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# Suicide cases in developed and emerging countries: an analysis using wavelets

*Casos de suicídio em países desenvolvidos e emergentes: uma análise usando ondaletas*

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## ABSTRACT

**Objective:** The aim of this study was to use a wavelet technique to determine whether the number of suicides is similar between developed and emerging countries. **Methods:** Annual data were obtained from World Health Organization (WHO) reports from 1986 to 2015. Discrete nondecimated wavelet transform was used for the analysis, and the Daubechies wavelet function was applied with five-level decomposition. Regarding clustering, energy (variance) was used to analyze the clusters and visualize the clustering process. We constructed a dendrogram using the Mahalanobis distance. The number of groups was set using a specific function in the R program. **Results:** The cluster analysis verified the formation of four groups as follows: Japan, the United States and Brazil were distinct and isolated groups, and other countries (Austria, Belgium, Chile, Israel, Mexico, Italy and the Netherlands) constituted a single group. **Conclusion:** The methods utilized in this paper enabled a detailed verification of countries with similar behaviors despite very distinct socioeconomic, geographic and climate characteristics.

## KEYWORDS

World Health Organization, mental disorders, wavelet transform, clusters.

## RESUMO

**Objetivo:** Verificar se existe relação de similaridade entre o número de suicídio em países desenvolvidos e emergentes usando a técnica de ondaletas. **Métodos:** Os dados anuais foram obtidos a partir do relatório da Organização Mundial da Saúde (OMS), no período de 1986 a 2015. Para análise, foi empregada a transformada discreta não decimada de ondaleta (NDWT), a função ondaleta aplicada foi a Daubechies com cinco níveis de decomposição. Com relação ao agrupamento, utilizou-se a energia (variância) para analisar os *clusters* e, para a visualização do processo de clusterização, trabalhamos com o dendrograma, no qual se empregou a distância de Mahalanobis. A quantidade de grupos foi definida por meio da função NbCluster. **Resultados:** A partir da análise de *cluster*, verificou-se a formação de quatro grupos. No qual, Japão e Estados Unidos e Brasil localizam-se em grupos distintos e isolados. E os demais países (Áustria, Bélgica, Chile, Israel, México, Itália e Holanda) em um único grupo. **Conclusão:** Utilizando esse método, foi possível verificar com mais detalhes quais países apresentaram comportamentos semelhantes, mesmo apresentando características bem distintas entre si, tanto socioeconômica, geográfica e climática.

## PALAVRAS-CHAVE

Organização Mundial de Saúde, transtornos mentais, transformada de ondaletas, *clusters*.

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## INTRODUCTION

The word “suicide” emerged in approximately the 12th century but was present in an even older context: in the 5th century, Saint Augustine bestowed a sinful connotation on self-death. In the Middle Ages, suicide began to be considered a crime because it harmed the Crown; therefore, the property of those who killed themselves was confiscated by the Crown rather than passed on to their families, and their corpses were fined. In the late Middle Ages, following the separation between the Crown and the church, the medical profession began to occupy a privileged place in societal control; therefore, doctors (health professionals authorized by the state to practice medicine) defined the negativity of voluntary death, replacing the phenomenon of sin with pathology and qualifying it as madness<sup>1</sup>.

The prospect of suicidal action is multifactorial and comprises biological, psychiatric, psychosocial, and cultural risk issues<sup>2-5</sup>. Suicidal behaviors (SBs) include suicidal ideation and attempted and completed suicide. The main factors associated with suicide include mental illness, behavioral genetics, family history of suicide, unsuccessful suicide attempts, lack of social support, stressful events, and sociodemographic characteristics, particularly poverty, unemployment, and low education levels<sup>2-7</sup>. Additionally, the presence of chronic diseases, such as AIDS, stroke, myocardial infarction, multiple sclerosis, Parkinson’s disease, and chronic respiratory failure of various etiologies, are considered risk factors. However, psychiatric aspects, including depression, anxiety, delirium, personality disorders, and psychoactive substances, including alcohol consumption, are the most reported risk factors<sup>8</sup>.

An interesting phenomenon that draws the most attention to suicides worldwide is the paradox that the highest suicide rates are registered in countries considered the happiest. For example, a study observed that the countries in the top positions in the list of the “happiest countries globally” according to Forbes magazine had matching higher suicide rates. These ten countries were Norway, Denmark, Finland, Australia, New Zealand, Sweden, Canada, Switzerland, the Netherlands, and the United States. Accordingly, the authors concluded that the countries most highlighted as happy were simultaneously those with the highest suicide rates<sup>9</sup>.

