

## **Alcohol and Heart - Health Nexus in Lower Middle-Income Countries: Cardiovascular Risks Study**

Janudi Gamage<sup>1</sup>, Anne Oshini<sup>1</sup>, Dinithi Palliyaguru<sup>1</sup>, Binguni Senarathne<sup>1</sup>, Lochana Rajamanthri<sup>1</sup> and Colinie Wichramarachchi<sup>2</sup>

### **Abstract**

Cardiovascular diseases have become a growing concern in lower-middle-income countries, not only as a public health challenge but also as a critical management issue influencing workforce productivity, absenteeism, and organizational performance. Understanding how lifestyle factors such as alcohol consumption affect cardiovascular health is vital for developing sustainable workplace health strategies. This study examines the impact of alcohol consumption—classified as wine, beer, and spirits—on cardiovascular diseases while incorporating key determinants such as cholesterol, diabetes, obesity, and tobacco use within lower-middle-income countries. Using panel data from 170 countries between 1990 and 2019, this study applies fixed and random effects regression models to explore the relationship between alcohol consumption patterns and cardiovascular disease prevalence. The analysis integrates major lifestyle and health variables to assess their combined impact on national and workforce health outcomes. Findings reveal that alcohol consumption, particularly beer and spirits, has a significant positive association with cardiovascular disease risk, while cholesterol, obesity, and tobacco use further exacerbate these effects. Interestingly, diabetes prevalence demonstrated a negative relationship with cardiovascular disease within lower-middle-income countries. The results underscore the economic and managerial implications of unmanaged lifestyle risks that contribute to lost productivity and healthcare burdens. This study highlights the critical intersection between health behavior and management, suggesting that promoting responsible alcohol consumption and preventive health measures can enhance workforce well-being and productivity. The insights provide valuable guidance for human resource professionals, organizational leaders, and

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<sup>1</sup> SLIIT Business School, Sri Lanka Institute of Information Technology, Malabe Sri Lanka

<sup>2</sup> SLIIT Business School, Sri Lanka Institute of Information Technology, Malabe Sri Lanka,  
Email: [colinie.w@sliit.lk](mailto:colinie.w@sliit.lk)

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policymakers in designing evidence-based wellness programs, occupational health policies, and strategic interventions aimed at reducing cardiovascular risks in developing economies.

**Keywords:** Alcohol consumption, Cardiovascular disease, Tobacco consumption, Panel regression, Lower-middle-income countries

## **Introduction**

Alcohol has been the foremost widely consumed luxury substance worldwide since the beginning of recorded history. It is generally consumed in the shape of alcoholic beverages: wine, beer, and spirits, which, in addition to pure ethanol, contains varying amounts of fructose and other substances such as antioxidants (Moissl et al., 2021). Within the Global Burden of Disease study from 2019, alcohol consumption was positioned ninth among the leading hazard factors (Smyth et al., 2015). Therefore, being positioned as a critical factor that can increase mortality and morbidity hazards (Moissl et al., 2021). Overall consumption of alcohol is influenced by cultural, economic, and policy factors and widespread availability, developing major concerns for researchers, policymakers, and public health officials (Wurie and Cappuccio, 2012).

Through the aforementioned concerns, this paper explores the impact of Cardiovascular Disease (CVD) in Lower-Middle-Income Countries (LMICs) caused by alcohol consumption. Both adverse and beneficial effects of alcohol consumption have been confirmed by biochemical pathways (Rehm and Roerecke, 2017, Smyth et al., 2015). The three categories of alcohol consumption; wine, beer, and spirits, were selected for noteworthy reasons, particularly in considering their interaction and impact on CVD. Unhealthy behavior patterns including alcohol consumption manifest physiologically as increased blood pressure, elevated blood glucose levels, elevated lipid levels, and obesity (Costa et al., 2015, Aditya et al., 2022).

The three types of alcohol used in the review can be separately identified for their consumption behaviour traits and side effects in the following manner.; Wine is not only a beverage but also a refined symbol of tradition, sophistication, and societal intricacies, often revered for its cultural and historical significance (Klatsky and

Armstrong, 1997). Beer, with its deep-rooted history and widespread consumption, holds prominence in numerous cultures (Roth et al., 2017, Roth et al., 2015). Spirits are characterised by their high percentage of alcohol content and diverse cultural significance (Grønbaek, 2007). While some individuals may find temporary euphoria in these beverages, others may experience adverse effects.

### *Significance of the study*

The study aims to investigate the long-term impact between alcohol consumption and CVD in LMICs spanning from 1990 to 2019. The impact of wine, beer, and spirits on CVD and the global desire to reduce cardiovascular health risks while considering cholesterol, diabetes, obesity, and tobacco consumption as control variables during the aforementioned period is elucidated and includes how the global sustainable development goal in reducing alcohol consumption is achieved.

This study was conducted from three distinct factors. Firstly, this research uses recent data collected over three decades, covering 170 countries. Notably, prior research has hitherto extensively not explored the impact within the scope of selected variables. In contrast, several studies have mainly focused on the impact of alcohol consumption on CVD. However, in this study, several control variables together, such as cholesterol, diabetes, obesity and tobacco use are considered. Secondly, a separate analysis is conducted for each country's income groups with a global level of analysis, which highlights the importance of the study. The unique variables bring a different perspective to the results, considering the overall effect of wine, beer, and spirits consumption on CVD, while mainly focusing on LMICs where the highest number of deaths are recorded. Finally, the results of these investigations were carefully combined using Panel regression methods followed by an analysis of the stepwise and significant effects between variables. In a nutshell, consideration of the above-mentioned variables provides an insight into the real and holistic situation in all LMICs.

This first part of this paper contains the introduction, which describes the background to this research. The second section comprises the literature review and contains a summary of related literature. Data and methodology are described in section three, along with summary

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statistical descriptions for critical variables. A discussion of the impact of variables such as beer, wine, spirits, cholesterol, diabetes, obesity, and tobacco use on CVD is next. The fourth section contains a discussion of the results and data analysis. Section five concludes with highlights and the limitations of the research.

### **Literature Review**

The burden of CVD in LMICs is high and rising. It is the second leading cause of death worldwide, accounting for 17.9 million deaths in a year (WHO, 2019). Populations in LMICs now account for 75% of cardiovascular deaths, which reduces the gross domestic product of these countries by seven per cent (WHO, 2011). Alcohol has a detrimental effect on cardiovascular health (Marjana, 2002) and is associated with oxidative stress (Minzer et al., 2020). Alcohol consumption is considered to be the third most important modifiable risk factor for death and disability (Liang and Chikritzhs, 2013). Behaviours such as unhealthy eating habits, smoking, excessive alcohol consumption, high blood pressure, high BMI, high cholesterol, uncontrolled blood sugar levels and insufficient physical activity are included (Wurie and Cappuccio, 2012, Aringazina et al., 2018). People of lower socioeconomic status experience more significant harm from alcohol consumption compared to those of higher socioeconomic status, irrespective of consumed amounts of alcohol. Additionally, considering income levels, the low and middle-income countries bear the burden of mortality compared to high-income countries (Rosengren et al., 2019). The effects of alcohol on cardiovascular health are not uniform due to individual factors such as age, genetics, overall health, and drinking patterns (Roth et al., 2015, Costa et al., 2015).

