

A country-level k-Means Clustering of stress and coping strategies during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic has substantially increased psychological stress worldwide, making it important to understand how countries differ in their coping strategies. Previous cross-national studies have primarily relied on descriptive or regression-based analyses, which are limited in identifying latent national coping-stress profiles based on multiple coping behaviours. To address this limitation, this study applies K-Means clustering to identify groups of countries with similar stress and coping characteristics. The analysis was conducted using aggregated country-level data from the COVIDiSTRESS Global Survey. The final dataset consisted of 25 countries. For the clustering analysis, each country was represented using 19 features, consisting of the mean values of 16 coping 16 coping strategies and the proportions of respondents in the low, moderate, and high stress categories. The optimal number of clusters was determined using the elbow method dan supported by the silhouette coefficient, resulting in a four-cluster solution. Four distinct national coping-stress profiles were identified. Cluster 1 (Czech Republic, France, Hungary, Japan) exhibited balanced stress levels with moderate engagement in social dan recreational coping activities. Cluster 2 (Argentina, Bosnia and Herzegovina, Bulgaria, Croatia, Mexico, Poland, Turkey, United States) recorded the highest stress levels and was characterised by intensive social interaction and entertainment-based coping. Cluster 3 (nine European countries) exhibited the lowest stress levels and predominantly relied on institutional trust and government information, Cluster 4 (Indonesia, Kosovo, Portugal, Taiwan) showed moderate stress levels and was characterised by greater adherence to government-related information, entertainment-based coping, and the highest use of religious or spiritual coping. These findings demonstrate that K-Means clustering provides a useful approach for identifying cross-national stress-coping profiles that may not be evident through conventional statistical analyses. The identified clusters offer insights into variations in coping behaviours across countries and may support the development of more context-specific mental health interventions.

Keywords:

COVID-19; Stress Levels; Coping Strategies; Cluster Analysis; K-Means Clustering.

Introduction

The COVID-19 pandemic has brought major disruptions to the international community, and its impacts have been far-reaching, affecting not only concerning physical but also mental well-being. The mental effects of this crisis have been quite extensive because uncertainty and lifestyle changes brought about by the pandemic have led to higher levels of stress and other forms of psychological distress such as depression among people across nations (Xiong et al., 2020).

In light of this, coping mechanisms are strategies individuals use to deal with this stress and have played a major role in how the different populations have reacted to this challenge. It is

important to understand different coping actions undertaken within countries because this has been crucial for developing sustainable and country-tailored actions to improve mental well-being when other international health crises arise in the future (Salari et al., 2020).

Previous studies have investigated the relationship between stress and coping using of descriptive analyses, classification techniques, and regression models. For example, Eisenbeck et al. (2021) employed the use of the descriptive method to chart the coping mechanisms employed in various countries in relation to stress, where physical activity and social support were found to be central in alleviating stress. Other authors, such as Rettie and Daniels (2021), employed the use of categorization to classify countries according to their level of stress, where countries that imposed more stringent lockdowns exhibited high stress. Other studies have applied regression analysis to examine government policies, unemployment, and socio-demographic factors associated with psychological outcomes. These studies primarily examine relationships between variables or compare countries descriptively, offering limited understanding of whether countries share similar overall stress-coping profiles.

Several important research gaps therefore remain. First, most previous studies have focused on individual-level analyses rather than examining countries as the unit of analysis. Second, cross-national studies have generally compared average stress levels across countries without identifying latent groups of countries that exhibit similar combinations of stress and coping behaviours. Third, conventional descriptive and regression approaches are designed to estimate associations among variables rather than uncover hidden multivariate structures within cross-national data. As a result, they provide limited insight into whether countries can be grouped according to shared stress-coping characteristics.

Addressing these gaps is important because coping behaviours are influenced by cultural, social, and institutional contexts that differ substantially across countries (Hofstede, 2001). Countries in different geographical regions may exhibit similar coping patterns, while neighbouring countries may respond differently depending on their cultural values, social support systems, and public health policies. Identifying such latent national profiles can therefore provide a broader understanding of cross-national behavioural responses during global health crises.

To investigate these cross-national patterns, a comprehensive international dataset is required. The COVIDiSTRESS Global Survey provides such a resource by collecting information on psychological well-being, perceived stress, and coping activities from more than 80,000 participants across multiple countries (Yamada et al., 2021). In the present study, the Perceived Stress Scale and sixteen coping activity variables were extracted from the survey and aggregated at the country level to characterise national stress-coping profiles.

Clustering offers an appropriate analytical approach for this objective because it identifies groups of countries with similar multivariate stress and coping characteristics without requiring predefined outcome variables. Rather than focusing on average relationships among variables, clustering reveals latent patterns that may remain hidden using conventional statistical approaches. Such information can provide a more comprehensive understanding of cross-national similarities and differences in stress and coping behaviours.