Worldwide, suicide among people aged 15 to 29 years is the second-highest causal agent resulting in death, indicating that suicide is a severe public health problem. A previous investigation found that 10.8% of primary education students in Ontario, Canada had suicidal ideation, while 3% reported having attempted suicide in the past 12 months<sup>10</sup>. Psychiatric illnesses, such as anxiety and depressive disorder, are present early in approximately 90% of those who commit suicide. However, the proportion of those who attempt or die by suicide with a diagnosable psychiatric disorder is inversely related to age, i.e., approximately 60% in people aged

16 years or younger and 80 to 90% in adolescents and young adults (up to 25 years)<sup>11</sup>. Notably, psychiatric disorders alone are not sufficient conditions for suicide-related behaviors because not all individuals who have psychiatric illnesses have thoughts of or attempt suicide<sup>12</sup>.

A novel study investigating their biological aspects suggested that SBs are related to a modified DNA methylation pattern at numerous genetic loci in the brains of suicide completers<sup>13</sup>. In a critical comprehensive review of genetic association analyses, the authors of one study<sup>14</sup> affirm that the genetic epidemiology in SB studies infers a quantitatively slightly weaker contribution from genetics than the environment. This study also indicates that the association-based examination of specific candidate genes and variants participating in the genetic diathesis of SBs has an unquestionably combined resolution. In this line, over the past 30 years, indirect evidence of the presence of a genetic component in the suicidal diathesis was mostly derived from investigations involving family, twin, and adoption studies. A series of genes and their potential SB phenotypes have been derived.

According to the authors of another study<sup>15</sup>, suicide and suicidal comportment are hereditary and highly familial and appear to be transmissible according to at least two components: predisposition to psychiatric disorders and predisposition to impulsive aggression. These authors also affirm that communal environment effects, such as abuse, imitation, or transmission of psychopathology, are other probable causes.

Global epidemiological data suggest that SBs constitute an important public health problem. According to a prediction by the World Health Organization (WHO), in 2020, it is expected that 1.53 million people worldwide will die by suicide. Additionally, the number of individuals who will attempt suicide is estimated to be 10 to 20 times higher in the future. This value represents one death by suicide every 20 seconds and one suicide attempt every two seconds<sup>16</sup>. Furthermore, the WHO prepared a guide with a mental health action plan from 2013 to 2020. This policy highlights four critical objectives, including more active guidance and governance for mental health; an outline of comprehensive, integrated mental health and social care services in community-based environments; the implementation of tactics for promotion and prevention; and the bolstering of information systems, evidence, and research<sup>17</sup>.

A recent editorial suggested a tendency for the suicide rate to increase in the face of the COVID-19 pandemic. This information was based on several articles based on mathematical modeling that predicted an increase of 1% to 145% in the suicide rate. One realistic pattern of suicide risk under the circumstances of the COVID-19 pandemic can be observed in Japan, where the rate initially decreased by 20%, but this change reversed in August to an increase of more than 7%, creating an alarming scenario<sup>18</sup>.

Chronologically, suicide has increased by 60% over the past 45 years and represents the 13th leading causal agent

of death worldwide. In 2012, 804,000 deaths by suicide were registered worldwide. Suicide affects all age groups and denotes the top agent of death among individuals aged 15 to 44 years in several countries. Recently, a study conducted by the WHO found that every 40 seconds, a person attempts to commit suicide. These estimates appear to be miscalculated, however, because some suicides are considered and/or recorded as accidents or deaths from undetermined causes<sup>19</sup>.

These high suicide rates are predominantly due to difficulties in treating persons with mental disorders and accessing information regarding mental health, the high cost of medications and therapies, the social taboos surrounding the topic, and failures in the academic training of physicians regarding mental health, including a lack of mental health specialists. Therefore, suicide prevention is critical for addressing this problem in modern society<sup>20</sup>.

The first step addresses the use of adequate statistical tools to quantify and monitor the aforementioned expansion in the percentage of suicide. In this regard, the wavelet technique is an excellent and suitable statistical cluster analysis option for examining and comprehending suicide cases globally. The wavelet technique involves a short-term wave function that rapidly fluctuates and is carefully constructed to possess certain mathematical properties. Its underlying theory is established based on the representation of functions at different scales and different resolutions (time scales). The entire set of wavelets is built from a single mother wavelet function, providing useful building block functions that can describe any large class of functions<sup>21</sup>.

