

“Harm per litre” as a concept and a measure in studying determinants of relations between alcohol consumption and harm

Robin Room¹ and Jürgen Rehm²

¹ Centre for Alcohol Policy Research, La Trobe University, Melbourne, Australia; Centre for Social Research on Alcohol and Drugs, Department of Public Health Sciences, Stockholm University, Stockholm, Sweden; R.Room@latrobe.edu.au

² Institute for Mental Health Policy Research, Centre for Addiction and Mental Health, Toronto, Canada; Dalla Lana School of Public Health & Department of Psychiatry, University of Toronto, Toronto, Canada; Institute of Clinical Psychology and Psychotherapy, Technische Universität Dresden, Dresden, Germany; Center for Interdisciplinary Addiction Research (ZIS), Department of Psychiatry and Psychotherapy, University Medical Center Hamburg-Eppendorf (UKE), Hamburg, Germany; jtrehm@gmail.com

Abstract

The term “harm per litre” has been increasingly used in alcohol research in recent years as a concept and a comparative measure of alcohol-attributable harm in comparisons between environments, circumstances, and patterns of drinking. This essay discusses the origins of the term in connection with analyses in terms of patterns as well as levels of drinking and with concerns about differential harms from drinking different beverage types. Also discussed is the term’s current primary usage, in the context of epidemiological concerns about differentially severe harms for poorer persons who drink. It is noted that these same concerns have been discussed, particularly in Britain, using the phrase “alcohol harm paradox”.

“Harm per litre” was initially most often used in comparisons between rates of alcohol-attributable harm by beverage type. After 2010, the expression was applied more broadly, particularly after its use in various World Health Organization-related discussions and documents. In addition, and especially from 2018 onwards when most of the papers using this term were published, it has been used in comparisons by socioeconomic status at the individual level, and by level of socioeconomic development at the country level. Almost all the findings indicate that people with lower socioeconomic status, and countries with lower average income, e.g., low income and lower-middle income countries, incur considerably higher harm per litre (with harm being expressed in disease burden and mortality) than upper middle-income and high-income countries.

“Harm per litre” is a practicable and easy-to-understand concept to compare groups of individuals or countries, and to quantify health inequalities. The next important step will need to be elucidating a better causal understanding of the processes underlying these inequalities, with an emphasis on factors which can be most easily changed by interventions.

Key words: alcohol – harm per litre – mortality – burden of disease – inequality – wealth – patterns of drinking

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Harm caused by alcohol is the main reason to initiate alcohol control policies (Babor, et al., 2023). This paper describes ways of thinking about, measuring, and accounting for differences in the relationship between alcohol consumption and harms sustained from drinking. In recent years, a common way of characterising such differences has been in terms of differences in the “harms per litre” of pure alcohol. We will characterize the use of this term embedded into a brief historical context of the development of alcohol epidemiology.

As we will discuss, in the relatively short timeframe of 15 years, harm per litre has been used as a concept and tool for comparison across several dimensions: across alcoholic beverage types, across the socioeconomic and other dimensions of users; and across levels of societal wealth and development. In the future, it may well be used for comparisons across other social divisions both at the level of individuals or families and at societal or other collectivity levels. We hope that this essay will help provide a starting point for such developments.

Two frames emerge for alcohol use as a risk factor: total consumption and heavy occasional drinking

The modern era of epidemiological studies of alcohol use—of looking at amounts and patterns of drinking in the general population and their relation to health and welfare problems—begins after the Second World War. Initially, such studies were mostly carried out in high-income countries such as the U.S., Finland, and Canada (Room, 1990; Savic & Room, 2014)—countries which historically had not only a strong temperance movement in the late 19th and early 20th centuries, eventually seeking alcohol prohibition, but also strong popular reactions against that tradition. In the mid-20th century, a period of reaction against temperance, the main frame in which discussions of alcohol problems could get a hearing was in terms of “alcoholism”, conceived of as an addictive disease caused by an unknown “predisposing X factor” (Jellinek, 1952). This frame, which focused on the consumer rather than on what was being consumed as the source of the problems and the element needing to change, was the most acceptable to alcohol producers and others with an economic interest in alcohol sales (Rubin, 1979).