This study makes three main contributions. First, while previous cross-national studies have examined coping using regression or descriptive methods, none have systematically applied clustering to aggregated country-level data from the COVIDiSTRESS Global Survey to identify national stress-coping profiles. Second, unlike prior clustering studies that focused on individual-level responses, this study investigates similarities and differences among countries as the unit of analysis. Third, the identified clusters are interpreted using cultural dimensions and social support theory, providing theoretically grounded explanations for cross-national differences in coping behaviours and perceived stress.

Therefore, this study aims to identify groups of countries with similar stress and coping characteristics using K-Means clustering. The resulting clusters are subsequently analysed to determine the coping strategies associated with different stress profiles and interpreted within established psychological frameworks. The findings are expected to contribute to the

development of evidence-based and context-specific mental health strategies for future global health emergencies.

Methods

Data

The data utilized in this study were obtained from the COVIDiSTRESS Global Survey, a large-scale international project designed to investigate psychological well-being, stress, and coping activities during the COVID-19 pandemic (Yamada et al., 2021). The survey collected responses from over 80,000 participants across multiple countries, covering various aspects of psychosocial functioning.

For the purposes of this study, two groups of variables were extracted stress levels, measured by the Perceived Stress Scale (PSS-10), a widely validated instrument for assessing perceived stress, and sixteen coping activities. These sixteen coping activities encompass a broad range of behavioural responses, including physical activities, social behaviors (e.g. contacting friends or family, communicating via social media), information seeking behaviors (e.g. following government guidelines, searching for official COVID-19 information), entertainment related activities (e.g. watching movies or television, playing games), mood regulation and leisure activities, avoidance-oriented behaviors as well as religious or spiritual practices such as praying. Table 1 provides an overview of the variable categories.

Table 1. Overview of the data

No	Variable Category	Description	Measurement Scale
1	Country	Country of the respondent	Categorical
2	PSS-10 Items	Ten items from Perceived Stress Scale, later aggregated into a perceived stress score	5-point Likert scale (1 = never, 5 = very often), total range 10-50
3	Coping Activities	Sixteen items assessing coping activities. Each item reflects the respondent's agreement with the activity as a way of coping	6-point agreement scale (1 = strongly disagree, 6 = strongly agree)

For brevity in the subsequent analysis, the sixteen coping activities were labelled C1 through C16. Table 2 maps each code to its original survey item and provides a brief description.

Table 2. Mapping of Coping Activity

Code	Description
C1	Information from Government
C2	Face-to-face friends/family
C3	Phone/Long range friends/family
C4	Face-to-face colleagues
C5	Phone/Long range colleague
C6	Social Media
C7	Video Games (Alone)
C8	Video Games (Online)
C9	Watching TV/Movies
C10	Helping others
C11	Preparing for crisis
C12	Following government advice
C13	Work/Vocation
C14	Activities/Hobbies
C15	Religion/Spirituality
C16	Government/Civil service knowledge

Source: COVIDiSTRESS Global Survey

All analyses were conducted at the country level, not at the individual respondent level. To enable cross-national comparison, individual-level responses were aggregated by country, computing the mean stress score and the mean score for each coping activity per country. Only countries with at least 1,000 respondents were retained to ensure reliable country-level estimates. For the clustering analysis, each country was represented using 19 input features, consisting the mean values of the 16 coping activities and the stress category proportions. The preprocessing steps were performed sequentially as described in Table 3.

Table 3. The Preprocessing Steps

Step	Description	Details
1	Missing value assessment	Observations with more than 50% missing values across PSS-10 and coping items were removed.
2	Missing value imputation	For remaining missing values in numeric variables, the median of each variable was used, as this approach is more robust to outliers than mean imputation.
3	Country information check	Observations lacking country information were excluded, because all subsequent analyses are conducted at the country level.
4	Reverse scoring	Negatively worded PSS-10 items (items 4,5,7,8) were reverse-scored (new score=6-original score) to ensure consistent interpretation across all items.
5	Stress score calculation	A total stress score was calculated by summing all ten PSS-10 items and adjusting the scale to range from 0 to 40, in accordance with standard PSS-10 scoring guidelines.
6	Stress categorization	Based on the total score, respondents were classified into three descriptive categories: low stress (score ≤ 13), moderate stress (score 14-26), and high stress (score ≥ 27).
7	Country filtering	Only countries with at least 1,000 respondents were retained. A total of 25 countries met this criterion.
8	Aggregation to country level	Individual-level responses were aggregated by country, computing the mean stress score and the mean score for each of the 16 coping activities.
9	Standardization	All features were standardized using the StandardScaler, because K-Means clustering is sensitive to variable scales.

