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Investigation of cause-specific mortality rates of European Union member and candidate countries by World Health Organization global health estimate categories

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ABSTRACT

Objectives: It is aimed to examine the position of our country and the European Union member and candidate countries in terms of mortality rates according to the motality causes defined in global health estimate categories determined by the World Health Organization and to reveal the similarities or differences.

Methods: According to the World Health Organization global health estimate categories given in the Global Burden of Disease 2019 study of World Health Organization, age-standardized mortality rates per 100,000 population were obtained for a total of 31 European Union member and candidate countries, and the muldimensional scaling analysis performed groups of the countries according to their dimensions obtained from multidimensional scale were determined and among these groups comparisons have been made.

Results: As a result of applying multidimensional scaling analysis, it was seen that countries can be represented in two-dimensional space according to the variables of interest.

Conclusions: It has been observed that our country differs from countries with cardiovascular diseases in the first dimension from the World Health Organization categories, while in the second dimension, infectious and parasitic diseases differ from countries with high standardized mortality rates.

Keywords: Multidimensional scaling, World Health Organization, global health estimate categories, Euclidean distance

Global, regional and country statistics on population and health indicators are critical for assessing development and health progress and guiding resource allocation [1]. Knowing the causes of death is important for the continuity of both preventive and curative services [2]. Understanding the causes of death of people enabling an effective response to changing epidemiological conditions, reducing preventable deaths and adapting health systems to respond effectively; will help improve health services in every country. This is as in the health policy of countries; it will guide the policies and resource allocations to be followed in different sectors such as transportation, food and agriculture.

The main cause of death is defined as the disease or injury that directly initiates the process resulting in death [3, 4]. The World Health Organization (WHO) is grouped the causes of death and disability into three large categories: communicable (infectious diseases, along with maternal, perinatal and nutritional conditions), noncommunicable (chronic diseases) and injuries. The sub-categories also have been given [1].

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Statistics of deaths by cause are reported annually to WHO by country, year, age and sex. These statistics are available from the WHO Mortality Database [5]. Societies may differ in terms of various characteristics that may affect mortality. Age distribution is one of the most important features [6]. For this reason, it is important to use standardized criteria, especially according to age and gender, when comparing countries, regions, etc. When Turkey's death statistics are analyzed according to their causes, circulatory system diseases took the first place with 36.8% in 2019. This cause of death was followed by benign and malignant tumors with 18.4% and respiratory system diseases with 12.9% [7].

In this study, with multidimensional scaling analysis, it is investigated how the European Union member and candidate countries are grouped according to different dimensions of cause-related mortality rates and from which variables the differences between these groups arise. In this direction, in this study, it is aimed to evaluate the current situation of Turkey among other countries in terms of cause-specific mortality rates.

METHODS

Multidimensional scaling (MDS) is a statistical analysis method used to classify objects or units by identifying similarities and differences with the help of various distance measures [8, 9]. MDS analysis is a graphical method that helps to obtain the representation of objects or units in a space consisting of an appropriate number of dimensions, using distances calculated by various techniques depending on the variables included in the analysis. Thus, it helps to determine the relationships between both units and variables [10]. It is a method that can be applied in many fields such as health sciences, social sciences, educational sciences, marketing research [11-13]. For example, MDS analysis was used to group patients with similar diagnoses in psychiatry according to their similarities and evaluate the course of the disease according to the disease groups determined [14]. Rouzier *et al*. [15] used multidimensional scaling analysis in their study where they suggested that the molecular classification of breast cancer be made based on the gene structures of human tumors.

Depending on the type of data, metric and non-metric scaling techniques are used in MDS analysis. While the metric MDS technique is used for data measured with the least interval scale, the non-metric MDS technique should be applied for data measured with an ordinal scale [16-19]. Observational differences and compatibility of distances are evaluated with Shepard diagram and R^2 value. The Shepard diagram shows the relationship between the observed distances and the configuration distances obtained by the MDS analysis [11, 16-18]. A R^2 value of ≥ 0.60 indicates a good fit [20].

In the MDS analysis, the stress value (i.e. the measure of correspondence between the original distances and the display distances), which is an expression of the difference between the multidimensional (p-dimensional) real shape and the predicted shape in reduced (k-dimensional) space, is calculated. The stress value is given in Equation (1) [20]. It is desirable that the stress value be close to zero [20-22].

$$\text{Stress}=\sqrt{\frac{\sum\sum(d_{ij}-\hat{d}_{ij})^2}{\sum(d_{ij})^2}} \quad (1)$$

d_{ij}: i. and j. configuration distance between individuals

$\hat{d}_{ij}$: i. and j. defined as the data distance between individuals.

