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Comparison of countries in European region according to risk factors of noncommunicable diseases by APLOCO method

Avrupa bölgesindeki ülkelerin APLOCO yöntemiyle bulaşıcı olmayan hastalıkların risk faktörlerine göre karşılaştırılması

Tevfik BULUT[1]

[1] Atılım University, Faculty of Health Science, Department of Nursing, 06836, Ankara-Turkey

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Abstract

Aim: The aim of the study was to compare countries in the WHO European Region according to key risk factors of NCDs.

Materials and Methods: Target population of study consists of 37 European Region countries. Weights of key risk factors were determined by Shannon Entropy and NMV weighting methods. APLOCO, one of the MCDM methods, was used to evaluate countries according to decision criteria.

Results: There is a significant and very strong positive monotonic relationship between score rankings obtained from NMV-based APLOCO and Shannon Entropy-based APLOCO methods. According to both the NMV-based and Shannon Entropy-based APLOCO methods, 14 European countries have above-average while 23 have below-average scores.

Conclusion: NCD risk factors are more prevalent in countries of the European Region with below-average NCD prevalence. NCDs may increase in countries of this region due to high risk factor prevalence.

Keywords: NMV; Shannon Entropy; MCDM, APLOCO; NCD risk factors.

Öz

Amaç: Çalışmanın amacı, DSÖ Avrupa Bölgesi'ndeki ülkeleri bulaşıcı olmayan hastalıkların temel risk faktörlerine göre karşılaştırmaktır.

Gereç ve Yöntemler: Çalışmanın hedef popülasyonunu Avrupa Bölgesi'ndeki 37 ülke oluşturmaktadır. Karar kriteri olarak kullanılan temel risk faktörlerinin ağırlıkları Shannon Entropi ve NMD objektif ağırlıklandırma yöntemleri ile belirlenmiştir. Ülkeleri karar kriterlerine göre değerlendirmek için ÇKKV yöntemlerinden biri olan APLOCO kullanılmıştır.

Bulgular: NMD tabanlı APLOCO ve Shannon Entropi tabanlı APLOCO yöntemlerinden elde edilen puan sıralamaları arasında anlamlı ve çok güçlü pozitif monoton bir ilişki vardır. NMD tabanlı APLOCO ve Shannon Entropi tabanlı APLOCO yöntemlerine göre Avrupa Bölgesi'nde ortalamanın üzerinde puana sahip ülke sayısı 14, ortalamanın altında puana sahip ülke sayısı ise 23'tür.

Sonuç: Bulaşıcı olmayan hastalık risk faktörlerinin prevelansı, ortalamanın altındaki Avrupa Bölgesi ülkelerinde daha yüksektir. Bulaşıcı olmayan hastalık risk faktörlerinin yüksek prevalansı, bu bölgedeki bulaşıcı olmayan hastalıkların prevalansını artırabilir.

Anahtar Kelimeler: NMD; Shannon Entropi; ÇKKV, APLOCO; BOH risk faktörleri.

Yazışma Adresi/Address for Correspondence: Tevfik BULUT, Atılım University, Faculty of Health Science, Department of Nursing, 06836, Ankara-Turkey, E-mail: buluttevfik@gmail.com

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Introduction

Noncommunicable diseases (NCDs) pose a significant health challenge on a global scale, and their impact continues to grow as a result of shifting demographic trends such as longer life expectancy, changing fertility rates, and evolving causes of death. In the WHO (World Health Organization) European Region, NCDs are responsible for 90% of all deaths and contribute to 85% of years lived with disability.[1,5]

A significant number of deaths in the WHO European Region occur before the age of 70 and are attributed to four major NCDs: cancers, chronic respiratory diseases, cardiovascular diseases, and diabetes. It is concerning that approximately 85% of the NCD burden is linked to preventable and controllable risk factors. Notably, the European Region has the poorest performance regarding two critical risk factors: alcohol and tobacco use.[2]

Proper healthcare can prevent a significant number of NCDs. The primary culprits behind most NCDs are four changeable behavioral risk factors: tobacco use, poor diet, insufficient physical activity, and the harmful consumption of alcohol. These behavioral risks contribute to biological risk factors, with obesity, high blood pressure, high glucose, and elevated cholesterol being the most prevalent. When combined, preventable risk factors account for more than two-thirds of the NCD burden in the region.[3]

The relationships among air pollution, various environmental elements, psychological, social, and economic hazards, as well as NCDs, have gained greater recognition in recent times. Premature mortality from NCDs serves as an appropriate gauge for evaluating the region's efforts to curb unhealthy behaviors and risk factors on the one hand, as well as the efficacy of its healthcare systems on the other. It's important to note that premature mortality captures only a fraction of the NCD burden in the region, as the majority of deaths occur after the age of 70. Progress on SDG 3.4 will significantly influence the success of at least nine other SDGs (Sustainable Development Goals), necessitating a unified approach across multiple sectors and leveraging effective economic tools such as price policies and insurance. NCDs disproportionately affect individuals with low socioeconomic status and are a leading cause of medical impoverishment. Besides causing health and well-being challenges, NCDs also impose significant economic losses. [4]