While population survey studies of drinking practices were uncommon before the 1960s, the longstanding traditions of excise taxes on alcoholic beverages meant that in many countries there were detailed records of quantities sold of different forms of alcohol, and analyses could be made at the population level of the relationship of *per capita* sales of alcoholic beverages and of causes of death known to be related to heavy alcohol consumption—in particular of cirrhosis mortality, which, in the form of the “Jellinek Formula”, was taken as an indicator of “alcoholism” rates (Roizen, Fillmore, & Kerr, 1999). Some scattered analyses did appear which showed a relationship between trends in alcohol sales and trends in deaths from cirrhosis, but little attention was paid initially to the public health implications of finding a direct connection between the level of drinking in a population and physical disease (Roizen, Fillmore, & Kerr, 1999). However, by the time the 1975 book, *Alcohol Control in Public Health Perspective*, was published by an international group of researchers, a clear statement could be made linking level of drinking in a population with adverse effects on health, without reference to the alcoholism frame—meaning, as the book put it, that “changes in the overall consumption of alcoholic beverages have a bearing on the health of the people in any society”. As a consequence, public health measures were indicated, including alcohol control policies (Bruun et al., 1975). But mainstream public health, at least in the US, was still resistant to discussions of alcohol use as a risk factor for health in any terms that extended beyond treatment for alcoholism (Room, 1984).

In the meantime, substantial traditions were emerging of survey studies of drinking patterns in the general population (Gmel & Rehm, 2004; Room, 1977). These studies paid as much attention to respondents’ patterns of drinking as to their overall level of alcohol consumption, particularly when distinguishing between two patterns that had similar overall volumes of alcohol consumption: frequent-light to moderate drinkers, who might drink one or two drinks every day but never more on any given day, and infrequent heavier drinkers, for instance drinking five or more drinks at a time on weekend days (Knupfer, 1966). In terms of the association of particular drinking patterns with rates of health and especially social problems, invariably those who drank more on an occasion reported more problems related to their drinking, even though many of them drank less frequently. As Hilton (1987) put it in his analysis of a U.S. general population survey, “high maximum drinking bears a much stronger relationship to drinking problems than does frequency of drinking”.

From different data sources, there were thus two separate perspectives emerging on the relationship between drinking patterns and the occurrence of alcohol problems. One perspective, based primarily on annual level of consumption at the population level, emphasized a strong relationship between the *per capita* consumption of alcohol and rates of alcohol problems, mainly mortality: more drinking meant more problems. The other perspective, based primarily on individual-level data such as population surveys, emphasized a strong relationship between pattern of drinking—whether a given amount of alcohol was consumed more frequently, a drink or two at a time, or less frequently in larger amounts—and the rate of alcohol problems, often social problems. These two traditions were reconciled to some extent by the work of Ledermann, Skog and others on the distribution of alcohol consumption in a population (Room & Livingston, 2017). Although there was little attention to patterns of drinking in Skog’s work, the finding that movements up and down in the amount of drinking tended to be shared among drinkers meant that the drinking of heavy drinkers (who accounted for the majority of the total consumption anyway) changed when the population’s total consumption changed (Room & Livingston, 2017).

“Pattern of drinking” as a second determinant of harm from drinking

Around the turn of the millennium, the World Health Organization (WHO) moved to describing alcohol use as a risk factor for health at the population level with two dimensions: volume of consumption and patterns of drinking. “Pattern” included drinking high amounts on an occasion, but was conceived of more broadly to include also circumstances of use: “the same amount of alcohol if consumed moderately with meals, for example, may have less detrimental or even beneficial effects compared to consumption as weekend or holiday binges” (Rehm et al., 2001, p. 139; for further discussion, see Rehm et al., 1996). A “Patterns of Drinking” measure put forward in this frame of reference was based on a raw score which ranged from 0 to 17 points, with up to 11 points for four aspects of the amount and concentration of drinking on heavy drinking occasions, 4 points for never or rarely drinking with meals, and 2 points for regularity of drinking in public places (Rehm et al., 2003). The summary score on pattern of drinking, derived from the raw score, ranged from 1 as the least hazardous to 4 (later 5) as the most hazardous, and was described as an “indicator of the hazard per litre of alcohol consumed” (e.g., Room, Babor & Rehm, 2005, p. 522; see World Health Organization, 2011). Also, in the original publication it is indicated that a “higher score implies a greater rate of harm per litre of alcohol” (Rehm, Rehn et al., 2003).