Source: Authors processing

K-Means Clustering

K-Means method divides a dataset into k clusters, grouping data points based on numerical attributes (Syakur et al., 2018). Before the clustering process, the elbow method is applied to identify the optimal number of clusters by evaluating compactness using the total within-cluster sum of squares as the assessment criterion (Ikotun et al., 2023). The total within-cluster sum of squares, denotes by J , is calculated using Equation (1).

$$J = \sum_{j=1}^k \sum_{x_i \in S_j} \|x_i - c_j\|^2 \quad (1)$$

K-Means method proceeds through the following iterative steps (Syakur et al., 2018).

- Determine the number of clusters k and the maximum number of iterations.
- Randomly initialize k initial centroids $C = \{c_1, c_2, \dots, c_k\}$ as the initial cluster centers.
- Assign each data point x_i to the nearest centroid c_j based on Euclidean distance in Equation [2]

$$d(x_i, c_j) = \sqrt{(x_{i1} - c_{j1})^2 + (x_{i2} - c_{j2})^2} \quad (2)$$

- After the assignment step, each centroid is recomputed as the mean of all data points assigned to that cluster. Formally, let $S_j = \{i: x_i \text{ is assigned to cluster } j\}$ and let $|S_j|$ be its cardinality. The update centroid c_j is given by:

$$c_j = \frac{1}{|S_j|} \sum_{x_i \in S_j} x_i \quad (3)$$

- e. If the centroids remain unchanged or the maximum number of iterations is reached, the process stops. Otherwise, return to step 3.

The elbow method was applied by plotting the within-cluster sum of squares (WCSS) against $k = 2, 3, \dots, 10$. The optimal k was selected at the point where the decrease in WCSS became less pronounced (the elbow). To validate this choice, the silhouette coefficient was also computed. For a data point i , the silhouette coefficient is defined as:

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}} \quad (4)$$

where $a(i)$ is the mean distance to other points in the same cluster and $b(i)$ is the mean distance to points in the nearest neighbouring cluster. The overall silhouette score (average over all points) ranges from -1 to 1. Higher values indicate better cluster separation.

Principal Component Analysis for Visualization

Principal Component Analysis (PCA) is a dimensionality reduction technique that transforms high dimensional data into a lower dimensional representation while preserving most of the variance (Jolliffe & Cadima, 2016). In this study, PCA was employed solely for visualization purposes to project the 19 dimensional clustering results (16 coping strategies and 3 stress level) into a two dimensional space. PCA is not used as a formal validation of cluster separation. It merely helps to illustrate the relative positions of clusters in a reduced space.

The first two principal components were extracted from the standardised data matrix. The percentage of variance explained by each component was recorded. Confidence ellipses were added to indicate the spread of each cluster. While the visualization is presented in two dimensions for interpretability, the K-Means clustering itself was performed on the original 19 dimensional data to retain the full information about stress and coping patterns.

Results and Discussions

From the COVIDiSTRESS dataset, only countries with at least 1,000 respondents were included to ensure data reliability. A total of 25 countries met this criterion. Finland contributed the highest number of respondents, 22,933, followed by France with 13,475, Denmark with 10,891, and Mexico with 9,169 respondents. Other countries had respondent counts ranging from 1,067 in Portugal to 8,255 in Lithuania.

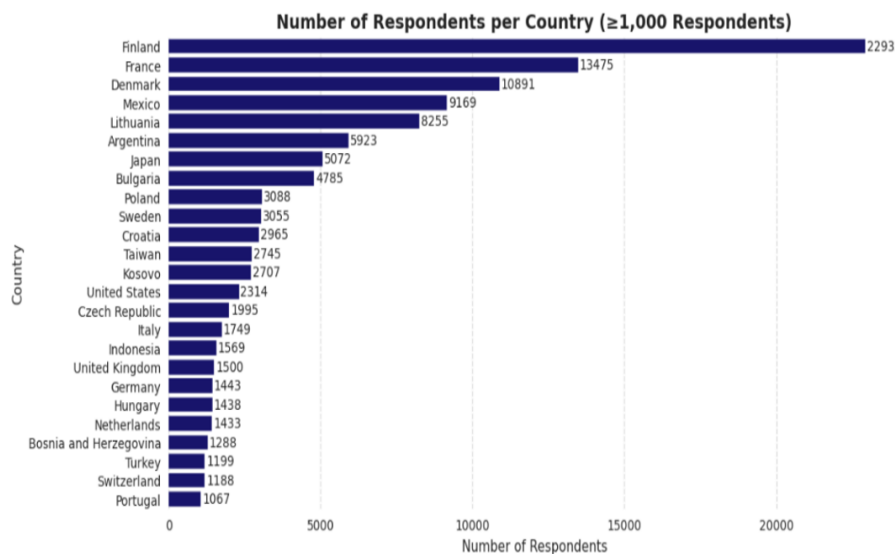


Figure 1. Number of Respondents per Country

Figure 2 represents boxplots of the mean PSS-10 scores across countries, illustrating both central tendencies and dispersion in perceived stress levels during the COVID-19 pandemic. Overall, substantial cross national variation is observed, with some countries such as Turkey, Portugal, and Poland exhibiting higher median stress scores, while others including Indonesia, Switzerland, and the Netherlands display relatively lower median levels. The width of the interquartile range also indicates variability in stress experiences even within the same national context. Several countries also show pronounced outliers at the upper end of the scale, reflecting subpopulations experiencing particularly high stress levels. These distributional differences highlight that pandemic-related stress was not uniformly experienced across countries.