The epidemiological analysis of suicide in developed and emerging countries has great relevance for public health policy. Developed countries are characterized by their purchasing power and include those with an adjusted US-dollar gross domestic product (GDP) per capita

higher than US\$ 23,000. In contrast, emerging countries are defined by a GDP per capita between US\$ 6,500 and US\$ 23,000<sup>22</sup>. The development of effective programs for the prevention of SBs requires expanding knowledge regarding the global relationship among countries. In this context, the main objective of this study is to determine whether there is similarity in the number of suicides between developed and emerging countries using wavelets by employing the WHO annual report data of the past 30 years.

## METHODS

The analyzed data were obtained freely from WHO reports from 1986 to 2015, corresponding to annual data of the number of suicide cases in the following arbitrarily chosen countries on three continents: Austria, Belgium, Italy, the Netherlands (Europe), Mexico and the United States (North America), Brazil and Chile (South America), Japan (Eastern Asia), and Israel (Western Asia). The developed countries include Austria, Belgium, Israel, Italy, Japan, the Netherlands, and the United States. In contrast, the emerging countries include Brazil, Chile, and Mexico.

Table 1 shows the characteristics of the countries included in this study. These characteristics include the human development index (HDI); the closer the HDI is to 1, the greater the level of human development in the country. Climate, which influences the health of humans and animals, is also included.

Nondecimated wavelet transform (NDWT) was used to analyze the time series concerning the number of suicides over time in each country. The Daubechies wavelet function, with four null moments and five decomposition levels, was used. Regarding clustering, the energy (variance) at each

**Table 1.** Characteristics of the countries under study

Country	Characteristics				
	HDI <sup>1</sup>	Population <sup>2</sup>	Extension <sup>2</sup>	Climate <sup>3</sup>	Crude suicide rates (per 100,000 population) in 2016 <sup>4</sup>
Austria	0.908	8,857,960	83,879	Temperate	15.6
Belgium	0.916	11,420,163	30,528	Temperate	20.7
Brazil	0.759	212,763,202	8,515,767	Wide-ranging variety	6.5
Chile	0.843	18,050,000	756,950	Mediterranean	10.6
Israel	0.903	9,069,960	20,770	Mediterranean	5.4
Italy	0.880	60,665,551	301,338	Mediterranean	8.2
Japan	0.909	126,440,000	377,873	Temperate	18.5
Mexico	0.774	123,675,325	1,958,201	Wide-ranging variety	5.1
Netherlands	0.931	17,100,475	41,528	Temperate	12.6
United States	0.924	325,719,178	9,371,175	Wide-ranging variety	15.3

<sup>1</sup>Information compiled by the United Nation Statistical Division available at <https://unstats.un.org/home/>.

<sup>2</sup>Information acquired separately in each official government website.

<sup>3</sup>Climate transparency reports 2020 available at [https://www.climate-transparency.org/media/climate-transparency-2020#:~:text=The%20Climate%20Transparency%20Report%20\(previously,a%20net%20zero%20emissions%20economy.](https://www.climate-transparency.org/media/climate-transparency-2020#:~:text=The%20Climate%20Transparency%20Report%20(previously,a%20net%20zero%20emissions%20economy.)

<sup>4</sup>Data obtained from World Health Organization available at <https://apps.who.int/gho/data/view.main.MHSUICIDEREV?lang=en>.

decomposition level of the countries was used, and a dendrogram based on the Mahalanobis distance was used to visualize the clustering process. The number of groups was defined using the NbClust function.

All analyses were performed using the free software R<sup>23</sup>.

### Nondecimated wavelet transform (NDWT)

Wavelet transforms can be considered mechanisms used to decompose series into their constituent parts, allowing the data to be analyzed in different frequency domains at a resolution of each component linked to its scale. With the decomposition of a series into resolution levels, it is possible to obtain different amounts of information at each level; thus, the degree of detail increases according to the number of levels analyzed such that limited information is available in the first levels and more information is available in the final levels. The number of levels to be analyzed is defined by the base-two logarithm of the signal size.

We chose to use NDWT because this approach maintains the same amount of data at different decomposition levels and the original length of the series does not need to be a power of two<sup>24</sup>. This does not hold for discrete decimated wavelet transform, where the original length of the series needs to be a power of two, and the amount of information at each resolution level is half that from the previous level.