The study used APLOCO (Approach of Logarithmic Concept), one of the MCDM methods, to compare countries in the WHO European Region based on key risk factors of NCDs. Weights of key risk factors determined as decision criteria were calculated by Shannon Entropy and NMV (Normalized Maximum Values) methods, which are objective weighting methods. With the study, APLOCO was used for the first time in solving multi-criteria decision making problems in the field of health. In addition, an updated version of the APLOCO method application algorithm was developed by revising the application algorithm with the R programming language in order to produce instant solutions in small and especially large-scale data sets.

Materials and Methods

Type of the study

The study was cross-sectional.

Universe and sample of the study

The population of the study consists of 53 European Region countries determined by WHO. However, the number of countries with complete observations in the variables used in the evaluation of the countries is 37. Therefore, 37 countries constitute the target population of the study.

Data collection tools

The data set of the study consists of the data set of noncommunicable diseases and key risk factors publicly published by WHO. The dataset was published on the https://ncdportal.org/ web page called "Noncommunicable Diseases Data Portal".[6] The values of all variables were taken as total without differentiation according to gender or rural and urban settlements. The R programming language was used to make the data suitable for analysis and for data analyses.[7] The number of decision criteria used in the comparison of the countries of the European Region according to key risk factors is 16, and the key risk factors are coded according to categories and given in Table 1. The years to which the values of the decision criteria belong are given on the far right of the table.

Table 1. Decision criteria and direction of decision criteria.

Category	Decision Criteria	Code	Direction of Criteria	Year
Air pollution	Mortality rate attributed to household and ambient air pollution	c1	Minimum	2019
	Exceedance of WHO PM guidelines (by a multiple of)	c2	Minimum	2019
Harmful alcohol use	Total alcohol per capita consumption	c4	Minimum	2019
	Heavy episodic drinking, adults aged 15+	c5	Minimum	2016
Obesity / Unhealthy diet	Overweight, adults aged 18+	c6	Minimum	2022
	Obesity, adults aged 18+	c7	Minimum	2022
	Overweight, adolescents aged 10–19	c8	Minimum	2022
	Obesity, adolescents aged 10–19	c9	Minimum	2022
	Overweight, children aged 5–9	c10	Minimum	2022
	Obesity, children aged 5–9	c11	Minimum	2022
	Mean population salt intake, adults aged 25+	c12	Minimum	2019
Physical inactivity	Physical inactivity, adults aged 18+	c13	Minimum	2022
	Physical inactivity, adolescents aged 11-17	c14	Minimum	2016
Tobacco use	Current tobacco use, adults aged 15+	c15	Minimum	2022
	Current tobacco smoking, adults aged 15+	c16	Minimum	2022

Data analysis

NMV and Shannon Entropy methods were used for the objective weighting of the decision criteria within NCD key risk factors, and the APLOCO method, one of the MCDM methods, was used to compare the countries of the European Region according to the decision criteria. The APLOCO,[8] which was developed as a MCDM method, was previously used in calculating node weights in complex networks and determining the central metrics of networks,[9-10] and determining vital nodes in terrorist networks.[11] In the study where the APLOCO and other decision-making methods were used, the APLOCO method showed higher performance than other methods and was recommended for analysis of terrorist networks.[11] Within the scope of this study, the APLOCO application algorithm,[12] which was previously developed and published in the R environment, was revised and updated and used in the analyses. Spearman rank correlation test was used to measure monotonic relationship between the score rankings obtained from APLOCO combinations based on weighting methods. Spearman's rank correlation test,[13] which is used to compare whether two rankings are statistically different from each other, is also widely used to compare the rankings obtained from MCDM methods.[14-17] The alternative hypothesis (H_A) established in correlation tests are as follows:

- H_A: There is a monotonic relationship between NVM Method and Entropy Method weight rankings.
- H_A: There is a monotonic relationship between the rankings of NMV-Based APLOCO method and Shannon Etropy-Based APLOCO method.

The decision matrix used for weighting the decision criteria and comparing the countries of the European Region (N = 37) according to the key risk factors according to the decision criteria is presented in Table 2.

Since NMV and Shannon Entropy methods are known in the literature, mathematical equations used in application steps of these methods are not included. On the other hand, since APLOCO is a relatively new approach to solving MCDM problems, the method's application steps and the mathematical equations involved in those steps are provided.

Table 2. Decision matrix.