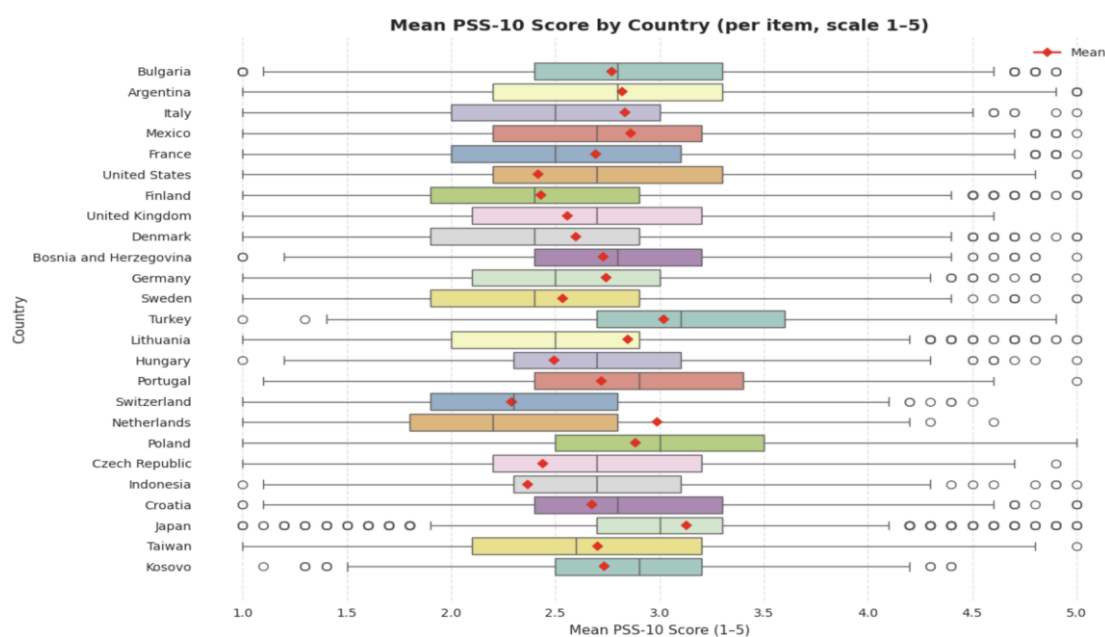


Figure 2. Mean PSS-10 Score by Country

The distribution of stress levels across countries during the pandemic is presented in Figure 3. The figure shows considerable variation among countries. Some countries, such as the Netherlands, Switzerland, Denmark, Sweden and Finland, exhibit a higher proportion of low stress levels (>45%), whereas others, including Turkey, Poland, and Portugal show a more pronounced proportion of high stress levels. Most countries display a dominant proportion of moderate stress, indicating that the majority of the population experienced moderate stress levels. These differences suggest a diversity in stress experiences across countries, likely influenced by social, cultural, and pandemic response policies specific to each country.

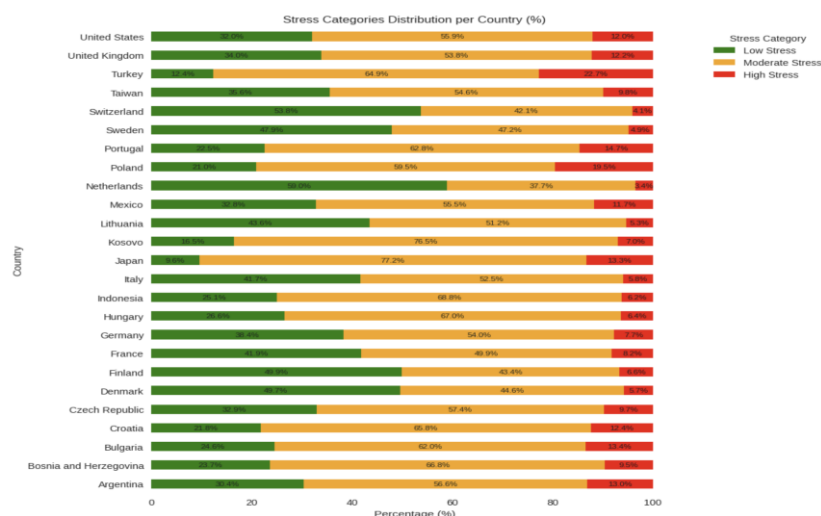


Figure 3. Stress Categories Distribution per Country

Figure 4 show the most respondent relied on socially oriented coping strategies, particularly staying in touch with friends or family, engaging in hobbies, and watching TV or movies. In contrast, strategies such as video gaming, crisis preparation, and religious or spiritual practices were used by a much smaller proportion of participants. This pattern suggests that during the pandemic, individuals tended to cope through social connection and light leisure activities rather than more solitary or intensive coping methods.