A low stress rate indicates that the MDS solution is appropriate. A high value indicates a bad fit. The fitness values corresponding to the stress value presented by Kruskal in 1964 are given in Table 1 [14, 20, 23, 24].

Generally, two or at most three dimensions are preferred for dimension selection in MDS analysis. The number of dimensions is decided according to the stress value, R^2 value, Shepard diagram [25-28].
There are various measures of distance and similarity that are used in calculating distances in MDS. These

Table 1. Interpretation of the stress value

Stress value	Compatibility
≤ 0.20	Incompatible display
0.10- < 0.20	Low fit
0.05 - < 0.10	Good fit
0.025- < 0.05	Perfect fit
0.00- < 0.025	Complete fit

can be listed as follows;

a) Euclidean (Euclidean) Distance Measure

In a p-variable structure i. and j. The euclidean distance between the observations is as follows.

It is one of the most commonly used distance measures.

$$d_{ij=}\sqrt{\sum_{k=1}^{p}\left(x_{ik-}x_{jk}\right)^2} \quad (2)$$

x_{ik}: i. observation k. variable value,
x_{jk}: j. observation k. variable value,
p: the number of variables.

Square Euclidean (Square Euclidean) measure of distance

$$d_{ij} = \sum_{k=1}^{p}\left(x_{ik-}x_{jk}\right)^2 \quad (3)$$

a) Chebychev distance measure

$$d_{ij} = max_k^p \, |x_{ik}\text{-}\, x_{jk}| \, (4)$$

b) Manhattan City-Block distance measure

$$d_{ij=} \sum_{k=1}^{p} |x_{ik} - x_{jk}| \, (5)$$

c) Minkowski distance measure

m=1 için Manhattan City-Block measure of distance, m=2 için returns the measure of Euclidean distance. As m increases, the distance approaches the Chebychev distance measure.

$$d_{ij} = \left[\sum_{k=1}^{p} |x_{ik} - x_{jk}|^m\right]^{\frac{1}{m}} \quad (6)$$

a) Karl Pearson distance measure/ Standardized Measure of Euclidean Distance is in the form [11].

$$d_{ij} = \sqrt{\sum_{k=1}^{p} \frac{1}{s_k^2}\left(x_{ik} - x_{jk}\right)^2} \quad (7)$$

In this study, age-standardized cause-related mortality rates were taken. Causes of death categories were made according to the Global Health Estimates (GHE) classification in the 2019 World Health Report and are given in Table 2 [1, 2]. In case of missing data for one or more countries in the sub-categories, the parent category to which that sub-category belongs was taken into account (Table 2). Euclidean distance was used in the determination of the distance matrix in the MDS. These data are has been obtained from 31 countries European Union members Germany, Austria, Belgium, Bulgaria, France, France, Netherlands, Finland, Ireland, France, Sweden, Italy, Cyprus, Let, Lithuania, Luxembourg, Hungary, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Greece and candidate countries Albania, Macedonia, Serbia and Turkey. Candidate country Montenegro was not in-