### Daubechies wavelets

Daubechies wavelets constitute a family of orthogonal wavelets characterized by a maximum number of null moments for a given support<sup>25</sup>. The null moments and smoothness are mathematically related as follows: the greater the number of null moments of a wave, the softer the wave. Moreover, the smoother the wavelet, the greater the probability of the

perfect reconstruction of the signal decomposed by the wavelet transform<sup>26</sup>.

Two advantages of using wavelets are their usefulness in multiresolution analyses and time-frequency locations<sup>27</sup>. Each type of Daubechies wavelet is associated with a scaling function called the parent wavelet that generates an orthogonal multiresolution analysis<sup>28</sup>. Another characteristic of the Daubechies wavelet is its ability to represent any polynomial whose order is not higher than its support<sup>29</sup>.

### Scalogram

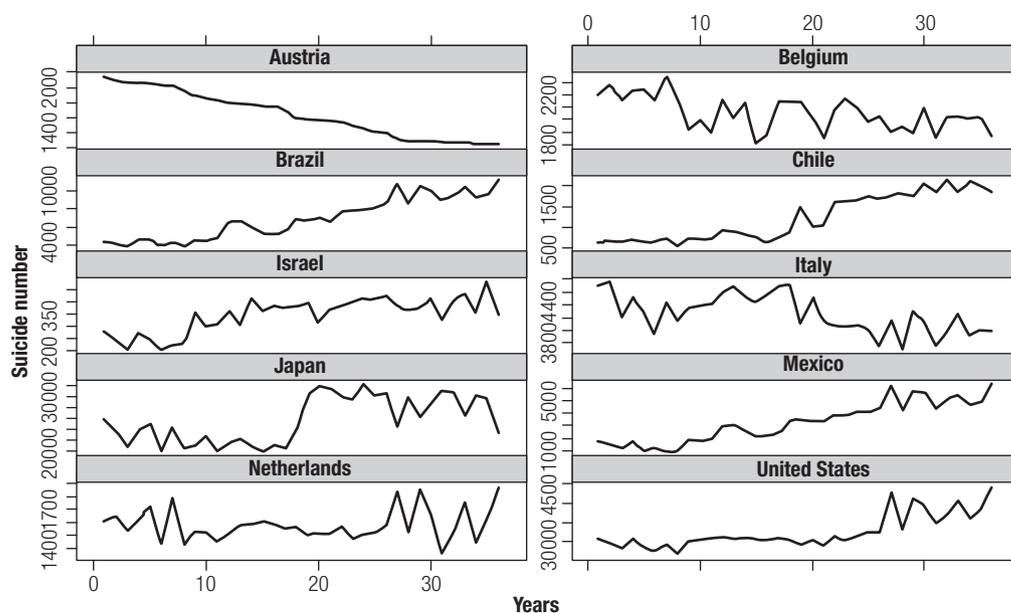
A scalogram (energy) is defined as a graph of the sum of squares of wavelet coefficients at different levels. In the context of discrete transformation, scalograms represent a decomposition of the energy of a function in the time-frequency (scale) plane<sup>30</sup>. One of its characteristics is the ability to detect periodic series components, i.e., different components that result in visible peaks in the scalogram.

In NDWT, the sum of the energy calculation extends from  $k = 0, \dots, n$ , where  $n$  is the total length of the analyzed series<sup>31</sup>.

## RESULTS

Figure 1 shows the time series behavior, indicating the number of suicides over time in each nation analyzed. The countries presenting a decreasing series, i.e., a decrease in the number of suicide cases, were Austria, Belgium, and Italy. In contrast, Brazil, Chile, Mexico, and the United States showed increasing series, especially since 2005, revealing rather worrying characteristics.

Figure 2 shows the decomposition levels obtained by NDWT for Japan. In the first levels (1 and 2), which correspond



**Figure 1.** Time series of the number of suicides in developed and emerging countries.

to levels with less detail, it was not possible to obtain much information. Starting at level 3, it was possible to observe a curve with greater smoothing, which became even smoother in the final levels. These levels contained more details.

The energy calculated at each decomposition level is represented in Figure 3. In Austria, Brazil, Israel, Japan, Chile,

Mexico and the United States, the energy was more concentrated in the final levels. In the Netherlands and Belgium, the energy was concentrated in the first levels. In Italy, the energy was higher in the first level and the final level.