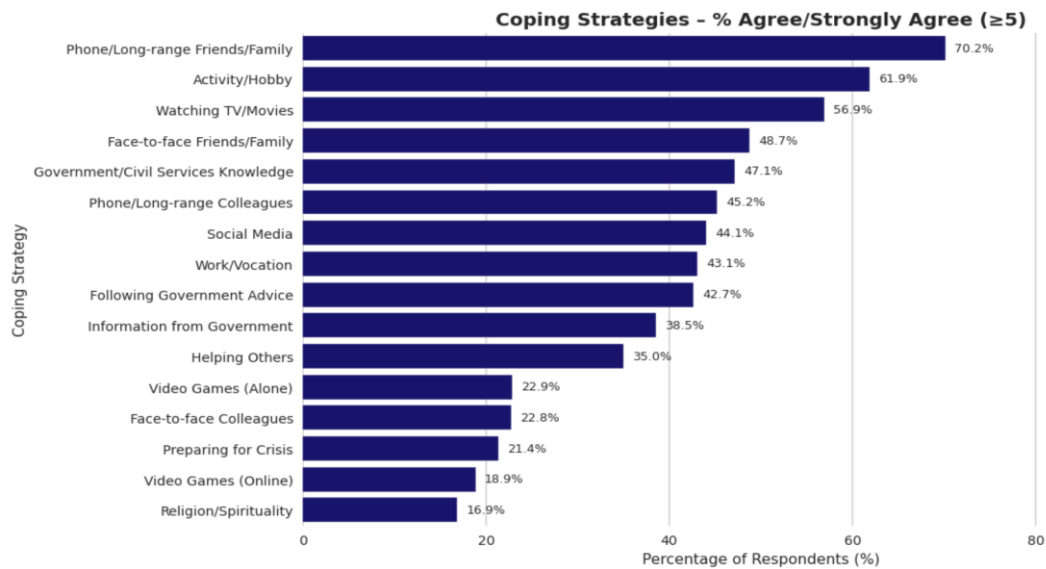


Figure 4. Percentage of Respondents Using Each Coping Strategy

This study performed K-Means clustering on 25 country-level observations (16 coping variables) to identify cross-national coping profiles during the COVID-19 pandemic. Before conducting the clustering, the optimal number of clusters was determined using the Elbow Method, in which the Sum of Squared Errors (SSE) was plotted against different values of k . The optimal point is indicated by location where the decrease in SSE begins to level off. Based on this Elbow curve, as shown in Figure 5, four clusters were selected for this study.

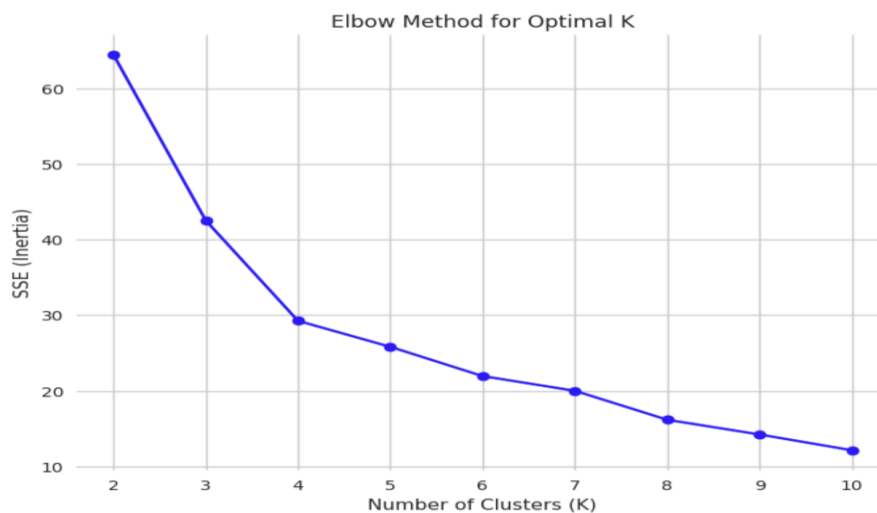


Figure 5 Determination of the optimal number of clusters using elbow method

To validate the choice of the optimal number of clusters, the silhouette coefficient was computed for each candidate k . Figure 6 displays the silhouette scores for $k = 2$ to 10. The highest silhouette score (0.298) occurred at $k = 2$, but this two-cluster solution was highly imbalanced

groups (19 and 6 countries). Such a coarse grouping offers limited insight into the heterogeneity of coping profiles across nations. In contrast, the four-cluster solution (silhouette = 0.274) produced a balanced and interpretable partition with cluster sizes 4,8,9,4. Therefore, consistent with the elbow method, $k = 4$ was retained for the main analysis.

