InterCriteria Analysis of Data Obtained from Patients with Behterev's Disease

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Abstract: *This paper continues series of research on application of the novel approach of InterCriteria Analysis (ICrA) to medical data. It describes a new method of analyzing the treatment results of patients with Behterev's disease in order to aid the decision making process for treatment course - InterCriteria Analysis. The ICrA analysis is applied on the results of medicine, physiotherapeutic treatment and kinesitherapeutical program characteristics. The main goal is an improvement of general quality of patients' life through practices of specific methodology of kinesitherapy and ergotherapy. The object of empirical study is health status of patients suffering Rheumatoid spondylitis in relation to their current life conditions. Here are analyzed the data from observation about 25 patients (14 women and 11 men, aged 25 to 67). The results confirm previously performed research, showing that the muscles in the human body are closely connected and the improving of one movement will lead to improving another. The obtained results also prove applicability of ICrA to the researched problem, give grounds for extending its application and potential of further in-depth study.*

Keywords: *InterCriteria analysis, Decision making, Bechterev's disease, Ankylosing spondylitis.*

Introduction

Behterev's disease is a chronic inflammatory disease, affecting the spine and the sacroiliac joints, and more rarely, the peripheral joints. There is a tendency to ossification and ankylosing (adhesion). It is possible that other organs like heart, eyes, lungs, etc. are also harmed [9, 14].

It is not totally clear yet what causes the Ankylosing spondylitis. What is already known is that some hereditary (genetic) factors, as well as some environmental factors (both inside and outside the system) can lead to the development of the disease. It is found out that the inclination to this development is transferred genetically and most of the patients having Behterev (about 90%) possess a gene from the complex of the tissue compatibility, called HLA-B27 [8]. The presence of this gene is not a cause of the disease, but increases the probability of its development when it appears showing its characteristic symptoms due to other environmental factors.

The most characteristic symptoms of the disease are:

- Pain in the sacroiliac region. At the beginning the pain is inconstant and one-sided. In a few months it becomes permanent and both-sided. The pain can radiate through the back surface of the femur to the knee joint. If costal-vertebrate joints are affected, there is also a pain in the chest. It becomes stronger while breathing and may cause restriction of the breathing movements. A few years after the beginning of the disease pains in the cervical sphere of the spine a stiff can appear [11, 13].
- Limited mobility. Gradually there is limitation in the movements of the spine. The pain and stiffness in the spine often wake up the patients during the night. There is some relief after moving. Spinal symptoms increase due to humidity and cold.
- Enthesopathy – painful inflammation on attachments places of tendon [7].
- Some patients may have arthritis of peripheral joint. Most commonly affected are the hip joints, less often the shoulder joints, the small joints of the hands and feet.
- Some common manifestation can also be observed – low grade fever, weakness, lack of appetite.

The main goal of the present study is to analyze the physical and functional condition of patients with Behterev's disease, before and after kinesitherapy course of treatment. For the purposes of this research we analyzed the results received from the observation of 25 patients – 14 women and 11 men, aged 25 to 67. The patients have been treated by specialized kinesitherapy methodology aiming at increasing the volume of movement in the cervical partition and decreasing limited mobility. While taking decisions about the treatment process we have applied InterCriteria Analysis (ICrA) of the data received from the observation of the patient's state in order to find the subordination between the restorations of the separate movements in the cervical partition of the spine. ICrA will permit discovery of new relations as it has been proven yet in medical object [12].

Kinesitherapy method

In the kinesitherapy method of research, applied in this article, the following criteria, listed below, have been applied, defining the dynamics in the patients' health condition.

Pain research

Quantity pain measurement (p) using the visual-analogue scale (VAS), where 0 degree stands for lack of pain, and 10 degree for maximum pain. In this research the patients themselves define the level of pain.

Angulation based on SFRT methodology

Angulation is a method of measuring the volume of movement of joints. The results are reported and written down by the SFRT methodology, where S is sagittal plane, F – frontal plane, T – transversal plane and after R – rotator moves are recorded. The results are represented with three numbers, the middle one pointing the starting (zero) position of the joint. The measurement of the physiological active volume of movement in the cervical partition is made with the help of a universal goniometer using the standard SFRT methodology. The flexibility of the cervical partition of the spine is measured in three movement axes – flexion/extension, lateral inclination left and right and rotations.