Country	c1	c2	c3	c4	c5	c6	c7	….	c13	c14	c15
Albania	92.5	3.2	5.1	24.6	62.2	23.4	20.7	….	21.9	24.3	73.9
Armenia	74.6	6.8	5.0	11.5	55.4	24.5	22.0	….	24.9	26.6	77.7
Austria	17.5	2.3	12.0	37.7	45.0	15.4	29.4	….	24.9	19.8	77.8
Belgium	15.3	2.3	10.3	36.6	51.1	20.0	21.6	….	24.8	25.4	83.5
Bulgaria	62.9	3.4	11.9	38.7	51.9	20.6	26.9	….	39.5	32.3	73.3
Croatia	31.3	7.3	8.5	32.1	64.2	30.6	25.0	….	37.0	28.4	76.8
Czechia	32.5	2.9	13.3	47.0	59.5	26.0	14.4	….	29.9	23.4	77.4
Denmark	12.9	1.9	9.4	34.0	44.9	13.3	18.4	….	16.2	12.1	84.5
Estonia	12.8	1.2	11.3	47.4	57.2	22.2	27.9	….	25.9	15.9	84.1
Finland	7.4	1.1	9.2	33.3	55.3	21.5	31.2	….	17.1	9.6	75.4
France	10.0	2.1	11.3	36.0	34.3	9.7	16.1	….	34.6	23.2	87.0
Germany	14.7	2.1	12.2	39.7	53.8	20.4	26.3	….	21.3	12.0	83.7
Greece	23.1	3.0	7.1	28.2	61.4	28.0	32.0	….	32.8	35.2	84.5
Hungary	42.3	2.8	10.6	37.9	62.2	31.7	31.7	….	32.2	29.4	79.5
Iceland	8.2	1.1	8.1	30.6	57.4	21.2	24.2	….	9.4	25.9	80.3
Ireland	12.8	1.6	11.7	40.5	64.7	28.3	25.2	….	19.3	21.9	71.8
Israel	15.1	3.9	3.0	18.4	54.3	22.5	23.5	….	20.4	26.6	84.7
Italy	15.0	2.7	8.0	25.0	49.1	17.3	24.2	….	22.4	40.1	88.6
Latvia	40.1	2.3	13.1	50.2	59.3	24.3	19.0	….	30.4	14.5	80.1
Lithuania	38.8	2.0	11.8	54.9	58.7	25.4	17.0	….	29.1	20.2	80.1
Luxembourg	12.5	1.8	11.5	51.2	51.5	18.4	21.1	….	23.0	13.9	79.2
Malta	20.9	2.5	8.5	25.6	64.7	32.3	25.5	….	24.7	40.7	81.4
Netherlands	13.2	2.1	9.3	31.6	45.9	14.5	16.7	….	21.3	9.4	80.2
Norway	7.9	1.3	6.8	35.4	57.5	19.1	23.1	….	14.2	35.1	83.5
Poland	40.9	3.7	11.6	38.9	62.7	27.5	21.8	….	23.6	37.0	78.8
Portugal	10.0	1.5	10.5	31.3	54.7	21.8	18.5	….	25.6	51.7	84.3
Moldova	68.9	2.4	11.4	28.6	61.2	23.0	16.8	….	28.2	10.8	75.7
Romania	67.8	2.6	17.0	39.0	65.1	34.0	20.4	….	29.4	36.8	79.5
Russian Federation	67.1	1.7	10.4	38.8	58.8	24.2	15.7	….	29.2	18.1	84.5
Slovakia	30.3	3.1	10.5	39.2	60.6	26.8	23.7	….	32.4	23.3	71.5
Slovenia	18.8	2.8	11.0	42.3	54.8	19.4	27.6	….	20.1	19.0	80.0
Spain	10.1	1.8	10.9	29.7	49.9	15.7	28.2	….	28.4	21.8	76.6
Sweden	8.1	1.1	9.3	32.4	50.6	15.3	25.3	….	12.6	8.7	84.7
Switzerland	10.4	1.8	10.4	39.9	40.6	12.1	23.7	….	25.5	19.0	85.7
Türkiye	45.5	4.6	1.8	1.5	67.6	33.3	32.8	….	30.5	44.4	81.3
Ukraine	78.9	2.6	8.7	20.2	56.1	23.6	13.1	….	24.9	12.8	76.7
United Kingdom	13.4	1.9	10.8	33.7	61.4	26.8	30.4	….	14.2	19.0	79.9

Objective weighting methods

This section provides the application steps for the NMV and Shannon Entropy weighting methods, which are objective weighting methods used to weigh decision criteria.

NMV weighting method

The NMV method, which functions as an objective weighting technique, is executed through four distinct steps. These steps include the following:[18-19]

1. Creating decision matrix
2. Obtaining ratio matrix
3. Determination of normalised values
4. Calculation of weights

Shannon entropy weighting method

Shannon Entropy represents an unbiased weighting approach used to calculate the weights of decision criteria.[20] In simpler terms, it does not incorporate the subjective opinions of the decision maker.[21] The steps for implementing Shannon Entropy are as follows:[22-23,29]

1. Creation of decision matrix
2. Normalizing decision matrix
3. Determination of entropy values
4. Determining the degrees of differentiation and weights

APLOCO MCDM method

This section provides both the APLOCO method's application steps and the revised

APLOCO application algorithm using the R programming language.

