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RESEARCH REPORT

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Classifying national drinking patterns in Europe between 2000 and 2019: A clustering approach using comparable exposure data

Daniela Correia[1,2,3,4] | Jakob Manthey[5,6] | Maria Neufeld[1] | Carina Ferreira-Borges[1] | Aleksandra Olsen[1] | Kevin Shield[7,8,9,10] | Jürgen Rehm[5,7,8,9,10,11,12,13]

[1]WHO Regional Office for Europe, Copenhagen, Denmark
[2]EPIUnit – Instituto de Saúde Pública, Universidade do Porto, Porto, Portugal
[3]Laboratório para a Investigação Integrativa e Translacional em Saúde Populacional (ITR), Porto, Portugal
[4]Departamento de Ciências da Saúde Pública e Forenses e Educação Médica, Faculdade de Medicina, Universidade do Porto, Porto, Portugal
[5]Centre of Interdisciplinary Addiction Research, Department of Psychiatry and Psychotherapy, University Medical Center Hamburg-Eppendorf (UKE), Hamburg, Germany
[6]Department of Psychiatry, Medical Faculty, University of Leipzig, Leipzig, Germany
[7]Institute for Mental Health Policy Research, Centre for Addiction and Mental Health, Toronto, Ontario, Canada
[8]Campbell Family Mental Health Research Institute, Centre for Addiction and Mental Health, Toronto, Ontario, Canada
[9]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada
[10]World Health Organization/Pan American Health Organization Collaborating Centre, Centre for Addiction and Mental Health, Toronto, Ontario, Canada
[11]Program on Substance Abuse and WHO European Region Collaboration Centre, Public Health Agency of Catalonia, Barcelona, Catalonia, Spain
[12]Department of Psychiatry, University of Toronto, Toronto, Ontario, Canada
[13]Institute of Medical Science, Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada

Abstract

Background and aims: Previously identified national drinking patterns in Europe lack comparability and might be no longer be valid due to changes in economic conditions and policy frameworks. We aimed to identify the most recent alcohol drinking patterns in Europe based on comparable alcohol exposure indicators using a data-driven approach, as well as identifying temporal changes and establishing empirical links between these patterns and indicators of alcohol-related harm.

Design: Data from the World Health Organization's monitoring system on alcohol exposure indicators were used. Repeated cross-sectional hierarchical cluster analyses were applied. Differences in alcohol-attributable harm between clusters of countries were analyzed via linear regression.

Setting: European Union countries, plus Iceland, Norway and Ukraine, for 2000, 2010, 2015 and 2019.

Participants/Cases: Observations consisted of annual country data, at four different time points for alcohol exposure. Harm indicators were only included for 2019.

Measurements: Alcohol exposure indicators included alcohol per capita consumption (APC), beverage-specific consumption and prevalence of drinking status indicators (lifetime abstainers, current drinkers, former drinkers and heavy episodic drinking). Alcohol-attributable harm was measured using age-standardized alcohol-attributable Disability-Adjusted Life Years (DALYs) lost and deaths per 100 000 people.

Findings: The same six clusters were identified in 2019, 2015 and 2010, mainly characterized by type of alcoholic beverage and prevalence drinking status indicators, with geographical interpretation. Two-thirds of the countries remained in the same cluster over time, with one additional cluster identified in 2000, characterized by low APC. The most recent drinking patterns were shown to be significantly associated with alcohol-attributable deaths and DALY rates. Compared with wine-drinking countries, the mortality rate per 100 000 people was significantly higher in Eastern Europe with high spirits and 'other' beverage consumption [$\widehat{\beta} = 90$, 95% confidence interval (CI) = 55–126], and

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Correspondence
Daniela Correia, Alcohol, Illicit Drugs and Prison Health, Special Initiative on NCDs and Innovation (SNI), WHO Regional Office for Europe, UN City, Marmorvej 51, 2100, Copenhagen, Denmark.
Email: dcorreia@who.int

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in Eastern Europe with high lifetime abstainers and high spirits consumption ($\hat{\beta}$ = 42, 95% CI = 4–78).

Conclusions: European drinking patterns appear to be clustered by level of beverage-specific consumption, with heavy episodic drinkers, current drinkers and lifetime abstainers being distinguishing factors between clusters. Despite the overall stability of the clusters over time, some countries shifted between drinking patterns from 2000 to 2019. Overall, patterns of drinking in the European Union seem to be stable and partly determined by geographical proximity.

KEYWORDS
alcohol, beverage consumption, cluster analysis, drinking patterns, mortality, public health

INTRODUCTION

Categorizing alcohol consumption into patterns has been common practice for decades (e.g. Room and Mäkelä) [1], often to understand its association with alcohol-attributable health and social harm [2, 3]. Room and Mäkelä [1] introduced 'drinking cultures', describing collective ways of drinking including shared norms, attitudes and beliefs regarding drinking practices [4, 5] They distinguished two main cultures: 'wet' cultures traditionally feature low abstinence, with wine often consumed daily during meals and high overall alcohol availability; and 'dry' cultures, leaning more toward abstinence, regulated alcohol availability and sporadic, intense drinking episodes typically occurring without meals, often resulting in intoxication.

