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An application of the InterCriteria Analysis approach to health-related quality of life

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Abstract: In this paper we present an application of the InterCriteria Analysis (ICA) approach to real data connected with health-related quality of life (HrQoL). The EQ-5D-3L questionnaire for measuring HrQoL for a representative sample of 1050 residents of Burgas is used. The aim is to analyze the correlations between the health indicators used by the questionnaire.
Keywords: InterCriteria Analysis, Health-related quality of Life, EQ-5D-3L questionnaire, Intuitionistic fuzzy sets, Index matrix, Multicriteria decision making.
AMS Classification: 03E72.

1 Introduction

Health promotion is the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities. Therefore, health promotion is not just the responsibility of the health sector, but goes beyond healthy life-styles to well-being [20].

In health promotion research and practices, health-related quality of life (HrQoL) has been increasingly acknowledged as a valid and appropriate indicator to measure health needs and outcomes. Measuring health rather than disease is a methodological challenge which has recently received more attention and should be further explored in target-setting exercises at a community level. Well-being targets, including health perception have to be currently mainstreamed [19].

The concept of HrQoL refers to a personal perception of physical and mental health, and social functioning over time. HrQoL-questionnaires have become an important component of health surveillance systems (although not a practice in Bulgaria, conducted by the country at national level yet). Researchers in the public health domain use HrQoL-instruments to measure the effects of health promotion interventions or to monitor the self-reported health in a community in order to identify population needs. Evaluation of HrQoL can identify health inequalities in different subgroups and can help to guide policies or interventions to improve the population health.

In this paper we present the first application of the ICA method for the health status data for measuring HrQoL.

The purpose of this development is to identify the most correlated indicators in the EQ-5D-3L questionnaire for measuring HrQoL. By applying the ICA approach over extracted data for HrQoL, we can find the indicators that have the highest dependencies, or opposite indicators and indicators that frequently are independent from each other. In this way we can observe the behavior of them in time. In the current investigation we analyze the data over the period 2010–2013.

2 Presentation of the ICA

The ICA method helps to discover the relationships and examine the correlations between the indicators used in the EQ-5D-3L questionnaire for measuring HrQoL. The ICA method is introduced by K. Atanassov, D. Mavrov and V. Atanassova in [4]. Several applications of the method have been already published [6–10]. The method is based on the theory of the intuitionistic fuzzy sets and the index matrices. The intuitionistic fuzzy sets are defined by Atanassov [2]. They are an extension of the concept of fuzzy sets defined by L. Zadeh [21]. The theory of index matrices is introduced in [3].

The objects can be estimated on the base of several criteria. The number of the criteria can be reduced by taking into account the correlations of each pair of criteria presented in the form of intuitionistic fuzzy pairs (IFs pairs) of values [5]. The intuitionistic fuzzy pairs of values are the intuitionistic fuzzy evaluations in the interval [0, 1]. The relations can be established between any two group of indicators C_w and C_t.

Let us have a number of C_q group of indicators, $q = 1, \ldots, n$, and a number of O_p residents, $p = 1, \ldots, m$. So we use the following sets: a set of group of indicators $C_q=\{C_1, \ldots, C_n\}$ and a set of residents $O_p = \{O_1, \ldots, O_m\}$.

We will evaluate 13 residents (objects) using 6 groups of criteria. We obtain an index matrix M that contains two sets of indeces, one for rows and another for columns. For for every p, q ($1 \le p \le m$, $1 \le q \le n$), O_p in an evaluated object, C_q is an evaluation criterion, and a_{O_p,C_q} is the evaluation of the p-th object against the q-th criterion, defined as a real number or another object that is comparable according to relation R with all the rest elements of the index matrix M.

$$M = \begin{array}{c|ccccccc} & C_1 & \dots & C_k & \dots & C_l & \dots & C_n \\ \hline O_1 & a_{O_1,C_1} & \dots & a_{O_1,C_k} & \dots & a_{O_1,C_l} & \dots & a_{O_1,C_n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ O_i & a_{O_i,C_1} & \dots & a_{O_i,C_k} & \dots & a_{O_i,C_l} & \dots & a_{O_i,C_n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ O_j & a_{O_j,C_1} & \dots & a_{O_j,C_k} & \dots & a_{O_j,C_l} & \dots & a_{O_j,C_n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ O_m & a_{O_m,C_1} & & a_{O_m,C_k} & & a_{O_m,C_l} & \dots & a_{O_m,C_n} \end{array}.$$