APLOCO Application Steps

In the APLOCO method developed as an MCDM method, the application steps are completed in 5 steps:[8]

1. Creating decision matrix: The decision matrix includes decision alternatives in columns and decision criteria in rows.
2. Determination of starting point criteria (SPC) values: When the criterion value needs to be maximized, we determine the maximum value among the relevant criterion values in that row. Conversely, when the criterion value needs to be minimized, we identify the minimum value among the relevant criterion values in that line. If the desired criterion condition is maximum, we subtract the criterion values in the row from the maximum value. Conversely, if the desired criterion condition is minimum, we subtract the minimum value from the criterion values in the corresponding row. These operations are given in equation (1). The matrix formed after these operations is given in Equation (2).
   $X_{ij} - \min_i p_{ij}$ where P_{ij} is minimum, and $\max_i p_{ij} - X_{ij}$ where P_{ij} is maximum. (1)
   $$P_{ij} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1r} \\ p_{21} & p_{22} & \cdots & p_{2r} \\ \cdots & \cdots & \cdots & \cdots \\ p_{c1} & p_{c2} & \cdots & p_{cr} \end{bmatrix} \quad (2)$$
3. Creating logarithmic conversion (LC) matrix: At this stage, P_{ij} matrix is normalised by taking inverse of each element of P_{ij} matrix according to multiplication by natural logarithm as shown in equation (3). With this operation, logarithmic transformation (LC) matrix (L_{ij}) is obtained.
   $$L_{ij} = \begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1r} \\ l_{21} & l_{22} & \cdots & l_{2r} \\ \cdots & \cdots & \cdots & \cdots \\ l_{c1} & l_{c2} & \cdots & l_{cr} \end{bmatrix} \text{ where } L_{ij} = \frac{1}{\ln(P_{ij}+2)} \quad (3)$$
4. Creating weighted logarithmic conversion (WLC) matrix: The weights (wj) of the decision criteria obtained by weighting methods are multiplied by the LC matrix (L_{ij}) to obtain the WLC matrix. This matrix (T_{ij}) is given in equation (4). This step is not mandatory and depends entirely on decision maker and nature of multi-criteria decision making problem.
   $$T_{ij} = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1r} \\ t_{21} & t_{22} & \cdots & t_{2r} \\ \cdots & \cdots & \cdots & \cdots \\ t_{c1} & t_{c2} & \cdots & t_{cr} \end{bmatrix} \quad (4)$$
5. Determination of optimal alternative: In this stage, the optimal solution values (β_j) are determined as the maximum values of the criteria in each row, and β_{sj} scores are obtained by taking the sum of these values. The scores for each alternative (θ) are determined by dividing the total scores of criteria values for alternatives (α_{si}) by the sum of the optimal solution values (β_{sj}). Equations (5) and (6) are used to perform these operations, respectively. The theta scores obtained from Equation (6) range from 0 to 1 and allow an evaluation within this range. The theta scores are then ranked from largest to smallest, and the top ranked alternative is considered the most optimal alternative.
   $a_{si} = \sum_{j=1}^{n} tj$ where decision criteria for WLC matrix are weighted or
   $a_{si} = \sum_{j=1}^{n} lj$ where decision criteria for LC matrix are not weighted (5)
   $\theta = \frac{a_{si}}{\beta_{sj}}$ where $0 \leq \theta \leq 1$ (6)

APLOCO application algorithm in R

The aploco() function, which represents the application algorithm of APLOCO, was created using the R programming language. You can directly copy and run this application algorithm within R without needing to install it as a package in an R environment. The aploco() function provides instant evaluation results across all sectors for both large-scale and small-scale data sets. The aploco() function's output is defined as a data frame in a list. Below is the code block for the APLOCO application algorithm in the R environment:

```
aploco<-function(dm=as.matrix(NULL),
dc=NULL, w=NULL){
        dm2 <- dm
        dc1=ifelse(dc=="max", 1, 0)
        for (r in 1:nrow(dm))
          for (c in 1:ncol(dm))
            if (dc1[r])
            {
                dm2[r,c] <- max(dm[r,]) -
dm[r,c]
            } else

            {
                dm2[r,c] <- dm[r,c] -
min(dm[r,])
            }

            dm3 <- 1 / logb(dm2 + 2)
            weights <- w
            dm4 <- dm3 * weights
            beta_j <- apply(dm4, 1, max)
            beta_sj <- sum(beta_j)
            a_si <- apply(dm4, 2, sum)
            theta_scores <- a_si / beta_sj

return(list(Decision_Matrix=as.matrix(dm),
SPC_Matrix=dm2, LC_Matrix= dm3,
WLC=dm4, Alpfa=a_si, Beta=beta_sj,
Theta_Scores=theta_scores))
          }
```

The arguments listed in the aploco() function are as follows:

- dm refers to decision matrix. The rows of dm contain decision criteria, while columns contain decision alternatives.
- w shows weights of decision criteria. If decision criteria are not weighted, value of w will be 1.
- dc represents direction of decision criteria, which is expressed in vector format. Put simply, "max" stands for maximum and "min" stands for minimum in argument dc.