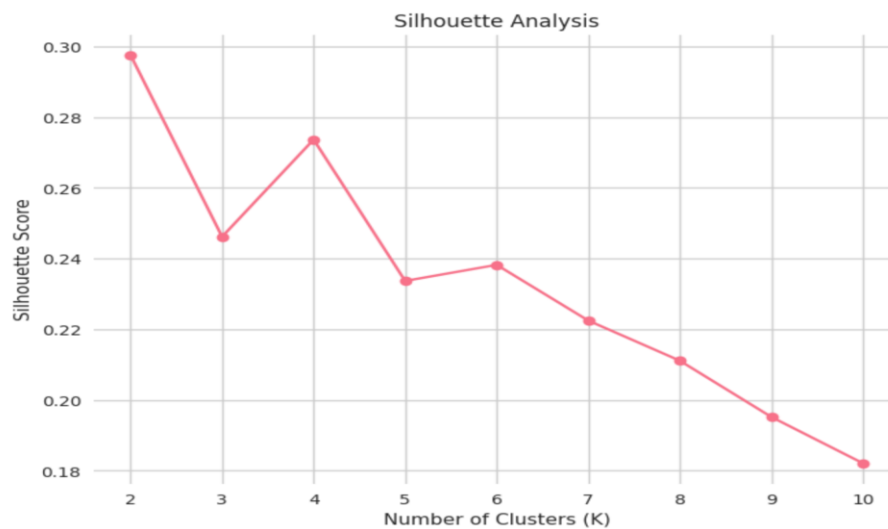


Figure 6. Silhouette analysis for optimal k

The PCA visualization of the clustering results is presented in Figure 7. The first two principal components explained 71.5% of the total variance. The remaining 28.5% of unexplained variance indicates that other unmeasured factors such as cultural values, economic conditions, or government policy stringency might contribute to cross-national differences in stress and coping.

Cluster 1 (green) forms a small group on the left side the plot. Cluster 2 (orange) is the most dispersed, spanning across the central and lower regions, indicating diverse patterns within this group. Cluster 3 (blue) exhibits tight clustering in the upper left quadrant, suggesting similar profiles among members. Cluster 4 (purple) is distinctly positioned on the right side, well separated from other clusters. Table 4 presents the countries assigned to each cluster.