The clustering of the countries is shown in Figure 4. Four clusters obtained through the NbClust function, which

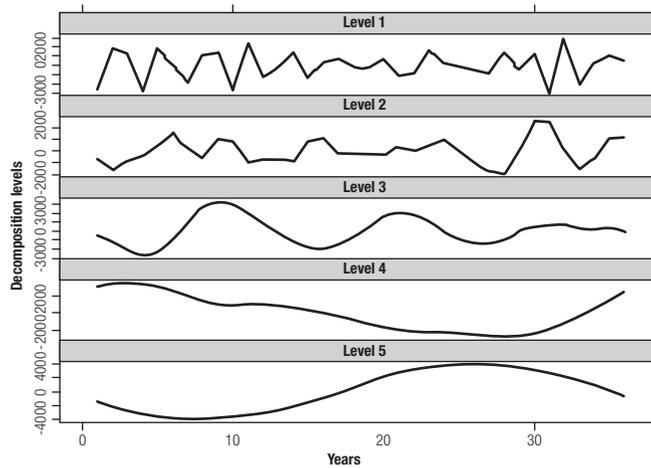


Figure 2. Graphical representation of the five decomposition levels in Japan.

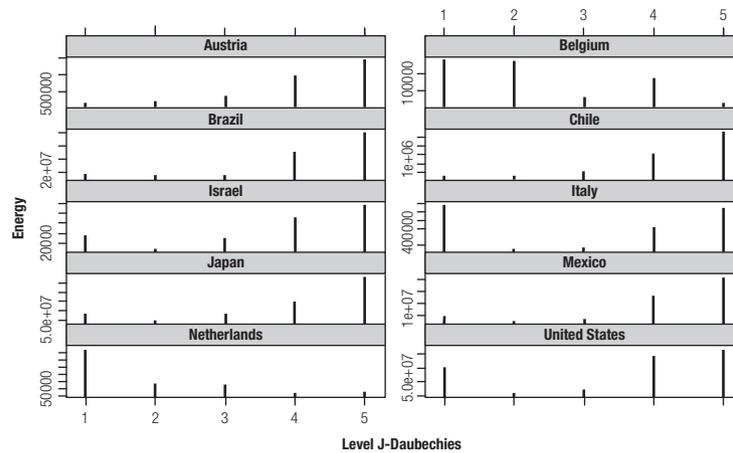


Figure 3. Scalogram of the energy of the study countries at each decomposition level.

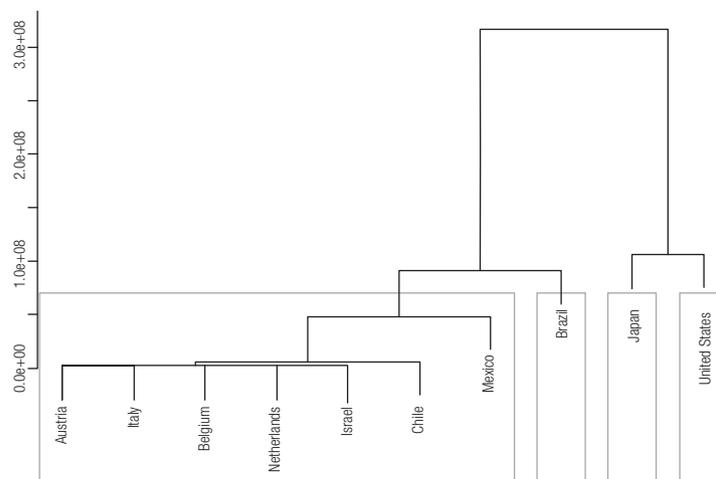


Figure 4. Dendrogram of country clusters based on the Mahalanobis distance derived from the energy at each decomposition level.

defined the correct number of clusters to be analyzed, were observed. In the largest cluster formed, the countries that showed similarities in the number of suicides were Austria, Italy, Belgium, the Netherlands, Israel, Chile and Mexico. The countries that formed isolated clusters were Brazil, Japan and the United States.

## DISCUSSION

Statistical signal processing is an approach that treats signals as stochastic processes and appropriates their statistical properties to implement signal-processing tasks; these processes accurately represent the data analyzed<sup>32</sup>. Statistical techniques, especially time series, primarily employ signal processing.

The analysis of a determined signal considers the energy obtained at each level of decomposition; thus, the distances of the energies, which correspond to the variances, are calculated to verify similarities. Using this approach, it is unlikely to observe relationship similarities in the original series graph of the number of suicide cases. Due to this difficulty in visualization, it is necessary to perform a more in-depth analysis of the data, which is achieved through the promising and relevant practical wavelet approach.