The aploco () function provides a list of outputs. Outputs are structured in a list format and include the following:

- Decision_Matrix indicates decision matrix in the first step.
- SPC_Matrix indicates starting point criteria (SPC) values in the second step.
- LC_Matrix indicates logarithmic conversion (LC) matrix in the third stage.
- WLC indicates weighted logarithmic conversion (WLC) matrix in the fourth stage. If decision criteria are not weighted, WLC matrix is equal to LC matrix in the third step.
- Alpha shows total scores of criteria values for decision alternatives (a_{si}) in the fifth stage.
- Beta shows sum of optimal solution values (β_{sj}) in the fifth stage. It is expressed as Beta scores.
- Theta_Scores shows final scores in the fifth stage.

Ethics committee approval

As the data used for the study has been publicly published by WHO, there is no need for ethics committee approval.

Results

Descriptive statistics of NCD key risk factors determined as decision criteria in the study are given in Table 3. The decision criterion with the highest mean value in the European Region countries is c13 (Physical inactivity, adolescents aged 11-17) (Mean = 80.2) in the physical inactivity category. Bu bulgu Avrupa Bölgesi ülkelerinde ortalama risk prevelansının "Physical inactivity, adolescents aged 11-17" risk faktöründe diğer risk faktörlerine göre daha yüksek olduğunu göstermektedir. The decision criterion with the highest standard deviation (Sd) and range value is c1 (Mortality rate attributed to household and ambient air pollution) (Sd = 49.1, Range = 196.4) in the air pollution category. In determining the weights of the decision criteria and evaluating the countries in the European Region according to the decision criteria, countries with no missing observations in all decision criteria were taken into account. Therefore, 37 countries were included in the analysis in the weighting of the decision criteria and in the evaluation of the countries according to the decision criteria. Table 4 shows the weights of the decision criteria according to the objective weighting method. According to NMV method, the first three decision criteria with the highest weights are as follows: c2 (Exceedance of WHO PM guidelines (by a multiple of)) (w_j = 0.105), c1 (Mortality rate attributed to household and ambient air pollution) (w_j = 0.078) and c15 (Current tobacco use, adults aged 15+) (w_j = 0.078). On the other hand, according to Shannon Entropy method, the first three decision criteria with the highest weight values are as follows: c1 (Mortality rate attributed to household and ambient air pollution) (w_j = 0.317), c2 (Exceedance of WHO PM guidelines (by a multiple of)) (w_j = 0.123) and c14 (Current tobacco use, adults aged 15+) (w_j = 0.105).There is a statistically significant strong positive monotonic relationship between the rankings obtained from NMV and Shannon Entropy weighting methods ($r_s(35)$ = 0.682, $p<0.05$, N = 37). Therefore, the alternative hypothesis (H_A) was accepted. The correlation between the two weighting methods is given in Figure 1.

Table 3. Descriptive statistics of decision criteria.

Criteria	Description	N	Mean	Sd	Min	Max	Range
c1	Mortality rate attributed to household and ambient air pollution	50	49.1	44.7	7.4	203.8	196.4
c2	Exceedance of WHO PM guidelines (by a multiple of)	53	3.2	1.9	1.1	10.3	9.2
c3	Total alcohol per capita consumption	51	8.9	3.5	0.9	17.0	16.1
c4	Heavy episodic drinking, adults aged 15+	51	30.4	11.9	1.5	54.9	53.4
c5	Overweight, adults aged 18+	52	56.2	6.7	34.3	67.6	33.3
c6	Obesity, adults aged 18+	52	23.0	5.7	9.7	34.7	25.0
c7	Overweight, adolescents aged 10–19	52	22.7	5.8	9.9	32.8	22.8
c8	Obesity, adolescents aged 10–19	52	7.3	2.9	1.3	13.7	12.4
c9	Overweight, children aged 5–9	52	26.8	6.6	8.1	38.8	30.7
c10	Obesity, children aged 5–9	52	10.7	3.9	1.8	18.4	16.6
c11	Mean population salt intake, adults aged 25+	53	9.2	2.2	5.2	14.1	8.9
c12	Physical inactivity, adults aged 18+	52	24.7	10.2	8.7	51.7	43.0
c13	Physical inactivity, adolescents aged 11-17	38	80.2	4.2	71.5	88.6	17.1
c14	Current tobacco use, adults aged 15+	49	26.2	7.5	5.6	39.5	33.9
c15	Current tobacco smoking, adults aged 15+	49	25.4	7.9	5.4	39.5	34.1

Table 4. Weights of decision criteria by weighting methods.