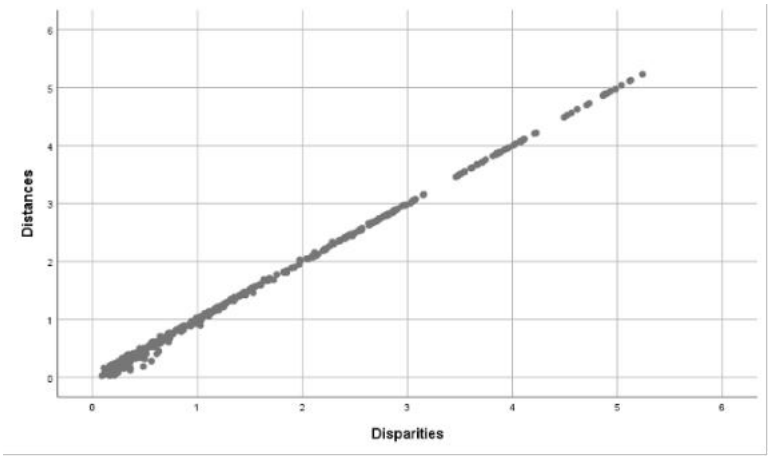

Fig. 1. Shepard diagram for observed distances and configuration distances

Table 2. Global health estimate cause categories and ICD-10 codes

GHE code	GHE cause	ICD-10 code
0	**All causes**	
10	**I. Communicable, maternal, perinatal and nutritional conditions[#]**	
20	I.A Infectious and parasitic diseases	A00-B99, G00-G04, G14, N70-N73, P37.3, P37.4
380	I.B. Respiratory Infectious	H65-H66, J00-J22, P23, U04
420	I.C. Maternal conditions	O00-O99
490	I.D. Neonatal conditions	P00-P96 (minus P23, P37.3, P37.4)
540	I.E. Nutritional deficiencies	D50-D53, D64.9, E00-E02, E40-E46, E50-E64
600	**II. Noncommunicable diseases[#]**	
610	II.A. Malignant neoplasms[#]	C00-C97
620	1. Mouth and oropharynx cancers	C00-C14
630	2. Oesophagus cancer	C15
640	3. Stomach cancer	C16
650	4. Colon and rectum cancers	C18-C21
660	5. Liver cancer	C22
670	6. Pancreas cancer	C25
680	7. Trachea, bronchus, lung cancers	C33-C34
690	8. Melanoma and other skin cancers	C43-C44
700	9. Breast cancer	C50
710	10. Cervix uteri cancer	C53
720	11. Corpus uteri cancer	C54
730	12. Ovary cancer	C56
740	13. Prostate cancer	C61
742	14. Testicular cancer*	C62
745	15. Kidney cancer	C64-C66
750	16. Bladder cancer	C67
751	17. Brain and nervous system cancers	C70-C72
752	18. Gallbladder and biliary tract cancer	C23-C24
753	19. Larynx cancer	C32
754	20. Thyroid cancer	C73
755	21. Mesothelioma	C45
760	22. Lymphomas, multiple myeloma	C81-C90, C96
770	23. Leukaemia	C91-C95
780	24. Other malignant neoplasms*	C17, C26-C31, C37-C41, C46-C49, C51, C52, C57-C60, C63, C68, C69, C74-C75, C77-C79
790	II.B. Other neoplasms*	D00-D48
800	II.C. Diabetes mellitus	E10-E14 (minus E10.2, E11.2, E12.2, E13.2, E14.2)
810	II.D. Endocrine, blood, immune disorders	D55-D64 (minus D64.9), D65-D89, E03-E07, E15-E34, E65-E88
820	II.E. Mental and substance use disorders	F04-F99, G72.1, Q86.0, X41-X42, X44, X45
940	II.F. Neurological conditions	F01-F03, G06-G98 (minus G14, G72.1)
1020	II.G. Sense organ diseases*	H00-H61, H68-H93
1100	II.H. Cardiovascular diseases	I00-I99
1170	II.I. Respiratory diseases	J30-J98
1210	II.J. Digestive diseases	K20-K92
1260	II.K. Genitourinary diseases	E10.2-E10.29,E11.2-E11.29,E12.2,E13.2-E13.29,E14.2, N00-N64, N75-N76, N80-N98
1330	II.L. Skin diseases	L00-L98
1340	II.M. Musculoskeletal diseases	M00-M99
1400	II.N. Congenital anomalies	Q00-Q99 (minus Q86.0)
1470	II.O. Oral conditions *	K00-K14
1505	II.P. Sudden infant death syndrome	R95
1510	**III. Injuries [#]**	
1520	III.A. Unintentional injuries	V01-X40, X43, X46-59, Y40-Y86, Y88, Y89
1600	III.B. Intentional injuries	X60-Y09, Y35-Y36, Y870, Y871

[#] Subcategories included, [*] Could not include due to lack of data.
GHE = Global health estimate cause categories defined in "WHO methods and data sources for country-level causes of death 2000-2019. (Global Health Estimates Technical Paper WHO/DDI/DNA/GHE/2020.2). Geneva, World Health Organization; 2020." [1]