The next step is to apply the InterCriteria Analysis for calculating the evaluations. The result is a new index matrix M^* with intuitionistic fuzzy pairs $\langle \mu_{C_k,C_l}, \nu_{C_k,C_l} \rangle$ that represents an intuitionistic fuzzy evaluation of the relations between every pair of criteria C_k and C_l. In this way the index matrix M that relates the evaluated objects with the evaluating criteria can be transformed to another index matrix M^* that gives the relations among the criteria:

$$M^* = \begin{array}{c|ccc} & C_1 & \dots & C_n \\ \hline C_1 & \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \dots & \langle \mu_{C_1,C_n}, \nu_{C_1,C_n} \rangle \\ \dots & \dots & \dots & \dots \\ C_n & \langle \mu_{C_q,C_1}, \nu_{C_q,C_1} \rangle & \dots & \langle \mu_{C_n,C_n}, \nu_{C_n,C_n} \rangle \end{array}$$

The last step of the algorithm is to determine the degrees of correlation between groups of indicators depending of the chosen threshold for μ and ν from the user. The correlations between the criteria are called "positive consonance", "negative consonance" or "dissonance". Here we use the scale used in previous studies that is shown in Figure 1, [1].

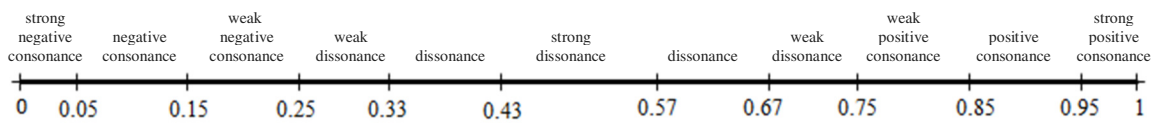

Figure 1. Scale for determination of the type of the correlations between the criteria

3 Application of the ICA to health-related quality of life

The HrQoL was observed in a community – the residents of Burgas, the fourth largest Bulgarian city, and further was assessed the influence of socio-economic, demographic, and behavioural factors on HrQoL. The relationship between HrQoL and social capital (SC) is analyzed through a network-based approach, namely, a membership in 2 types of organizations [14]. Applying the learnings from the results, policies and interventions are proposed which can be a vehicle in the decision-making processes for HrQoL improvement in the community. The ambition was to generate relevant data and to provide analysis and evidence that would assist policymakers and local non-governmental organizations (NGOs) to build their programs aiming at improving health status and/or managing health issues. The preliminary results have

been reported to 29th Conference of the EuroQol Foundation in Rotterdam, 2012 [16], recently published in the peer-reviewed journal Health Promotion International [18] and reported during the 8th European Public Health Conference in Milan [17]. EQ-5D-3L questionnaire for measuring HrQoL is used for the first time in Bulgaria at a community level and the Bulgarian version was provided by the EuroQol Group, especially for the project. The EQ-5D-3L is a standardized generic self-administered questionnaire which defines health in five dimensions including mobility, self-care, usual activities (work, study, housework, family, or leisure), pain or discomfort, and anxiety or depression. Each dimension has three levels ranging from "no problem", then "some problem", and to "extreme problem". Furthermore, EQ-5D-3L consists of two components. The first part is a questionnaire, a descriptive element with the five dimensions. Respondents rating their health status are asked to select the level of dimension which describes at best their "health today". On the second part respondents record each their self-rating of health on a 20-cm Visual Analogue Scale (VAS – "Thermometer" type) anchored by "100 – denoting as best imaginable health state" and "0 – denoting as worst imaginable health state." The validity and reliability of the EQ-5D-3L questionnaire have been tested extensively [11, 12, 15]. Since 2013 the EQ-5D-3L instrument has been used in 20 national surveys and 7 regional population surveys [13].

