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ORIGINAL ARTICLE

Alcohol Consumption and Stroke Mortality: Global Patterns, Risks and Public Health Implications

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Abstract
Globally, stroke remains a leading cause of mortality and disability, while alcohol consumption continues to vary widely across regions, prompting concern over its health impacts. This study examines the association between different alcoholic beverages and stroke mortality, using secondary data from 1990 to 2020. Alcohol consumption and stroke death rates across 189 countries were categorized into five levels, from very high to very low, and averaged over two periods (1990–1999 and 2011–2020). Multiple Correspondence Analysis (MCA) was applied to assess relationships among four categorical variables. The findings indicate a significant association between very high alcohol consumption and increased stroke mortality, with eight countries showing elevated death rates. Conversely, moderate beer consumption was linked to reduced stroke mortality, suggesting nuanced effects based on beverage type and quantity. These insights offer a foundation for targeted public health policies and emphasize the need for further investigation into the mechanisms driving alcohol-related stroke risks.

Keywords Alcohol consumption · Alcohol · Global · Stroke · Multiple correspondence analysis · Mortality

Stroke is the second-leading cause of mortality and the primary global cause of disability (Pacheco-Barrios et al., 2022). According to the Global Stroke Factsheet published in 2022, the lifetime risk of having a stroke has increased by 50% over the past 17 years, and currently 1 in 4 people are predicted to experience a stroke throughout their lifetime. The stroke rate increased by 70%, the number of stroke-related deaths increased by 43%, the prevalence of stroke increased by 102%, and the number of Disability Balanced Life Years (DALY) increased by 143% from 1990 to 2019 (WHO, 2022a). Global stroke mortality has seen significant geographic shifts over the past two decades, particularly in low- and middle-income countries where alcohol consumption is rising (Ungvari & Kunutsor, 2024).

Alcohol drinking may be a noteworthy cause of chance for stroke (Bazzano et al., 2007; Caicoya et al., 1999; Hillbom, 1998; Lip & Beevers, 1995; Paolo et al., 1999; Rantakomi et al., 2014; Stewart-Wynne & Jamrozik, 1995). Numerous methods, all of which are

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physiologically plausible, may be used to explain how alcohol affects the likelihood of having an ischemic stroke. Drinking alcohol may increase the risk of stroke due to factors such as alcohol-induced vasoconstriction or platelet thinning, elevated blood pressure, arrhythmias and myocardiopathy.

Overindulgence in alcohol consumption has been linked to an increased risk of stroke (Chung et al., 2023). Additionally, alcohol raises blood pressure (Tasnim et al., 2020), leading to blood vessel hypertension and a significant increase in the risk of stroke. Therefore, it is not surprising that communities with high incidence of stroke also have relatively low rates of coronary heart disease (Hillbom, 1987; Paolo et al., 1999; Robinson et al., 2023). The estimation of the risk of every stroke incident includes drinking habits such the frequency of (Hillbom, 1998; Rantakomi et al., 2014) alcohol consumption. People who consume really large amounts of alcohol run a higher risk of dying from a stroke (Caicoya et al., 1999; Mostofsky et al., 2010). It has been proven that intracerebral traumatic bleeding during strokes is substantially correlated with alcohol consumption (Thangameeran et al., 2024), which makes sense given that an intoxicated person is more likely to sustain an injury. The greatest risk factor for all types of traumatic haemorrhagic strokes is unquestionably alcoholism (Chen et al., 2017). Recent studies have emphasized the urgency of understanding the role of alcohol consumption as a driver of stroke-related mortality, especially as noncommunicable diseases like stroke and heart disease now account for over 6 million annual deaths globally, with alcohol being a major behavioural risk factor in many regions (Ungvari & Kunutsor, 2024).

Another indicator of causality is the correlation between the duration and frequency of alcohol consumption, which shows that the latter is associated with an increased risk of dying from a stroke (Paolo et al., 1999; Rantakomi et al., 2014). The likelihood of dying from a stroke was highest for men who drank most frequently each week (Hillbom, 1998; Hillbom, 1987; Paolo et al., 1999; Rantakomi et al., 2014; Smyth et al., 2023). Additionally, among light-to-moderate drinkers, either an elevated risk of ischemic stroke exists or there is no association. As a result, those who consume too much alcohol have an increased risk of dying from a stroke.

