Ranking of provinces according to the health index and health inequalities in Türkiye

Türkiye'de illerin sağlık endeksine göre sıralaması ve sağlık eşitsizlikleri

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Abstract

Due to the multidimensional nature of health, composite indices have become popular in health research as a method to transform health indicators into meaningful information. This study aims to rank the provinces in Türkiye based on their health status and to uncover the health inequalities between provinces, using a composite health index that considers both health determinants and health outcomes. Within the scope of the study, publications from various organizations, publicly accessible databases and several research reports were reviewed as sources of data. A hierarchical arrangement was used to categorize the 29 variables into sub-dimensions, dimensions, sub-indexes, and composite health index. After establishing the theoretical framework and structuring the variables, the composite index was constructed by applying normalization, weighting, and aggregation processes. Following the classification of provinces by their health index scores, quantitative measurements were used to assess health inequalities. Bolu, Karabük, Ankara, Trabzon, and İstanbul ranked highest in the composite health index, while Hakkâri, Şanlıurfa, Muş, Ağrı, and Şırnak ranked lowest. When the provinces were classified based on the composite health index score, a difference of 44 points in absolute terms and a 2.17-fold difference in relative terms was found between the most advantaged and disadvantaged classes. Our composite health index showed that the provinces in Western Anatolia, Aegean, Mediterranean, Marmara, and Eastern Black Sea regions were in the top classes, whereas provinces in the Eastern and Southeastern regions were in the lower classes. Our study demonstrates the applicability of composite indices for health assessments, paving the way for evidence-based policies and more comprehensive future studies.

Keywords: Composite health index, health determinants, health inequalities

Özet

Sağlığın çok boyutlu yapısı nedeniyle, bileşik endeksler sağlık göstergelerini anlamlı bilgilere dönüştürme yöntemi olarak sağlık araştırmalarında popüler hale gelmiştir. Bu çalışmanın amacı, hem sağlığın belirleyicilerini hem de sağlık çıktılarını dikkate alan bir bileşik sağlık endeksi kullanarak Türkiye'deki illeri sağlık durumlarına göre sıralamak ve sağlık eşitsizliklerini ortaya koymaktır. Çalışma kapsamında farklı kurumlar tarafından yayımlanan raporlar, kamuya açık veri tabanları ve çeşitli araştırma raporları veri kaynağı olarak incelenmiştir. Hiyerarşik bir düzenleme kullanılarak 29 değişken, alt boyutlar, boyutlar, alt endeksler ve bileşik sağlık endeksi olarak sınıflandırılmıştır. Kuramsal çerçeve oluşturulduktan ve değişkenler yapılandırıldıktan sonra normalizasyon, ağırlıklandırma ve birleştirme işlemleri uygulanarak bileşik endeks oluşturulmuştur. İllerin sağlık endeksi puanlarına göre sınıflandırılmasının ardından sağlık eşitsizliklerinin değerlendirimesinde nicel ölçümler kullanılmıştır. Bileşik sağlık endeksinde Bolu, Karabük, Ankara, Trabzon ve İstanbul en yüksek sıraları alırken, Hakkari, Şanlıurfa, Muş, Ağrı ve Şırnak en düşük sıraları almıştır. Bileşik sağlık endeksi puanına göre iller sınıflandırıldığında en avantajlı ve en dezavantajlı sınıflar arasında mutlak olarak 44 puanlık, göreli olarak ise 2,17 kat fark saptanmıştır. Bileşik sağlık endeksimiz, Batı Anadolu, Ege, Akdeniz, Marmara ve Doğu Karadeniz bölgelerindeki illerin üst sınıflarda, Doğu ve Güneydoğu bölgelerindeki illerin ise alt sınıflarda bulunduğunu göstermiştir. Çalışmamız sağlık değerlendirmelerinde bileşik endekslerin kullanılabilirliğini ortaya koyarak kanıta dayalı politikalara ve gelecekteki daha kapsamlı araştırmalara zemin hazırlamaktadır.

Anahtar Kelimeler: Bileşik sağlık endeksi, sağlığın belirleyicileri, sağlık eşitsizlikleri

Introduction

Throughout human history, cultures have explored the concept of health, resulting in numerous shifts in defining health that reflect the specific beliefs and scientific understanding of different eras (1). Following the World Health Organization's (WHO) 1948 redefinition of health to include physical, social, and mental well-being, there has been a greater recognition of the importance of considering health holistically and the relationship between social factors and health (2).

The circumstances in which individuals are born, raised, work, live, and age, along with the broader set of influences and frameworks that shape daily living, are known as social determinants of health. The social determinants of health encompass factors such as income, employment, working conditions, social support, education, housing, environmental characteristics, social cohesion, and access to healthcare services (3). The unequal distribution of social and structural factors among different societal groups significantly contributes to health inequalities (4).

Although health inequalities are a complex and vague concept, they can be measured using various statistical techniques. At the most basic level, inequality measures are divided into two groups: simple and complex measures. Simple measures only allow for comparisons between two subgroups, while complex measures take into account data from all subgroups to evaluate health inequalities. It is possible to express both simple measures and complex measures in the form of absolute and relative measures (5).

When evaluating and organizing health services in a society, it is important to measure, interpret, and understand the health status of both the society and the individuals within it. An individual's health status is evaluated by factors like health perception, functionality, and quality of life. For society, health status is evaluated based on factors such as life expectancy, the frequency of preventable diseases, causes and magnitude of premature deaths, and prevalence of disease risk factors (6).

Health indicators are summary measures that provide insight into the health status of individuals or societies, as well as different characteristics of the healthcare system. Ecological or environmental indicators refer to the physical characteristics of the place where a population group lives or works. Global indicators, such as population density and gross domestic product per capita, are measurements that refer to the characteristics of a group or place that do not have direct equivalents at the individual level. The selection of indicators may vary depending on the purpose, available resources, and expected users (7).

When analyzing changes in the health status of various social groups and residential regions, it is essential to factor in a variety of elements like social, geographical, economic, and environmental determinants, in addition to health indicators. Health outcomes are regarded as signs of the current state, while health determinants are seen as the predictors of future health outcomes (8).

With the understanding of the multidimensional nature of health, the composite index method has gained popularity in the assessment of health, as it transforms indicators into meaningful data. The composite health index is created by averaging different indicators or sub-indexes, allowing multiple indicators to be represented by a single index value. By using composite health indices, it is possible to gain insight

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into the health status of the entire population, identify disadvantaged groups, monitor progress towards health targets, evaluate the effectiveness of community-level interventions, and establish evidence-based health policies (9). However, studies on the use of composite indices to measure public health or determine health inequalities are quite limited in Türkiye.