The term 'drinking pattern' is usually defined more narrowly than drinking culture and only includes variables directly describing drinking behaviours, such as drinking status (current drinker, former drinker and lifetime abstainer), heavy episodic drinking or beverage preference. Therefore, this term has been used to describe the categorization of countries beyond merely their level of drinking, usually measured by adult (15 + year-olds) per capita consumption of alcohol (APC), but there is no consensus on which indicators should be included in the patterns. Studies often focus on the most consumed beverage type (classifying countries as beer-, wine- or spirits-drinking countries) [6, 7], consumption frequency [8] and the prevalence of heavy episodic drinking or intoxication [9].

In Europe, countries have historically been categorized based on geography and beverage-type consumption levels [10, 11]. The Mediterranean drinking pattern is known for having wine as the predominant beverage, daily and almost-daily drinking, often with meals and relatively rare drinking to the point of intoxication [12]. The Central and Western European pattern features beer as the predominant beverage, a mix of alcohol use with and without meals, and a higher intoxication level compared to the Mediterranean style [10]. Finally, the spirits-dominant pattern of drinking, traditionally seen in Nordic and Eastern countries, involves frequent days of abstinence, mainly drinking on weekends and festive occasions, often without meals and leading to intoxication. It has been linked to higher rates of violence and injury, as well as undiagnosed and untreated alcohol use disorders [13].

However, globalization, economic changes and shifts in policy frameworks may influence alcohol consumption behaviors, preferences for types of alcoholic beverages and social norms surrounding drinking. Therefore, the traditional classification of drinking patterns in Europe may no longer be valid [13]. Moreover, previous assessments of national drinking patterns have been limited as they were confined to cross-sectional analyses [8], often focusing on one or a few countries [14], lacking direct comparisons across nations using consistent and comparable datasets. The introduction of the World Health Organization's (WHO) monitoring system [15] allows us to overcome these limitations, by using, for the first time, collected and comparable data from different time points over the past two decades.

Therefore, the main objectives of this study are threefold. First, we aim to classify European drinking patterns using a data-driven approach on country-comparable indicators for alcohol exposure for 2019, because it is the most recent year available in the WHO monitoring system. Second, we aim to identify changes in this classification from 2000 to 2019 and the overall stability of patterns and countries, using the years 2000, 2010, 2015 and 2019 as measurement points. Third, we aim to explore whether the often-postulated links between drinking patterns and alcohol-attributable harm indicators, such as mortality or burden of disease (e.g. Koroyayev *et al.* [15], Devaux and Marsaudon [16] and Babor *et al.* [17]), can be empirically established in the most recent year. In addition, we aim to discuss how policies might have influenced countries to change between drinking patterns, and the potential consequences for future alcohol control policies [17, 18].

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METHODS

Data sources

For the classification of drinking patterns, we used harmonized country-specific alcohol exposure data from the WHO Global Monitoring System on Alcohol and Health [19, 20]. All data considered are systematically collected and comprise comparable estimates on all relevant alcohol indicators, which have been validated by the Member States before release [21]. The statistical procedures for estimating these data are extensively detailed elsewhere [22], but in short, the estimation process is based on data from official records (sales/taxation or production plus import minus export) and country surveys, harmonized through three main statistical models. The first model estimates annual APCs in litres of pure alcohol. The largest contributor to APC is recorded consumption, mainly based on sales and taxation records and further divided by type of alcoholic beverage (beer, wine, spirits and other), followed by unrecorded consumption, estimated based on national surveys (e.g. Probst *et al*. [23] and Manthey *et al*. [24]). APC is further adjusted for 'tourist consumption' (i.e. for the consumption of alcohol by non-residents of the country where the alcohol is bought and consumed). The second model estimates the prevalence of current drinkers (CD) (people who have consumed alcohol in the past 12 months), former drinkers (FD) and lifetime abstainers (LA), by sex in adults (≥15 years old), and separately among 15- to 19-year-olds, based on data from country surveys, APC and other influencing factors such as gross domestic product at purchasing power parity (GDP PPP). Finally, the prevalence of heavy episodic drinkers (HED) (people who have consumed 60 g or more of pure alcohol at least once a month in the past 12 months) is estimated for the same groups, using data from country surveys and the previously estimated indicators. For a comprehensive list of all country surveys used (n = 311 surveys) in these models, please refer to the Supporting Information, section S1.

For the associations between drinking patterns and alcohol-attributable harm, two indicators were used from the WHO [25]: age-standardized rates of alcohol-attributable disability-adjusted life years (DALYs) lost and deaths per 100 000 people.

Scope of the study

The year 2019 was used as the most recent year because of the significant impact of the coronavirus disease 2019 (COVID-19) pandemic on drinking patterns in European countries [26]. Projections indicate, however, a return to pre-COVID-19 patterns in the coming years [25]. The countries included were European Union (EU) countries plus Iceland, Norway and Ukraine, (i.e. countries that are participating in the ongoing WHO-EU Evidence into Action Alcohol Project 2022–2026) to which this publication contributes. There were no missing data for either the alcohol exposure indicators or alcohol-attributable harm indicators in the countries included in this analysis. These countries comprised an adult population (15+) of ∼420 million people in 2019, and 399 million in 2000 [27].