This study examines the relationship between alcohol use and the rates of stroke deaths. The findings provide a substantial addition to the body of current information. This study stands apart from related research due to three key differences. Firstly, a thorough analysis utilizing Multiple Correspondence Analysis (MCA) was conducted to ascertain if variables were connected or independent. This made it possible to conduct complete research, which improved the study's ability to determine how various alcoholic beverages, and the risk of stroke are related. Secondly, in order to provide results that are both accurate and useful, the study focuses on the nations with the highest current rates of stroke death while taking into account the timeframes 1990 to 1999 and 2011 to 2020. Thirdly, the study's inclusion of 189 countries enables the researcher to pinpoint the nations that exhibit underlying stroke-related concerns and further examine how links between alcohol consumption and stroke deaths manifest among countries.

The outcome of this investigation will also help individuals working on public health programs to make educated choices about alcohol consumption. The benefits and drawbacks of alcohol consumption are explored, and a broad explanation for these events is determined for future debate. It also develops a more benevolent and informed global community via cooperative efforts that is aware of the possible risks linked with alcohol and use evidence-based practices to safeguard both individual and social health.

Materials and Methods

Using data sourced from two reputable databases, Our World in Data (OurWorldInData), and the World Health Organization (WHO, 2022b), an MCA was conducted to determine the association between alcohol and stroke. The data file used for the study is presented as the Appendix. The collected data was converted into distinct categories by considering their highest and lowest values. The six categorical variables: country, the death rate of stroke, beer consumption, wine consumption and spirit consumption, are further classified into five levels: very low, low, moderate, high and very high. Table 1 presents the sources of the original data which was gathered to conduct the study.

The levels that were used to categorize the above variables differ from one to another. The different levels that were used are displayed in Table 2. The study used STATA 17 software to analyse and used R to visualise data.

MCA is an analytical technique that extends the scope of Correspondence Analysis to analyse complex and sizable datasets utilising specialised visualisation techniques, which can be interpreted to ascertain the patterns, relationships and associations among the categories and individuals (Alhuzali et al., 2022). The dataset is used within the MCA as a contingency table, with rows denoting individuals and columns indicating distinct categories (Sivasankaran & Balasubramanian, 2020). Rows and columns are visually represented as points on a graph, providing an understanding of complicated data sets. Most studies utilise Burt's matrix $B = Z'Z$ or an indicator matrix Z to conduct an MCA (Greenacre & Blasius, 2006). The Burt matrix is a representation of categorical data that utilises diagonal blocks to show the frequency of the data symmetrically and understandably. Generally, a Burt matrix is a two-way contingency table represented within a matrix (Beh & Lombardo, 2014; Gower et al., 2010; Khangar &

Table 1 Data sources

Variables	Measure	Source
Stroke	Death rate per 100,000 people	Our World in Data (2020) https://ourworldindata.org/grapher/stroke-death-rates
Alcohol Consumption	In litres of pure alcohol consumed	WHO (2020) https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption

Sources: Data archived from OurWorldInData and WHO, 2022b

Table 2 Division of variables

Beer		Wine		Spirit		Stroke	
0–1.6	Very low	0–1.6	Very low	0–1.4	Very low	23–85	Very low
1.6–3.2	Low	1.6–3.2	Low	1.4–2.8	Low	85–143	Low
3.2–4.8	Moderate	3.2–4.8	Moderate	2.8–4.2	Moderate	143–200	Moderate
4.8–6.4	High	4.8–6.4	High	4.2–5.6	High	200–258	High
6.4–8	Very high	6.4–8	Very high	5.6–7	Very high	258–315	Very high

Source: Authors' compilation based on WHO, 2022b

Kamalja, 2017). There are several advantages when using the Burt matrix compared to other methods. One of the main factors is that the Burt matrix typically has fewer computations complex, than alternative methods. Moreover, this also allows researchers to analyse and graphically present complex data using a bi-dimensional plane.