In light of the growing usage of composite indices in the health sector, the aim of this study is to rank the provinces in Türkiye according to the health status by using health index which includes health determinants such as socioeconomic, demographic, environmental and health system characteristics as well as health indicators and to uncover the existing health inequalities between provinces.

Material and Method

This ecological study was conducted between September 2021 and August 2022. Our research process started with a detailed review of data sources. We then selected the variables and constructed the composite health index in six systematic steps. After creating the composite health index, the differences in health outcomes between the most disadvantaged and advantaged groups were measured using both absolute and relative terms. The construction process of the composite health index is presented in Figure 1.

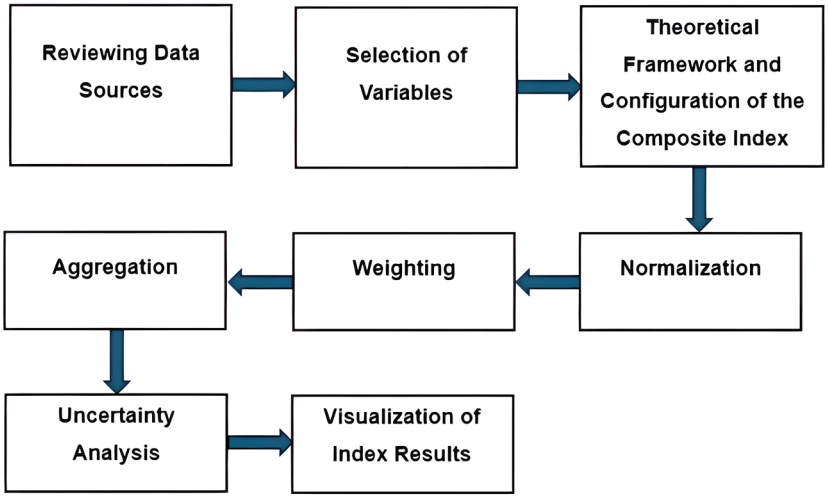

Figure 1: Flowchart of the process of the composite health index construction

Reviewing data sources and selection of variables

During the data source review, reports from the Turkish Statistical Institute (TURKSTAT), the Ministry of National Education, the Ministry of Health, the Ministry of Environment, Urbanization and Climate Change, public databases, and various research reports were examined regarding health outcomes and health determinants.

Following a comprehensive review of the data sources, we identified the variables that have been associated with health in literature. From these variables, we selected 29 variables to be included in the composite index, taking into consideration their validity, timeliness, measurability, relevance, reproducibility, sustainability and importance. The calculation of the 29 selected variables and the rationale for including them in the composite health index were explained in Supplementary 1.

Construction of the composite health index

The methodology for constructing of the composite health index was based on the handbook titled "Handbook on Constructing Composite Indicators: Methodology and User Guide" which was jointly prepared by the Organization for Economic Co-operation and Development (OECD) and the Econometrics and Applied Statistics Unit of the Joint Research Centre (JRC) of the European Commission (10).

Apart from the handbook, the annual 12-hour online training organized by the JRC for constructing composite index and indicator tables

was completed, providing hands-on experience in creating the composite index. The procedures implemented during the construction of the composite index were as follows:

Theoretical framework and configuration of the health index

When establishing the theoretical framework of the study, the concept of health was not only evaluated based on health outcomes but also considered social factors that shape the process of being healthy. As shown in Table 1, the 29 selected variables were structured hierarchically as sub-dimensions, dimensions, sub-indexes and finally the composite health index, reflecting the measurement of similar phenomena.

Table 1: Variables in the composite health index and their characteristics

Variables	Sub-dimension	Dimension	Sub-index	Time Scope
Life expectancy at birth	-	-	Health outcomes	2017-2019
Maternal mortality ratio	-	-	Health outcomes	2015-2019
The years of potential life lost (YPLL)	-	-	Health outcomes	2017-2019
Under-Five mortality rate	-	-	Health outcomes	2017-2019
Dependency ratio	Demography	Sociodemography	Health Determinants	2020
Consanguineous marriage rate	Demography	Sociodemography	Health Determinants	2020
Adolescent fertility rate	Demography	Sociodemography	Health Determinants	2020
Graduation rate from universities and other higher educational institutions (Aged 25 years or above)	Education	Sociodemography	Health Determinants	2020
Net enrollment rate in pre-primary education	Education	Sociodemography	Health Determinants	2019
Illiteratecy rate (Aged 15 years or above)	Education	Sociodemography	Health Determinants	2019
Gross domestic product per capita by provinces	Income	Sociodemography	Health Determinants	2020
Average daily earnings subject to contributions	Income	Sociodemography	Health Determinants	2020
Percentage of population covered by social security	Employment-Social security	Sociodemography	Health Determinants	2020
Unemployment rate (Aged 15 years or above)	Employment-Social security	Sociodemography	Health Determinants	2020
Annual average concentration of PM2.5	Air quality	Environment	Health Determinants	2016-2020
Annual average concentration of PM10	Air quality	Environment	Health Determinants	2016-2020
Proportion of forest areas	Physical Environment	Environment	Health Determinants	2020

The percentage of the built-up area of cities that is open space for public use for all	Physical Environment	Environment	Health Determinants	2019
The percentage of the total municipal population served by sewerage system	Housing-Infrastructure	Environment	Health Determinants	2020
The percentage of the total municipal population served by wastewater treatment plants	Housing-Infrastructure	Environment	Health Determinants	2020
Proportion of municipal solid waste gathered and treated in regulated facilities compared to the total municipal waste	Housing-Infrastructure	Environment	Health Determinants	2018
Average household size by provinces	Housing-Infrastructure	Environment	Health Determinants	2020
The number of intensive care unit beds per 10 000 people	Health Infrastructure	Health System	Health Determinants	2020
The number of hospital beds per 10 000 people	Health Infrastructure	Health System	Health Determinants	2020
The number of qualified beds per 10 000 people	Health Infrastructure	Health System	Health Determinants	2020
The number of pharmacists per 10 000 people	Health Workforce	Health System	Health Determinants	2020
The number of dentists per 10 000 people	Health Workforce	Health System	Health Determinants	2020
The number of nurses and midwives per 10 000 people	Health Workforce	Health System	Health Determinants	2020
The number of physicians per 10 000 people	Health Workforce	Health System	Health Determinants	2020

Normalization

A rescaling process was applied to combine variables with different units of measurement. With the normalization, the indicator is rescaled to have a minimum value of I, and a maximum value of u, creating a range of u - I and is as follows:

$$\overline{X} = \frac{X - X_{min}}{X - X_{max}} \times (u - l) + l$$

where "$\overline{X}$" is the normalized value of the indicator. The lowest normalized value was set at one, while the highest normalized value was set at 100. In the normalization process, values in variables with a negative direction for the health index are multiplied by minus one.