Using the STROBE guidelines [28] including its checklist, this study follows recommended reporting standards for observational research. Moreover, the primary research question and analysis plan for this study were not pre-registered on a publicly available platform, and therefore, the analysis should be regarded as exploratory.

Cluster analysis

To classify national alcohol drinking patterns in Europe for the year 2019, hierarchical cluster analysis (HCA) [29] was performed for indicators from the same year. The initial set of variables included all indicators for alcohol exposure previously described, including their disaggregation by sex (female and male) and age group (all adult population age 15+, and age group 15–19), whenever available, and sex and age-group ratios for those variables (Supporting Information, section S2). However, collinear indicators were excluded (e.g. CD + FD + LA = 1; so CD was dropped), as well as indicators highly correlated with each other (higher than 0.85 or lower than −0.85) (Supporting Information, section S3). Therefore, the final set of indicators used for the cluster analysis were: (a) APC in its constituents in absolute values, namely recorded beer, wine, spirits and other beverages, and tourist and unrecorded consumption (the latter log-transformed, given its asymmetric distribution); (b) drinking status indicators, namely FD, LA and age-standardized HED in the population; and (c) sex and age group-specific indicators (e.g. the ratio of alcohol consumption between males and females, or the ratio of drinkers in the age group 15–19 and all-adult population). The final set of indicators used for HCA is indicated in Supporting Information, Figure S2 and is available in Supporting Information, Data S1.

Before the analysis, all indicators were *z*-standardized (i.e. transformed to have a mean of zero and a SD of one) to ensure that each variable contributes equally to the analysis. Distances between countries were calculated using Euclidean distance and countries were agglomerated using Ward's method, which minimizes the total within-cluster variance, after obtaining the best agglomerative coefficient among several methods. The results were plotted using a dendrogram (Figure S3), and the number of clusters defined as k = 6 after visual inspection of the distances obtained.

After performing a cross-sectional HCA for 2019, the same approach was replicated for 2015, 2010 and 2000. In the year 2000, data suggested an additional cluster, and therefore, the number of clusters increased to k = 7.

The cluster-specific drinking patterns identified in 2000, 2010, 2015 and 2019 were analysed in terms of alcohol consumption and drinking status indicators. Because clusters identified in 2019 exhibited notable consistency in terms of alcohol consumption and drinking status over time, we used the same names and colors to describe them over time. Clusters were named based on the characteristics that both define and distinguish them (i.e. having the highest or second-highest values for specific characteristics in the year under

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consideration) (Figure S4). The only exception to this rule pertained to the clusters related to beer consumption, for which clusters occasionally ranked third.

Statistical methods

The patterns were described for all four time points by means and SDs. Analysis of variance (ANOVA) was used to assess differences in mean values across the identified drinking patterns for each variable. The homogeneity of variance across group assumption was tested using the Levene Test and Welch's ANOVA used if violated.

For 2019, potential cluster differences in age-standardized alcohol-attributable DALYs lost and deaths per 100 000 people were tested through linear regression analyses, using the previously identified drinking patterns as dummy variables, and the cluster with the lowest mean DALYs and deaths serving as the reference point. Adding to the known associations between economic wealth with mortality and burden of disease (e.g. Deaton and Rehm *et al.*) [30, 31], and consequently with alcohol-attributable mortality and burden, we anticipated that economic wealth might also influence drinking patterns as it may impact lifestyle choices and access to alcoholic beverages [32], potentially confounding the association between drinking patterns and alcohol-attributable deaths and DALYs lost. Therefore, the linear regression analyses were adjusted for GDP PPP per capita, obtained by the World Bank [33], to account for this potential confounding effect.

All analyses were performed in R software version 4.2.1, and the hierarchical cluster analysis was performed using the 'cluster' library [34]. A significance level of $\alpha = 0.05$ was used for all statistical tests.

RESULTS

Objective 1: Drinking patterns in 2019

In 2019, six alcohol drinking patterns were identified in Europe (Figure 1). After analysing the differences between these patterns in terms of alcohol consumption and drinking status (Table 1), they can be described as follows:

Wine-drinking countries are characterized by the highest consumption of wine, but the lowest consumption of beer and spirits as well as the lowest overall alcohol consumption, located mainly in the south of Europe. The countries included are France, Greece, Italy, Portugal and Sweden (31.3% of the adult population of all 30 countries).

High beer and low spirits consumption countries in Central-Western Europe are characterized by a high consumption of beer and relatively low consumption of spirits and are further characterized by having the highest tourist consumption. The countries included are Austria, Belgium, Denmark, Germany, Netherlands, Norway, Slovenia and Spain (36.9% of the population).

High beer consumption and (prevalence of) HED among CD countries in Eastern Europe are characterized by having the highest consumption of beer and the highest prevalence of HED among CD and additionally, has a high consumption of spirits. The countries included are Croatia, Czech Republic, Hungary, Poland, Romania and Slovakia (17.7% of the population).