By analyzing the energy graphs of countries classified into clusters separately from other countries, we can observe that Brazil has very limited energy at the first three energy levels, whereas Japan already has more energy than Brazil at levels one and three. Furthermore, the United States has more energy at levels 1, 3, and 4 than Brazil. Additionally, the United States has more energy at levels one and four than Japan, which is probably what differentiates these two countries.

Of the countries that formed isolated clusters, Japan and the United States are developed countries, and Brazil is an emerging country. The cluster results show that Japan and the United States group separately. In Japan, the number of suicides per 100,000 inhabitants between 2000 and 2012 decreased from 18.8 to 18.1; in contrast, in the United States, this value increased from 9.8 to 12.1<sup>33</sup>. This opposite behavior in terms of the number of suicides, specifically over the past ten years regarding their time series, may also possibly validate the distinct isolation of the two countries into different clusters.

According to the WHO, Brazil ranks eighth among the countries with the highest numbers of suicides, following India, China, the United States, Russia, Japan, South Korea and Pakistan. The mean rate of mortality by suicide in Brazil during the 2004-2010 period was 5.7% (7.3% among males and 1.9% among females). Compared with other countries, this rate is considered low. The rates of mortality by suicide between 1980 and 1994 remained stable in the country,

with a mean of 4.5 deaths per 100,000 inhabitants. During the 1995-1997 triennium, these rates increased to a mean of 5.4 per 100,000 inhabitants and remained stable until 2006; this finding represents a 29.5% increase in the rate of mortality by suicide between 1980 and 2006. An important finding from these data is that the rate of mortality by suicide has increased in Brazil among men aged 20 to 59 years<sup>6,34</sup>. In 2012, 11,821 deaths by suicide were recorded, with a rate of 5.3 suicides per 100,000 inhabitants, corresponding to more than 30 deaths per day<sup>35</sup>.

An interesting comparison was carried out to analyze data from 2006 to 2015 in Brazil. In this study, the authors found that the crude rate of suicide was lower than the national indices in large urban regions, although the rate increased in both populations. The authors believe that an explanation is that in large urban centers, resources and searches for help are more frequent. Additionally, the authors detected an inverse relationship between unemployment and the suicide rate, which contradicts the expected correlation rates reported in several other scientific studies<sup>36</sup>. Another study using a time series comparison of suicide deaths in Brazil and the United States showed that the decreasing economic inequality in Brazil was not significantly related to a decrease in the crude suicide rate as hypothesized<sup>37</sup>. An additional comprehensive investigation of the trend in suicide rates conducted in Brazil using data from 1997 to 2015 reported an increase, which is alarming<sup>38</sup>.

In a study addressing the spatial and socioeconomic determinants of suicide in Brazil that analyzed data from 1998 to 2002, the authors reported that the degree of rurality positively influenced the rate of suicide in the country. Furthermore, the authors used Moran's I statistical tool, which is a global measure of spatial autocorrelation, and built a detailed dispersion map exhibiting a clear spatial dependence of the suicide rate in Brazil, with the highest rate of association in the south and midwest regions. The authors also argued that problematic access to the health and services network in general, the economic decline in some rural areas, and the handling of pesticides, which could trigger depressive conditions via neurological or endocrine mechanisms in farmers, might increase the risk of suicide in these areas<sup>39</sup>.

A study conducted in Rio Grande do Sul, which historically has the highest suicide rate in Brazil, addressing the epidemiological and toxicological profile of suicide victims in 2017 showed that depression was the most prominent cause and accounted for more than double the risk of the second most common factor. Additionally, alcohol was detected in 30% of the analyzed samples collected from suicide victims, suggesting that a link exists between alcoholism and the precipitation of suicidal behavior<sup>40</sup>.

A realistic intervention example occurred in the state of Paraná in Brazil. In 2001, this state established a state mental health policy that municipalities were responsible for

implementing. With this approach, more financial resources were allocated to outpatient clinics, which had more inclusive control over the dispensing of medications and supervision of the population at risk, and psychiatric emergency beds in general hospitals, psychosocial care (CAPS), and primary health care (PHC). Consequently, this well-intentioned strategy was correlated with an annual decrease of 0.16 deaths by suicide per 100,000 inhabitants, with the most significant decrease in mortality among males aged over 65 years<sup>41</sup>. This policy demonstrates the practical importance of government investment in public mental health.