Weighting

Principal component analysis, a statistical technique used for weighting, was selected to assign weights to the variables in the composite index, as well as the sub-dimensions and dimensions derived from these variables. Before conducting principal component analysis, the distribution of variables and potential outliers within the multivariate data was examined first, as these factors could greatly impact the results. The outlier map defined by Hubert et al. was used to detect outliers in the multivariate dataset (11).

Since a significant portion of the variables in our study have a skewed distribution and some provinces have outlier observations in the outlier map, we preferred to use robust principal component analysis instead of classical principal component analysis for more accurate results in the weighting phase.

While conducting robust principal component analysis, we first assessed the suitability of the variables for the analysis by using Kaiser-Meyer-Olkin and Bartlett tests. The Kaiser criterion and

scree plot were utilized to determine the number of principal components necessary for explaining the highest variance. Once the number of principal components was determined, the weights for both each principal component and the variables within these components were calculated based on their factor loadings. In the last stage, the final weights were obtained by multiplying the weight of the variables in the principal component with the highest weight by the weight of that principal component, and then scaling by one. While the same steps were followed in weighting the sub-dimensions and dimensions, the health determinants and the health outcomes sub-indexes that form the composite health index were weighted equally.

Aggregation

In this stage, the hierarchical structure of the index allowed us to obtain sub-dimension, dimension, sub-index, and composite health index scores. Different aggregation methods were used at various levels of the composite index. The weighted arithmetic mean method was selected to combine variables, assuming that a low score on one variable could be balanced by a high score on another variable within the same sub-dimension. With the same approach, the weighted arithmetic average was also preferred in combining the sub-dimensions. When combining the dimensions and sub-indexes, the weighted geometric mean method was used since compensability was desired to be minimal.

Uncertainty analysis

Following the construction of the composite index, uncertainty analysis was conducted to evaluate the impact of alternative choices on the composite index. The Monte Carlo simulation was carried out to see how different options could affect the health index scores of the provinces. The Monte Carlo simulation took into account for normalization, weighting, and aggregation stages, which encompassed multiple alternatives.

Assumptions included in the simulation within the scope of normalization consist of the rescaling method used in the composite index and standardization technique based on z-scores. In order to evaluate the impact of different weights on the index rankings, a weight set was integrated into the simulation for each variable, sub-dimension, dimension, and sub-index, where the weights randomly changed within +/- 25%. Assumptions at the aggregation stage included applying arithmetic aggregation at all levels, implementing geometric aggregation at all levels, and maintaining the original index's aggregation method. All these assumptions were analyzed simultaneously in 5000 Monte Carlo simulations.

Visualization of index results

Composite health index scores of the provinces were visualized with choropleth maps. In the visualization phase, we initially determined the number of classes based on the goodness of variance fit value. Subsequently, we classified the provinces using the Jenks natural breakdown algorithm.

Monitoring health inequality

After classifying the provinces based on their health index scores, quantitative measurements were used to assess health inequalities. Health inequalities were measured using the slope index of inequality (SII) as an absolute measure, and the relative index of inequality (RII) as a relative measure.

When calculating the SII, we ranked the classes from the most disadvantaged to the most advantaged. Then, we calculated the estimated index values for the most disadvantaged and advantaged classes using the weighted linear regression model. The SII was calculated by subtracting the estimated values for these two classes, and the RII was calculated by proportioning the estimated values to each other.

Statistical analysis

All analyses within the study were conducted using R Studio software (version 2022.02.2 + 485). Maps for visualizing composite health index results were created using the geographic information system software QGIS (version 3.26). Descriptive statistics are expressed as mean and median. The significance level for the tests applied in the study was set at $p < 0.05$.

Ethical Consideration

Prior to the study, an application was submitted to Uludağ University Faculty of Medicine Clinical Research Ethics Committee for ethical permission, and according to the decision of the committee, it was reported that ethics committee approval was not required (Decision No:2021-12/14).

Results

Rankings and scores of provinces on health index and sub-indexes

Table 2 shows the rankings of 81 provinces regarding the health index and sub-indexes and their scores paired with the heat map. The health index scores of the provinces range from 12.61 to 77.21, and the median score of the 81 provinces is 59.67. Bolu (77.21), Karabük (76.10), Ankara (75.64), Trabzon (74.78), and İstanbul (74.76) were the top five provinces in terms of health index scores. Hakkâri (12.61), Şanlıurfa (21.77), Muş (23.36), Ağrı (25.20), and Şırnak (25.21) were the provinces with the lowest health index scores.

When assessing the health determinants sub-index scores in the provinces, it can be observed that the score ranges from 74.99 to 15.11, with a median score of 54.89. Eskişehir (74.99), Bolu (73.60), İstanbul (73.10), Ankara (71.20), and Isparta (69.65) were the top five provinces in terms of the health determinants sub-index. Muş (15.11), Şanlıurfa (17.87), Ağrı (19.30), Şırnak (19.73), and Mardin (24.05) were the provinces with the lowest scores in the health determinants sub-index.

The health outcomes sub-index shows that the scores of the provinces range from 92.55 to 6.09, with a median score of 63.47. Gümüşhane (92.55), Karabük (89.69), Tunceli (85.78), Giresun (82.73), and Trabzon (82.33) were the top five provinces in terms of health outcomes sub-index. Hakkâri (6.09), Kilis (15.97), Şanlıurfa (26.52), Gaziantep (28.14), and Şırnak (32.21) were the provinces with the lowest scores in the health outcomes sub-index.

Table 2: Provincial rankings and scores for the composite health index and its sub-indexes

Provinces	Health Index Ranking	Health Determinants Sub-Index Ranking	Health Outcomes Sub-Index Ranking	Health Index Score	Health Determinants Sub-Index Score	Health Outcomes Sub-Index Score
Bolu	1	2	7	77.21	73.60	80.98
Karabük	2	11	2	76.10	64.58	89.69
Ankara	3	4	8	75.64	71.20	80.35
Trabzon	4	6	5	74.78	67.92	82.33
İstanbul	5	3	13	74.76	73.10	76.46
Eskişehir	6	1	17	74.17	74.99	73.36
Giresun	7	15	4	72.25	63.10	82.73
İzmir	8	9	14	71.08	67.29	75.08
Çanakkale	9	7	16	70.64	67.65	73.77
Antalya	10	17	9	70.53	61.98	80.25
Yalova	11	12	15	68.74	63.52	74.39
Isparta	12	5	30	68.68	69.65	67.72
Kocaeli	13	8	25	68.11	67.56	68.67
Erzincan	14	30	6	68.06	56.95	81.33
Tunceli	15	45	3	67.78	53.56	85.78