A cross-sectional study was conducted in March–May 2011, using a representative sample of the citizens of Burgas (n = 1050, ≥ 18 years old) with a single exclusion criteria being institutionalised people. The survey sample was drawn using the method of two-stage random selection – first selecting the living area and then randomly selecting respondents from a particular neighborhood (10 quarters). The number of the respondents was determined by the official regional statistics (Burgas-GRAO-municipality register) for age, gender and number of people living in each neighborhood. The interviews were conducted by employees of the municipality under the supervision of the NGO "PublicHealth-99". If the individual selected at random was unavailable, a substitute was selected at random from the same living quarter, age and gender. Thus the planned sample reached the number of 1050 respondents and it could be stated that the response rate for the EQ-5D-3L-questionnaire is 100% (substitution was allowed). The population of Burgas from the last census and the EQ-5D-sample are similar in proportions according to the demographic characteristic of Burgas (age and gender). Also our sample is roughly representing the ethnic structure of the urban Bulgarian population, reported during the last census. Only pensioners are over-represented which corresponds with our interest towards health-related problems of the elderly in the community.

3.1 Applying the method for a representative sample of the citizens of Burgas

The testing matrices which contain μ-values and ν-values for representative sample of the 1050 citizens of Burgas are presented in the Tables 1a and 1b. The indicators are mobility, self-care, usual activities, pain or discomfort, and anxiety or depression, VAS – "Thermometer" type and Age.

μ	mobility	self_care	usual_act	pain_discomf	anxiety_depr	VAS	Age
mobility	1.000	0.725	0.735	0.577	0.461	0.098	0.376
self_care	0.725	1.000	0.793	0.537	0.439	0.080	0.311
usual_act	0.735	0.793	1.000	0.567	0.457	0.091	0.337
pain_discomf	0.577	0.537	0.567	1.000	0.513	0.110	0.428
anxiety_depr	0.461	0.439	0.457	0.513	1.000	0.188	0.385
VAS	0.098	0.080	0.091	0.110	0.188	1.000	0.222
Age	0.376	0.311	0.337	0.428	0.385	0.222	1.000

Table 1a. Membership part of the intuitionistic fuzzy pairs for a representative sample

ν	mobility	self_care	usual_act	pain_discomf	anxiety_depr	VAS	Age
mobility	0.000	0.007	0.010	0.016	0.068	0.380	0.088
self_care	0.007	0.000	0.006	0.013	0.064	0.316	0.065
usual_act	0.010	0.006	0.000	0.011	0.064	0.351	0.089
pain_discomf	0.016	0.013	0.011	0.000	0.056	0.434	0.107
anxiety_depr	0.068	0.064	0.064	0.056	0.000	0.399	0.201
VAS	0.380	0.316	0.351	0.434	0.399	0.000	0.718
Age	0.088	0.065	0.089	0.107	0.201	0.718	0.000

Table 1b. Non-membership part of the intuitionistic fuzzy pairs for a representative sample

From the Tables 1a and 1b following outcomes are obtained:

- According the scale for determination of the type of the correlations from Figure 1 there is no strong dependence among the indicators. The correlations between them are principally in dissonance and negative consonance;
- There is one pair of indicators than is weak positive consonance: "self_care – usual_act": ⟨0.792842; 0.00563258⟩;
- There is one pair of indicators than is with high ν-value: "VAS - Age": ⟨0.221586; 0.718103⟩. This correlation means that with increasing the age self-rating of health decrease.
- Two pairs of indicators are in weak dissonance ("mobility – usual_act", "mobility – self_care"), five pairs of indicators are in disonance ("mobility – pain_discomf", "pain_discomf – Age", "anxiety_depr – Age", "mobility – Age", "usual_act – Age"), six pairs of indicators are in strong dissonance ("usual_act – pain_discomf", "self_care – pain_discomf", "pain_discomf – anxiety_depr", "mobility – anxiety_depr", "usual_act – anxiety_depr", "self_care – anxiety_depr"), one is in weak dissonance ("self_care – Age"), two are in weak negative consonance ("VAS – Age", "anxiety_depr – VAS"), four are in negative consonance ("pain_discomf – VAS", "usual_act – VAS", "mobility – VAS", "self_care – VAS").

3.2 Applying the method for a representative sample of the citizens of Burgas by age

The interviewed 1050 people are distributed in the following age intervals: 18–24, 25–34, 35–44, 45–54, 55–64, 65–74 and over 75 years. In Table 2 the numbers of pairs of criteria by age

intervals obtained by applying the ICA method are shown. In Table 3 are given the intuitionistic fuzzy pairs for a representative sample of the 1050 citizens of Burgas by age intervals.