Within a Burt matrix, the total inertia is defined as (Jayathilaka, 2014; StataCorp, 2023):

$$\left[\frac{q}{q-1}\right]\sum\phi_t^2 - \left[\frac{(J-q)}{q^2}\right]$$

Within an MCA, the total variation between the categories within the dataset explained by the analysis falls under the term "inertia". It is used in assessing associations and patterns between different categorical variables in the analysis. Eigenvalues generally explain the variation and information that is captured in each dimension, the higher the inertia within the first two planes, the more accurate the analysis is (Abdi & Valentin, 2007; Greenacre & Blasius, 2006; Kroonenberg & Greenacre, 2004). High eigenvalues indicate more significant total variances among variables of one dimension (Natarajan et al., 2020). The coordinates for the MCA plot are calculated within the Burt matrix, where all similar distributions are plotted near one another, and the different distributions are plotted further away from each other in a cloud-like manner where associated categories are placed within a close cluster (Das & Sun, 2015). This allows us to gauge the relationships and associations between the variables used to run the MCA (Everitt & Dunn, 2010; Kroonenberg & Greenacre, 2004). The main advantage of MCA is that it is a reliable multivariate statistical method used to evaluate and visually represent multivariate categorical data in massive, complicated datasets. MCA helps identify underlying associations and dependencies by examining the contribution of each variable to each dimension. The variables that influence or are most associated with the data structure can be identified, and the focus of the analysis can be adjusted accordingly. Additionally, MCA facilitates exploratory data analysis by providing insights into the system and patterns within the dataset.

Results

To visualise and further examine the associations that may exist between alcohol consumption and stroke, an analysis comprising globally available data was conducted. Death rates were classified into five distinct categories based on the highest and lowest values, out of which some types hold a higher range to provide a better representation of the data. The data was then plotted onto a pair of maps to determine the countries that exhibit prevailing high death rates. To avoid data inaccuracy caused by external factors, 10-year averages of the earliest and latest years were calculated. Figure 1 represents the average death rates for the years ranging from 1990 to 1999, and Fig. 2 illustrates the years 2011 to 2020.

For both maps, the countries with the highest stroke death rates are listed below each figure, while the maps provide a visual representation of the corresponding global distribution and represents the high death rated in bold letters. A declining death rate can be observed among the highlighted countries, specifically North Macedonia recorded the highest stroke death rate during 1990–1999 at 314 deaths per 100,000 population, while Nauru reported the highest rate during 2011–2020 at 244 deaths per 100,000 population. This represents a 22.4% reduction in mortality between the two periods. Countries that have not been marked do not highlight a significant overall change and are not presented for further discussions. Within the time frames taken into consideration, a visual decrease

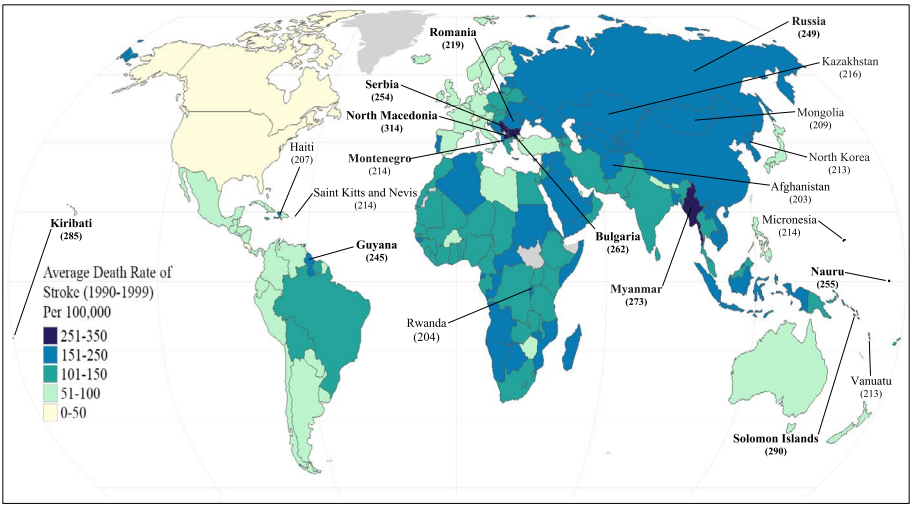

Fig. 1 Map of average death rate of stroke per 100,000 in 1990–1999. Source: Authors' illustration based on OurWorldInData