High spirits and 'other' beverage consumption countries in Eastern Europe are characterized by the highest consumption of spirits and 'other' alcoholic beverages, also presents high overall alcohol consumption and beer consumption and furthermore, has the lowest wine consumption and prevalence of LA, and low HED. The countries included are Estonia, Latvia and Lithuania (1.2% of the population).

High (prevalence of) LA with high spirits consumption countries in Eastern Europe, presents the highest prevalence of LA and lowest prevalence of drinkers as well as the lowest prevalence of HED, while having a high consumption of spirits. The countries included are Ukraine, Bulgaria and Cyprus (10.6% of the population).

High (prevalence of) CD and HED countries are group of countries not geographically clustered, but with the highest prevalence of drinkers, as well as the highest prevalence of HED, both considering the total adult population and only among drinkers. The countries included are Finland, Iceland, Ireland, Luxembourg and Malta (2.3% of the population).

Objective 2: Changes in drinking patterns in 2000 to 2019

The clusters representing drinking patterns identified in 2015, 2010 and 2000 are also presented in Figure 1, obtained by applying the same methodology to the data of the corresponding year. Overall, the same clusters were identified from 2000 to 2019, with two-thirds of the countries (20 of 30) staying in the same cluster for all measurements. On average, there were five shifts of 30 countries between each pair of consecutive time points. The countries that shifted between clusters at least once were Greece, Iceland, Luxembourg, Malta, Norway, Poland, Slovenia, Spain, Sweden and Ukraine.

In 2015, patterns closely mirroring those of 2019 were evident (Table S1). The sole change in country patterns between 2015 and 2019 occurred in Sweden, which in 2015 fit best with the 'High beer and low spirits consumption countries in Central-Western Europe' cluster.

In 2010, there was a stronger representation of wine-drinking countries, with nine nations conforming to this pattern, at that time including Malta, Spain, Iceland and Norway, in addition to the original five countries (Figure 1). Moreover, the 'High beer and low spirits consumption countries in Central-Western Europe' cluster was reduced to Austria, Belgium, Denmark, Germany and Netherlands. In addition, at this time, Slovenia was closer to the 'High beer consumption and HED among CD countries in Eastern Europe' cluster, whereas Ukraine was grouped in the 'High spirits and 'other' beverages consumption countries in Eastern Europe', all former Soviet Union countries. The remaining countries retained their 2019 patterns.

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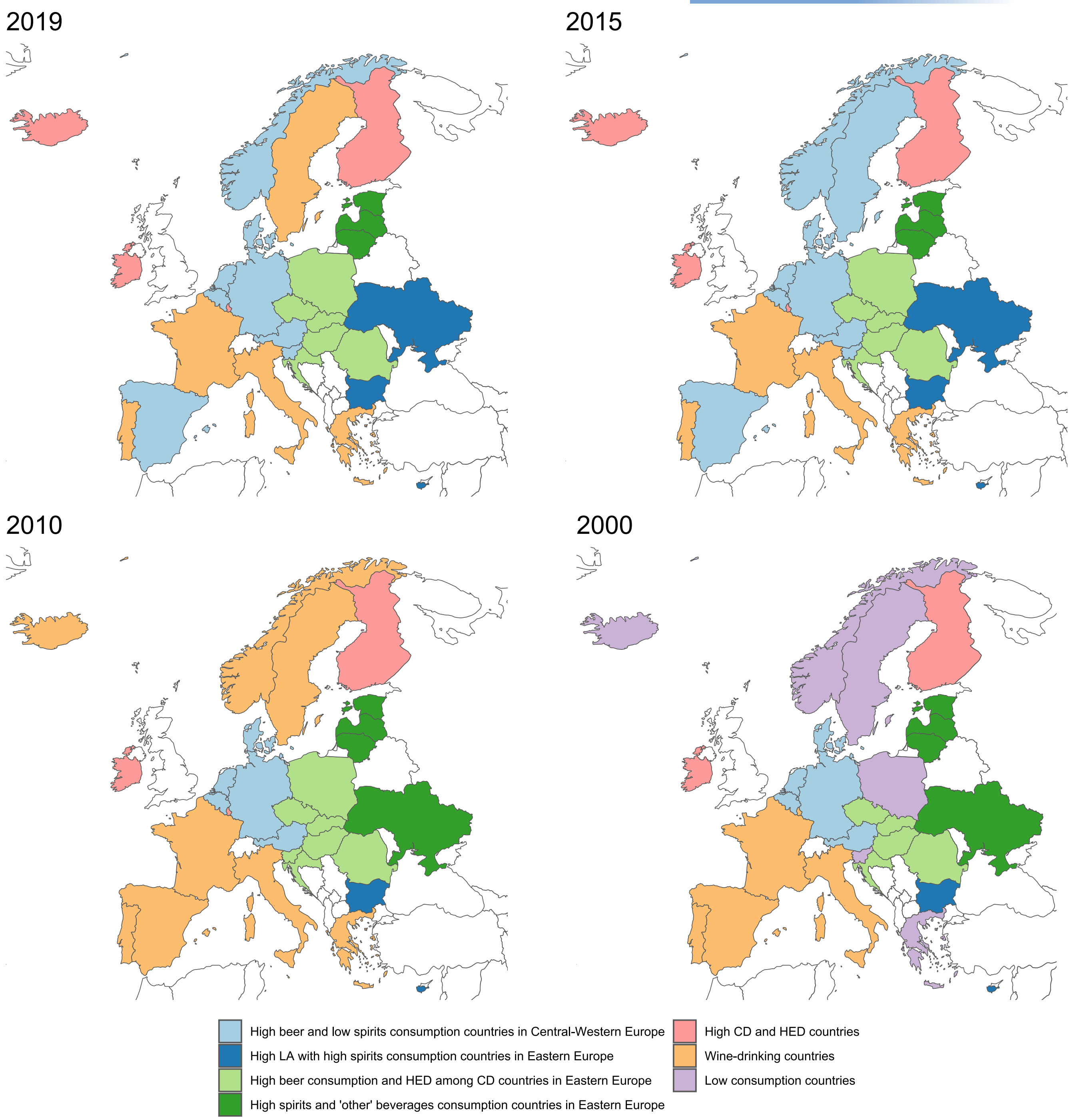