Bursa	16	19	18	66.96	61.83	72.52
Rize	17	14	24	66.41	63.30	69.67
Gümüşhane	18	59	1	66.40	47.63	92.55
Muğla	19	36	10	65.85	55.55	78.05
Kırklareli	20	13	29	65.70	63.45	68.04
Zonguldak	21	16	31	64.87	62.58	67.24
Amasya	22	43	11	64.63	54.19	77.08
Edirne	23	10	47	64.43	67.23	61.75
Bilecik	24	25	26	63.97	59.60	68.66
Sinop	25	34	19	63.53	55.97	72.10
Denizli	26	22	36	63.23	61.04	65.49
Aydın	27	32	27	62.10	56.43	68.34
Artvin	28	42	21	61.75	54.41	70.07
Çorum	29	44	23	61.48	54.06	69.91
Tekirdağ	30	23	45	61.26	60.25	62.28
Burdur	31	35	32	61.18	55.66	67.23
Elazığ	32	28	37	61.05	57.01	65.38
Ordu	33	47	20	61.04	52.25	71.32
Çankırı	34	54	12	61.03	48.40	76.97
Sakarya	35	37	33	61.01	55.54	67.02
Samsun	36	20	51	60.76	61.65	59.88
Kırıkkale	37	18	52	60.23	61.88	58.63
Konya	38	40	34	60.19	55.02	65.84
Karaman	39	38	38	60.04	55.34	65.14
Düzce	40	50	22	59.84	51.22	69.92
Tokat	41	29	43	59.67	56.97	62.49
Malatya	42	46	35	58.86	52.70	65.74
Balıkesir	43	24	54	58.82	59.63	58.03
Sivas	44	41	44	58.48	54.89	62.29
Mersin	45	48	40	57.55	52.16	63.50
Bartın	46	58	28	57.08	47.83	68.12

Kastamonu	47	33	56	56.50	56.06	56.94
Kütahya	48	21	64	55.89	61.29	50.97
Kayseri	49	39	58	55.48	55.17	55.79
Adana	50	31	60	55.31	56.82	53.84
Bayburt	51	57	41	55.13	47.89	63.47
Yozgat	52	52	50	54.37	49.29	59.98
Kırşehir	53	51	55	54.15	51.18	57.30
Uşak	54	26	65	54.07	57.59	50.76
Aksaray	55	64	46	51.94	43.48	62.05
Bingöl	56	65	39	51.88	41.66	64.61
Manisa	57	27	69	51.37	57.19	46.14
Nevşehir	58	53	62	50.37	48.81	51.98
Niğde	59	63	57	50.11	44.55	56.36
Osmaniye	60	60	61	49.97	46.57	53.61
Afyon	61	49	68	49.10	52.09	46.28
Maraş	62	67	49	49.04	40.00	60.13
Adıyaman	63	69	42	48.63	37.27	63.45
Hatay	64	61	63	48.38	45.47	51.48
Erzurum	65	56	67	48.28	48.31	48.24
Batman	66	70	48	47.08	36.38	60.93
Diyarbakır	67	71	53	45.58	35.67	58.24
Ardahan	68	66	73	39.50	41.40	37.68
Iğdır	69	75	59	38.87	27.33	55.27
Kars	70	68	74	38.35	39.11	37.60
Bitlis	71	73	70	37.56	32.03	44.04
Siirt	72	72	72	36.96	32.67	41.81
Van	73	74	71	35.75	29.39	43.50
Gaziantep	74	62	78	35.48	44.73	28.14
Mardin	75	77	66	34.87	24.05	50.57
Kilis	76	55	80	27.78	48.34	15.97
Şırnak	77	78	77	25.21	19.73	32.21

Ağrı	78	79	76	25.20	19.30	32.89
Muş	79	81	75	23.36	15.11	36.11
Şanlıurfa	80	80	79	21.77	17.87	26.52
Hakkâri	81	76	81	12.61	26.11	6.09
Median	**-**	**-**	**-**	**59.67**	**54.89**	**63.47**

Findings on interprovincial health inequalities within the scope of the health index

Figure 2 shows the change graph of goodness of variance fit values as the number of classes changes. After observing that increasing the number of classes beyond five did not notably increase the goodness of variance fit value, the decision was made to maintain the number of classes at five.

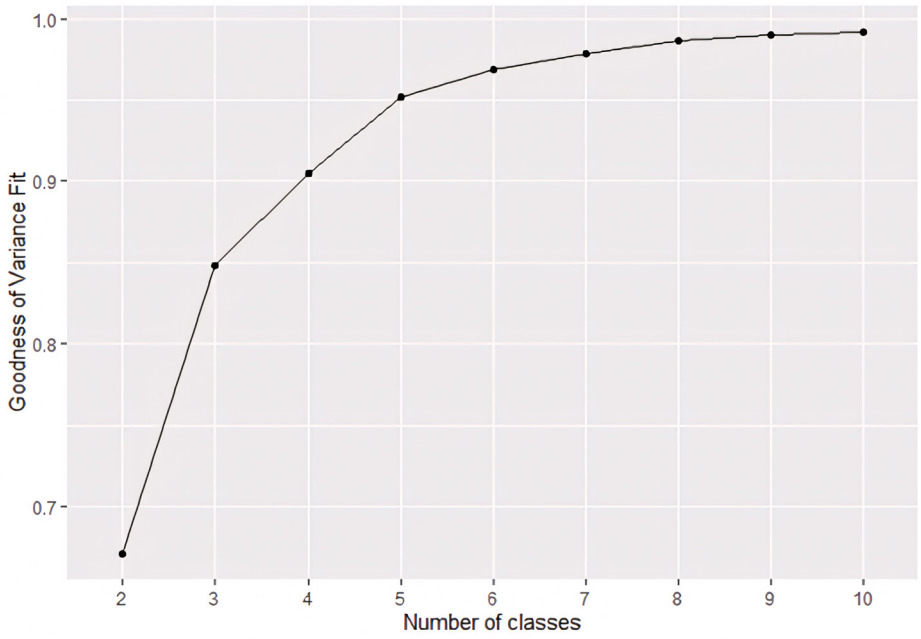

Figure 2: Change in goodness of variance fit values based on the number of classes

The distribution of provinces based on the classes determined as a result of the Jenks natural breakdown algorithm was presented on the choropleth map in Figure 3. In the first class, the 18 provinces had the health index scores ranging from 77.21 to 66.40, with the mean score of 71.01. The second class comprised 29 provinces with scores ranging from 65.85 to 56.50, and the mean score for the class was 61.24. The health index scores of 20 provinces in the third class range from 55.89 to 45.58, with the mean score of 51.30. In the fourth class, there were 8 provinces with scores varying between 34.87 to 39.50, and the mean score for this class was 37.16. The provinces of Kilis, Şırnak, Şanlıurfa, Hakkâri, Muş, and Ağrı scored between 27.78 and 12.61 in the last class, with the mean score of 22.65.