As the weighting in the score's composition reflects, the primary emphasis in the score is on how much of the drinking in the society consists of heavy drinking occasions: a cultural pattern of drinking large amounts infrequently tends to result in more health and social problems than the same amount spread over daily drinking occasions, with the extra harm concentrated in specific problems (Bobak et al., 2004; Norström et al., 2002; Rehm et al., 2007).

This summary score was applied at the country level across the globe as part of WHO's estimates of alcohol use as a risk factor in the burden of disease. But the breadth of application meant that its primary basis was necessarily via judgement by key informants, though the resultant scores had a fairly good relation to scores derived from quantitative epidemiological data (Astudillo et al., 2010). The measure became for a while a routine characterisation of each country's alcohol summary statistics in WHO's *Global Information System on Alcohol and Health* (GISAH) (World Health Organization, 2022b), with the country's score included in each country's summary page in the 2014 Global Status Report (World Health Organization, 2014).

The Patterns of Drinking score was replaced in the 2018 Global Status Report by a simpler indicator of "alcohol consumption risk", Heavy Episodic Drinking, which was defined in the 2018 report as drinking 60 grams at least once a month (World Health Organization, 2018, p. 47). Accordingly, on the GISAH website, it is Heavy Episodic Drinking which now accompanies per capita volume of consumption in characterizing consumption among those who drink any amount of alcohol. Nevertheless, a more recent analysis argues that alcohol consumption per capita aged 15+ should be the preferred indicator if only a single indicator of harmful use of alcohol is being used (Rehm et al., 2020), such as in the indicators for the Sustainable Development Goals (United Nations Department of Economic and Social Affairs, 2022).

Focusing on the ratio: harm/consumption level

In the background of patterns of drinking measures is the implication that the same average amount of alcohol consumed causes different amounts of harm, which pointed to a new metric which researchers have termed "harm per litre". In the following, we describe the different subliteratures which have used the "harm per litre" terminology in chronological order of appearance, and for the most recent—concerning differences in harmful effects per unit of alcohol by socioeconomic status—bring in a parallel literature not using the term,

before concluding with some suggestions on further use of the harm per litre concept and measure.

In preparation for this essay, we searched for the term “harm per litre” in English and American spelling (liter) in PubMed and Google Scholar in July 2022, together with the key word “alcohol”. In addition, we searched the reference lists of publications cited. Among publications which included the term “harm per litre”, we focused on those where the term was a central concept to the paper, and which were impactful as measured in citations.

The searches resulted in 37 hits using Google Scholar, and in no hits with the quoted phrase using PubMed. A wider search in the latter databank without a quoted phrase resulted in 22 hits. Of the 37 hits in Google Scholar, 31 were retained for analyses, along with one found via hand search (Rehm et al., 2003) (data available upon request). Most of the publications were published between 2018 and 2022 (23 out of 32; 72%), and almost all of these used the term in connection with health inequalities (see below for details).

The advent of “harm per litre”: comparing beverage types as determinants of harm, 2007-2011

We have noted that there was occasional use of such phrases as “hazard/harm per litre” in referring to what was being measured by the Patterns of Drinking score. And Bobak et al. (2004, Table 3) had made use of ratio measures of harm per alcohol intake indicator which showed clear differences between countries. But the formulation “harm per litre” (or “harm per liter”) was first used as a key term in **the abstract of** a 2007 paper by Mäkelä et al. (Mäkelä, Mustonen & Österberg, 2007) looking at differences in harm caused by beverage type. This is also the earliest entry retrieved from the Google Scholar search. Variations in “harm per litre of pure alcohol” are also mentioned in the context of comparisons of beverage types in a 2009 paper reviewing the international monitoring of alcohol consumption and harm (Rehm & Room, 2009).