Since the primary cause of suicide is depression and most cases worldwide occur in rural areas, an assertive form of intervention involves the use of all available media, i.e., radio, television, etc., to discuss, clarify, and deconstruct the stigma of mental health to directly reach a large audience and encourage people, particularly those residing in rural and peripheral areas, to seek help.

Another study investigated a successful intervention involving the “*Bolsa Família*” cash transfer program using data collected from 2004-2012. The results reflected a reduction in crude suicide death among women but not men. According to the authors, a possible explanation is that women are the principal beneficiaries of this program because they are more vulnerable to economic crises, and the resources provided by the program are intended to support family welfare<sup>42</sup>.

In Japan, suicide has become an essential social issue. According to the WHO, Japan has one of the highest suicide rates (16.8 per 100,000 person-years in 2016), ranking sixth in the industrialized world. In 2006, this issue was so critical that the Japanese government enacted the “Basic Act on Preventing Suicide” programs, followed by the launch of “General Policies of Comprehensive Measures against Suicide” in 2007. The government further implemented a comprehensive suicide prevention strategy in 2012 and approved a budget of over \$260 million per year to support suicide prevention activities. Japanese suicide rates plateaued among the cohorts who encountered post-War accelerated economic growth (women born in 1951-1956 and men born in 1916-1961). However, the authors of one study<sup>43</sup> detected a very high incidence of suicide in the youngest age groups (20-24 and 25-29 years) in Japan when scrutinizing data from 1951 to 2015. This pattern probably indicates the poor mental health of the younger generation throughout the immediate post-World War II demobilization and reconstruction phase. Therefore, the Japanese government should pay more attention to suicide prevention in contemporary birth cohorts and young adults in their 20s.

According to the Statistics and Information Department Minister’s Secretariat Ministry of Health, Labor, and Welfare Japan, 2017<sup>44</sup>, suicide ranks between the second and fourth leading causes of death among middle-aged (40 to 64 years)

adults in Japan. Consequently, public health efforts for suicide prevention represent a vital issue in Japan. The main factors linked to suicide are unemployment (due to the economic recession in the 1990s), financial problems, stressful life expectancy events, depression and social pressure. Many couples divorced during the economic recession, triggering a wave of distress; in Japan, more than 60% of individuals who committed suicide were identified as depressive<sup>45</sup>. The Internet, which has more impact than printed media, is also associated with suicide in Japan. Concomitantly, suicide-related websites have proliferated in Japan, and more than 600,000 Japanese websites provided information regarding potential suicide methods since the Suicide Manual, which illustrates suicide methods, was published on July 4, 1993. Several cases suggesting an association between visits to suicide websites or chatrooms and actual suicides have been reported<sup>46</sup>.

One investigation in Japan conducted a nationwide psychological autopsy case-control study and concluded that some factors, such as alcohol-related disorders, anxiety disorders, and slight psychotic disorders, are significantly correlated with the risk of suicide. In addition, this study addressed mood disorders, highlighting that major depressive disorders were more robustly associated with suicide in that country<sup>47</sup>. A different study in Japan<sup>48</sup> addressed occupational mental disorders and suicide in employees over five years (2010-2015). Regardless of sex, the 30- to 39-year age group had the most significant incidence of mental disorders. A critical finding of this study was that the incidence concerning compensation for mental disorders was the highest among young employees, especially those aged 29 years or younger, in particular industries, such as information and communication. Once again, a series of studies suggested that public policies for suicide prevention in Japan must emphasize younger age groups.

In the United States, 30,575 people committed suicide in 1998, representing a rate of 11.3 per 100,000 inhabitants. The suicide rates remained at approximately 12 per 100,000 inhabitants in the 1980s and 1990s, rendering suicide the eighth leading cause of death in 1998 and the third leading cause of death among people aged 15 to 24 years. Among all suicides in 1998, the leading method was via firearm, i.e., 57% (17,424), accounting for three times the number of suicide cases using the following leading method<sup>49</sup>. In 2005, suicide was the second leading cause of death among Americans aged 40 years or younger. Among Americans of all ages, more than half of all suicides are performed using firearms. In 2005, an average of 46 Americans per day committed suicide with a firearm, representing 53% of all completed suicides. Suicide by firearm during this period represented 40% more deaths than homicide by firearm<sup>50</sup>.