The results concerning the SII and RII, which were utilized to assess the inequalities between the most advantaged and disadvantaged groups, were presented in Figure 4. The SII, defined as the difference between the estimated values for these two classes, was calculated as 44.76. The RII value was calculated by dividing the estimated values of 82.73 and 37.97 for the most advantaged and disadvantaged classes. Accordingly, the health index score for the most advantaged class was found to be 2.17 times higher than the score for the most disadvantaged class.

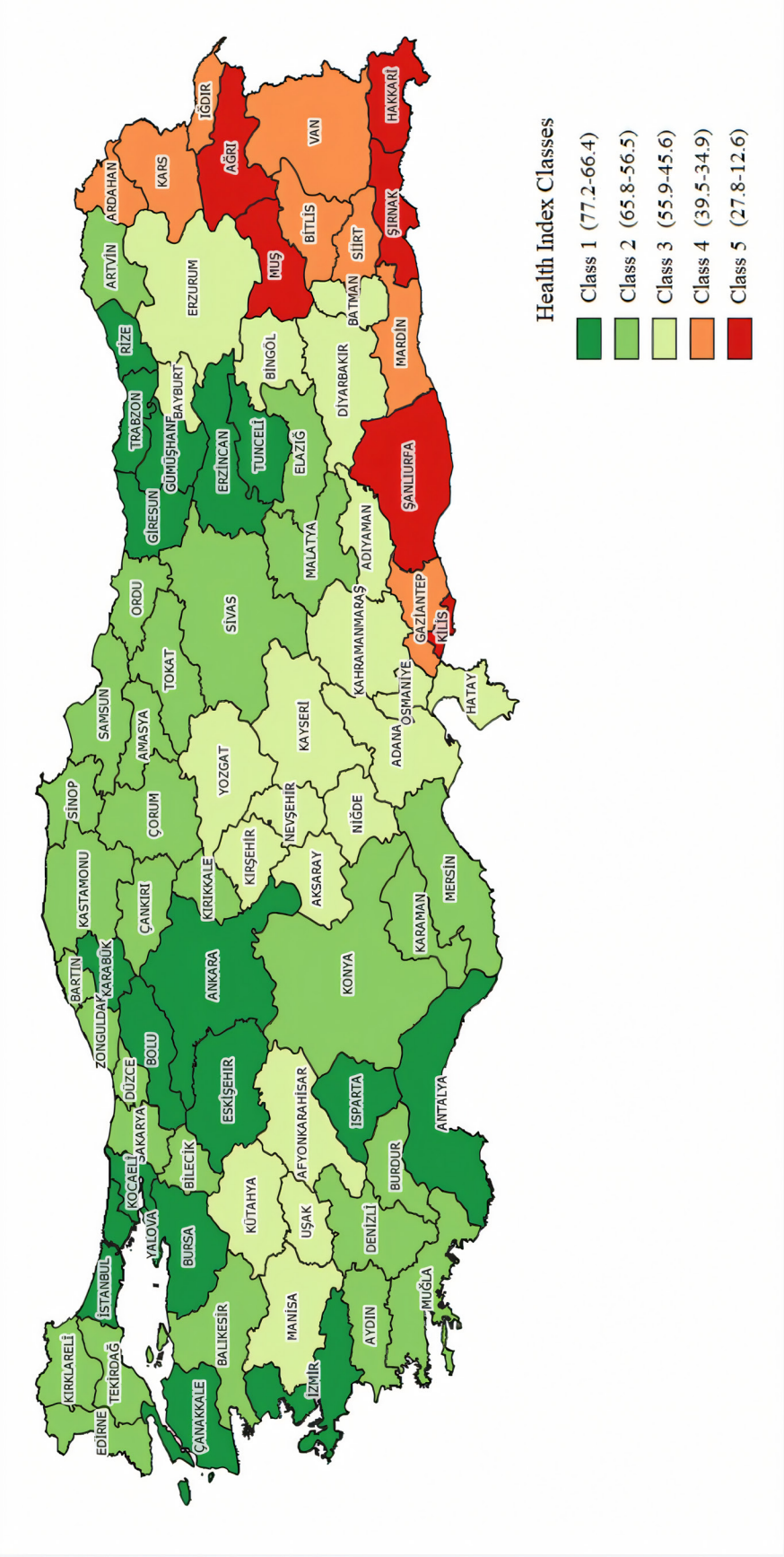

Figure 3: Classes of provinces in the health index

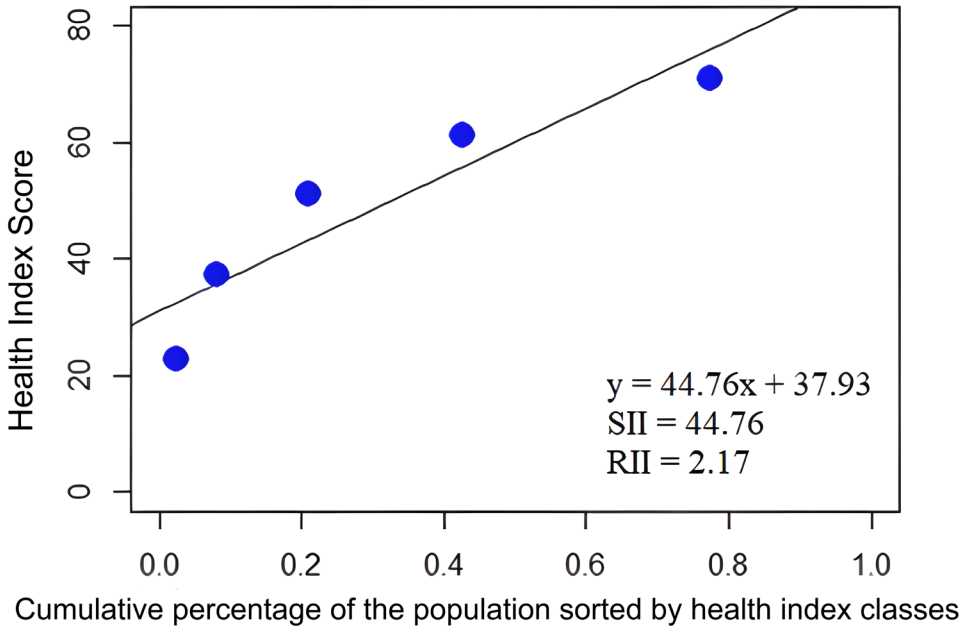

Figure 4: Slope index of inequality (SII) and relative index of inequality (RII) values for the health index

Uncertainty analysis of the health index

The results of the Monte Carlo simulation, which cover 5000 scenarios involving various options in weighting, normalization, and aggregation stages were shown in Figure 5. The median value of the provinces' rankings in 5000 simulations was denoted by a black dot, while the red bars showed the 95% confidence interval of these rankings.