NMV			**Shannon Entropy**		
Decision Criteria	**w_j**	**Rank**	**Decision Criteria**	**w_j**	**Rank**
Exceedance of WHO PM guidelines (by a multiple of)	0.105	1	Mortality rate attributed to household and ambient air pollution	0.317	1
Mortality rate attributed to household and ambient air pollution	0.078	2	Exceedance of WHO PM guidelines (by a multiple of)	0.123	2
Current tobacco use, adults aged 15+	0.078	2	Current tobacco use, adults aged 15+	0.105	3
Total alcohol per capita consumption	0.075	3	Obesity, adolescents aged 10–19	0.070	4
Obesity, adolescents aged 10–19	0.068	4	Heavy episodic drinking, adults aged 15+	0.064	5
Mean population salt intake, adults aged 25+	0.067	5	Total alcohol per capita consumption	0.055	6
Overweight, children aged 5–9	0.065	6	Obesity, children aged 5–9	0.054	7
Physical inactivity, adolescents aged 11-17	0.064	7	Physical inactivity, adolescents aged 11-17	0.043	8
Physical inactivity, adults aged 18+	0.063	8	Obesity, adults aged 18+	0.040	9
Current tobacco smoking, adults aged 15+	0.060	9	Physical inactivity, adults aged 18+	0.038	10
Heavy episodic drinking, adults aged 15+	0.059	10	Mean population salt intake, adults aged 25+	0.033	11
Obesity, children aged 5–9	0.058	11	Overweight, adolescents aged 10–19	0.028	12
Obesity, adults aged 18+	0.057	12	Overweight, children aged 5–9	0.020	13
Overweight, adolescents aged 10–19	0.054	13	Overweight, adults aged 18+	0.010	14
Overweight, adults aged 18+	0.048	14	Current tobacco smoking, adults aged 15+	0.002	15

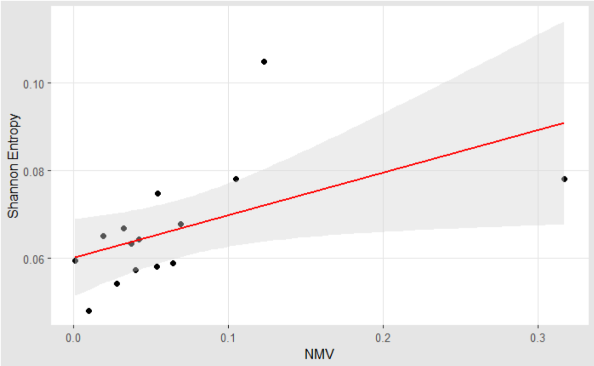

Figure 1. Correlation between NMV and shannon entropy weighting methods.

The comparative results of key risk factors for 37 European Region countries of APLOCO based on NMV and Shannon Entropy are presented in Table 5. Due to space constraints, the findings of the application steps preceding the final step of APLOCO method are not included. According to NMV-based APLOCO method, the number of countries with above average theta score (θ = 0.353) in the European Region is 14 and the number of countries with below average score is 23. The 14 countries with above average scores are as follows: France (θ = 0.520), Iceland (θ = 0.493), Sweden (θ = 0.460), Finland (θ = 0.449), Netherlands (θ = 0.429), Norway (θ = 0.427), Ukraine (θ = 0.417), Türkiye (θ = 0.405), Denmark (θ = 0.401), Moldova (θ = 0.386), Switzerland (θ = 0.385), Ireland (θ = 0.379), Estonia (θ = 0.370) and Luxembourg (θ = 0.357). These countries are also the top 14 countries with the highest theta (θ) score according to risk factors.

Table 5. NMV and shannon entropy based APLOCO scores.