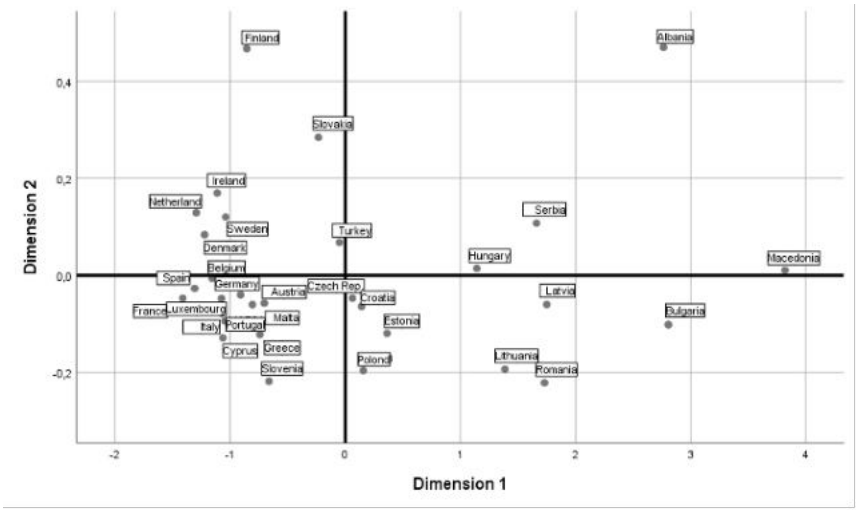

Fig. 2. **Graph of the Euclidean distance model**

cluded in the study due to lack of data.

Statistical Analysis

IBM Statistics SPSS for Windows v. 25.0 package program was used. The significance level was accepted as $\alpha = 0.05$. According to the analysis results obtained, the Kruskall stress statistic was found to be 0.022 for the r = 2 dimension. Accordingly, we can say that 2 dimensional scaling adequately reflects the data set we have. The Shepard graph showing the observed distances and the distribution of the configuration distances was found as in Fig. 1. The R^2 value is 0.99. Accordingly, it has been determined that there is a linear relationship between two different distance values and that a suitable solution can be presented with a linear model to the data. The positions of each country relative to each other in terms of cause-specific mortality rates selected by WHO are given in the two-dimensional graph of the Euclidean distance model in Fig. 2. Germany, Austria, Belgium, Czechia, Den-

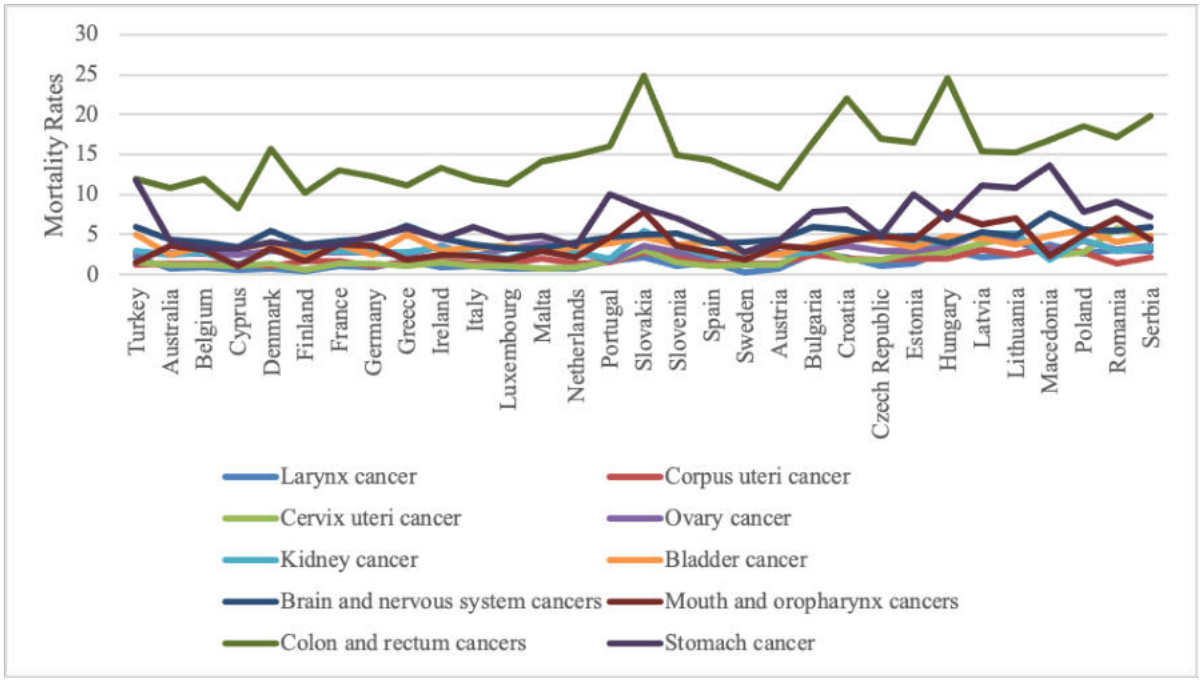

Fig. 3. **Distribution of mortality rates of countries according to cancer types which are found significant according fo first dimension**