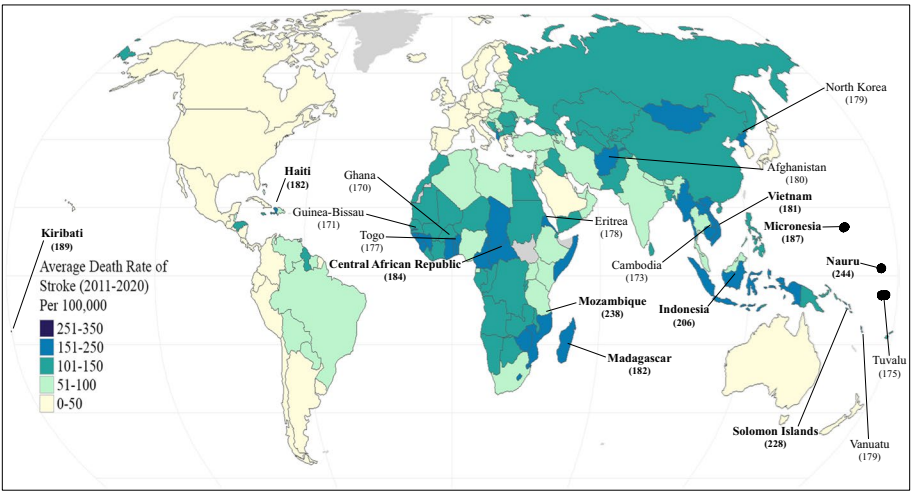

Fig. 2 Map of average death rate of stroke per 100,000 in 2011–2020. Source: Authors' illustration based on OurWorldInData

can be observed in the overall death rate of stroke globally, with the more significant part of the countries.

Stroke showed a relatively higher average prevalence in the European region compared to other regions during the period 1990–1999, with some of the highest average death rates recorded in geographically proximate countries, notably Romania (0.81%), Bulgaria (0.11%), Serbia (0.46%), Montenegro (1.50%) and North Macedonia (1.41%). High death rates can also be identified in small island nations that appear isolated from the mainland.

While these values may seem comparatively lower, considering the quantity and the country's population, it is more severe than at first glance. However, the Asian region does not seem to be affected much by stroke, as presented by the below-par death rates.

Within Fig. 2, Nauru, Solomon Islands and Kiribati show prevailing high death rates; Kiribati exhibits the largest drop at −26%, with Nauru and Solomon Islands displaying a drop of −22.4% and −19.9% respectively. Micronesia and Haiti also appear to have overall high death rates, with a declining rate of −26.6% and −25.4%, respectively. While Afghanistan, Vanuatu and North Korea shows a healthy declining rate of 16.1%, 16.5% and 16.5% respectively.

The 30-year period presents several more countries that have become increasingly unsafe within the African region. Mozambique, Lesotho, Madagascar, Eritrea, Togo, Guinea-Bissau and Ghana can be observed in the recent years, depicting a dangerous climb in the death rates. With Mozambique, Lesotho and Togo exhibiting a substantial increase of 35.6%, 38.6% and 30.3% respectively, While Madagascar shows a steady decline in the death rate by −4.0%. Within the remaining four countries depicted in the African region, Eritrea and Ghana reveal an increasing rate at 14.4% and 17.4%, respectively. Central African Republic and Guinea-Bissau display a slow and steady increase at 4.1% and 8.9%, respectively. While the global death rates of stroke have reduced in most of the world, a small percentage of countries still show increasing death rates. These countries are primarily identified as island nations and lesser developed countries, thus leading to speculation that lack of knowledge and healthcare availability might influence stroke death rate. Before the results from the MCA can be visualised, an additional measure needs to be undertaken. Detailed MCA dimensions and eigenvalues results are presented in the below Table 3 but only the dimensions with the highest eigenvalues are utilised to visualise the results of the MCA. Figure 3 shows the Screeplot of the total inertia captured by each size. The first two dimensions charge 69.95% and 5.01% of the complete inactivity, implying a strong 74.96% of the association between the four categorical variables being described in the resulting Biplot. The Country IDs have been added to the MCA as an auxiliary variable, hence only appearing as an overlayed set of points over the actual MCA and not influencing the overall results of the MCA.

The detailed results of all the variables used for the analysis can be found in Table 3. The variables include four types of alcohol, their individual consumption levels, the chosen disease and its respective death rate. Based on the MCA, the below Fig. 4 depicts the stroke mortality trends from 1990 to 2020 across those eight countries Solomon Islands, Nauru, Kiribati, Micronesia, Haiti, Vanuatu, Afghanistan and North Korea as having significant associations with stroke mortality.

The resulting coordinates are plotted within the Biplot. To understand how each category contributed to the Biplot's total inertia and principal coordinates, consider Table 3. The Quality of each category within the country variable is displayed in the third column. The quality of North Korea and Haiti at 1.23 and 0.94 depicts the respective countries' contribution for the association between alcohol consumption and stroke. However, some countries could be represented better within the MCA; Afghanistan in particular exhibits the poorest quality. Indicating that it is less represented by the dimensions captured within the Biplot.