FIGURE 1 Drinking patterns identified in Europe, based on alcohol per capita consumption and drinking status indicators. CD, current drinkers; HED, heavy episodic drinkers; LA, lifetime abstainers.

At the turn of the millennium, an additional cluster was identified, 'Low alcohol consumption countries', characterized, as the name suggests, by relatively low general alcohol consumption (i.e. 34% lower APC than the rest of the countries), but also by a low level of spirits consumption (Figure 1 and Table S5). This cluster included Greece, Iceland, Malta, Norway, Poland, Slovenia and Sweden; and in the year 2000, it represented 13.4% of the adult population, but it then disappeared for the other measurement points. Apart from this change, the only difference observed in comparison to 2010 was for Luxembourg, which in 2000 had been clustered as a wine-drinking country.

Objective 3: Association with alcohol-attributable harm

In 2019, significant associations were found between drinking patterns and age-standardized alcohol-attributable deaths and DALYs

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TABLE 1 Mean and SD of APC and drinking status indicators in 2019, by drinking patterns identified in the same year.

	Wine-drinking countries	High beer and low spirits consumption countries in Central-Western Europe	High beer consumption and HED among CD countries in Eastern Europe	High spirits and 'other' beverages consumption countries in Eastern Europe	High LA with high spirits consumption countries in Eastern Europe	High CD and HED countries	*P*-value[a]
Total APC	9.2 (1.72)	10.2 (1.74)	11.9 (2.93)	12.0 (0.94)	9.6 (2.07)	9.8 (1.71)	0.194
Recorded APC	8.6 (2.12)	9.6 (1.82)	11.0 (1.01)	11.9 (0.97)	8.3 (2.94)	9.5 (1.63)	0.078
Unrecorded APC, log-transformed	−0.3 (0.64)	−0.8 (0.11)	0.0 (0.99)	0.1 (0.31)	0.0 (0.97)	−1.0 (0.39)	0.055
Tourist APC	−0.3 (0.23)	0.2 (0.41)	−0.7 (0.85)	−1.0 (0.88)	−0.2 (0.27)	−0.1 (0.55)	**0.038**
Beer	2.3 (0.30)	4.4 (1.13)	5.1 (1.14)	4.7 (0.49)	3.2 (1.20)	4.2 (0.49)	**0.001**
Wine	4.7 (1.56)	3.5 (0.74)	2.7 (0.97)	1.5 (0.58)	1.5 (1.01)	2.8 (1.26)	**0.002**
Spirits	1.4 (0.60)	1.6 (0.51)	3.1 (1.16)	4.9 (0.36)	3.6 (1.09)	1.9 (0.54)	**<0.001**
Other alcoholic beverages	0.2 (0.14)	0.1 (0.13)	0.1 (0.17)	0.9 (0.33)	0.1 (0.11)	0.6 (0.54)	0.077
Prevalence of LA	14.4 (2.70)	11.7 (0.82)	12.8 (2.03)	7.8 (0.15)	18.5 (3.18)	9.0 (3.44)	**<0.001**
Prevalence of FD	9.8 (0.48)	10.7 (1.76)	14.0 (0.68)	17.2 (0.35)	14.6 (4.43)	10.0 (0.70)	**<0.001**
Prevalence of CD	75.7 (2.72)	77.6 (2.27)	73.2 (2.55)	74.9 (0.29)	66.9 (1.41)	80.9 (2.86)	**<0.001**
Age-standardized HED	33.6 (5.95)	33.6 (1.99)	37.9 (3.89)	30.5 (0.61)	21.8 (1.25)	44.1 (3.15)	**<0.001**
Age-standardized HED among CD	43.2 (6.57)	42.4 (1.72)	50.7 (3.77)	39.5 (0.55)	32.1 (1.81)	53.8 (2.42)	**<0.001**