Biochemical mechanisms (Gaziano et al., 2010) have proved that alcohol use has both negative and positive consequences. To the best of our knowledge, most individuals who drink responsibly enjoy drinking and experience few adverse effects. However, for a few individuals or under certain circumstances, even low or direct levels of alcohol can be risky (Antai et al., 2014). Consumers of all three beverages (beer, wine and spirits) showed the highest percentage of a heavy drinking pattern compared to consumers of a single beverage type in low/ moderate amounts (Wiel and Lange, 2008). The rapid growth of CVD burden in

many countries LMICs are driven by socioeconomic change, increased life expectancy, and acquisition of lifestyle-related risk factors (Gaziano et al., 2010).

In contrast to other types of alcohol, the popularity of alcoholic beverages, especially wine, has increased due to their positive effects on cardiovascular health over the past two decades (Wiel and Lange, 2008). Mainly, red wine contains compounds such as polyphenols and antioxidants such as resveratrol, which have been linked to cardiovascular health benefits, including improving heart function, and reducing inflammation. Marketers indicate that individuals consume more wine to unwind after a stressful workday as wine is positioned as a beverage for relaxation purposes (Gronbaek et al., 2004). In addition, the cultural context of wine consumption often involves moderate and regular consumption, supporting cardiovascular health compared with heavy drinking or abstinence. Compared to Americans and Finns, the French consume more wine, but show lower rates of CVD (Gronbaek et al., 2004).

Moderate consumption and a lower paradox suggest a more favourable effect of wine than other alcoholic drinks (Wiel and Lange, 2008). Moreover, adopting wine drinking habits may coincide with a shift to healthier dietary patterns, such as the Mediterranean diet, which emphasises fruits, vegetables, and whole grains, which further contribute to cardiovascular well-being. Excessive drinking acts as an intoxicant and increases blood pressure, causing the heart muscle to weaken (Roth et al., 2015). As a result, moderation is essential in alcohol consumption to minimise morbidity and mortality.

In considering beer consumption patterns, a socio-economic disparity is highlighted. The lower socio-economic population experiences more alcohol-related harm, disproportionately compared to their counterparts of higher socio-economic status, irrespective of the consumption level (Wurie and Cappuccio, 2012). With its relative affordability compared to other alcoholic beverages, beer is becoming popular among people with low disposable income (Wiel and Lange, 2008). Moreover, the widespread availability and accessibility of beer, and its cultural significance as a beverage for social gatherings and celebrations, contribute to its high consumption rate. Rapid urbanisation

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and globalisation further fuel this trend, as younger populations are exposed to Western drinking habits and marketing influences (Gaziano et al., 2010). Additionally, in regions with a warm climate, beer acts as a refreshing alternative and further increases its popularity. Thus, high beer consumption in LMICs reflects a combination of affordability, accessibility, cultural significance, and changing social dynamics. Beer consumption highlights a socio-economic disparity.

Unlike wine, beer, and spirits are often favoured in LMICs due to several interrelated factors. Despite their potentially higher cost per unit compared to beer, spirits provide a higher alcohol content per serving and are considered more economically efficient in providing intoxication. Spirits usually have an alcohol content of about 35%, while liqueurs have the same alcohol content, but the sugar levels can vary. Both are distilled beverages that lack significant bioactive compounds such as polyphenols. Due to these compositional differences compared to beer and wine, spirits and liquors can have adverse health effects, mainly due to their less bioactive components (Smyth et al., 2015).

Moreover, the cultural significance of spirits, often tied to traditions, festivals, and social gatherings, contributes to their popularity (Gaziano et al., 2010). Also, aggressive marketing strategies by alcohol companies targeting emerging markets, along with less stringent regulations on advertising, develop the appeal of spirits (Arora et al., 2022). Although wine consumption appears to correlate with a lower risk of CVD, injury, hospitalisations, and overall adverse outcomes compared with spirits or beer consumption, this observation may be influenced by the behavioural traits of wine consumers. Factors such as higher socioeconomic status, education levels, and healthy eating habits among wine drinkers may contribute to these findings rather than the act of drinking wine (Chudzinska et al., 2022). With increased disposable income, spirits may become associated with social status and prestige.

This comprehensive approach addresses the critical need for longitudinal studies conducted in LMICs and offers fresh perspectives by drawing on diverse nationalities. By delving into this comprehensive database, research not only fills existing gaps in knowledge but also provides empirical evidence to strengthen targeted interventions aimed at curbing alcohol consumption and addressing cardiovascular health

challenges. The study illustrates how the dynamic interplay between policy and economic conditions influences the relationship between alcohol consumption and cardiovascular health outcomes. Moreover, it acknowledges an extensive body of research examining the impact of CVD and alcohol consumption, emphasising the multifaceted nature of cardiovascular health as influenced by factors such as cholesterol, diabetes, obesity, and tobacco use.

### *Impact of cholesterol on CVD*

The incidence of high cholesterol is increasing in LMICs (Marcus et al., 2021). Cholesterol, often depicted as protagonist and antagonist, navigates the sensitive balance between blood vessel strengthening and plaque-induced compromise. CVD is currently the leading cause of death in LMICs and is expected to rise significantly in the coming decades (Marcus et al., 2021, Chang et al., 2017). Hypercholesterolemia, characterised by abnormal blood lipid levels, particularly elevated fasting total cholesterol (TC), remains the second most influential physiological risk factor for CVD (Marcus et al., 2021). Notably, many cholesterol-rich foods are also high in saturated fatty acids, which may increase the risk of CVD due to saturated fatty acid concentrations (Peiris et al., 2021). Cholesterol can accumulate in the walls of blood vessels, and elevated levels can lead to heart failure. The circulatory system transports protein-bound cholesterol. For every 1% increase in blood cholesterol, the incidence of ischemic heart disease or coronary heart diseases increases by 2%.