Figure 5 presents the Biplot generated using the statistics that are presented beforehand. Similarly, specific subcategories within the variables were also dropped as none of the countries considered showed them.

Within the results, a clear visualisation of how stroke interacts with beer, wine and spirit can be observed. The close cluster of points relative to the origin of the plot indicates how

Table 3 Results of MCA for stroke

Dimensions	Principal inertia	%	Cumulative %
Dim 1	0.1011974	69.95	69.95
Dim 2	0.0072466	5.01	74.96

Statistics for column categories in standard normalisation

Category	Overall			Dimension 1		Dimension 2	
	Mass	Quality	% inertia	Coordinate	Square correlation	Coordinate	Square correlation
Country ID							
1. Afghanistan	0.125	0.013	1.728	− 0.329	0.005	−1.426	0.007
2. Haiti	0.125	0.948	1.728	− 0.793	0.032	−15.904	0.916
3. Kiribati	0.125	0.265	1.728	− 1.816	0.167	5.193	0.098
4. Micronesia	0.125	0.208	1.728	2.025	0.207	0.261	0
5. Nauru	0.125	0.265	1.728	− 1.816	0.167	5.193	0.098
6. North Korea	0.125	1.234	1.728	4.876	1.203	2.915	0.031
7. Solomon Islands	0.125	0.265	1.728	− 1.816	0.167	5.193	0.098
8. Vanuatu	0.125	0.013	1.728	− 0.329	0.005	− 1.426	0.007

Categories	Overall			Dimension 1			Dimension 2		
	Mass	**Quality**	**% inertia**	**Coordinate**	**Square correlation**	**Contribution**	**Coordinate**	**Square correlation**	**Contribution**
Types of alcohol beverages and consumption Levels									
Beer consumption									
Very low consumption	0.188	0.757	0.097	− 0.749	0.755	0.105	− 0.144	0.002	0.004
Low consumption	0.063	0.757	0.292	2.247	0.755	0.315	0.431	0.002	0.012
Wine consumption									
Very low consumption	0.219	0.821	0.038	− 0.454	0.818	0.045	− 0.113	0.004	0.003
Low consumption	0.031	0.821	0.269	3.175	0.818	0.315	0.791	0.004	0.020
Spirit consumption									
Very low consumption	0.219	0.451	0.051	0.074	0.075	0.001	0.616	0.376	0.083

Table 3 (continued)

Moderate consumption	0.031	0.451	0.043	− 0.516	0.075	0.008	− 4.314	0.376	0.582
Death rate of stroke									
High	0.156	0.756	0.080	0.710	0.686	0.079	− 0.845	0.070	0.112
Very high	0.094	0.756	0.134	− 1.183	0.686	0.131	1.409	0.070	0.186

Multiple/joint correspondence analysis; method; Burt/adjusted inertias; number of observations:189; number of axes: 2

Note: Coordinates closer to 0 indicate weaker association

Source: Authors' compilation based on data

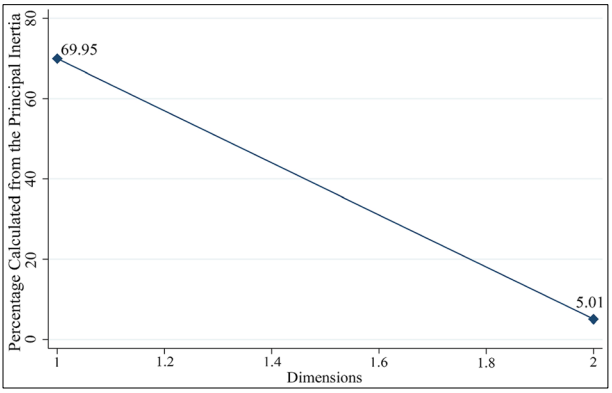

Fig. 3 Plot of dimensions produced by MCA. Source: Authors' illustration using Stata 17