Regarding Mexico, which was grouped in the largest cluster, the authors of one study<sup>51</sup> concluded that some basic strategies had been used to prevent suicide attempts

or completed suicides. These strategies include the identification and treatment of individuals considered to have some form of mental disorder. Additionally, these authors report that it is crucial to search for a history of attempted suicide or suicidal potential during clinical psychological/psychiatric interviews and that a broad study of mental disorders should focus on more than only treating depressive disorder. The authors of another study<sup>52</sup> reported that the high temperatures in Mexico are associated with the prevalence of suicide. Similarly, a time-series study conducted in São Paulo City (Brazil) between 1996 and 2011 detected a significant (95% confidence interval) increase of approximately 2% in the crude suicide rate per 1° Celsius increase in the weekly average minimum temperature, corroborating the findings presented in the previous study conducted in Mexico<sup>53</sup>.

According to the authors of another study<sup>54</sup>, suicide in countries, such as Italy and Chile, is related to the Mediterranean climate (see Table 1), which is characterized by rainy winters and dry summers. It has been reported that in Australia, a link exists between the suicide rate and hours of sunlight, while the annual fluctuation in temperature and rainfall, although evident, was not associated with the seasonal recurrence of suicides. A link between exposure to daylight and the occurrence of suicide in Chile was also identified. Italy is also affected by an increase in mean temperature that is correlated with greater exposure to sunlight, which is associated with the increased occurrence of suicides during the hottest months of the year regardless of the health state of individuals.

Regarding the Netherlands, the authors of one study<sup>55</sup> stated that all types of greenery are beneficial to health and that the country has a temperate climate and predominantly temperate forests; however, the quality of such greenery is also important. In addition, similar to Austria and Germany, there is substantial variability in suicide risk across the Netherlands. A plausible explanation is that some regions have quality greenery, thus reducing stress. Greenery directly affects the psychological functioning of people, rendering them less vulnerable to stressful life events. Thus, relieving stress can reduce suicidal thoughts.

Regarding Belgium, which is the nation with the highest crude death rates (20.7 per 100,000 population) evaluated in this investigation, the authors of one study<sup>56</sup> explained that the high levels of suicide in some regions may be related to an acceptance of suicide culture. It was also found that the geographic region directly affected the suicide rate, with urbanized regions contributing to suicide prevention. As shown in Table 1, there is a similar relationship in Israel as the authors of one study<sup>57</sup> reported that emigration due to socioeconomic and regional factors triggers a pattern of suicide in Israel that differs from that in Western countries.

A study conducted in Austria reported that in 1990, a crude suicide rate of 23.6 per 100,000 inhabitants was recorded; this high value progressively decreased in the country to 15.6 per 100,000 inhabitants in 2016 as a result of a national suicide prevention strategy. The authors also indicated that this proportion was higher in age groups older than 65 years, particularly among elderly males<sup>58</sup>. Similarly, research involving time series of children and adolescents conducted between 2001-2014 also revealed a decrease in suicides among minors from slightly over 6% to approximately 4.5%; however, the decrease was significant only among males<sup>59</sup>.

History has provided evidence concerning suicide rates following the spread of pandemics, i.e., the influenza pandemic in 1918-1919 in the United States and severe acute respiratory syndrome (SARS) epidemic in 2003 in Hong Kong were associated with increased deaths by suicide<sup>60</sup>. Furthermore, the expected profound mental health effects related to the reality of the coronavirus disease 2019 (COVID-19) pandemic should guide governments worldwide to formulate preventative actions in a wide-ranging interdisciplinary response aiming to minimize the consequences by possibly applying these activities and making society aware of this serious world public health problem.

## CONCLUSIONS

Through an in-depth analysis, the wavelet method allowed the determination of countries with similar behaviors in terms of the number of suicides despite their very different socioeconomic, geographic, and climate characteristics.

In this work, we applied the Daubechies wavelet; in the future, this analysis can be expanded to include other wavelets to increase the efficiency of the analysis to detect similarities in suicide rates.

## INDIVIDUAL CONTRIBUTIONS

**Leila Maria Ferreira** – Defined the methodology, performed the literature review and wrote the manuscript.

**Kelly Pereira de Lima** – Performed the data collection and data analysis and wrote the manuscript.

**Augusto Ramalho de Morais** – Reviewed the manuscript.

**Thelma Safadi** – Reviewed the manuscript.

**Juliano Lino Ferreira** – Helped with the bibliographic references and wrote the manuscript.

## CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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