NMV-Based APLOCO					Shannon Entropy-Based APLOCO				
Country	a_{si}	β_{sj}	**θ**	**Rank**	**Country**	a_{si}	β_{sj}	**θ**	**Rank**
France	0.751	1.443	0.520	1	Finland	0.919	1.443	0.637	1
Iceland	0.711	1.443	0.493	2	Sweden	0.851	1.443	0.590	2
Sweden	0.664	1.443	0.460	3	Iceland	0.811	1.443	0.562	3
Finland	0.648	1.443	0.449	4	Norway	0.785	1.443	0.544	4
Netherlands	0.618	1.443	0.429	5	France	0.703	1.443	0.487	5
Norway	0.616	1.443	0.427	6	Netherlands	0.631	1.443	0.437	6
Ukraine	0.601	1.443	0.417	7	Switzerland	0.592	1.443	0.410	7
Türkiye	0.585	1.443	0.405	8	Denmark	0.587	1.443	0.407	8
Denmark	0.578	1.443	0.401	9	Portugal	0.575	1.443	0.399	9
Moldova	0.557	1.443	0.386	10	Estonia	0.560	1.443	0.388	10
Switzerland	0.556	1.443	0.385	11	Spain	0.551	1.443	0.382	11
Ireland	0.547	1.443	0.379	12	Luxembourg	0.542	1.443	0.376	12
Estonia	0.533	1.443	0.370	13	Ukraine	0.531	1.443	0.368	13
Luxembourg	0.515	1.443	0.357	14	Ireland	0.527	1.443	0.365	14
Portugal	0.505	1.443	0.350	15	Türkiye	0.516	1.443	0.358	15
Russian Federation	0.496	1.443	0.344	16	Germany	0.512	1.443	0.355	16
Belgium	0.495	1.443	0.343	17	United Kingdom	0.509	1.443	0.353	17
Germany	0.492	1.443	0.341	18	Moldova	0.502	1.443	0.348	18
United Kingdom	0.492	1.443	0.341	18	Belgium	0.495	1.443	0.343	19
Spain	0.488	1.443	0.338	19	Israel	0.476	1.443	0.330	20
Israel	0.481	1.443	0.334	20	Russian Federation	0.467	1.443	0.324	21
Czechia	0.473	1.443	0.328	21	Austria	0.461	1.443	0.319	22
Lithuania	0.474	1.443	0.328	21	Italy	0.457	1.443	0.317	23
Latvia	0.471	1.443	0.326	22	Latvia	0.448	1.443	0.310	24
Slovakia	0.469	1.443	0.325	23	Lithuania	0.447	1.443	0.310	24
Austria	0.463	1.443	0.321	24	Czechia	0.437	1.443	0.303	25
Albania	0.455	1.443	0.316	25	Slovenia	0.436	1.443	0.302	26
Italy	0.441	1.443	0.306	26	Malta	0.422	1.443	0.292	27
Slovenia	0.43	1.443	0.298	27	Greece	0.410	1.443	0.284	28
Armenia	0.422	1.443	0.292	28	Slovakia	0.399	1.443	0.277	29
Malta	0.422	1.443	0.292	28	Albania	0.399	1.443	0.276	30
Poland	0.421	1.443	0.292	28	Poland	0.392	1.443	0.272	31
Greece	0.412	1.443	0.285	29	Romania	0.380	1.443	0.263	32
Romania	0.407	1.443	0.282	30	Armenia	0.375	1.443	0.260	33
Bulgaria	0.406	1.443	0.281	31	Hungary	0.374	1.443	0.259	34
Hungary	0.389	1.443	0.270	32	Croatia	0.366	1.443	0.254	35
Croatia	0.386	1.443	0.267	33	Bulgaria	0.361	1.443	0.250	36
Average			**0.353**		**Average**			**0.360**	

On the other hand, according to Shannon Entropy-based APLOCO method, the number of countries with a theta score above the average theta score (θ = 0.360) in the European Region is 14 as in the NMV-based APLOCO method, and the number of countries with a theta score below the average is 23. According to Shannon Entropy based APLOCO method, 14 countries with above average scores are as follows: Finland (θ = 0.637), Sweden (θ = 0.590), Iceland (θ = 0.562), Norway (θ = 0.544), France (θ = 0.487), Netherlands (θ = 0.437), Switzerland (θ = 0.410), Denmark (θ = 0.407), Portugal (θ = 0.399), Estonia (θ = 0.388), Spain (θ = 0.382), Luxembourg (θ = 0.376), Ukraine (θ = 0.368) and Ireland (θ = 0.365). However, as can be seen, score rankings of the countries are different in the Shannon Entropy based APLOCO method. There is a statistically significant and very strong positive monotonic relationship between score rankings obtained from NMV-based APLOCO and Shannon Entropy-based APLOCO methods ($r_s(35) = 0.938$, $p<0.05$, N = 37). Therefore, the alternative hypothesis (H_A) was accepted. The correlation between NMV-based APLOCO and Shannon Entropy-based APLOCO methods is given in Figure 2.

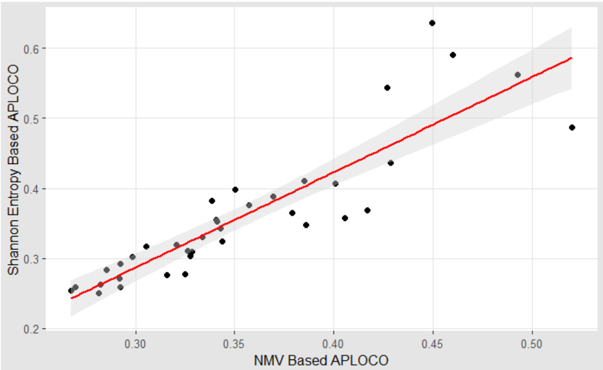

Figure 2. Correlation between NMV based APLOCO and shannon entropy based APLOCO methods.