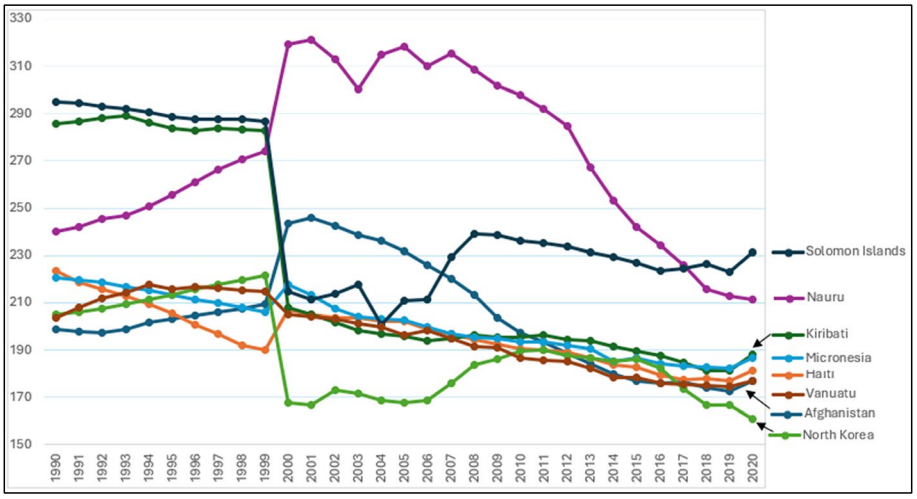

Fig. 4 Stroke mortality trends (1990–2020) in countries with elevated risk identified by MCA. Source: Authors' illustration using Stata 17

stroke displays a very high prevalence when alcohol consumption levels of beer, wine and spirit alcohol types are deficient. Stroke, however, shows a different relationship with alcohol depending on its alcoholic content. Beer, which contains the lowest alcohol percentage among the three beverages considered, is associated with lower stroke mortality at low consumption levels. Specially, countries with low (but not high) beer consumprion tend to exhibit lower stroke mortality reates. This does not imply a protective effect of increased beer intake but rathe indicates a potential non-linear association at low consumprion thesholds, as observed in orher epidemiological studies. In contrast to beer, sprit consumption demonstrates a positive association with stroke mortality. As the level of spirit intake increases from very low to moderate, countries tend to align more closely with higher stroke mortality categories in the MCA plot. Although average spirit consumption appears to a certain degree associated with high stroke mortality in the MCA plot, this relationship is less prominent compared to other alcohol categories, as it is positioned closer to

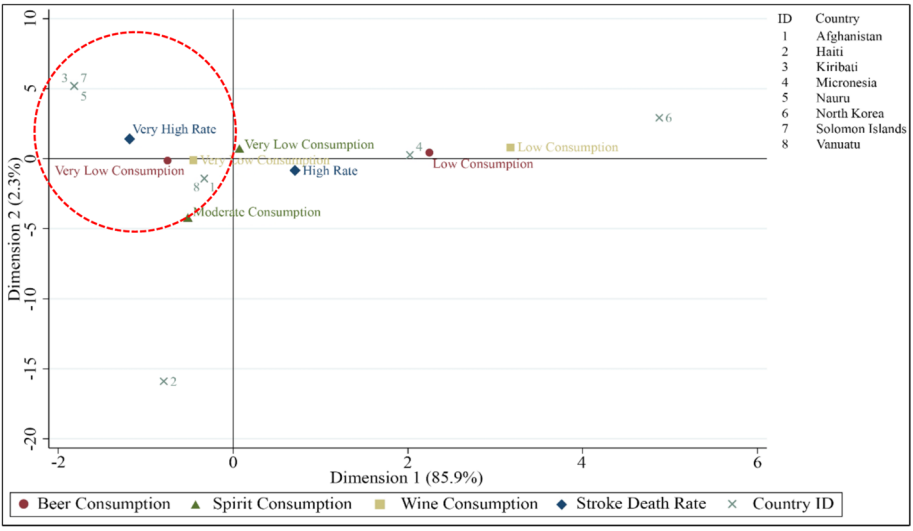

Fig. 5 Biplot of Stroke MCA. The biplot generates by the statistics that are presented beforehand. Source: Authors' illustration using Stata 17

the origin—indicating a weaker overall contribution to the observed pattern. Wine consumption follows a similar relationship as beer, The increase from very low to low consumption aligns with lower death rates of stroke. This further reinforces the patters that are visible within stroke and beer. The countries plotted within the MCA represent which category they are closely associated with. Similarly, points that appear nearby to each other or within a cluster show that they are closely associated with each other.