- Flexion (FL. H.) – the maximum flexion of the head reaches 80-90°. Tentatively, if volume is normal, the mandible should reach the sternum with lips closed, or the distance should be no more than two fingers.

- Extension (Ext. H.) – the normal volume of extension is approximately 70°. Normally, when extension is at its maximum, the nose and the forehead should stand horizontally.
- Lateral inclinations (L. L./L. R.) – the normal volume of lateral inclinations is about 20-45°. While examining the lateral inclinations attention should be paid to moving the ear towards the shoulder and not raising the shoulder towards the ear.
- Head rotation (H. R.) – the normal rotation is 70-90° and the mandible should not reach the frontal plane.

Specialized test

- Ottis test – shows the flexibility of the chest department of the spine – it is used to measure the flexion of the thoracic portion. The patient is on upright position. We measure 30 cm from the caudally and mark it with a pencil. The patient makes full flexion of the body and the same distance is measured again. Normal flexibility is when the distance is 3.5-5 cm bigger.
- Forestier's test – it measures the extension in the thoracic partition. The patients stand with his back to the wall and heels touching it.

Aims, tasks and means of the applied kinesitherapy

Aim of kinesitherapy: preserving and increasing the flexibility and functions of the spine – cervical partition.

Tasks of kinesitherapy: decrease of pain symptoms; improving joint nutrition; overcoming the limited mobility in the cervical partition of the spine; increase of the painless volume of movement in the cervical partition of the spine; relaxation and increase of elasticity of the muscles; impact on the psycho-emotional tonus; improvement of life quality.

Means of kinesitherapy: massage; specialized techniques for muscular relaxation and stretching; soft tissue techniques; passive gymnastics; active gymnastics; respiratory exercises.

Kinesitherapy methodology

The kinesitherapy methodology is individual for every patient. The first aim is to make the patients take active part in the process of rehabilitation. The kinesitherapy should influence the psycho-emotional tonus of the patient by means of increasing his self-confidence and belief in his own abilities. We have applied a conservative methodology of kinesitherapy (Table 1) during remission of patients with Ankylosing spondylitis. Patients have individual programmers lasting 60 min. The massage is applied in order to decrease pair symptoms and prepare tissues for active motor therapy. The massage improves blood circulation and the nutrition of the back tissues. It influences the central nervous system – relaxing, pain relief and increasing the psycho emotional tonus.

The aim of the muscular relaxation and stretching is to improve the function of the soft structures and joints whose movements are limited by the hypertension of the hypertonic or shortened muscles. With patients undergoing remission from ankylosing spondylitis we have successfully applied the techniques of stretching the muscles and facilitating the volume of movement in the cervical partition of the spine.

The application of soft-tissue techniques leads to decreasing the tension, improving the flexibility of the cervical partition and regaining the correct posture of the head and neck.

Table 1. Exemplary methodology of kinesitherapy

	Constance	Dosage	Tasks	Instructions
Preparatory part	1. Massage 2. Passive gymnastic for cervical partition 3. Respiratory exercises	4. Massage – 10 min 5. Passive gymnastic – 3-5 min 6. Respiratory exercises – 2-3 min	1. Improving blood circulation 2. Improving the limited volume of activity. 3. Preparation of the body for subsequent loading. 4. Improving respiratory function.	The preparatory massage is toning, stronger techniques are used. The patient should be relaxed in a maximum way. Inhalation is through the nose and exhale – through the mouth.
Main part	1. Specialized techniques from muscular relaxation and stretching 2. Soft tissue techniques 3. Active gymnastic	1. Specialized techniques from muscular relaxation and stretching – 20 min 2. Soft tissue techniques – 10 min 3. Active gymnastic – 10 min	4. Relaxation of the muscular 5. Improving mobility of the spine 6. Overcoming stiffness in the cervical partition of the spine.	The duration of the isometric contraction is defined according to the age and abilities of the patient. Initial positions: lying on the back. Sitting and standing.
Closing part	1. Autostreching 2. Respiratory exercises 3. Relaxing massage	1. Autostreching – 5 min 2. Respiratory exercises – 2-3 min 3. Relaxing massage – 10 min	General relaxation of the patient	The patient should be relaxed. Inhalation is through the nose and exhale – through the mouth.