Note: Wine-drinking countries: France, Greece, Italy, Portugal, Sweden. High beer and low spirits consumption countries in Central-Western Europe: Austria, Belgium, Denmark, Germany, Netherlands, Norway, Slovenia, Spain. High beer consumption and HED among CD countries in Eastern Europe: Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia. High spirits and 'other' beverages consumption countries in Eastern Europe: Estonia, Latvia, Lithuania. High LA with high spirits consumption countries in Eastern Europe: Bulgaria, Cyprus, Ukraine.
High CD and HED countries: Finland, Iceland, Ireland, Luxembourg, Malta.
Abbreviations: ANOVA, analysis of variance; APC, alcohol per capita consumption for the adult population (15+), per year, in litres of pure alcohol; CD, current drinkers; FD, former drinkers; HED, heavy episodic drinkers; LA, lifetime abstainers; SD, standard deviation.
[a]ANOVA *P*-values for differences in means among groups. Homogeneity of variance across groups was tested using Levene Test and considered in the ANOVA results. Bold values highlight statistically significant differences (*P*-value <0.05).

lost per 100 000 people (both *P*-values <0.001, Figure 2). The cluster 'High spirits and 'other' beverages consumption countries in Eastern Europe' had the highest average burden, with its three countries consistently ranking in the top four for DALYs and deaths. Eastern European countries with high LA and with high spirits consumption displayed the second highest mean DALYs and deaths. Although this was mainly because of alcohol-attributable health burden in Ukraine, Cyprus—the only other country in this cluster apart from Bulgaria—showed the lowest burden. Additionally, countries in the 'High beer consumption and HED among CD countries in Eastern Europe' cluster presented a consistent mortality and burden of disease pattern, with the third-highest averages and consistently clustering in the upper half of rankings for both indicators.

The relationship between 2019 drinking patterns and alcohol-attributable deaths and DALYs lost indicators persisted after adjusting for countries' GDP PPP (Table 2). On average, compared to the wine-drinking cluster, which exhibited the lowest age-standardized alcohol-attributable DALYs and deaths per 100 000 people, the cluster 'High spirits and 'other' beverages consumption countries in Eastern Europe' had 3102 (95% CI = 1890–4314) more DALYs and 90 (95% CI = 55–126) more deaths, whereas the 'High LA with high spirits consumption countries in Eastern Europe' showed 1653 (95% CI = 441–2865) more DALYs and 42 (95% CI = 5–78) more deaths, per 100 000 people. Furthermore, the 'High beer consumption and HED among CD countries in Eastern Europe' experienced 1226 (95% CI = 221–2231) additional DALYs per 100 000 people than the wine-drinking cluster. The 'High beer and low spirits consumption countries in Central-Western Europe' and 'High CD and HED countries' showed no statistically significant difference in alcohol-attributable deaths or DALYs lost from the 'Wine-drinking countries' cluster.

DISCUSSION

A repeated cross-sectional clustering of countries for the years 2000, 2010, 2015 and 2019 of all countries of the EU plus Iceland, Norway

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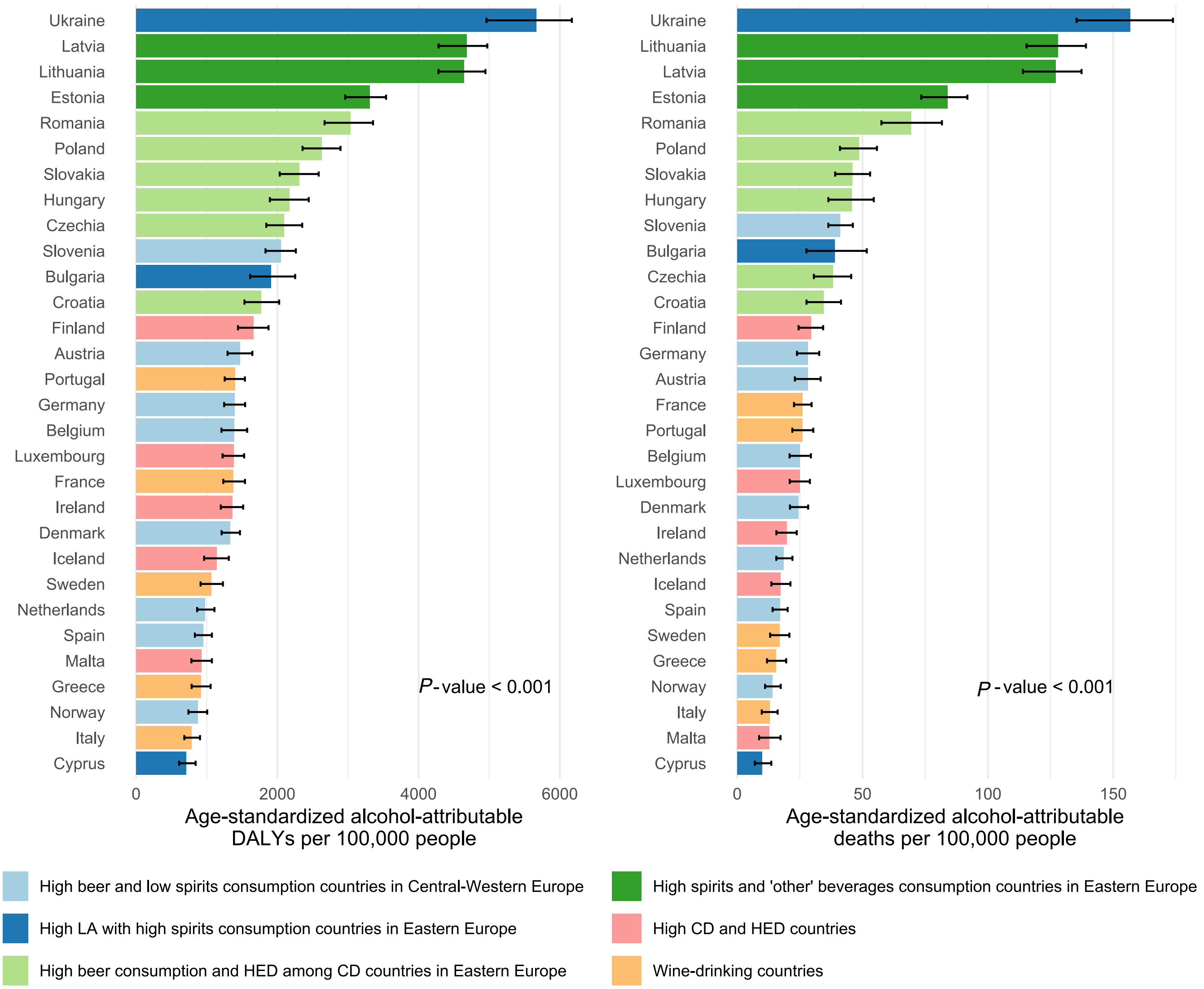