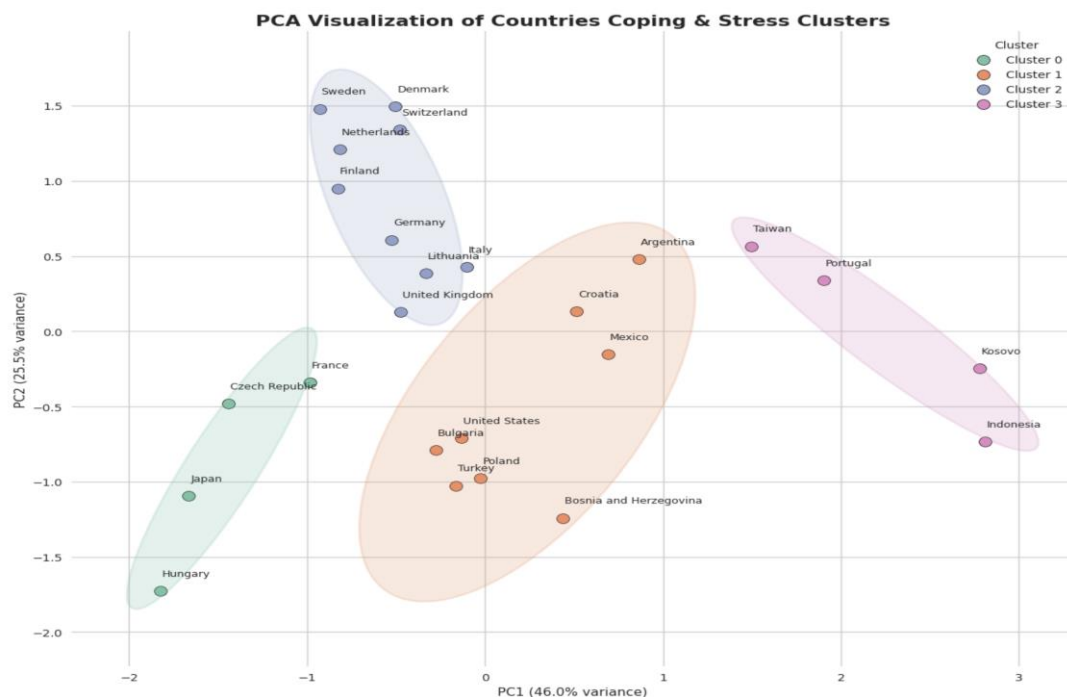


Figure 7. PCA Visualization of Clustering Results

Table 4. Country composition of the four K-Means clusters

Cluster	Country names
1	Czech Republic, France, Hungary, Japan
2	Argentina, Bosnia and Herzegovina, Bulgaria, Croatia, Mexico, Poland, Turkey, United States
3	Denmark, Finland, Germany, Italy, Lithuania, Netherlands, Sweden, Switzerland, United Kingdom
4	Indonesia, Kosovo, Portugal, Taiwan

Mean values of variables for the four distinct clusters is shown in Figure 8. The figure highlights noticeable variations in the main ways each cluster tends to cope, as well as their corresponding stress levels. These differences are described in greater detail by the stress and coping profiles provided in Table 5.

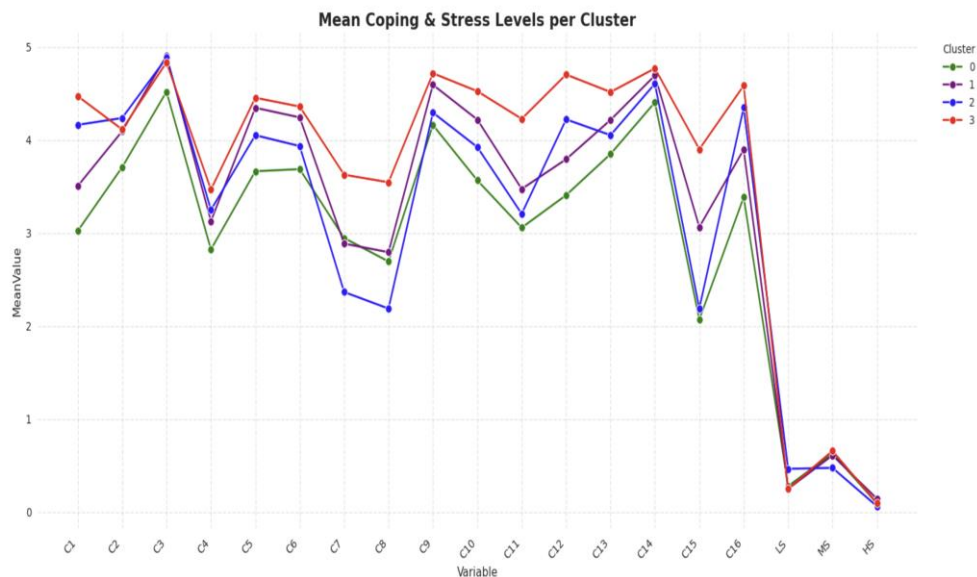


Figure 8. Mean values of variables for K-Means cluster

Table 5. Stress and Coping Profile by Cluster

Cluster	Characteristic Stress	High (Dominant) Coping	Low (Minimal) Coping
1	Balanced stress with moderate dominance	- Phone/Long-range Friends/Family (4,5) - Activity/Hobby (4,4) - Watching TV/Movies (4,2) - Work/Vocation (3,9) - Face-to-face Friends/Family (3,7)	- Video Games (Online) (2,7) - Religion/Spirituality (2,1) - Face-to-face Colleagues (2,8) - Video Games (Alone) (2,9) - Information from Government (3)
2	High proportion of high stress	- Phone/Long-range Friends/Family (4,9) - Activity/Hobby (4,7) - Watching TV/Movies (4,6) - Phone/Long-range Colleagues (4,3)	- Video Games (Online) (2,8) - Video Games (Alone) (2,9) - Religion/Spirituality (3,1) - Face-to-face Colleagues (3,1) - Preparing for Crisis (3,5)

Cluster	Characteristic Stress	High (Dominant) Coping	Low (Minimal) Coping
		- Social Media (4,2)	
3	High proportion of low stress	- Phone/Long-range Friends/Family (4,9) - Activity/Hobby (4,6) - Government/Civil Services Knowledge (4,4) - Watching TV/Movies (4,3) - Face-to-face Friends/Family (4,2)	- Religion/Spirituality (2,2) - Video Games (Online) (2,2) - Video Games (Alone) (2,4) - Preparing for Crisis (3,2) - Face-to-face Colleagues (3,3)
4	High proportion of moderate stress	- Phone/Long-range Friends/Family (4,8) - Activity/Hobby (4,8) - Watching TV/Movies (4,7) - Following Government Advice (4,7) - Government/Civil Services Knowledge (4,6)	- Face-to-face Colleagues (3,5) - Video Games (Online) (3,6) - Video Games (Alone) (3,6) - Religion/Spirituality (3,9) - Face-to-face Friends/Family (4,1)

Cluster 1 consisted of the Czech Republic, France, Hungary, Japan. This cluster exhibits balanced stress levels and moderate engagement in coping activities. The dominant coping behaviours included phone communication, face-to-face interaction with family members, watching entertainment, and engaging in hobbies. Low use of religious coping suggests that religiosity is not a primary stress management mechanism in these countries.