There is a long tradition in Nordic countries of policy differentiation between beer, wine, and spirits, with a major emphasis in the 1960s and 1970s on policies which succeeded in substantially diminishing spirits’ share of the alcohol consumption (though primarily by differentially increasing the consumption of wine and beer). The abstract of the 2007 paper on this topic (Mäkelä, et al., 2007) relates the tax differences between the different alcoholic

beverages to their “harm per litre of ethyl alcohol”. The assumption of differential harmfulness for a given level of pure alcohol consumption was then re-examined by Nordic researchers, in an international project conducted in response to questions about the Nordic experience raised by Russian researchers at a 2007 Moscow conference (Hellman et al., 2011). The papers resulting from the first stage of this project on “trouble per liter: the effects of policies favoring lighter beverages” were published together in a 2011 journal issue. All five papers are based on the concept of “harm per litre”, even if the majority used the term “trouble per litre” for their analyses and explanations (Landberg, 2011; Mäkelä, 2011; Mäkelä et al., 2011; Ramstedt & Boman, 2011; Room et al., 2011; for additional analyses on the same topic see Landberg & Hübner, 2014).

Using “harm per litre” in comparing populations

The focus on differences in harm from different beverage types did not persist, but the formulation in terms of “harm per litre” began to be applied in comparisons of other dimensions, often in association with drinking patterns. For instance, a paper appeared applying the formulation to cross-country comparisons, arguing that there was an elevated “harm per litre of alcohol” in countries with “detrimental drinking patterns” (Norström & Stickley, 2013). The formulation was also applied to global regions; thus, a paper on alcohol-related stressors in family life in rural Sri Lanka references the WHO’s 2014 Global Status Report to note that South-East Asia has a relatively high rate of “harm per litre of alcohol” (Sørensen et al., 2017), and a recent review of the public health importance of per capita alcohol consumption notes findings that “more harm per liter is experienced in regions or cultures characterized by a more hazardous drinking pattern” (Rossow & Mäkelä, 2021, p. 10).

Harm per litre and socioeconomic status, individual or societal: 2010 onward

Current use of the “harm per litre” concept and related formulations seems most often to be in connection with socioeconomic status (SES), whether at the individual or the societal level. From the Google Scholar search, the earliest use of “harm per litre” in this connection appears to be in a 2010 WHO-commissioned book chapter. The chapter argues that “what is important from a health equity perspective” is “to examine the question of harm per litre....

The differential harm from a given amount of drinking is a crucial variable in tackling alcohol problems among the poor and particularly the marginalized”, including the “harm to others in the social context of problem drinkers” (Schmidt et al., 2010, p. 24). A similar concept was labelled “burden/deaths per litre” in a publication comparing different WHO regions for a WHO “Global Expert Meeting on Alcohol, Health and Social Development” in Stockholm. This analysis found high correlations between economic development and disability (DALY) or mortality harms per litre (Rehm, et al., 2009). At the same time, in a review co-financed by the European Union, Anderson concluded that within the European Union, the wealth of countries was positively associated with level of alcohol consumption but inversely with harm per litre of alcohol consumed. Thus, the less wealthy a country, the “greater burden of alcohol-related harm per litre of alcohol consumed” (Anderson, 2010, p. 4).

There is now considerable evidence that harm per litre of pure alcohol is generally considerably greater for poorer than for richer people who drink and their families, and also considerably greater in poorer than in richer societies (Room, Cook, & Laslett, 2022). These points about “alcohol and inequalities”—that “the ‘harm per litre’ of alcohol is substantially greater for poorer drinkers than for richer ones”, and that “harms from a given level or pattern of drinking may also be higher for a lower-income society than for a high-income one”, are clearly made in the WHO’s *Global Status Report on Alcohol and Health, 2018* (World Health Organization, 2018, pp. 14-17), and the points, along with the terminology, have been picked up from there in a broader range of recent research papers and editorials (e.g., Mehta & Sheron, 2019; Moissl et al., 2020; Moriarty, 2020; Schess et al., 2020; Rehm et al., 2021, p. 7). The formulation in terms of greater “harm per litre” for poorer people who drink is picked up in a WHO Euro “fact sheet” on “Alcohol consumption and sustainable development” (World Health Organization, European Office, 2020, p. 3) and in a *Lancet* seminar paper for clinicians on alcohol use disorders (Carvalho et al., 2019, p. 782). The point about greater harm per litre in poorer world regions and countries is picked up in a review paper on alcohol patterns and issues in sub-Saharan Africa (Morojele et al., 2021, p. 416), in a review considering the impact of societal development on the burden of disease from alcohol (Shield & Rehm, 2021, pp. 2326, 2335), and in a paper on prioritizing action on alcohol for health and development in the context of the WHO’s focus on risk factors in non-communicable diseases (Rekve et al., 2019).

