00, 1.00)
(c) Occasional drinker	Age (centered)	1.029*** (1.01, 1.04)	1.035*** (1.02, 1.05)	1.033*** (1.02, 1.05)	1.017 (0.92, 1.12)
	Age^2	1.001*** (1.00, 1.00)	1.001*** (1.00, 1.00)	1.001*** (0.99, 1.00)	1.002 (1.00, 1.01)
	Constant	2.68*** (1.74, 4.12)	1.517 (0.85, 2.72)	1.554 (0.82, 2.94)	3.468 (0.60, 20.18)
	HDI	–	–	0.983 (0.93, 1.04)	–
	HDI × age			1.000 (1.00, 1.00)	
	HDI × age^2			1.000 (1.00, 1.00)	
	Prices (log)			–	0.711 (0.37, 1.37)
	Prices × age				1.006 (0.97, 1.04)
	Prices × age^2				0.999 (1.00, 1.00)
(d) Moderate drinker	Age (centered)	5.403*** (3.88, 7.53)	1.043*** (1.03 – 1.05)	1.039*** (1.03, 1.05)	1.039 (0.96, 1.13)
	Age^2	5.403*** (3.88, 7.53)	1.001*** (1.00, 1.00)	1.000 (0.99, 1.00)	1.001 (1.00, 1.00)
	Constant	5.40*** (3.88, 7.53)	9.51*** (6.13, 14.74)	8.416*** (5.25, 13.48)	33.812*** (8.11141.03)
	HDI	–	–	1.023 (1.00, 1.05)	–
	HDI × age			1.000 (1.00, 1.00)	
	HDI × age^2			1.000 (1.00, 1.00)	

(***Continues***)

Table 3. (Continued)

		Model 1	*Model 2*	*Model 3*	*Model 4*
Outcome	*Exposure*	*RRR (95% CI)*	*RRR (95% CI)*	*RRR (95% CI)*	*RRR (95% CI)*
	Prices (log)			–	0.608 (0.35, 1.05)
	Prices × age				1.001 (0.97, 1.03)
	Prices × age^2				1.000 (1.00, 1.00)
Individual-level covariates		No	Yes	Yes	Yes
Variance partitioning:					
Total variance		3.9863 (100%)	4.0841 (100%)	4.0813 (100%)	3.9999 (100%)
Predicted drinking categories		0.1139 (2.86%)	0.1631 (3.99%)	0.1953 (4.79%)	0.1989 (4.97%)
Individual-level residual		$\pi^2/3 = 3.28$ (82.28%)	$\pi^2/3 = 3.28$ (80.31%)	$\pi^2/3 = 3.28$ (80.37%)	$\pi^2/3 = 3.28$ (82.00%)
Random country intercept		0.5924 (14.86%)	0.641 (15.70%)	0.6055 (14.85%)	0.5196 (13.03%)
Random age slope		0.0338	0.0308	0.0302	0.0304
Explained variance		–	–	0.07%	2.06%
Likelihood-ratio test for random slopes		P-value < 0.001	P-value < 0.001	P-value < 0.001	P-value < 0.001

RRR = relative risk ratio; CI = confidence interval. Reference category is heavy drinker. Full results for covariates are presented in Supporting information, Tables S3, S4 and S5. The random slope for age^2 was dropped across models (likelihood ratio P-value > 0.05). Total variance was calculated as random country intercept, plus predicted drinking categories variance, plus residuals variance following a logistic distribution of $\pi^2/3$. Explained variance was calculated using the total variance from model 2 as the denominator. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.



Notes: Marginal predictions based on the multinomial multilevel model 2 from Table 3; model-estimated prevalence of heavy drinking was calculated setting covariates to the following reference groups: male, no limitations to perform activities of daily living, normal weight, no chronic diseases, very good health, college completed or more, and married. Predictions are expressed as absolute prevalence (probability*100), without a reference category.

Figure 4 Adjusted age trends in the prevalence of heavy drinking, by country.

DISCUSSION

We modeled alcohol consumption among adults aged 50 and older across 22 countries using large nationally representative samples observed in or near 2010. Although alcohol consumption tends to decrease with age due to well-established physiological, metabolic and medication profile changes [16–22], we documented substantial cross-national variation in the quantity and patterns of drinking in older age [9,32,34]. Our results suggest that cross-country differences in the age trends in alcohol consumption are only partly due to the composition of country populations, which is something that ecological studies with aggregate data cannot model, as they do not have micro-level data [29–33].

We found that a large proportion of between country variation in the weekly number of standard drink units (SDUs) and cross-sectional SDUs age trends were associated with countries' development level and alcohol prices. Relative to less developed countries with higher alcohol prices, older adults living in countries that are more developed and have lower alcohol prices tend to drink more SDUs when they are in their 50s, although this pattern becomes less clear at older ages.

Cross-country variation in age trends in heavy drinking was not adequately explained by countries' development level or alcohol prices. Possibly, cultural values pertaining to alcohol consumption, gender roles and majority religious denomination play a stronger role than development level and alcohol prices in explaining heavy drinking [8,34,64–68]. These factors may also contribute explaining cross-country variation in SDUs, which was not completely explained by development and prices.