For all provinces except Çankırı and Düzce, the difference between their original health index rank and the median rank in the simulated scenarios was five or less. The provinces with the widest confidence intervals in the simulated scenarios were Tunceli (38 ranks), Gümüşhane (34 ranks) and Çankırı (23 ranks). While Hakkâri province consistently ranked last in all simulated scenarios, the provinces with the narrowest confidence intervals were Şanlıurfa (one rank), Kilis (two ranks) and Bolu (two ranks).

Discussion

Although examples of using composite indices to measure health have increased in the literature, their implementation in this field is quite limited for Türkiye. In a few studies where provinces were ranked based on a composite health index in Türkiye, it is observed that the provinces with the highest and lowest scores aligned closely with the results of our study. In Çağlar and Keten's study, Trabzon and Bolu were listed among the top 10 provinces with the highest scores in a composite health index, which considered infrastructure, human resources, service, and health indicators. Conversely, Şırnak, Hakkâri, Ağrı, Muş, Van and Şanlıurfa provinces were among the last 10 provinces with the lowest score (12).

TURKSTAT's 2015 research on the "Well-Being Index" is a notable example of employing the composite index approach for provinces within Türkiye. In this research, the composite index was developed to combine various dimensions of life quality into a single measure (13). In Alpaykut's study, in which he weighted the variables in "Well-Being Index" with principal component analysis and ranked the provinces with the TOPSIS method, the index rankings of the provinces largely overlapped with the rankings of the provinces in our study. In common with our study, the provinces of İstanbul, Ankara, İzmir, Trabzon, Antalya, Karabük and Eskişehir were in the top 10, while Şanlıurfa, Hakkâri, Mardin, Şırnak, Ağrı, Kilis, Muş and Siirt were in the bottom 10 (14). In this context, it is possible to infer that the concepts of a well-being and health are closely related in terms of their components and results.

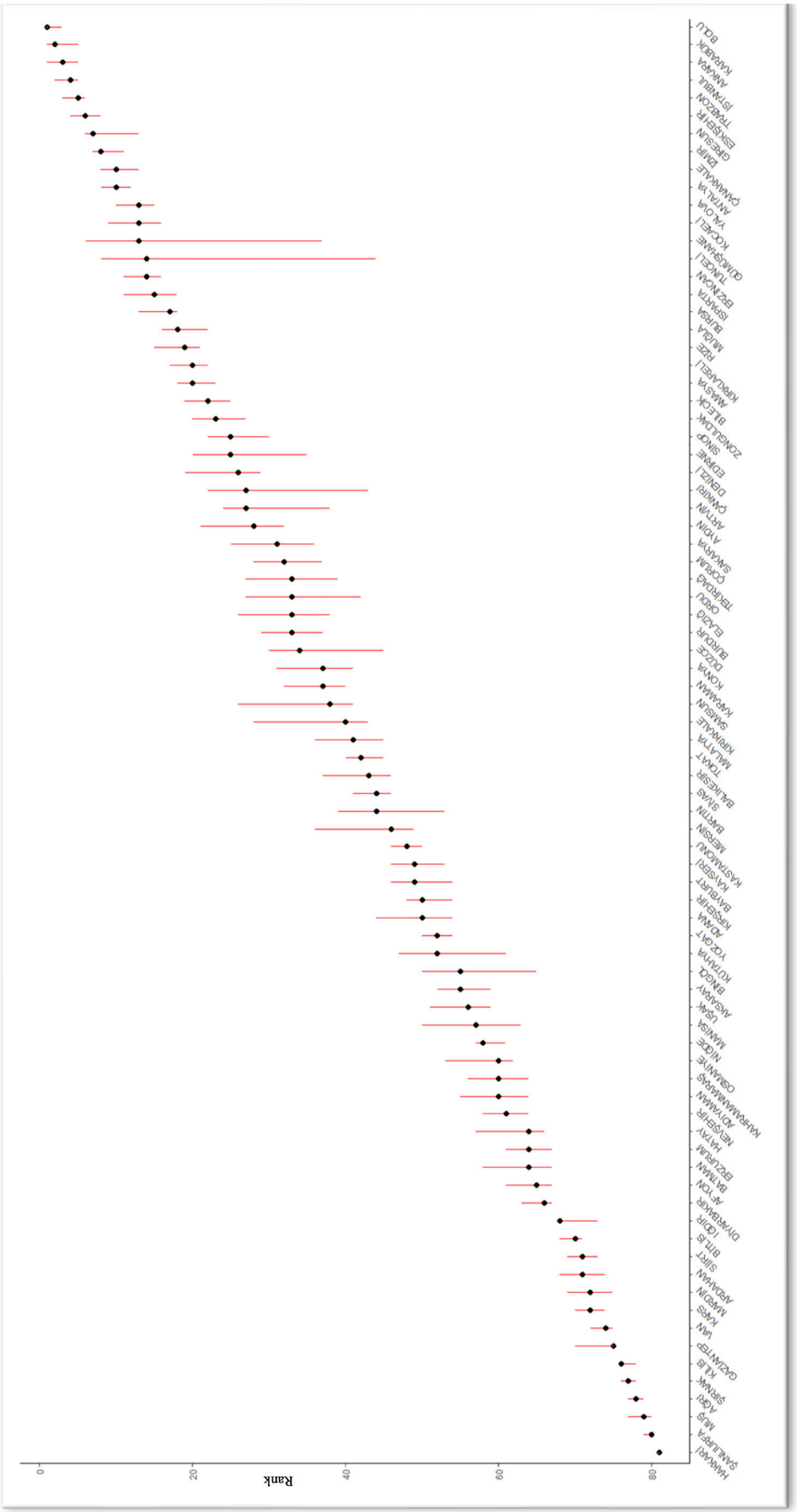

Figure 5: Median ranks and 95% confidence intervals of provinces in Monte Carlo simulation

In Türkiye, another instance of research that utilizes the composite index methodology is the "*Socioeconomic Development Index*" (SEGE) studies, which analyze and compare the development levels of provinces through variables that capture various dimensions of socioeconomic development, including health. In the SEGE 2017 study, similar to our index rankings, the provinces of İstanbul, Ankara, İzmir, Antalya, and Eskişehir were listed in the top 10, while the provinces of Şanlıurfa, Mardin, Siirt, Van, Hakkâri, Muş, Ağrı, and Şırnak were listed in the bottom 10 (15). These findings emphasize that socioeconomic development and health are inextricably linked, implying that prioritizing policies to enhance socioeconomic development is essential for reducing health inequalities.