Several factors contribute to the trend of increase in blood cholesterol levels involving CVD. Firstly, changes in dietary habits, such as increased consumption of processed foods containing saturated fat, sugar and cholesterol, play a significant role. Limited access to nutritious and balanced diets and affording cheaper, less healthy food options exacerbates this problem. In addition, sedentary lifestyles and lack of access to healthcare and preventive measures exacerbate the problem. Adequate healthcare infrastructure and awareness programs may lead to delayed diagnosis and management of conditions such as hypercholesterolemia, allowing CVD to progress unchecked (Marcus et al., 2021). Socioeconomic factors such as limited education and income disparities also contribute to disparities in healthcare access and adherence to healthy behaviours. The burden of CVD can be diminished, and cardiovascular outcomes can be improved by using an

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integrated approach incorporating good dietary practices, frequent exercise, and medicinal therapies (Langsted et al., 2020). As a result, in LMICs, elevated cholesterol levels and subsequent CVD may reflect a complex interplay of dietary, lifestyle, economic, and healthcare-related challenges.

### *Impact of diabetes on CVD*

Diabetes is a multifaceted actor that offers a narrative of high blood sugar that's closely connected to inflammation and atherosclerosis. Diabetes is closely associated with CVD and is the primary cause of mortality and depression in those with diabetes (Grundy et al., 2015). Diabetes prevalence has increased from 153 million to 347 million globally (Bowry et al., 2015). Patients with diabetes are more likely to have Cardiovascular risk factors such as obesity, dyslipidaemia and hypertension, which increase their chance of cardiac events (Grundy et al., 2015, Sharma et al., 2020). In expansion, diabetic patients' significant risk of CVD is freely increased by biological pathways related to the disease (Grundy et al., 2015). Therefore, focusing on cardiovascular risk factors in patients with diabetes is essential to reduce the long-term cardiovascular complications of the disease (Grundy et al., 2015, Preiss et al., 2012). Nearly 422 million individuals worldwide suffer from diabetes (Preiss et al., 2012), with most of them residing in LMICs; the disease is directly responsible for 1.5 million deaths annually (Preiss et al., 2012). Both the number of cases and the prevalence of diabetes have been steadily increasing over the past few years. Individuals with diabetes had a greater prevalence rate of CVD than individuals without diabetes in their medical history, and the chance of CVD rises consistently with rapid growth in fasting blood sugar levels, even before reaching levels sufficient for a diabetes diagnosis.

Type 2 diabetes affects life expectancy by up to ten years, and CVD is the major leading cause of mortality in people who have type 2 diabetes (De Rosa et al., 2018). Besides, when compared to non-diabetic individuals who have type 2 diabetes, they have been excessively influenced by CVD. Death rates in type 2 diabetes patients were 15.4% in those with no earlier myocardial localised necrosis and 42.0% in those with a history of myocardial infarction (De Rosa et al., 2018). In patients without type 2 diabetes, the mortality rates from CVD were 2.1 and 15.9%, respectively (Preiss et al., 2012). As a result, a rise in the prevalence of diabetes will almost certainly be accompanied by an

increase in the prevalence of CVD. Whereas, in most of the LMICs, diabetes occurs more often at a younger age and is mainly type 1 diabetes, which may have a different cardiovascular risk profile compared to type 2 diabetes. Additionally, reduced access to health care resources and diagnostic tools may lead to underdiagnosis and undertreatment of diabetes, potentially masking its impact on CVD risk.

### *Impact of obesity on CVD*

In LMICs, the burden of overweight is disproportionately more significant in urban settings than in rural ones, indicating an upward trend in epidemiological patterns. The transition in health care from communicable diseases to non-communicable diseases (NCDs), including diabetes and cardiovascular disorders, is mainly attributed to the increase in obesity (Ford et al., 2017). Obesity-related burdens are rising significantly in LMICs and are expected to double or more in the next forty years, making it the sixth greatest cause of Disability Adjusted Life Years (DALYs) worldwide. Interestingly, ten nations account for almost half of the world's 671 million obese people, eight of which are LMICs. This suggests that there is a serious worldwide health issue. The availability of low-cost, high-calorie foods is causing rapid dietary habit changes in LMICs, causing obesity rates to grow faster than in High-Income Countries (HICs) (Popkin et al., 2002). Urbanisation, which creates circumstances that encourage decreased physical activity and increased intake of sugar-sweetened drinks, exacerbates this situation even more. Furthermore, trade liberalisation and globalisation are reshaping LMICs food systems, influencing the dynamics of food pricing and availability (Ford et al., 2017).

In addition to sleep loss, chronic stress resulting from socioeconomic problems such as poverty, unemployment, and a lack of safety is also linked to the increased incidence of obesity in LMICs. Moreover, the dual burden, malnutrition in children and overnutrition in adults, poses additional difficulties for health systems and may increase the risk of cardiometabolic illnesses associated with obesity (Sazlina et al., 2020). Because hunger and poor access to proper nutrition are prevalent challenges in many LMICs, the alarming pattern of rising obesity is alarming. The combined burden of these two conditions adds to the strain on developing health systems and complicates attempts to treat CVD. These interrelated issues need to be addressed immediately given the concerning increase in overweight children in LMICs (Ford et al.,

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2017).

The complex interplay between globalisation, urbanisation, dietary changes, and socioeconomic variables highlights how complicated the obesity pandemic is in LMICs. According to World Health Organization (WHO) projections, by 2030, over a billion people will be obese, and 2.16 billion will be overweight. Obesity increases the risk of many chronic, non-communicable diseases, including diabetes and high blood pressure (WHO, 2019). To provide fair access to nutrition and NCD prevention measures and reduce the burden on healthcare systems, immediate action is necessary to mitigate its impact on public health.

### ***Impact of tobacco consumption on CVD***

Consumption of tobacco products is a significant and avoidable risk factor for CVD (Sharma et al., 2024). Cigarette smoking, the most common tobacco use worldwide, is one of the main lifestyle choices associated with an increased risk of CVD. It is alarming to note that in LMICs, dwelling of roughly 80% of the 1.3 billion smokers worldwide, this hazardous trend continues to grow significantly (Benowitz and Liakoni, 2022). Smoking is harmful in all types of tobacco use, not only cigarettes, as they all pose severe risks to cardiovascular health. The burden of CVD is increased in LMICs by rising cigarette sales despite growing evidence of the harmful effects of tobacco usage. Nicotine, the leading cause of long-term tobacco use, plays a role in the addictive nature of tobacco (Saleheen et al., 2014). Research indicates a worrisome association between smoking cigarettes daily and the risk of Coronary Heart Disease (CHD), with a more marked effect shown in younger people (Benowitz and Liakoni, 2022). This is considering how quickly smoking addiction develops in LMICs. However, there is some optimism since data indicates that the risk of CVD is lower in past smokers than in current smokers, although it is still greater than in non-smokers. Interestingly, this risk gradually decreases after quitting smoking, supporting the importance of cessation therapies in reducing the burden of CVD.