The application of passive exercises in painless volume aims at improving the nutrition of the cervical partition of the spine without causing pain. The multiple repetitions of passive exercises give the patient the opportunity of making movement easier. Passive movements are performed following the physiological axes.

Active physical exercises also have a considerable effect on keeping the volume of movement of the cervical partition of the spine. Active respiratory gymnastics is also widely applied. It leads to improving the respiratory abilities.

InterCriteria analysis

The presented multicriteria decision making method is based on two fundamental concepts: Intuitionistic Fuzzy Sets (IFSs) and Index Matrices (IMs). The concept of InterCriteria Analysis (ICrA) is based on the apparatus of IMs [5] and IFSs [1-4]. The approach is specifically developed for situations in multicriteria decision making, where some of the criteria come at a higher cost than others, for instance are harder, more expensive, more human resource or time consuming to measure or evaluate. While these criteria are considered unfavorable, the method aims to identify high enough levels of correlation between these criteria and others that are easier, cheaper or quicker to measure or evaluate, in order to disregard the unfavorable ones from the further decision making process [6, 10].

IFSs are one of the most popular extensions of Zadeh's concept of fuzzy sets. Fuzzy sets extend the classical notion of set by introducing membership function, allowing the gradual assessment of the membership of elements to a set with values from the [0; 1]-interval. Furthermore, Atanassov's intuitionistic fuzzy sets extend the concept of fuzzy sets by introducing an additional function of non-membership, evaluated in the same interval, with the requirement that both degrees are in the unit interval, and their sum also belongs to that interval. Briefly, the IFS is formally denoted by $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in E\}$, where $\mu_A(x)$ defines the membership of an element x to the set A, evaluated in the [0; 1]-interval; $\nu_A(x)$ defines the non-membership of the element x to the set A, where $\mu_A(x) \in [0; 1]$, $\nu_A(x) \in [0; 1]$, and $(\mu_A(x) + \nu_A(x)) \in [0; 1]$. Comparison between elements of two IFSs, involves pairwise comparisons between the degrees of membership and non-membership of the elements of both sets. Let us have an IM M with elements $a_{p,q}$, $p = 1, ..., m$; $q = 1, ..., n$,

$$M = \begin{array}{c|cccccccc} & O_1 & \dots & O_k & \dots & O_l & \dots & O_n \\ \hline C_1 & a_{C_1,O_1} & \dots & a_{C_1,O_k} & \dots & a_{C_1,O_l} & \dots & a_{C_1,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_i & a_{C_i,O_1} & \dots & a_{C_i,O_k} & \dots & a_{C_i,O_l} & \dots & a_{C_i,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_j & a_{C_j,O_1} & \dots & a_{C_j,O_k} & \dots & a_{C_j,O_l} & \dots & a_{C_j,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_m & a_{C_m,O_1} & \dots & a_{C_m,O_j} & \dots & a_{C_m,O_l} & \dots & a_{C_m,O_n} \end{array}, \quad (1)$$

where C_p is a criterion, taking part in the evaluation; O_q is an object, being evaluated; $a_{p,q}$ is the evaluation of the q-th object against the p-th criterion, and it is 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, so the relation $R(a_{C_kO_i}, a_{C_kO_j})$ holds for each i, j, k. The relation R has dual relation $\overline{R}$, which is true in the cases when relation R is false, and vice versa.