Table 3. Comparison of variables according to the first dimension

Cause of death categories	x < 0	x > 0	*p* - value
Infectious and parasitic diseases	6.40 (1.90-17.50)	6.35 (2.70-12.70)	0.968
Respiratory infectious	8.40 (2.80-20.30)	10.85 (5.60-26.30)	0.311
Maternal conditions	0.10 (0.00-0.10)	0.10 (0.00-0.30)	0.115
Neonatal conditions	2.40 (1.30-6.20)	2.60 (1.30-6.60)	0.556
Nutritional deficiencies	0.70 (0.00-1.90)	0.35 (0.10-1.30)	0.061
Mouth and oropharynx cancers	2.70 (1.10-7.90)	4.60 (1.90-7.90)	**0.004**
Oesophagus cancer	2.50 (0.50-5.80)	2.45 (1.00-4.20)	0.871
Stomach cancer	4.50 (2.70-11.70)	8.65 (4.80-13.70)	**0.001**
Colon and rectum cancers	12.50 (8.30-24.90)	16.90 (4.30-24.50)	**0.001**
Liver cancer	4.50 (3.20-6.70)	4.35 (3.10-9.00)	0.382
Pancreas cancer	7.80 (5.50-9.50)	8.10 (4.80-10.40)	0.291
Trachea, bronchus, lung cancers	24.80 (16.10-39.70)	26.15 (21.50-43.50)	0.156
Melanoma and other skin cancers	2.10 (1.50-3.90)	2.80 (1.40-4.00)	0.059
Breast cancer	9.90 (6.40-11.00)	10.75 (5.50-14.20)	**0.024**
Cervix uteri cancer	1.20 (0.60-3.10)	2.80 (1.10-5.80)	**< 0.001**
Corpus uteri cancer	1.40 (1.10-2.80)	2.10 (0.90-3.30)	**0.004**
Ovary cancer	2.70 (1.70-3.90)	3.30 (0.90-5.20)	**0.009**
Prostate cancer	6.00 (3.90-9.50)	7.10 (5.40-8.90)	0.155
Kidney cancer	2.80 (1.20-5.50)	4.00 (1.90-5.30)	**0.033**
Bladder cancer	3.50 (2.00-5.00)	4.55 (3.40-6.60)	**0.003**
Brain and nervous system cancers	4.20 (3.20-6.10)	5.55 (3.90-7.70)	**0.004**
Gallbladder and biliary tract cancer	1.30 (0.60-3.80)	2.15 (0.90-3.30)	0.053
Larynx cancer	0.90 (0.30-2.20)	2.55 (1.10-3.70)	**< 0.001**
Thyroid cancer	0.40 (0.30-2.20)	0.40 (0.30-0.60)	0.180
Mesothelioma	0.70 (0.20-1.50)	0.20 (0.00-0.90)	**< 0.001**
Lymphomas, multiple myeloma	5.60 (4.70-9.00)	5.30 (1.60-6.80)	**0.046**
Leukaemia	4.20 (2.80-5.60)	4.50 (3.30-4.90)	0.556
Diabetes mellitus	6.50 (3.50-20.10)	10.80 (4.20-32.60)	0.081
Endocrine, blood, immune disorders	3.90 (1.90-5.90)	1.65 (0.50-3.50)	**< 0.001**
Mental and substance use disorders	4.60 (1.30-14.60)	4.60 (0.80-13.80)	0.823
Neurological conditions	28.20 (14.80-66.10)	17.95 (6.50-48.10)	**0.001**
Cardiovascular diseases	96.50 (68.90-173.50)	295.25 (182.30-470.60)	**< 0.001**
Respiratory diseases	22.90 (11.90-35)	21.85 (9.40-37.70)	0.968
Digestive Diseases	16.10 (11.10-33.80)	28.50 (14.10-45.00)	**< 0.001**
Genitourinary Diseases	8.80 (2.40-20.50)	9.50 (5.80-23.00)	0.516
Skin diseases	0.60 (0.10-1.80)	0.60 (0.00-1.50)	0.553
Musculoskeletal Diseases	1.80 (0.90-3.00)	1.20 (0.20-2.40)	**0.047**
Congenital anomalies	2.80 (1.40-6.00)	2.85 (1.80-4.40)	0.984
Sudden infant death syndrome	0.20 (0.00-0.40)	0.15 (0.10-0.40)	0.847
Unintentional injuries	16.60 (10.40-29.70)	21.55 (13.40-35.30)	**0.002**
Intentional injuries	9.10 (4.30-15.10)	10.00 (7.00-24.40)	0.282