Cluster 2 comprised Argentina, Bosnia and Herzegovina, Bulgaria, Croatia, Mexico, Poland, Turkey, United States. This cluster demonstrated the highest stress level among all clusters. Countries in this cluster showed relatively high engagement in social interaction and entertainment-based coping strategies, including social media use, long-distance communication, and watching TV/movies.

Cluster 3 included Denmark, Finland, Germany, Italy, Lithuania, Netherlands, Sweden, Switzerland, and United Kingdom. This cluster exhibited the lowest stress levels. Countries in this cluster were characterised by frequent use of government information and family-based social interactions as their dominant coping strategies.

Cluster 4 consisted of Indonesia, Kosovo, Portugal, and Taiwan. Countries in this cluster exhibited moderate stress levels. Their coping profile was characterised by frequent adherence to government recommendations, the use of public service information, and moderate engagement in religious coping activities.

The identified clusters demonstrate that stress levels are associated with different coping profiles across countries. Rather than showing a single coping pattern, the results indicate that countries adopt different combinations of coping strategies during the COVID-19 pandemic. Cluster 1 exhibited balanced stress levels together with moderate coping engagement. Stable social interaction through phone calls and face-to-face family communication, accompanied by recreational activities, may contribute to maintaining emotional well-being. The relatively low use of religious coping suggests that secular coping strategies may play a more prominent role in these countries. This finding is consistent with previous studies highlighting the importance of social support in reducing psychological distress (Eisenbeck et al., 2021).

Cluster 2 exhibited the highest stress levels despite intensive use of social interaction and entertainment-based coping strategies. Previous studies have reported that excessive social media exposure during the COVID-19 pandemic may increase anxiety and psychological distress (Gao et al., 2020). Several countries within this cluster are also characterised by relatively high

uncertainty avoidance (Hofstede, 2001), which may contribute to stronger psychological responses during periods of prolonged uncertainty.

In contrast, Cluster 3 exhibited the lowest stress levels together with strong information-oriented coping and family-based social support. This pattern is consistent with Lazarus and Folkman's transactional model of stress and coping, which suggests that problem-focused coping strategies are generally more adaptive when stressful situations are perceived as manageable (Lazarus & Folkman, 1984). Similar findings were reported by Eisenbeck et al. (2021), who identified social support as an important coping resource during the pandemic.

Cluster 4 demonstrated a coping profile characterised by adherence to government recommendations, utilisation of public service information, and moderate religious coping. This combination may reflect to coexistence of institutional trust and cultural values in shaping coping behaviours across countries (Hofstede, 2001).

Overall, these present findings extend previous studies that primarily relied on descriptive or regression analyses. By applying K-Means clustering, this study identifies groups of countries with similar multivariate stress and coping profiles, providing a broader perspective on cross-national psychological responses during the COVID-19 pandemic.

This study has several limitations. First, the analysis was conducted using aggregated country-level data, which may not capture variations among individuals within each country. Second, the cross-sectional nature of the dataset prevents causal interpretation between coping strategies and stress levels. Finally, the K-Means algorithm assumes relatively homogeneous clusters, and future studies may compare alternative clustering techniques and include longitudinal data to further validate these findings.

Conclusion

This study applied K-Means clustering to identify cross-national stress and coping profiles using data from the COVIDiSTRESS survey covering 25 countries. Four distinct clusters of countries were identified, demonstrating that stress levels were associated with different combinations of coping strategies. Countries with the lowest stress levels (Cluster 3) were characterised by high information-seeking and family based social coping, whereas countries with the highest stress levels (Cluster 2) showed greater reliance on entertainment-oriented coping strategies. Cluster 1 and 4 exhibited intermediate stress levels but differed in their dominant coping behaviours.

These findings demonstrate that K-Means provides a useful approach for identifying similarities in national stress-coping profiles that may not be apparent through conventional descriptive analyses. The identified clusters offer insights into cross-national variations in coping behaviours and may support the development of more context-specific mental health interventions during future public health emergencies.

This study has several limitations, including the use of aggregated country-level data and the cross-sectional data. Future studies should include a larger number of countries, employ longitudinal data, and compare alternative clustering methods to further validate the identified stress-coping profiles.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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