Discussion

NCDs represent a major risk to global public health, leading to elevated rates of mortality and morbidity. These diseases are linked to common behavioral risk factors such as smoking, excessive alcohol consumption, physical inactivity and an unhealthy diet. Moreover, they are also associated with modifiable risk factors like hypertension, elevated total cholesterol, obesity, and diabetes. NCDs can be avoided by making healthy lifestyle choices that affect modifiable risk factors such as physical inactivity, smoking, and poor diet, as well as their physical outcomes like elevated cholesterol levels, obesity, high blood pressure, and diabetes.[24-26]

From a more regional perspective, ninety percent of deaths in the WHO European Region are caused by NCDs, and risk factors are directly responsible for about two thirds of these deaths.[5] For this purpose, initially, it is necessary to objectively determine weights of NCD key risk factors determined by WHO in the context of WHO European Region and to determine the prominent countries in this region in terms of risk factors by evaluating the WHO European Region countries relatively according to NCD risk factors. In this context, firstly, NCD key risk factors were weighted by NMV and Shannon Entropy methods, which are objective weighting methods. Subsequently, the WHO European Region countries were evaluated by APLOCO method and the relative prevalence of NCD risk factors of the countries was revealed.

There is a strong monotonic positive relationship between the rankings obtained from NMV and Shannon Entropy weighting methods. Similarly, a very strong monotonic relationship was found between NMV-based APLOCO and Shannon Entropy-based APLOCO methods. However, the scores and rankings of the countries obtained from both combinations are not the same. This is because the theoretical concept of NVM and Shannon Entropy weighting methods are different from each other. This is because the theoretical concepts of NVM and Shannon Entropy weighting methods are different from each other.

According to NMV-based APLOCO method, the top three European Region countries with the lowest prevalence of NCD risk factors (closest to the optimal solution) are France, Iceland and Sweden, while the top three European Region countries with the highest prevalence (furthest from the optimal solution) are Croatia, Hungary and Bulgaria. Among the 37 countries in the European Region, the country with the lowest prevalence of NCD risk factors is France and the country with the highest prevalence of risk factors is Croatia.

On the other hand, according to Shannon Entropy-based APLOCO method, the top three European Region countries with the lowest prevalence of NCD risk factors are Finland, Sweden and Iceland, while the top three European Region countries with the farthest distance from the optimal solution are Bulgaria, Croatia and Hungary. Unlike the country rankings obtained from NMV-based APLOCO method, according to the Shannon Entropy-based APLOCO method, Finland has the lowest prevalence of NCD risk factors, while Bulgaria has the highest prevalence of NCD risk factors.

In both NMV-based and Shannon Entropy APLOCO methods, the prevalence of NCD risk factors is higher in European Region countries below the average theta (θ) score compared to other European Region countries. The high prevalence of NCD risk factors can increase the prevalence of NCDs in the countries of the European Region.[5] High NCD prevalence opens the door to many problems. Human development is severely hampered by NCD pandemic in social, cultural, and economic spheres. NCDs cause poverty and lower productivity. Health systems are significantly impacted by NCDs, and their financial cost on national economies is only increasing.[27] Patients with multiple NCDs often have high out-of-pocket health expenditures due to both non-medical and medical expenses.[28]

Limitations

All European Region countries could not be included in the study due to the lack of observations and data on the key risk factors determined as decision criteria. Since the study is a cross-sectional study, it is aimed to take a snapshot of the current situation. Therefore, the study does not aim to forecast the future.

Conclusion

The NMV-based APLOCO method ranks France, Iceland, and Sweden as the top three European countries with the lowest NCD risk factors, while Croatia, Hungary, and Bulgaria rank highest. In the European Region, France has the lowest prevalence, while Croatia has the highest. The Shannon Entropy-based APLOCO method places Finland, Sweden, and Iceland as the lowest risk countries, with Bulgaria, Croatia, and Hungary as the highest. Finland has the lowest prevalence according to this method, while Bulgaria has the highest. According to both the NMV-based and Shannon Entropy-based APLOCO methods, countries in the European Region with below-average theta scores have more NCD risk factors than other countries in the European Region.

In this study, furthermore, an updated version of the APLOCO application algorithm was developed by revising the APLOCO application algorithm using the R programming language. Thus, with the application algorithm, in solving multi-criteria decision making problems, decision makers and field workers are provided with the opportunity to produce instant solutions in small and especially large-scale data sets in all sectors, regardless of the health sector.

Ethics Committee Approval

As the data used for the study has been publicly published by WHO, there is no need for ethics committee approval.

Informed Consent

Author have approved the manuscript and consent for publication.

Author Contributions

T.B. contributed 100% to the entire process of writing the manuscript.

Conflict of Interest

The author declared no potential conflicts of interest.

Financial Disclosure

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Peer-review

Externally peer-reviewed.

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