FIGURE 2 All causes age-standardized disability-adjusted life years (DALYs) lost and death rates in Europe by country, in 2019. Analysis of variance *P*-values for differences in means among groups.

and Ukraine revealed that clusters were mostly stable and resembled the classic classification system, which divided countries into primarily wine-, beer- or spirits-drinking countries, based on geography and drinking traditions (i.e. drinking patterns, which have been shared by neighboring countries for some time). The only exception to the stability was the addition of a cluster in 2000, which could be characterized by lower APC. Interestingly, not a single cluster where spirits are dominant could be identified, but we find that spirits consumption is relatively high in all three clusters, including Eastern European countries. Moreover, one cluster emerged that is neither characterized by beverage type nor by geography, but by high prevalence of heavy episodic drinking.

Clusters were associated with different mortality and burden of disease rates, and these differences cannot be fully explained by wealth. After adjusting for GDP PPP, all three clusters involving Eastern European countries showed higher alcohol-attributable health harm (with the 'High beer consumption and HED among CD countries' only being significant for DALYs lost) (see Table 2).

How can we explain the results? First, the clusters in 2019 show clear continuity with several previously used classification systems in the field based on alcohol beverage preference and geography. Together with our findings of mostly stable clusters, this indicates overall culturally influenced patterns of drinking, which seem to be relatively stable over time. Second, let us more systematically examine the changes. The biggest change in clusters was the disappearance of the low APC cluster between 2000 and 2010. What factors may have played a role here? The loosening of alcohol control policy seems to be involved in several of the countries. Interestingly, in 2000, four of the countries in this cluster (Norway, Poland, Iceland and Sweden) had the four highest rankings in alcohol control policies in comparative analyses of all the Organization for Economic Cooperation and Development (OECD) countries at that time [35]. During this time period, all four of these countries had

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TABLE 2 Linear regression models for the association between the drinking patterns identified in 2019 and age-standardized alcohol-attributable mortality and DALYs lost rates per 100 000 population in the same year, adjusted for GDP PPP.

	Adjusted $\hat{\beta}$ (95% CI)	
	DALYs lost	**Deaths**
Wine-drinking countries	Ref	Ref
High beer and low spirits consumption countries in Central-Western Europe	374 (−595, 1343)	10 (−18, 39)
High beer consumption and HED among CD countries in Eastern Europe	**1226 (221, 2231)**	24 (−6, 53)
High spirits and 'other' beverages consumption countries in Eastern Europe	**3102 (1890, 4314)**	**90 (55, 126)**
High LA with high spirits consumption countries in Eastern Europe	**1653 (441, 2865)**	**42 (5, 78)**
High CD and HED countries	186 (−864, 1235)	15 (−22, 51)

Note: Coefficients statistically different from zero are highlighted in bold. Abbreviations: CD, current drinkers; DALYs, disability-adjusted life years; GDP PPP, gross domestic product at purchasing power parity; HED, heavy episodic drinking; LA, lifetime.

relaxed their alcohol policies [17, 36, 37]. Meanwhile, the remaining countries in the 2000's low consumption cluster—Greece, Malta and Slovenia—can all be characterized by being located in the southern part of the EU, having a GDP-PPP under 20 000 international dollars ($ Int.) in 2000, being wine producers with relatively high wine consumption, and having relatively high informal control [16]. Moreover, for Greece and Slovenia, the APC did not increase between 2000 and 2010. Therefore, although the cluster of low APC seemingly disappeared, this does not suggest that all of the countries in this cluster increased their consumption.

Although drinking-pattern clusters were defined in part by a beverage type's consumption level, it should be noted that there is a definite link between the beverage consumed and intoxication because of more rapid ingestion of ethanol via spirits [38]. However, health outcomes are largely equal per standard drink of beer, wine, spirits and other alcoholic beverages consumed, as ethanol is the main component of alcoholic beverages which impacts health [39].