Table 4. Comparison of variables according to the second dimension

Cause of death categories	y < 0	y > 0	*p* - value
Infectious and parasitic diseases	7.00 (1.90-17.50)	4.00 (2.20-7.90)	**0.022**
Respiratory infectious	10.60 (4.30-26.30)	10.50 (2.80-20.30)	0.726
Maternal conditions	0.10 (0.00-0.30)	0.10 (0.00-0.20)	0.783
Neonatal conditions	2.30 (1.30-4.70)	3.00 (1.30-6.60)	0.103
Nutritional deficiencies	0.50 (0.00-1.90)	0.40 (0.10-1.00)	0.507
Mouth and oropharynx cancers	3.55 (1.10-7.10)	2.30 (1.50-7.90)	0.173
Oesophagus cancer	2.45 (0.50-4.20)	2.50 (1.00-5.80)	0.695
Stomach cancer	5.90 (3.30-11.20)	6.80 (2.70-13.70)	0.918
Colon and rectum cancers	14.60 (8.30-22.10)	15.00 (4.30-24.90)	0.710
Liver cancer	4.50 (3.10-8.30)	4.20 (3.20-9.00)	0.804
Pancreas cancer	7.80 (5.50-10.30)	8.00 (4.80-10.40)	0.741
Trachea, bronchus, lung cancers	23.80 (16.60-34.90)	28.80 (16.10-43.50)	0.215
Melanoma and other skin cancers	2.20 (1.50-3.90)	2.90 (1.40-4.00)	0.086
Breast cancer	9.90 (6.90-11.50)	10.10 (5.50-14.20)	0.820
Cervix uteri cancer	1.45 (0.70-5.80)	1.50 (0.60-4.60)	0.918
Corpus uteri cancer	1.55 (1.10-3.10)	1.60 (0.90-3.30)	0.663
Ovary cancer	2.90 (1.70-5.20)	2.90 (0.90-3.60)	0.852
Prostate cancer	5.80 (3.90-8.90)	6.80 (5.70-9.50)	**0.039**
Kidney cancer	2.85 (1.20-5.30)	3.00 (1.90-5.50)	0.710
Bladder cancer	3.75 (2.50-5.60)	4.60 (2.00-6.60)	0.374
Brain and nervous system cancers	4.70 (3.20-6.10)	5.00 (3.80-7.70)	0.374
Gallbladder and biliary tract cancer	1.30 (0.60-3.30)	1.40 (0.70-3.80)	0.320
Larynx cancer	1.20 (0.50-3.10)	2.00 (0.30-3.70)	0.984
Thyroid cancer	0.40 (0.30-0.60)	0.40 (0.30-0.90)	0.692
Mesothelioma	0.55 (0.10-1.10)	0.40 (0.00-1.50)	0.559
Lymphomas, multiple myeloma	5.60 (3.80-9.00)	5.30 (1.60-7.40)	0.663
Leukaemia	4.35 (3.10-5.00)	4.10 (2.80-5.60)	0.508
Diabetes mellitus	7.95 (4.20-16.50)	7.40 (3.50-32.60)	0.853
Endocrine, blood, immune disorders	3.05 (0.60-5.90)	3.00 (0.50-4.40)	0.353
Mental and substance use disorders	4.90 (1.40-14.60)	4.10 (0.80-11.00)	0.509
Neurological conditions	23.05 (6.50-34.50)	40.40 (9.60-66.10)	**0.003**
Cardiovascular diseases	121.85 (68.90-393.80)	160.20 (79.10-470.60)	0.741
Respiratory diseases	20.35 (9.40-37.70)	30.10 (11.90-35.60)	0.052
Digestive Diseases	19.15 (11.10-45.00)	16.20 (11.70-34.60)	0.364
Genitourinary Diseases	9.65(3.80-15.40)	8.40(2.40-23.00)	0.901
Skin diseases	0.60 (0.10-1.80)	0.60 (0.00-1.60)	0.289
Musculoskeletal Diseases	1.75 (0.20-3.00)	1.50 (0.20-2.70)	0.725
Congenital anomalies	2.60 (1.40-5.00)	3.20 (2.00-6.00)	0.148
Sudden infant death syndrome	0.20 (0.00-0.40)	0.20 (0.00-0.40)	0.646
Unintentional injuries	19.05 (11.00-35.30)	15.60 (10.40-29.70)	0.098
Intentional injuries	9.55 (4.30-24.40)	9.70 (7.00-14.50)	0.934