Each year, tobacco kills more than eight million people (WHO, 2022). More than seven million of those deaths are the result of direct tobacco use, and 1.2 million are the result of passive smoking. More than 80% of the world's 1.3 billion tobacco users are in LMICs (WHO, 2022). A vicious cycle of tobacco uses and disease continues to exist by weak tobacco control laws and a lack of knowledge about the many risks

associated with tobacco use. Tobacco-related mortality exacts a staggering toll; half of all tobacco-related fatalities worldwide occur in LMICs, where the burden is most significant. Projections provide a dire picture of rising tobacco-related mortality in LMICs if uncontrolled, emphasising the critical need for efficient intervention measures.

The growing burden of CVDs in LMICs, where these diseases have become the leading cause of morbidity and death, is further exacerbated by the absence of effective tobacco control policies (Benowitz and Liakoni, 2022). With its extensive effects on people, communities, and healthcare systems, tobacco use is not only a health issue but also a socioeconomic one that must be addressed. To stop the growing tide of tobacco-related cardiovascular illnesses and ensure a healthy future for everybody, concentrated efforts must be made to adopt comprehensive tobacco control legislation and raise awareness (Gun et al., 2006).

### **Data**

The data set used in this study consists of observations spanning across different cross-sections over time, facilitating comprehensive analysis through panel regression. The dataset, which was collected during the period 1990 to 2019, contains data from 170 countries categorised by their income group. Variables examined include indicators of cardiovascular health, as well as metrics related to consumption of wine, beer, and spirits and metrics of controlling variables such as cholesterol, diabetes, obesity, and tobacco use. The cardiovascular death rate per 100,000 people served as the primary measure to assess cardiovascular health, pure alcohol litre consumption served as a proxy for wine, beer, and spirits consumption. Data collection spanned a total of 170 countries, all of which were classified under HICs, Upper Middle-Income Countries (UMICs), LMICs and LICs. For the countries with missing annual data, the researchers used forecasted values based on the average value of the nearest two years. A solid basis for the study investigation was provided by this dataset, which had 5100 observations in total. The data file used for the study (can be given upon request) and has employed Stata statistical software for data analysis. The variables and data sources are shown in Table 1.

**Table 1. Variables and the respective data sources**

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<b>Variable</b>	<b>Measurement unit</b>	<b>Source</b>
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Cardiovascular Diseases	Death rate per 100 000 people	Our World in Data (2023) <a href="https://ourworldindata.org/grapher/cardiovascular-disease-death-rates">https://ourworldindata.org/grapher/cardiovascular-disease-death-rates</a>
Diabetes	Diabetes prevalence	Our World in Data (2023) <a href="https://data.worldbank.org/indicator/SH.STA.DIAB.ZS">https://data.worldbank.org/indicator/SH.STA.DIAB.ZS</a>
Cholesterol	Mean total cholesterol	World Health Organization (2023) <a href="https://www.who.int/data/gho/data/indicators/indicator-details/GHO/mean-total-cholesterol-(crude-estimate)">https://www.who.int/data/gho/data/indicators/indicator-details/GHO/mean-total-cholesterol-(crude-estimate)</a>
Obesity	Death rate per 100 000 people	Our World in Data (2023) <a href="https://ourworldindata.org/grapher/death-rate-from-obesity">https://ourworldindata.org/grapher/death-rate-from-obesity</a>
Tobacco	Tobacco consumption	Our World in Data (2023) <a href="https://ourworldindata.org/grapher/prevalence-of-tobacco-use-sdgs">https://ourworldindata.org/grapher/prevalence-of-tobacco-use-sdgs</a>
Alcohol Consumption	In litres of pure alcohol consumed	World Health Organization (2023) <a href="https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption">https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption</a>

### Methodology

The primary victims of CVD were determined by looking at violin plots and using a chi-square test. The complex dynamics around CVD were then revealed by doing a panel regression analysis after validating these findings. This approach applies as it aggregates data over a specific timeline using multiple variables. A further level of complexity is introduced by the panel structure, which enables the examination of significant impacts within and between individual entities across the panel. This study aims to examine the impact of different types of alcohol, such as wine, beer, and spirit, which are

taken as independent variables while taking into consideration the impacts of cholesterol, diabetes, obesity, and tobacco consumption as controlling variables on CVD taken as the dependent variable. In accordance with Eq.1, wine, beer, spirit, cholesterol, diabetes, and tobacco consumption variables were converted into log variables.

$$CVD_{it} = \beta_0 + \beta_1 (\ln Wine)_{it} + \beta_2 (\ln Beer)_{it} + \beta_3 (\ln Spirit)_{it} + \beta_4 (\ln Cholesterol)_{it} + \beta_5 (Obesity)_{it} + \beta_6 (\ln Diabetes)_{it} + \beta_7 (\ln Tobacco)_{it} + \varepsilon_{2it}$$

(Eq. 1)

The above static linear model can be used to measure the impact of CVD in selected LMICs over period of 30 years. Here, 'i' indicates the relevant country, and 't' indicates the year taken into consideration. 'ε<sub>it</sub>' shows the standard error of the above equation. The present study has used 170 countries, which reduces the problems of multicollinearity and generalisation assumptions and strengthens the reliability of the findings. As the dataset has variability and changes over time with country-specific effects, the panel data approach is the most suitable model for data analysis. Three potential estimation models of balanced panel data regression, namely Pooled Ordinary Least Square (POLS), Fixed Effects (FE) and Random Effects (RE) models, were used. As indicated in Eq.1, the POLS model was used to explore its impact on CVD.

Conversely, the FE model, captures the unobserved effects of variables that are constant across countries but may vary over time. The Breusch-Pagan LM test, F test and Hausman test were used to compare the expected model fit. After obtaining the hypothesis test results of each test method, the best model is selected after a sensitivity analysis. F test was used to select the best model between POLS and FE. The Lagrange Multiplier test is conducted with POLS and RE to select the appropriate model for the next step. For RE and FE, Hausman's test is performed to determine which model is the best. To reduce the problem related to heteroscedasticity, the data were transformed into robust standard errors.