Type of correlations	Age intervals						
	18–24	25–34	35–44	45–54	55–64	65–74	over 75
positive consonance [0,85; 0,95)	1	3	3	0	0	0	0
weak positive consonance [0,75; 0,85)	3	0	0	1	0	0	1
weak dissonance [0,67; 0,75)	2	0	0	2	1	1	0
dissonance [0,57; 0,67)	1	0	0	0	2	2	3
strong dissonance [0,43; 0,57)	3	7	7	7	4	4	3
dissonance [0,33; 0,43)	2	1	1	2	6	5	8
weak dissonance [0,25; 0,33)	1	2	2	2	4	5	1
weak negative consonance [0,15; 0,25)	5	4	3	2	3	1	1
negative consonance [0,05; 0,15)	3	4	5	5	1	3	4

Table 2. Numbers of pairs of criteria by age intervals

IFs pairs	18–24	25–34	35–44	45–54	55–64	65–74	over 75
self_care-usual_act	⟨0.898,0.001⟩	⟨0.861,0.002⟩	⟨0.885,0.002⟩	⟨0.711,0.009⟩	⟨0.693,0.013⟩	⟨0.744,0.008⟩	⟨0.762,0.009⟩
mobility-self_care	⟨0.829,0.001⟩	⟨0.875,0.000⟩	⟨0.874,0.001⟩	⟨0.707,0.004⟩	⟨0.573,0.034⟩	⟨0.653,0.010⟩	⟨0.618,0.012⟩
mobility-usual_act	⟨0.805,0.004⟩	⟨0.860,0.003⟩	⟨0.885,0.001⟩	⟨0.815,0.004⟩	⟨0.599,0.034⟩	⟨0.590,0.024⟩	⟨0.632,0.017⟩
usual_act-pain_discomf	⟨0.770,0.000⟩	⟨0.552,0.016⟩	⟨0.544,0.000⟩	⟨0.514,0.000⟩	⟨0.516,0.037⟩	⟨0.543,0.011⟩	⟨0.555,0.015⟩
mobility-pain_discomf	⟨0.720,0.011⟩	⟨0.537,0.023⟩	⟨0.527,0.017⟩	⟨0.524,0.005⟩	⟨0.544,0.024⟩	⟨0.562,0.012⟩	⟨0.576,0.015⟩
self_care-pain_discomf	⟨0.689,0.05⟩	⟨0.535,0.009⟩	⟨0.531,0.005⟩	⟨0.497,0.000⟩	⟨0.485,0.033⟩	⟨0.510,0.016⟩	⟨0.557,0.021⟩
pain_discomf-anxiety_depr	⟨0.571,0.035⟩	⟨0.546,0.044⟩	⟨0.533,0.049⟩	⟨0.509,0.034⟩	⟨0.469,0.064⟩	⟨0.447,0.060⟩	⟨0.451,0.054⟩
self_care-anxiety_depr	⟨0.538,0.014⟩	⟨0.475,0.008⟩	⟨0.487,0.003⟩	⟨0.479,0.028⟩	⟨0.367,0.131⟩	⟨0.411,0.102⟩	⟨0.389,0.146⟩
usual_act-anxiety_depr	⟨0.531,0.018⟩	⟨0.515,0.021⟩	⟨0.518,0.003⟩	⟨0.473,0.028⟩	⟨0.374,0.131⟩	⟨0.400,0.110⟩	⟨0.409,0.118⟩
mobility-anxiety_depr	⟨0.506,0.037⟩	⟨0.491,0.028⟩	⟨0.509,0.017⟩	⟨0.501,0.035⟩	⟨0.394,0.111⟩	⟨0.422,0.084⟩	⟨0.414,0.092⟩
VAS-Age	⟨0.365,0.403⟩	⟨0.428,0.380⟩	⟨0.395,0.423⟩	⟨0.415,0.452⟩	⟨0.296,0.545⟩	⟨0.354,0.497⟩	⟨0.361,0.501⟩
anxiety_depr-Age	⟨0.335,0.156⟩	⟨0.269,0.261⟩	⟨0.289,0.228⟩	⟨0.319,0.206⟩	⟨0.340,0.221⟩	⟨0.339,0.233⟩	⟨0.306,0.280⟩
pain_discomf-Age	⟨0.271,0.097⟩	⟨0.271,0.204⟩	⟨0.303,0.180⟩	⟨0.334,0.162⟩	⟨0.335,0.124⟩	⟨0.260,0.143⟩	⟨0.354,0.149⟩
anxiety_depr-VAS	⟨0.236,0.262⟩	⟨0.174,0.376⟩	⟨0.192,0.341⟩	⟨0.137,0.393⟩	⟨0.252,0.320⟩	⟨0.269,0.316⟩	⟨0.237,0.370⟩
mobility-Age	⟨0.209,0.096⟩	⟨0.179,0.091⟩	⟨0.195,0.058⟩	⟨0.259,0.124⟩	⟨0.360,0.148⟩	⟨0.289,0.191⟩	⟨0.331,0.159⟩
usual_act-Age	⟨0.182,0.057⟩	⟨0.183,0.080⟩	⟨0.144,0.059⟩	⟨0.229,0.109⟩	⟨0.329,0.181⟩	⟨0.303,0.217⟩	⟨0.354,0.210⟩
self_care-Age	⟨0.169,0.041⟩	⟨0.147,0.034⟩	⟨0.141,0.034⟩	⟨0.194,0.025⟩	⟨0.300,1.888⟩	⟨0.309,0.212⟩	⟨0.364,0.208⟩
pain_discomf-VAS	⟨0.160,0.225⟩	⟨0.179,0.326⟩	⟨0.185,0.304⟩	⟨0.112,0.388⟩	⟨0.146,0.319⟩	⟨0.115,0.289⟩	⟨0.110,0.332⟩
mobility-VAS	⟨0.141,0.153⟩	⟨0.138,0.152⟩	⟨0.113,0.123⟩	⟨0.091,0.278⟩	⟨0.187,0.313⟩	⟨0.152,0.328⟩	⟨0.118,0.389⟩
usual_act-VAS	⟨0.124,0.098⟩	⟨0.134,0.149⟩	⟨0.098,0.091⟩	⟨0.078,0.238⟩	⟨0.170,0.345⟩	⟨0.143,0.387⟩	⟨0.138,0.446⟩
self_care-VAS	⟨0.119,0.064⟩	⟨0.124,0.072⟩	⟨0.103,0.051⟩	⟨0.063,0.116⟩	⟨0.171,0.315⟩	⟨0.114,0.426⟩	⟨0.121,0.471⟩