Current alternative framings of SES variations in the relationship between consumption and harm

There is by now a substantial literature of individual-level analyses of variation in rates of alcohol-attributable harm within a society by socioeconomic status, though mostly without use of the harm per litre terminology or measure. Often the measure used for comparison is the difference between socioeconomic groups in their ratio of alcohol-attributable mortality to all-cause mortality (Probst et al., 2014; see also Probst et al., 2021).

Another tradition focusing on socioeconomic status and rates of alcohol-related harm takes as its terminology the “alcohol harm paradox”, referring to findings that “the most alcohol-related harms [are] experienced by deprived socioeconomic groups, despite the fact that they generally consume no more, or perhaps less, alcohol than the most affluent groups”, as it was stated in one of the reports introducing the paradox terminology in 2014 (Smith & Foster, 2014, p. 13). Late in the previous year, the report of the 2012 Health Survey for England also noted and named the “alcohol harm paradox”, with a footnote that “Alcohol Research UK have funded the Centre for Public Health at John Moores University to investigate this paradox”, and that initial findings had been presented at a 2013 conference (Fuller, 2013. pp. 3, 13). When the final report of that project was published (Bellis et al., 2016), the concept of the “alcohol harm paradox” received some initial publicity (e.g., Marmot, 2014), and promotion of the concept to general audiences has continued (e.g., Public Health England, 2016, pp. 26-27; Canadian Institute for Health Information (CIHI), 2017; Russell, 2020; Windle, n.d.), most recently in a WHO policy brief (World Health Organization, 2021, p. 13). It should be noted that the paradox referred to is different from the “prevention paradox”, introduced to alcohol studies two decades before by Norman Kreitman (1986) – where the paradox is that “the majority of alcohol-related harms tend to occur among low and moderate-risk drinkers, simply because they are more numerous than high-risk drinkers, who still have a higher individual risk of experiencing harm” (O’Dwyer et al., 2019, p. 2).

An early analysis using a large English dataset collected for other purposes reported that whether the alcohol harm paradox was found depended on which measure of socioeconomic status was used (Beard et al., 2016). Other lines of work set out to study potential explanatory factors for the alcohol harm paradox, focusing initially on individual-level factors which could explain the higher rates of alcohol-attributable harm in “deprived

populations”. Mentioning also the possibility of differential accuracy in reporting consumption, Bellis and colleagues studied the contributions of more hazardous drinking histories and patterns of consumption, and of interactions with other negative health risks such as poor diet and smoking, finding in an English telephone survey sample that “increased risk drinkers in deprived communities were 10.9 times more likely to carry the additional burden of not just smoking but also unhealthy lifestyle and excess weight” (Bellis et al., 2016, p. 8). More recent mortality cohort studies in Scotland (Katikireddi et al. 2017) and Finland (Peña et al., 2021), testing for the effects of confounding and interactive risk factors, have found a large residual differential effect of socioeconomic status on alcohol-related mortality, and a methodological study in eight countries (Peña et al., 2020) found that the differential measurement bias by socioeconomic status was not a major factor accounting for the alcohol harm paradox.

Studies focusing on the alcohol harm paradox do not appear to have used the formulation of harm per litre, instead using standard multivariate analysis calculations and terminology such as percentage increased risk, relative risks, and risk ratios (e.g., Shuai et al., 2022), and odds ratios (e.g., Beard et al., 2016). Perhaps the most important contribution of analyses in the Alcohol Harm Paradox tradition has come recently, in directing attention to the need to consider and measure the potential contribution of multiple and diverse causes for the finding of more trouble per litre for poorer versus richer people who drink. Boyd et al. (2021) argued for the need to look beyond individual behaviour, taking into account the variety of variables considered in four different theories of health inequality: social determinants of health; fundamental cause theory; political economy of health; and eco-social models. This was backed up with a systematic review of “causal mechanisms proposed for the alcohol harm paradox” (Boyd et al., 2022), which found 41 distinct explanations offered, along 16 different thematic lines, in the research papers and commentaries. Although individual risk behaviour was the most common thematic area covered in the studies, the causal mechanisms proposed included variables and patterns at diverse levels, both collective and historical. Another research group, initiating empirical work on establishing “risk pathways contributing to the Alcohol Harm Paradox”, hypothesized and found empirical support for a “multistage causal risk pathway” linking socioeconomic deprivation to an “alcohol susceptibility score” which essentially measured harm per litre (Shuai et al., 2022, pp. 4, 9).