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**Results**

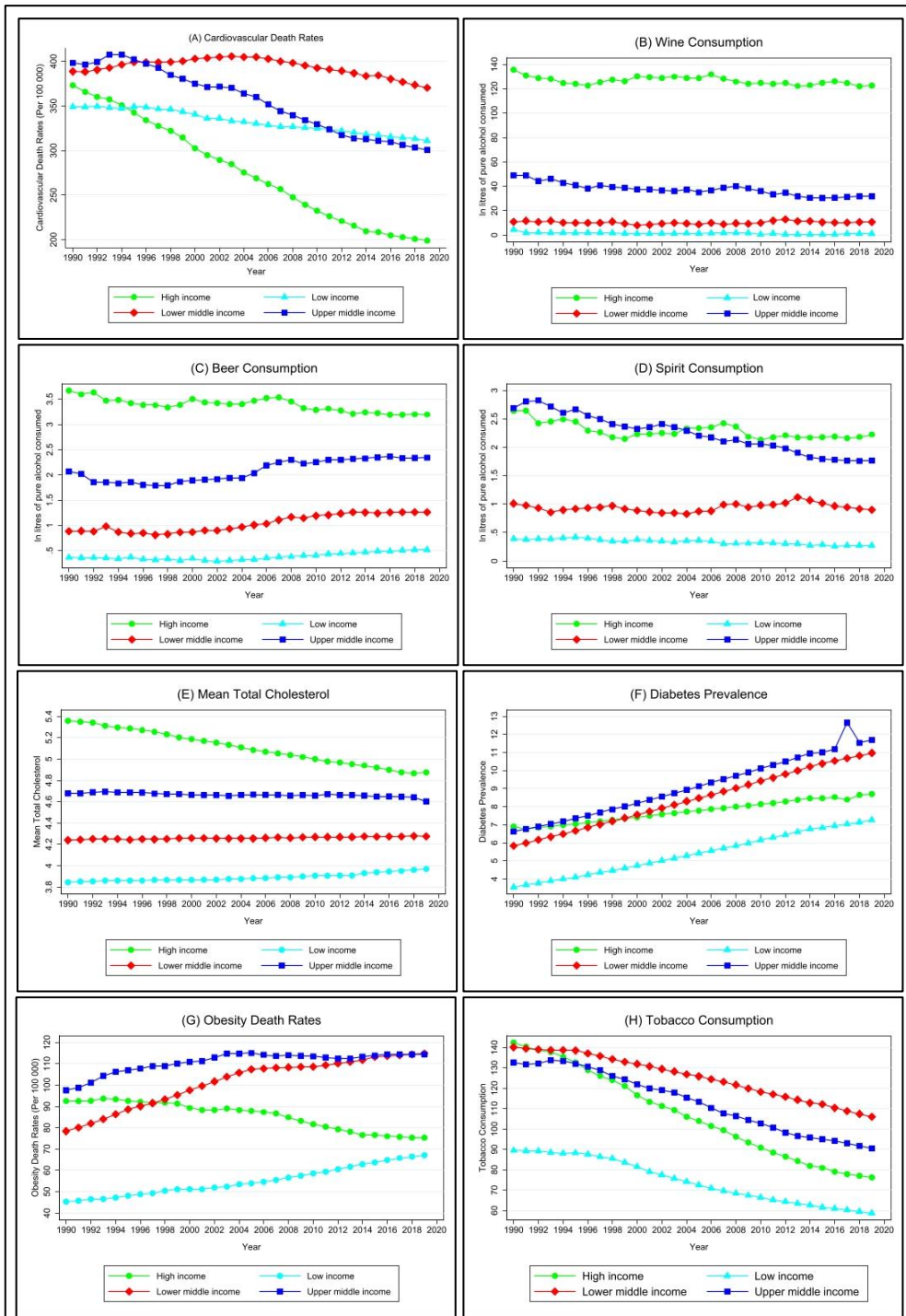
This section initiates significant major discoveries made using the empirical methods. Fig. 1 presents a comparison of income-wise averaged values of all the eight variables in the study. Fig. 1A - 1H demonstrates the trend of death rate of CVD, wine, beer, and spirits as well as the control variables such as cholesterol, diabetes, obesity, and tobacco consumption across four income categories between 1990 to 2019.

Based on Fig. 1A, LMICs reported the highest prevalence of cardiovascular mortality among the other income groups shown, with a notable peak in cardiovascular mortality in the early 2000s, followed by a sharp decline before reaching a stable state. This suggests that cardiovascular mortality varies among other income groups, with cardiovascular mortality in LMICs requiring special attention due to its rapidly increasing trend and HICs showing strong cardiovascular progress due to its decline. Cardiovascular mortality trends over the years. The increased compliance observed in other countries may refer to consistent reporting and diagnostic standards or well-established and functional health infrastructure. According to Fig. 1B and 1C, HICs are the largest consumers of wine and beer among the listed income groups, although they are entering a relatively stable phase with minor fluctuations, perhaps due to changes in consumer tastes or mature markets. In Fig. 1D, compared to HICs and UMICs, LMICs consume relatively less spirits. In LICs, wine, beer, and spirits consumption remains the lowest of all income groups, with a positive effect over the years on the lowest number of reported cardiovascular deaths, according to Fig. 1E, HICs top the group with the highest mean total cholesterol, which has steadily declined since 1990. Both UMICs and LMICs show a stable situation with fewer fluctuations in the number of victims who have high cholesterol. Fig. 1F further illustrates a trend of increasing diabetes prevalence in all income groups over the years due to a complex interplay of various factors in countries, including genetics, lifestyle, and healthcare infrastructure. Based on Fig. 1G,

UMICs reported the highest median number of obesity-related deaths over the year, while LMICs and LICs also showed a gradual increase in obesity-related deaths over the years. HICs show a dynamic trend with a notable peak in mortality from obesity in the early 2000s, and fortunately, the average mortality has gradually decreased over the years. In Fig. 1H, LMICs report the highest tobacco consumption, which is a significant contributor to CVD. However, on a positive note, a decrease in tobacco consumption has been seen since 1990.

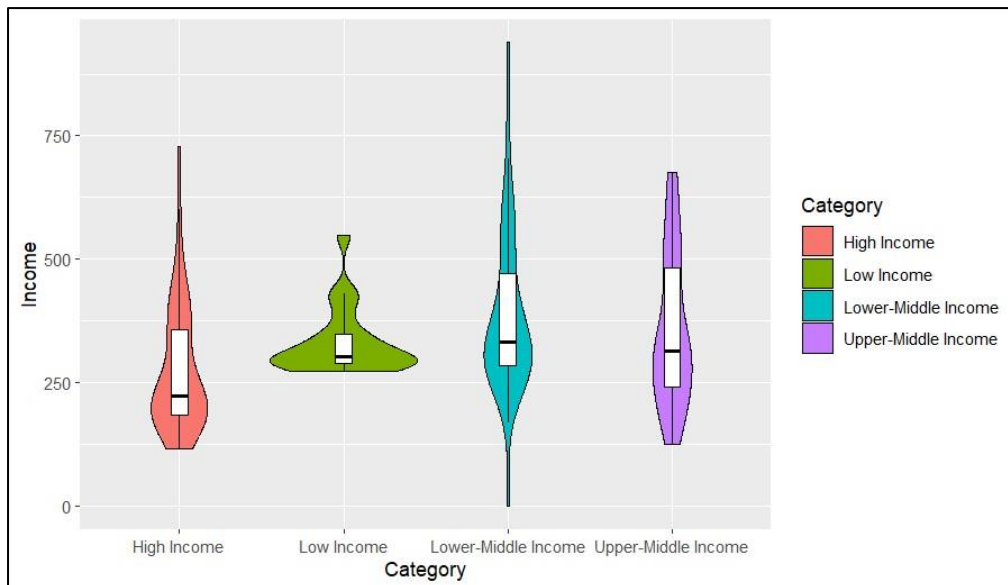
Secondly, a comprehensive analysis was conducted to find any significant differences between CVD and each income group; the findings provide valuable insight into the complex relationship between income levels and cardiovascular health, shedding light on disparities and potential areas for intervention and policy development. In Fig. 2, violin plots vividly depict the prevalence of CVD in different income groups. Notably, CVD rates exhibit clusters within each income group, falling below the mean across all income groups in the country. The findings highlight a significant disparity, particularly in LMICs, where CVD rates surpass other income groups. Moreover, data points representing CVD show less variability in HICs and form a more uniform cluster within the distribution. The violin plots highlight the different expression patterns observed in CVD concerning income groups, which show significant differences between the four income groups. Overall, these results highlight a striking association between CVD prevalence in LMICs, emphasising the importance of targeted interventions in addressing this disparity.