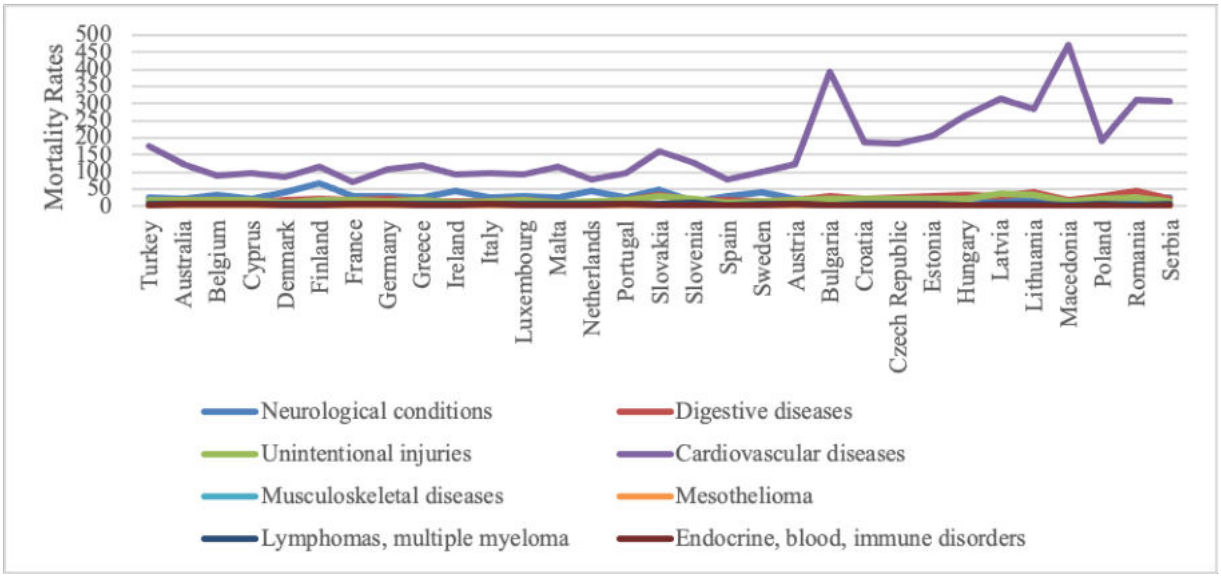

Fig. 4. Distribution of mortality rates of countries according to other causes of death which are found significant according to first dimension.

mark, France, Netherlands, Ireland, Spain, Sweden, Italy, Cyprus, Luxembourg, Malta, Portugal and Greece, which are close to each other in both dimensions, form a group; it has been observed that Turkey is close to these countries in terms of both dimensions.

RESULTS

According to the first dimension, the countries were divided into two groups according to the 0 abscissa, and the differences between the groups were analyzed according to the causes of death examined. Accordingly, the groups in the first dimension include cancers of the mouth and oropharynx, stomach, colon and rectum, breast, cervix, uterus, ovary, kidney, bladder, brain and nervous system, laryngeal cancers, cardiovascular diseases, digestive diseases, mesothelioma, lymphoma and multiple myelomas, endocrine, blood and immunity diseases, neurological disorders, musculoskeletal system diseases and unintentional injuries statistically significant difference