In our study, after determining the composite index scores and their rankings, we divided the provinces with similar scores into five classes based on the Jenks natural breakdown algorithm. The first class included 18 provinces, predominantly from the Western Marmara, Eastern Marmara, Aegean, Western Anatolia, Mediterranean, and Western Black Sea regions. However, the majority of the provinces in Southern and Eastern Anatolia regions were in the fourth or fifth class. Although different statistical methods and variable structures were used in various studies aiming to classify provinces based on their health levels, a common theme, similar to our findings, was that the provinces in the most advantaged group were predominantly located in Western Anatolia, Aegean, Mediterranean, Marmara, and Eastern Black Sea regions. Conversely, the provinces in the most disadvantaged group were mostly in Eastern and Southeastern Anatolia regions (16, 17).

The application of the Monte Carlo simulation in our analysis revealed that the confidence intervals for provinces in the most advantaged and disadvantaged classes were mostly narrow. This finding supports the view that there was a real difference in health inequality between classes, regardless of the methodology used. In light of this, our health index can serve as a decision support system for health authorities at national and local levels. At the national level, the composite health index can be integrated into strategic plans to reduce health inequalities and used as a policy tool in resource allocation, health workforce planning, and high-risk areas determination processes. Within the local context, our composite health index can function as a guide for provincial health and development plans to reduce health inequalities by providing concrete evidence to highlight the province's health strengths and weaknesses, identify priority investment areas, and strengthen intersectoral collaboration. In addition, since our health index is based on routinely collected data, it can also be updated annually and used as an early warning tool in monitoring and evaluating health inequalities.

A few provinces in our study exhibited considerable differences in their rankings between the health determinants and the health outcomes sub-indexes. For instance, Gümüşhane and Tunceli provinces had a better ranking in the health outcomes sub-index compared to the health determinants sub-index. Given that all variables in the health outcomes sub-index pertained to mortality, it is essential to take into account the comprehensiveness of the death notification system when assessing provincial scores in this sub-index.

Before the death notification system was revised, multiple studies indicated that some deaths did not have complete death certificates and there were notable deficiencies and errors in the completed documents (18, 19). Even though data has indicated a significant improvement in nationwide death notification comprehensiveness in recent years, there is a lack of data regarding the extent of this improvement at a provincial level (20).

Unlike Gümüşhane and Tunceli, Kilis and Gaziantep provinces had a better ranking in the health determinants sub-index compared to the health outcomes sub-index. One of the common features of these two provinces is that they have the highest ratio of registered Syrian population under temporary protection to the provincial population. The registered Syrian population accounted for 17.9% of the total population in Gaziantep and 38.4% in Kilis (21).

According to Aygün et al. health system experienced a substantial strain due to the arrival of refugees, leading to a worsening of several indicators including the per capita numbers of doctors,

midwives, hospitals, and adult intensive care units (22). However, Verme and Schuettler's study reported that the impact of refugees on the well-being of households was largely positive due to the expansionary effects of the economy (23). While we do not have specific data on how the health outcomes of the local people have changed in the provinces where Syrian refugees are concentrated, such as Gaziantep and Kilis, these studies suggest that impacts are conditional on baseline capacity and response ability rather than being intrinsically linked to the presence of refugees.

One possible explanation for the difference in rankings between the health outcomes and the health determinants sub-indexes is the lack of data on social determinants like health behaviors, healthcare accessibility, healthcare quality, income inequality, and social capital at the provincial level.

There were some limitations in our study. The primary limitation of our study stemmed from the lack of data. The availability of data was the most crucial factor in selecting the variables for the composite health index. In the absence of provincial data on morbidity and quality of life, the health outcomes sub-index was established based on mortality variables. Also, there was a limitation in terms of not knowing the extent to which the data quality criteria for data obtained from different institutions and organizations were met. Despite these limitations, health was consolidated into a composite index using a well-accepted methodology that evaluates not only health outcomes but also the social determinants of health in alignment with the biopsychosocial health model.

Conclusions

In conclusion, our composite health index, which took a multidimensional approach to health, showed that the provinces in Western Anatolia, Aegean, Mediterranean, Marmara, and Eastern Black Sea regions were in the top classes, whereas provinces in the Eastern and Southeastern regions were in the lower classes. Nevertheless, the narrow confidence intervals in the Monte Carlo simulation for the rankings of provinces in the most advantaged and the most disadvantaged classes indicated that health inequalities between these classes were independent of the methodological choices. The use of the composite health index to rank provinces and uncover health inequalities should be considered a key tool for assessing community health and developing evidence-based policies. There is a need to enhance studies in this area within Türkiye. Given that the validity and reliability of a composite index are closely linked to the scope and quality of the data, it is crucial to improve the data system for our country. Utilizing data derived from districts or smaller spatial units to formulate composite health indices will help uncover health inequalities at a microscale which in turn enables the strategic adjustments of regional health investments towards disadvantaged areas. In accordance with the social determinants of health framework, a multi-stakeholder strategy that engages not only the health sector but also other relevant sectors should be considered as a critical step towards broadening the scope of health data and drawing the attention of policymakers.

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Supplementary 1: Calculation of variables in the index and rationale for their inclusion

Variables	Calculation	Rationale
Life expectancy at birth	It is calculated through the life tables without employing Bennett-Horiuchi technique based on data obtained from TURKSTAT.	It is a key measure of health risks, the frequency and severity of diseases, the effectiveness of healthcare strategies, and indicates the general mortality rate in a population.
Maternal mortality ratio	$\left(\frac{\text{Number of maternal deaths}}{\text{Total number of live births}}\right) \times 100\,000$	Reflects the ability of health systems to provide effective healthcare to prevent and address complications arising during pregnancy.
The years of potential life lost (YPLL)	Total YPLL=∑ [(Number of deaths in each age group) × (75 - midpoint of each age group)] YPLL Rate= (Total YPLL / Population under 75 years of age) × 100 000	Determining the level and causes of deaths at younger ages is an important measure for developing effective public health services and interventions.
Under-five mortality rate	$\left(\frac{\text{Number of deaths under 5 years of age}}{\text{Total number of live births}}\right) \times 1000$	In most cases, it reflects the social, economic, and environmental conditions, including healthcare, of children and others in the community.
Dependency ratio	$\left(\frac{\text{Population (0-14)+ Population (65+)}}{\text{Population (15-64)}}\right) \times 100$	The dependency ratio reflects general trends regarding social support demands and how shifts in the age structure of the population could affect social, economic, and health-related factors.
Consanguineous marriage rate	$\left(\frac{\text{Number of consanguineous marriage}}{\text{Total number of marriages}}\right) \times 100$	Consanguineous marriages are linked to negative pregnancy results and various reproductive and fertility complications that can have harmful effects on both mothers and their children.