Conclusions and Recommendations

Our informal review of studies using the concept of harm per litre has drawn on our inside knowledge from having been part of this research literature as well as some index searching, but may have missed some relevant material. Where our knowledge is clearly not systematic is concerning “grey literature” of working papers and official reports, and community discourse in newspapers, magazines and social media. It would be an interesting next step to see whether and to what extent the conceptualisations we have discussed have made their way both into policymaking circles and into popular discourse, and with what modifications and responses.

“Harm per litre” first emerged in the research literature as a concept and a measure in comparisons of the harm resulting from the drinking of different alcoholic beverages. Though it clearly can be and has been used for other comparisons between populations or their subcategories, “harm per litre” as a concept and as a measure has primarily been used in recent years for comparisons between socioeconomic status categories. In this topical area, another conceptualisation—the “alcohol harm paradox”—has been substantially used, largely in a British context, although there has now been some branching out to studies in other populations (e.g., 8 EU countries: Directorate-General for Health and Food Safety, 2018; Peña, 2021). The literatures using each concept have been somewhat separate, and to our knowledge the two concepts have not been used in the same study, although this would clearly be possible. There has been a worthwhile expansion in the alcohol harm paradox studies beyond individual-level characteristics to include interactive, environmental and social structural factors in studying determinants of differences in harm per litre – though any given study will presumably only be able to include a selection of the 41 different potential explanations Boyd and colleagues (Boyd et al., 2022) found in the literature. In choosing which potential explanations to include in further studies, from a policy viewpoint it would make sense to put a priority on factors which are more open to change.

Using the “harm per litre” formulation has the advantage of being immediately understandable to a general audience, for whom formulations such as “ratio of Odds Ratios” may be opaque. But it needs to be used with care, given that it is litres of ethanol (pure alcohol) that are being referred to, not litres of the alcoholic beverage at the strength at which it is sold and consumed. For most harms from alcohol – harms to health and harms involving intoxication – it is the amount of ethanol consumed, and not the quantity of liquid which matters. So, it is wise to introduce the concept with a formulation making clear that it is

ethanol content that is referred to, a formulation such as “harm per litre of pure alcohol” or “... per litre of ethanol”.

It may also be wise, in using the phrase, to say something about the use of the word “harm”, which, with reference to alcohol use, has become somewhat politicized in recent decades. Under pressure from country delegations influenced by alcohol beverage interests, the World Health Assembly, the WHO’s governing council, adopted in 2010 WHO’s current Global Strategy not on “alcohol”, but on the “harmful use of alcohol”. But this is then defined in the Strategy quite broadly, as “drinking that causes detrimental health and social consequences for the drinker, the people around the drinker and society at large, as well as patterns of drinking that are associated with increased risk of adverse health outcomes”. Quoting this in its current “action plan” to improve the Global Strategy, the WHO notes that this “concept is much broader than the clinical concept of the diagnostic category of ‘harmful pattern of use’, which represents a part of the spectrum of ‘alcohol use disorders’ in the International Classification of Diseases” (World Health Organization, 2022a).

The overall scope of harms from drinking, whether arising from its toxicity, intoxication or dependence, thus potentially includes interpersonal and social problems as well as acute and chronic health problems, and problems for others as well as for the drinker (Babor et al., 2023, pp. 16-23). In using the phrase “harm per litre”, it would thus be wise to indicate the limits of the harms which are included in the phrase.

Using a “harm per litre” measure has a particular advantage in studies and statistics that have measurements of harm at the population rather than at an individual level, since globally the most widely available quantification of alcohol consumption, as already noted, is the recorded consumption of specific alcoholic beverages. Particularly in low- and middle-income countries, there may be a need to take account of unrecorded alcohol (Okaru et al., 2019; Rehm et al., 2014). For population surveys, there is the complication that alcohol consumption is likely to be substantially underreported (Stockwell et al., 2018). These nuances need to be noted in the limitations section of the report.

Despite these caveats, much can be learned from comparative analyses using harm per litre as a measure. However, we agree with Boyd and colleagues that there is a need to put more focus on the contribution and interactions of the diverse factors which account for the differences measured, with attention paid to potential means for preventing the occurrence of alcohol-attributable harm.

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