Table 3. Intuitionistic fuzzy pairs by age intervals

From Table 2 and Table 3, the following outcomes are obtained:

- The pair of indicators “self_care – usual_act” is in positive consonance in age period 18–44, and then becomes in weak dissonance in age period 45–74. Over 75 year the correlation between indicators increases to weak positive consonance;

- For pairs of indicators “mobility – self_care” and “mobility – usual_act” the correlations decrease. They become from weak positive consonance in age period 18–24 to positive consonance in age period 25-44, and then decrease to dissonance;
- The correlations between other indicators are in dissonance.

We can conclude that by ICA method is possible to observe which indicator has strong dependencies with others and whether the correlation appears periodically. In order to determine the behavior of each indicator over time we should observe the results of the application of InterCriteria Analysis (ICA) method for several years. If this criterion has a strong correlation, again, in the next step we can try to ignore it. Therefore the ICA method is helpful for determining the behavior of the indicators. When comparing the results of applying ICA approach over the data connected with HrQoL over the years we can observe the possible differences or changes between them.

4 Conclusions

We used the ICA method to find some hidden patterns in the data connected with HrQoL. We analyzed the data to identify the best correlations between the indicators, to discover dependent and independent indicators and the relationships between them. The comparison can help to describe the behavior of the used indicators and their assessment. In the next research the authors will analyze the indicators individually – it will make possible to compare a single indicator with all the rest ones.

The increase of the coefficient of consonance and the entry in the zone of strong positive consonance means strong correlation between the respective pair of criteria, which may justify the removal of one of the criteria in the pair on the basis that its informational values is lesser. Removal of indicators leads to simplification of the process of evaluation.

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