Can a pattern of relatively high APC and low mortality such as that seen in Western Europe be achieved by changing drinking patterns? This question evokes the principles spelled out by Room [40] in his seminal paper on the 'impossible dream', where he described two possible solutions to be used in countries with a high degree of heavy episodic drinking, such as the countries in Northern and Eastern Europe. Room described [40] a 'wet' approach, achieved by gradually replacing the drinking culture, and a 'dry' strategy, achieved by imposing strict regulatory measures. The 'wet solution', with a Mediterranean drinking pattern and low mortality, seems to have been achieved in Sweden. Sweden has switched from a low alcohol consumption pattern in 2000 to the drinking pattern of a wine-drinking country, including all other characteristics such as lower rates of HED and overall still relatively low per capita consumption, maintaining a low alcohol-attributable burden of disease and mortality (Figure 2). However, this transition seems to be the exception, as most other countries remained in their cluster and retained the respective characteristics. It may be speculated that such a transition was facilitated by a strong alcohol monopoly, covering the vast majority of alcohol sales [41].

Last, the associations between patterns of drinking and harm persisted after adjusting for GDP PPP, but because they show a basic regional pattern of more Eastern countries being associated with higher alcohol-attributable harm, other factors may play a role. Most importantly, Eastern European countries not only have lower GDP PPP, but also higher overall deaths and DALYs lost [42]. Clearly, the overall level of burden of disease and mortality will determine the alcohol-attributable level and, therefore, future research will need to separate these two influencing factors and their interactions.

Strengths and limitations

The WHO's monitoring system is based on two main data sources, official records, which underlie recorded alcohol per capita consumption data [21,43], and survey-based estimates, which are then triangulated for harm estimates to avoid an underestimation of the real level of drinking—as is customarily done when using survey data [22,44]. Two potential biases may result from this approach. First, surveys are based on subjective reports, which are subject to many biases and, which may have affected several indicators of drinking status [45,46]. Second, in the process of triangulation some assumptions about the relationship between alcohol per capita consumption and the level of consumption in different groups defined by sex and age may be found to be wrong. In most approaches, including the one used in the comparative risk assessment of WHO [22,44], it is implicitly assumed that undercoverage is the same for each sex and age group, and this assumption may not hold [47]. Additionally, to estimate other indicators such as CD, LA and HED, APC is used [22], which may lead to overestimating correlations and may introduce indirect collinearity. Although these biases cannot be excluded, it is not clear in which way they may have affected our results. Moreover, it is reassuring that one of the key distinctions between clusters—namely, distribution of most common alcoholic beverages in a country—is estimated based on the sales data, which is usually considered the most reliable and valid data source [48]. Another strength of our methods is the underlying amount and comparability of the data collected over the past two decades (for survey sources see Supporting Information, section S1) (for APC see WHO) [20].

Another limitation of our study is the sample size for conducting cluster analysis (n = 30), which limits the feasibility of using traditional validation methods like cross-validation and bootstrap resampling. However, the stability of our results for the four time points is noteworthy, and strengthens the reliability of our findings.

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CONCLUSION

Europe is still a region with clearly distinct drinking patterns, which seem to be deeply rooted in culture, and are, therefore, difficult to change. Exceptions such as Sweden only underscore this generalization. Because drinking patterns are still strongly associated with burden of disease and mortality, we need to find ways to change the patterns, which characterize the clusters with the highest alcohol-attributable burden, which is HED with its high volume of consumption, and frequent link to spirits consumption without meals. Alcohol policies for this change are available [37] and should be considered by all European countries, as the overall level of drinking is still high in this region.

AUTHOR CONTRIBUTIONS

Daniela Correia: Data curation (supporting); formal analysis (lead); methodology (lead); visualization (lead); writing—original draft (lead). **Jakob Manthey:** Formal analysis (supporting); investigation (supporting); methodology (supporting); validation (supporting); writing—review and editing (supporting). **Maria Neufeld:** Funding acquisition (supporting); project administration (lead); resources (supporting); writing—review and editing (supporting). **Carina Ferreira-Borges:** Funding acquisition (lead); resources (lead); supervision (supporting). **Aleksandra Olsen:** Project administration (supporting); resources (supporting); validation (supporting). **Kevin D. Shield:** Data curation (lead); software (lead); writing—review and editing (supporting). **Jurgen Rehm:** Conceptualization (lead); formal analysis (supporting); methodology (supporting); supervision (lead); validation (lead); writing—original draft (supporting); writing—review and editing (lead).

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CONFLICT OF INTEREST STATEMENT

C.F.B., M.N. and A.O. are staff members of the World Health Organization; D.C., J.R., J.M. and K.S. served as consultants to the WHO and other health organizations. The authors alone are responsible for the views expressed here and these do not necessarily represent the decisions or the stated policy of the WHO.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the Supporting Information of this article.

ORCID

Daniela Correia https://orcid.org/0000-0001-8886-3211
Jakob Manthey https://orcid.org/0000-0003-1231-3760
Kevin Shield https://orcid.org/0000-0003-1871-8849
Jürgen Rehm https://orcid.org/0000-0001-5665-0385

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