**Fig 1. Income wise averaged variables from 1990 and 2019**



Source: Authors' illustrations based on the STATA software.

**Fig 2. CVD and income groups**



Source: Authors' illustrations based on the R software

Thirdly, a meta-analysis using the chi-square method was performed to find a significant association between mean CVD values and income groups across four different categories: high income, upper middle income, lower middle income, and low income. In Table 2 the observed mean values for CVD were carefully stratified by income range, revealing identifiable patterns unique to each income group, whereas the parenthesis shows the expected values. The observed frequencies of cardiovascular cases across different income groups were compared to those expected under the assumption of independence between CVD and income categories. The null hypothesis of the chi-square test brings out that there is no association between CVD and the income categories. In contrast, the alternative hypothesis suggests a significant association between the variables. The test calculates a chi-square statistic and compares it to a critical value from the chi-square distribution, considering the degrees of freedom and chosen significance level. The results of the chi-square test revealed a calculated value of 51.187 with 9 degrees of freedom. This value exceeded the tabular value of 21.666 at a significance level of 0.01, indicating a significant association between CVD and income categories. Therefore, the income level is indeed

associated with the prevalence of CVD.

**Table 2. Cardiovascular mean values and income categories**

<b>Income groups</b> <b>Categories</b>	<b>High Income</b>	<b>Upper Middle Income</b>	<b>Lower Middle Income</b>	<b>Low Income</b>	<b>Total</b>
0.03 - 234.84	28 (12.847)	11 (12.106)	03 (12.106)	0 (4.941)	42
234.85 - 469.68	20 (29.671)	25 (27.959)	33 (27.959)	19 (11.412)	97
469.69 - 704.52	03 (8.565)	13 (8.071)	11 (8.071)	01 (3.294)	28
704.53 - 939.36	01 (0.918)	0 (0.865)	02 (0.865)	0 (0.353)	03
<b>Total (N)</b>	<b>52</b>	<b>49</b>	<b>49</b>	<b>20</b>	<b>170</b>

Note: Differences are statistically significant  $\alpha=0.01$  level (Pearson's Chi-Square). Parentheses represent the expected values.

Fourthly, descriptive statistics of CVD in LMICs are presented in the S1 Appendix. The descriptive statistics of the top ten LMICs, which record the highest number of cardiovascular cases, are highlighted in green. Including a number of observations, mean value, standard deviation, and minimum and maximum values for cardiovascular, wine, beer, spirit, cholesterol, diabetes, obesity, and tobacco consumption. As per the descriptive statistics summary, the highest number of cardiovascular deaths in LMICs is 939.36 in Uzbekistan, and the lowest number in LMICs is 167.77 in El Salvador, while recording an average of 393.50.

The results of the panel data specification evaluations are presented in Table 3. Based on the F test and Breusch-Pagan LM test results for LMICs, the null hypothesis is rejected. Rejection of this POLS model at 1% significance, suggests its needs to be revised for the present

analysis. Consequently, the Hausman test selects between FE and RE models. Notably, the analysis for LMICs rejects the null hypothesis, indicating that the estimates obtained from the FE model exhibit greater efficiency compared to the RE model. According to the overall  $R^2$  values on LMICs, over 46% of the variation in CVD can be explained and fits the model for LMICs.

Across the LMICs, the F test yields a highly significant result of 271.41\*\*\*, indicating a strong impact between the variables considered. Similarly, the Breusch-Pagan LM test produces a significant result of 11120.78\*\*\*, suggesting significant variability in cardiovascular indices across the LMICs. The Hausman test, aimed at identifying the most appropriate model specification, shows strong evidence against the null hypothesis in favour of the FE model, with a significant statistic of 118.58\*\*\*.

The effect of wine, beer, spirit, cholesterol, obesity, diabetes, and tobacco consumption on CVD is shown in the S2 Appendix on a global and income-level basis. The statistical summary presents coefficients, robust standard errors, and significance levels. Over 56% of the variation in CVD can be explained, and the model fits all nations, according to the overall  $R^2$  values. To choose between the FE and RE models, the Hausman test is employed. The test for all countries, HICs, and LMICs has rejected the null hypothesis, which states that the results of the FE model's estimations are more efficient than RE model. However, the tests on UMICs and LICs were unable to reject the null hypothesis, indicating that the estimation result of RE model is more efficient than the FE model. Therefore, the FE model was applicable to all countries, high income and lower middle-income nations, whereas upper middle income and low-income countries, were continued with the RE model. After obtaining the regression results, we performed a stepwise regression analysis to confirm the significance of the variables, followed by a stationary test to evaluate the stationary of the dependent variable further.

**Table 3. Fixed effect and random effect estimation**

<i>Variables</i>	<b>CVD</b>	<b>Fixed Effect (FE)</b>	<b>Random Effect (RE)</b>
<i>Wine</i>		-9.40*** (4.30)	-9.09*** (4.38)
<i>Beer</i>		2.91** (3.30)	2.18 (3.20)
<i>Spirit</i>		0.28 (2.90)	0.36 (2.97)
<i>Cholesterol</i>		54.24 (113.52)	41.33 (107.18)
<i>Diabetes</i>		-14.37* (31.18)	-27.36*** (29.62)
<i>Obesity</i>		1.48*** (0.52)	1.52*** (0.53)
<i>Tobacco</i>		191.04*** (36.74)	170.87*** (28.64)
<i>Constant</i>		-721.92*** (290.92)	-587.12** (234.79)
<b>N</b>		1470	1470
<b>R<sup>2</sup> within</b>		0.57	0.57
<b>R<sup>2</sup> Between</b>		0.46	0.47
<b>R<sup>2</sup> Overall</b>		0.46	0.47
<b>F Test</b>		271.41***	
<b>LM Test</b>		11120.78***	
<b>Hausman Test</b>		118.58***	