Discussion

The results of this research paper provide clear evidence of an association between alcohol consumption and stroke death rates. MCA allowed for a descriptive multidimensional visualization of the associations among variables by considering different alcohol types (beer, wine and spirits) and their respective alcoholic content. The results from the MCA indicate that, in the context of selected countries, moderate levels of beer and wine consumption are associated with lower stroke death rates. This association should not be interpreted as a general endorsement of increased alcohol intake but rather as an observation of a non-linear relationship where low-to-moderate consumption may correspond with lower stroke mortality in certain contexts. Conversely, high levels of alcohol consumption—especially spirits—are associated with higher stroke death rates. Recent research across low- and middle-income countries has shown similar population-level patterns, with alcohol-attributable mortality varying by socioeconomic status and national income level (Manthey et al., 2023; Xu et al., 2022). Similar studies (Jeong et al., 2022; Soo Joo et al., 2015; Wang et al., 2021) have reported comparable findings, particularly in contexts where light-to-moderate consumption of alcohol, especially beer or wine, was linked to a reduced prevalence of stroke. These findings, while not indicative of causality, suggest a potential protective effect under specific consumption thresholds. This pattern aligns with our observations and

enhances the credibility of the MCA results in highlighting possible associations at moderate intake levels.

Beer consumption shows a negative association with stroke mortality across the selected countries. Nations with moderate beer consumption levels tend to align with lower stroke death rates, suggesting a possible protective effect. However, this trend is not strictly linear, and the strength of association varies slightly across consumption levels. This suggests lower beer consumption may protect against stroke (Truelsen et al., 1998). However, this effect is reduced when beer crosses the threshold of very low, where low beer consumption shows an increase in stroke death rates over very low to no beer consumption. This nonlinear association has also been documented in regional alcohol burden analyses that show protective effects at low doses and harm at higher thresholds (Safiri et al., 2022).

Spirit consumption exhibits a different type of relationship to compared to beer, where higher the consumption, the death rate of stroke increases. This is caused due to the higher alcoholic content within these beverages, resulting in adverse health effects. Wine consumption demonstrates a negative association with the increase in wine consumption resulting in reduced stroke death rates. The results, however, cannot find the association in high alcohol consumption, as countries considered for the analysis do not show such consumption levels. Nevertheless, cross-country studies show that even moderate disparities in alcohol access or taxation can widen health inequalities, highlighting the policy relevance of this finding (Probst et al., 2021).

Conclusion

The primary intent of this study is to investigate the association between alcohol consumption and Stroke from 1990 to 2020 using the MCA method. The results demonstrate that countries with lower alcohol consumption have a greater incidence of stroke deaths. Higher alcohol consumption does not reduce the risk of stroke. However, stroke risk may be reduced when beer is consumed at moderate levels, suggesting a potential protective effect at this specific level of intake. At the same time, spirit consumption has a positive association. However, wine in the chosen nation has no significant association with stroke. World maps illustrated how the fatality rate from stroke has declined over the past 30 years, from 1990 to 2020.

Policies regarding moderate alcohol consumption could be implemented to help reduce the risk of stroke. Such policies may include providing a maximum volume of daily consumption, which may also reduce the risk of stroke. Education campaigns should be implemented to warn of the link between alcohol consumption and stroke. Implement restrictions on alcohol marketing and advertising to reduce the influence of inaccurate or glamourised depictions of alcohol consumption. Implementing limitations on alcohol advertising for vulnerable groups, such as underage individuals and people with a higher risk of stroke, policies and supporting centres for such individuals can be constructed to reduce excessive drinking and promote healthier habits.

Limitations

Considering the recent pandemic, data collection after 2020 was halted globally. Due to this situation, newer studies cannot incorporate data for the following years. Other alcohol consumption was also dropped as no significant consumption was observed over the

countries considered. Similarly, illicit and illegal alcohol consumption rates are not fully captured within the used dataset. While such factors limit this study, future studies can incorporate additional variables and attempt to identify factors such as the advancement of health care, income levels, gender and age groups.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11469-025-01498-y.

Author Contribution RJ conceptualised the study. TK, KM, GD, KR, LR and CW contributed to the design and conduction of the study. TK, KM, GD and KR curated the data. TK, KM, GD and RJ. LR undertook data analysis and interpreted the data. TK, KM, CW and RJ drafted the first manuscript. RJ Supervised the entire study. All authors critically reviewed, edited and approved the final manuscript.

Data Availability All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethical Approval This study was approved by the Sri Lanka Institute of Information Technology, Sri Lanka (PVC/RI/EC/2023/03).

Consent to Participate Not applicable.

Conflict of interest The authors declare no competing interests.

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