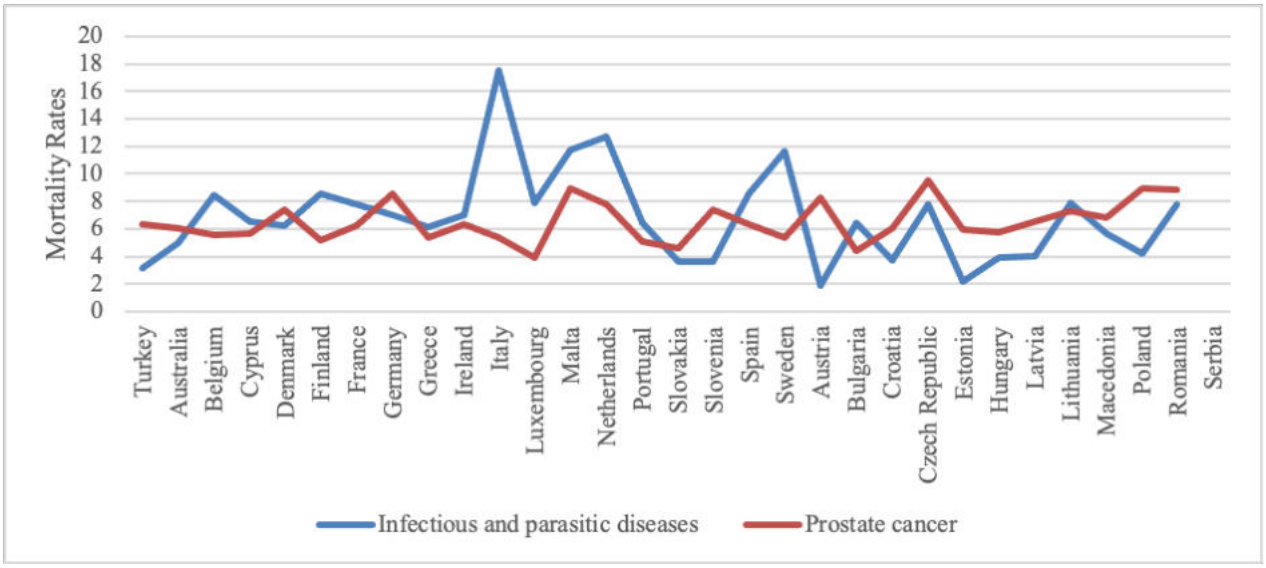

Fig. 5. Distribution of mortality rates of countries according to causes of death which are found significant according to second dimension.

was found in terms of mortality rates due to (Table 3, Fig. 3).

According to the second dimension, when the countries are divided into two groups according to the 0 ordinate; A statistically significant difference was found between the two groups in terms of mortality rates due to infectious and parasitic diseases, prostate cancer and neurological diseases (Table 4, Fig. 4).

DISCUSSION

MDS, which is used to visually reveal the relationships between objects or units in a less dimensional space; it can be applied on various data types measured with ordinal, evenly spaced, proportional scale and is widely used [18, 19].

This study was carried out by taking into account the age-standardized mortality rates per 100,000 population according to the GHE categories of the European Union member and candidate countries. In this study, a MDS analysis was carried out in order to understand which variables caused the distinction between European Union member countries and candidate countries. As a result of examining the literature on the subject among 31 European Union member and candidate countries (Montenegro could not be included in the study due to lack of data), 41 variables were included in the analysis by considering a standard classification criterion for disease-specific mortality rates.

In the first dimension, countries, especially in terms of other cancer types except prostate cancer, in the second dimension, it is seen that it differs especially in terms of moratality rates due to infectious and parasitic diseases and prostate cancer. For both dimensions, the countries of Germany, Austria, Belgium, Czechia, Denmark, France, Croatia, Netherlands, Ireland, Spain, Sweden, Italy, Cyprus, Luxembourg, Malta, Portugal, Slovenia, Greece formed a close group and Turkey's were found to be close to these countries in both groups. In the first group, especially Albania, Macedonia and Bulgaria, Serbia, Latvia, Romania, Lithuania and Hungary differ from other countries, in the second group, it is seen that especially Finland, Albania and Slovakia differ from other countries.

As can be seen from Fig. 3 in the first dimension of the GSE categories, our country differed from countries with high rates of colon rectum cancer, especially Slovakia and Hungary, and it was observed that it got closer to countries with low mortality rates. As can be seen from Fig. 4 in the first dimension of the GSE categories, our country differs from countries such as Bulgaria and Macedonia with high rates of cardiovascular diseases. As can be seen from Fig. 5 in the second dimension of the GSE categories, our country differs from countries with high rates of infectious and parasitic diseases, such as Greece and Romania, and converges with countries with low mortality rates.

CONCLUSION

The solution of health problems has been one of the important and determining factors in every age, the goal of people to live a modern, contemporary and prosperous life. It would be beneficial to determine the standardized mortality rates according to GHE by comparing them with European Union member states and to carry out studies to solve them by taking into account the negative aspects.

Authors' Contribution

Study Conception: DS, SK; Study Design: DS; Supervision: DS; Funding: DS; Materials: DS; Data Collection and/or Processing: DS; Statistical Analysis and/or Data Interpretation: SK; Literature Review: DS; Manuscript Preparation: DS, SK and Critical Review: DS, SK.

Conflict of interest

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