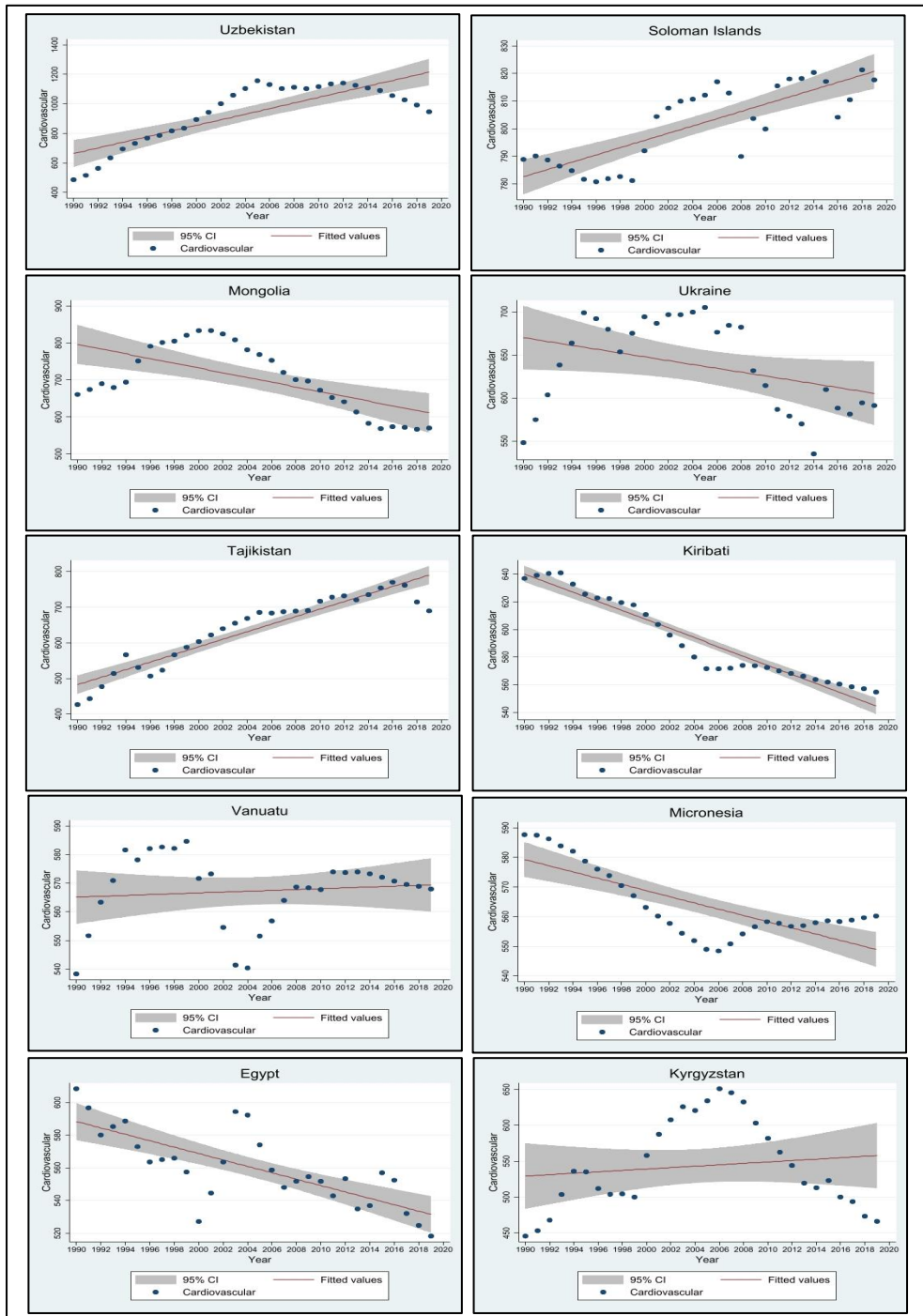
Note: The symbols\*, \*\*and \*\*\* represent 10%, 5% and 1% significance levels, respectively.

Parentheses represent the robust standard error. N represent number of observations.

Finally, according to Fig. 3, cardiovascular health trends across the top ten LMICs are examined. The scatterplots in Uzbekistan, Solomon Island and Tajikistan reveal a subtly striking pattern: a steady upward slope of the trendline, signalling a clear positive correlation between cardiovascular health indicators and years. This upward trend suggests an increase in cardiovascular health problems as the years progress in these nations. In contrast, a narrative emerges from scatter plots in Mongolia, Ukraine, Kiribati, Micronesia, and Egypt, where a distinct downward slope of the regression lines indicates a negative impact between cardiovascular health and time. This divergence reflects a large decline in cardiovascular health over the years in these countries. Kyrgyzstan and Vanuatu show a neutral trend; the regression line would likely be relatively flat, showing neither a clear upward nor downward slope due to high fluctuations in the cardiovascular death rates.

Furthermore, careful observation reveals differences in data presentation. Some plots show a tight cluster of data points around the regression line, indicating a strong relationship between cardiovascular health and years. In contrast, others show a more scattered distribution, hinting at more significant variability in the data or potential influencing factors worthy of further exploration.

**Fig 3. Top 10 lower-middle-income countries of CVD**



Source: Authors' illustrations based on the STATA software.

## **Discussion**

The primary focus of this study was to determine the impact of wine, beer, and spirit consumption on CVD by considering cholesterol, diabetes, obesity, and tobacco use. The panel results in the table provides a detailed summary of the statistical tests conducted to examine the impact between alcohol consumption and alcohol consumption on cardiovascular indicators in these countries. Statistical analysis of both FE and RE panel data regressions reveals that these variables can positively and negatively affect CVD. Beer consumption, spirit consumption, cholesterol, obesity, and tobacco use have a positive effect, where an increase in the following variables can lead to an increased CVD burden in LMICs. Comparably, wine consumption and diabetes harm cardiovascular health. Notably, the findings suggest that alcohol consumption of any type may contribute to increased CVD in LMICs whereas at times it can be beneficial.

Examining beer consumption reveals a striking and positive trend, particularly in LMICs where beer is in significant demand in both the fixed effect model and the random effect model. However, in LMICs, beer consumption is high due to its high availability and low cost. According to the findings of these studies, Micronesia is the country with the highest beer consumption. This high demand can be attributed to the drinks' affordability and wider availability compared to wine and spirits (Fogarty, 2010). Research findings indicate that beer consumption positively correlated with cardiovascular health in both fixed effects (FE) and random effects (RE) estimates. The data further underscores those consumers in LMICs exhibit a preference for beer over other types of alcohol and allocate more of their spending to it. However, the allure of special pricing on beer often prompts consumers to stock up on the drink, inadvertently increasing their risk of CVD (Fogarty, 2010). This phenomenon is widespread in cultures with a strong beer tradition, where it is served as an after-work treat instead of wine (Brunner and Siegrist, 2015). Research on alcohol consumption patterns and cardiovascular health further reinforces the

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benefits of light to moderate beer consumption, with heavy drinking being associated with higher risks. Interestingly, people who abstain from alcohol tend to have less healthy lifestyles compared to moderate drinkers in LMICs. These observations underscore the complex interplay between socioeconomic factors, work environment, and alcohol consumption, revealing the nuanced relationship between beer, cardiovascular health, and lifestyle choices in these regions.