Several limitations should be acknowledged. Although a rigorous harmonization process was followed, questions, response categories and sample features sometimes differed across surveys: SDUs include an estimated average content between 12.3 and 14 g of ethanol [57], and binge drinking was not treated as an outcome of interest in itself. Alcohol prices were not available before 2017 and potentially relevant risk factors, such as household wealth or depressive symptomatology, could not be successfully harmonized due to survey differences and measurement error. Given the cross-sectional design of our study, estimates conflate age and cohort effects and do not provide enough statistical power at the country-level to test for two contextual factors simultaneously. However, strengths outweigh limitations, incorporating a uniquely large sample size of individuals, nationally representative studies, statistical control for possible confounding factors, models appropriate for outcome distributions and sensitivity analyses producing consistent estimates.

Overall, our findings highlight substantial cross-national variation in cross-sectional age trends in alcohol consumption among older adults, both in quantity and patterns of use. Considering that part of this cross-country variation is due to the compositional characteristics of the countries' populations, policies and interventions should address specific individual-level characteristics such as health conditions and socio-economic inequalities to avoid misspecification and unfair comparisons when adopting laws intending to reduce heavy alcohol consumption. Policies and interventions to reduce alcohol use are generally not targeted to specific ages (exceptions being minimum legal purchasing ages) and, as such, they may have alcohol-related health impacts at board age ranges. Considering that another part of this cross-country variation is due to contextual factors, further research should explore population-level strategies to address alcohol consumption, both among older adults and the general population. Countries' development level and alcohol prices are two relevant contextual factors explaining cross-country variation in age trends in the quantity of drinking, but are less relevant to explain cross-country variation in the age trends of heavy drinking patterns. As countries develop and expand human capabilities to make choices, there may be a greater need for policies regulating alcohol consumption, potentially combining minimum alcohol prices, taxation, sale and marketing regulations and cessation programs [35].

In future studies, using longitudinally harmonized data, age trajectories could be modeled and disentangled from period and cohort effects. Longitudinal data and inclusion of other countries will increase statistical power at the country-level to explore more complex and dynamic associations between alcohol consumption and both individual and country characteristics, considering changes in development and prices, together with changes in regulation, values and norms pertaining to drinking, old-age pension benefits or life expectancy at age 60. Understanding the extent to which these context-specific but time-varying country-level factors produce or potentiate risk will aid in developing a clearer understanding of the circumstances in which population-level strategies to address alcohol consumption in old age may be more or less efficacious, and transportable to other countries. Alcohol consumption continues to be among the most prevalent preventable causes of global morbidity and mortality [31], and estimates of global consumption forecast increases in the coming decade [4–8,32]. By understanding cross-national differences in alcohol consumption and the ways in which policy, culture and population composition contribute to alcohol-related harms, a globally focused research program is critical to improving global population health.

Declaration of interests

None.

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Author contributions

Esteban Calvo: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing-original draft; writing-review & editing. **Kasim Allel:** Data curation; formal analysis; investigation; methodology; visualization; writing-original draft. **Ursula M. Staudinger:** Conceptualization; funding acquisition; investigation; writing-original draft; writing-review & editing. **Alvaro Castillo-Carniglia:** Formal analysis; investigation; methodology; writing-review & editing. **Jose T. Medina:** Data curation; validation; writing-review & editing. **Katherine M. Keyes:** Conceptualization; formal analysis; funding acquisition; investigation; methodology; writing-original draft; writing-review & editing.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 Survey year, number of observations and population characteristics, by country.

Table S2 Covariate results from negative binomial multilevel models for the number of SDUs per week (N = 106 180).

Table S3 Full model 2, Table 3. Multinomial multilevel regression for alcohol consumption categories (N = 106 180).

Table S4 Full model 3, Table 3. Multinomial multilevel regression for alcohol consumption categories (N = 106 180).

Table S5 Full model 4, Table 3. Multinomial multilevel regression for alcohol consumption categories (N = 106 180).

Table S5 Goodness of fit of a zero inflated negative binomial model *versus* alternative fixed-effect specifications (N = 106 180).

Table S6 Zero inflated negative binomial and negative binomial multilevel results for SDUs per week (N = 106 180).

Table S7 Country coefficients from models ZINB 2 and NBMM 2, from Table A6 (N = 106 180).

Table S8 Multinomial logistic fixed-effects regression results for alcohol consumption categories (N = 106 180).

Table S9 Comparison of unweighted and weighted analyses using model 2 from Table 2.

Table S10 Raw drink volume of different types of beverages and estimated average alcohol content of the harmonized standardized drink unit.

Figure S1 Unadjusted age trends in the number of standard drink units per week, by country.

Figure S2 Unadjusted age trends in the prevalence of heavy drinking, by country.

Figure S3 Average age trends in the number of standard drink units per week – model 1, Table 2.

Figure S4 Average age trends in the number of standard drink units per week – model 2, Table 2.

Figure S5 Average age trends in the prevalence of heavy drinking – model 1, Table 3.

Figure S6 Average age trends in the prevalence of heavy drinking – model 2, Table 3.

Figure S7 Adjusted age trends in the number of standard drink units per week, by country, from a zero inflated negative binomial model using country dummies.

Figure S8 Adjusted age trends in the prevalence of heavy drinking, by country, from a multinomial model using country dummies.