Adolescent fertility rate	$\left(\frac{\text{Number of live births in women aged 15-19}}{\text{Total number of women aged 15-19}}\right) \times 1000$	Adolescent pregnancies are linked to a greater risk of complications and death during pregnancy and childbirth. Adolescent pregnancies, in addition to their direct health effects, significantly restrict women's opportunities for socioeconomic development.
Graduation rate from universities and other higher educational institutions. (Aged 25 years or above)	$\left(\frac{\text{Number of universities or other higher institution graduates (Aged 25 years or above)}}{\text{Population aged 25 years or above)}}\right) \times 100$	Higher levels of education are associated with improved employment and income prospects, as well as more favorable health and social outcomes compared to individuals with lower education levels.
Net enrollment rate in pre-primary education	$\left(\frac{\text{Number of students attending pre-primary education aged 3-5 years}}{\text{Total number of children aged 3-5 years}}\right) \times 100$	Early childhood education has the potential to be a protective factor against future diseases and disabilities by enhancing children's cognitive and social development.
Illiteratecy rate (Aged 15 years or above)	$\left(\frac{\text{Number of illiterate people (Aged 15 years or above)}}{\text{Population aged 15 years or above}}\right) \times 100$	Literacy is the most important factor in helping every child, young person and adult acquire the basic life skills that enable them to cope with the challenges they face in life.

Gross domestic product per capita by provinces	$\left(\frac{\text{Gross domestic product of provinces}}{\text{Mid-year population of provinces}}\right)$	GDP is closely connected to other indicators that measure the social, economic, and environmental well-being, along with the health status of the country and its people.
Average daily earnings subject to contributions	$\left(\frac{\text{Amount of earnings subject to contributions in a year}}{\text{Number of contributions payment days in a year}}\right)$	A province with a high average daily earnings indicates a strong added value, widespread employment in various sectors, and a high-quality workforce.

Percentage of population covered by social security	$\left(\frac{\text{Number of people covered by social security}}{\text{Total population}}\right) \times 100$	Evidence from various studies using different data sources and analytical approaches consistently supports the notion that social insurance coverage is linked to increased use of health services and positive health outcomes.
Unemployment rate (Aged 15 years or above)*	$\left(\frac{\text{Number of unemployed people}}{\text{Total population in the labor force}}\right) \times 100$	The presence of unemployment is a potential contributor to health disparities and has a significant role in sustaining overall health and wellness.

**Since there is no data at the provincial level for the relevant indicator, the data obtained at the NUTS-2 level was included in the index as a proxy indicator for provincial estimates.*

Annual average concentration of $PM_{2.5}$	The average annual PM2.5 levels were calculated by averaging the measurements from stations that recorded data on 75% or more days in a year within the provinces, following the criterion set by the European Environment Agency. In provinces that do not meet this criterion, we calculated the annual PM2.5 averages by using the PM10 values measured at 75% and above, multiplied by the conversion coefficient recommended by the World Health Organization (0.66327).	PM2.5 is one of the most important air pollutants and a major risk factor for health. PM2.5 levels are often used to monitor air pollution trends, identify high-risk areas, and assess the impact of air quality policies.
Annual average concentration of PM_{10}	The average annual PM10 levels were calculated by averaging the measurements from stations that recorded data on 75% or more days in a year within the provinces, following the criterion set by the European Environment Agency.	PM10 levels are another indicator used to monitor air pollution trends, identify high-risk areas, and evaluate the effects of air quality policies.
Proportion of forest areas	$\left(\frac{\text{Total forest area (ha)}}{\text{Total land area (ha)}}\right) \times 100$	Natural areas, especially forests have positive effects on physical and mental health in numerous ways.

The percentage of the built-up area of cities that is open space for public use for all	$\left(\frac{\text{Total surface of open public space + Total surface of land allocated to streets}}{\text{Total surface of built up area of the urban agglomeration}}\right) \times 100$	The availability of urban spaces is a crucial factor in maintaining public health, as they offer opportunities for physical activity, social interaction, and neighborhood harmony.
The percentage of the total municipal population served by sewerage system	$\left(\frac{\text{Total municipal population served by sewerage system}}{\text{Total municipal population}}\right) \times 100$	Sanitation services, such as providing sufficient water and sewerage systems, are crucial for health and well-being, and are also recognized as a human right.
The percentage of the total municipal population served by wastewater treatment plants	$\left(\frac{\text{Total municipal population served by wastewater treatment plants}}{\text{Total municipal population}}\right) \times 100$	A reliable wastewater treatment system is an important indicator of the level of local development and public health. Improving water treatment has been shown to reduce the occurrence of various waterborne diseases.
Proportion of municipal solid waste gathered and treated in regulated facilities compared to the total municipal waste	$\left(\frac{\text{Total municipal solid waste collected and managed in a controlled facility}}{\text{Total municipal solid waste generated by the city}}\right) \times 100$	Proper management of waste materials has significant long-term effects on community health, economic stability, and ecological systems.
Average household size by provinces	$\left(\frac{\text{Total population of households}}{\text{Total number of households}}\right)$	Space per person in a dwelling is commonly related to particular health risks and is therefore considered a key criterion for identifying poor housing conditions.
The number of intensive care unit beds per 10 000 people	$\left(\frac{\text{Total number of intensive care unit beds}}{\text{Total population}}\right) \times 10\,000$	Monitoring the count of intensive care units is crucial for the healthcare system to respond effectively to critical situations and prevent negative health outcomes.
The number of hospital beds per 10 000 people	$\left(\frac{\text{Total number of hospital beds}}{\text{Total population}}\right) \times 10\,000$	Monitoring the number of beds is not only a general indicator of health service capacity but also an important indicator of inequalities in the allocation of health resources.

The number of qualified beds per 10 000 people	$\left(\frac{\text{Total number of qualified hospital beds}}{\text{Total population}}\right) \times 10\,000$	Various qualities of hospital beds may affect the overall quality of care. Hospital rooms with single beds have been linked to lower rates of nosocomial infections and decreased need for patient transfers.
The number of pharmacists per 10 000 people	$\left(\frac{\text{Total number of pharmacists}}{\text{Total population}}\right) \times 10\,000$	Pharmacists serve an important function in healthcare by managing the distribution of medicines to consumers and promoting their safe and effective use.
The number of dentists per 10 000 people	$\left(\frac{\text{Total number of dentists}}{\text{Total population}}\right) \times 10\,000$	The initial stage in organizing basic oral and dental health services is keeping track of the dentist count as well as oral and dental health centers.
The number of nurses and midwives per 10 000 people	$\left(\frac{\text{Total number of nurses and midwives}}{\text{Total population}}\right) \times 10\,000$	Nursing and midwifery services are crucial for health promotion, disease prevention and the provision of primary and community care.
The number of physicians per 10 000 people	$\left(\frac{\text{Total number of physicians}}{\text{Total population}}\right) \times 10\,000$	The number of physicians is closely related to many health outcomes, such as immunization coverage, infant and child mortality, and all-cause mortality.