Examining wine consumption reveals a noteworthy negative impact, especially concerning its association with CVD. This negative correlation is compounded by the relatively lower prevalence of wine consumption in LMICs, primarily attributable to its higher cost than beer and spirits. Research findings (Brunner and Siegrist, 2015) emphasise this disparity, indicating that consumers in HICs and UMICs show higher wine consumption rates and allocate more expenditure towards wine compared to their counterparts in LMICs and LICs. Despite its ethanol content, the wine offers additional heart-protective benefits. France has remarkably maintained a comparatively low rate of CVD despite prevalent smoking habits and a high-fat diet. The inclusion of wine in dietary habits has been suggested as a contributing factor to this phenomenon, and it plays a role in the prevention of CVD. Multiple prospective population studies reinforce that wine exhibits the highest protective effects among alcoholic beverages. Notably, countries with the highest wine consumption rates, such as the Solomon Islands, Mongolia and Kyrgyzstan, underscore the global importance of this trend. Consequently, an increase in wine consumption in LMICs may coincide with a decrease in CVD, highlighting the potential positive effect of moderate wine consumption in a balanced lifestyle.

When examining the effect of alcohol consumption on CVD, spirits had a markedly different effect compared with wine and beer, as indicated by both RE and FE estimates. In contrast to wine and beer, which may exhibit different effects on CVD, hard liquor consumption consistently shows a positively significant association with cardiovascular health.

Researchers generally state that the most potent protective effect against CVD is associated with moderate alcohol consumption, usually defined as 20-30 grams per day, which is roughly equivalent to 2-3 standard alcoholic drinks. In the case of spirits, a standard alcohol unit equals to 10 grams usually translates to 30-37.5 ml of 40% alcohol, depending on the volume of spirits. However, a detailed analysis of alcohol consumption patterns needs to establish a beneficial relationship with cardiovascular health. In LMICs, where beer consumption generally exceeds spirits consumption, the price remains a significant factor influencing consumption levels (Chudzinska et al., 2022). These findings are consistent with evidence from HICs, where high prices may act as a deterrent to heavy alcohol consumption, thereby influencing cardiovascular health outcomes.

In LMICs, significant coefficients emerge for cholesterol, obesity, and tobacco consumption, revealing a positive impact on the CVD burden. These findings underscore the critical role of modifiable traditional risk factors in shaping CVD outcomes, including smoking, history of diabetes, obesity, unhealthy eating habits, sedentary lifestyle, heavy alcohol consumption, high cholesterol levels, and psychosocial factors. Notably, these eight risk factors collectively account for 61% of global CVD deaths, with 84% disproportionately concentrated in LMICs (Wurie and Cappuccio, 2012). However, amid these related trends, diabetes presents a contrasting picture, with a negative impact on CVD in LMICs. The prevalence of diabetes, particularly type 1 diabetes at a young age, interacts with low access to health care resources, underdiagnosis and undertreatment, which may mask its impact on CVD risk.

Furthermore, lifestyle factors such as low obesity and healthy eating patterns reduce some of the cardiovascular risks associated with diabetes (Chaudhary et al., 2024). One aspect highlighted in the findings is the unclear understanding of the relationship between diabetes and increased heart disease risk. Some researchers suggest that an interaction between high blood sugar and gene changes

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affected by environmental factors may explain the link. Starting treatment in newly diagnosed diabetics can lead to better heart health outcomes. However, there is inadequate solid evidence for screen for hidden signs of artery disease in asymptomatic diabetics. Awareness of diabetes as a significant health problem varies across demographics and income levels, and its negative impact on CVD underscores the complex interplay of health factors in LMICs.

### *Conclusion and policy implications*

Numerous empirical studies have demonstrated that alcohol consumption and its misuse can negatively influence not only public health but also the economic productivity and social stability of communities. In this context, the present study contributes by offering an evidence-based examination of how alcohol consumption specifically wine, beer, and spirits interacts with CVD risk factors such as cholesterol, diabetes, obesity, and tobacco use in LMICs. Using panel data across 170 countries over three decades, this research provides new managerial and policy insights into how lifestyle behaviors directly and indirectly affect population health and, consequently, workforce performance and national productivity.

The analysis revealed that beer consumption significantly contributes to the CVD burden in LMICs, largely due to its affordability and widespread accessibility, which make it a preferred choice among lower-income groups. Spirit consumption showed no beneficial effects on cardiovascular health, whereas moderate wine consumption exhibited cardioprotective tendencies, aligning with epidemiological evidence. These patterns underscore how lifestyle choices linked to socio-economic and cultural contexts can translate into measurable health and productivity outcomes.

From a management and human resource perspective, the findings emphasize the economic implications of workforce ill-health associated with alcohol-related cardiovascular risks. High rates of absenteeism, decreased productivity, and increased healthcare costs

are likely outcomes in regions where alcohol misuse and related health issues prevail. Thus, policy recommendations extend beyond public health frameworks to include strategic workplace interventions, such as promoting employee wellness programs, incorporating preventive health education, and encouraging balanced lifestyle practices within organizational cultures.

Moreover, traditional risk factors cholesterol, obesity, and tobacco use exacerbate the cardiovascular burden, highlighting the need for multi-level management strategies that integrate occupational health initiatives with national policy measures. Encouraging moderation in alcohol consumption, implementing awareness campaigns, and embedding health-oriented policies within both public and private institutions can serve as catalysts for sustainable workforce well-being.

In conclusion, this study underscores the critical intersection between health behavior and business management in LMICs. By illuminating how alcohol consumption patterns and modifiable lifestyle risks influence cardiovascular health, the research provides actionable insights for policymakers, organizational leaders, and human resource professionals. Designing evidence-based, workplace-centered health promotion initiatives can foster not only cardiovascular well-being but also enhance employee engagement, retention, and overall productivity.

For future research, it is recommended to explore how organizational health policies, leadership practices, and employee wellness frameworks can mediate or moderate the relationship between alcohol-related behaviors and productivity outcomes. Such studies would deepen the understanding of how health-oriented management practices can contribute to sustainable economic development and workforce resilience across diverse socio-economic contexts.

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Alcohol and Heart - Health Nexus in Lower Middle-Income Countries:  
Cardiovascular Risks Study

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