If the number of cases for which the relations $R(a_{C_kO_i}, a_{C_kO_j})$ and $R(a_{C_lO_i}, a_{C_lO_j})$ are simultaneously satisfied is $S^{\mu}_{k,l}$ and the number of cases for which the relations $R(a_{C_kO_i}, a_{C_kO_j})$ and its dual $\overline{R}(a_{C_lO_i}, a_{C_lO_j})$ are simultaneously satisfied is $S^{\nu}_{k,l}$, then

$$0 \le S^{\mu}_{k,l} + S^{\nu}_{k,l} \le \frac{n(n-1)}{2}. \quad (2)$$

Since the total number of pairwise comparisons between the object is $n(n-1)/2$. For every k, l, such that $1 \le k \le l \le m$, and for $n \ge 2$ two numbers are defined:

$$\mu_{C_k,C_l} = 2\frac{S^{\mu}_{k,l}}{n(n-1)}, \nu_{C_k,C_l} = 2\frac{S^{\nu}_{k,l}}{n(n-1)}. \quad (3)$$

The pair, constructed from these two numbers, plays the role of the intuitionistic fuzzy evaluation of the relations that can be established between any two criteria C_k and C_l. In this way the index matrix M that relates evaluated objects with evaluating criteria can be transformed to another index matrix M^* that gives the relations among the criteria

$$M^* = \begin{array}{c|ccc} & C_1 & \dots & C_m \\ \hline C_1 & \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \dots & \langle \mu_{C_1,C_m}, \nu_{C_1,C_m} \rangle \\ \vdots & \vdots & \ddots & \vdots \\ C_m & \langle \mu_{C_m,C_1}, \nu_{C_1,C_m} \rangle & \dots & \langle \mu_{C_m,C_m}, \nu_{C_m,C_m} \rangle \end{array}. \quad (4)$$

Alternatively, it is practical to work with two index matrices M^{μ} and M^{ν}, rather than with the index matrix M^* of IF pairs. The two criteria are in relation of either 'positive consonance', or 'negative consonance', or 'dissonance', depending on their InterCriteria pair's comparison [6].

Results and discussion

In this research we analyzed the results received from the observation of 25 patients – 14 women and 11 men, aged 25 to 67. The patients have been treated by specialized kinesitherapy methodology aiming at increasing the volume of movement in the cervical partition and decreasing limited mobility. As a result of kinesiterapeutical program the following summarized result have been presented in Table 2 for the beginning of the course and in Table 3 for the end of the course of treatment of the observed patients.

Table 2. Results before the kinesitherapy course

Patient	Pain	Fl. H.	Ext. H.	L. L.	H. R.	Ottis test	Forestier's test
1	6	45	30	15	13	2.5	4
2	6	30	35	12	14	2.5	4
3	7	35	31	7	10	2	5
4	8	30	40	4	6	2	6
5	6	45	50	17	20	2.5	5
6	7	15	45	8	6	2.5	7
7	6	30	44	25	20	2.5	3
8	6	40	50	30	25	2.5	4
9	8	45	28	6	6	1.5	7
10	10	15	30	5	6	1	8
11	6	50	40	15	13	2	3
12	7	30	43	6	7	2	5
13	7	30	45	5	7	1.5	6
14	8	15	28	4	8	1	8
15	8	20	30	6	8	1.5	9
16	6	45	48	20	20	2.5	4
17	6	40	50	25	22	2	3
18	5	55	50	20	20	2.5	3
19	5	60	54	15	10	2.5	4
20	7	30	28	7	5	2	5
21	10	10	30	5	6	0.5	8
22	10	15	25	6	8	1	9
23	6	50	40	10	12	2	5
24	6	45	45	12	12	2.5	4
25	5	60	50	20	25	2	3

Table 3. Results after the kinesitherapy course

Patient	Pain	Fl. H.	Ext. H.	L. L.	H. R.	Ottis test	Forestier's test
1	4	50	37	22	20	3.3	3
2	5	36	38	15	19	3	2
3	4	39	45	15	15	3.3	3
4	4	42	50	13	17	3	4
5	3	55	55	20	25	3.5	2
6	4	30	50	16	13	3.5	4
7	4	50	50	30	30	3.3	2
8	3	60	55	38	33	3.5	2
9	5	50	35	18	16	2.5	4
10	5	23	38	15	13	2.2	4
11	5	62	47	25	25	3	0
12	4	52	50	18	15	3.5	3
13	5	45	55	28	20	2.5	4
14	4	20	34	12	16	2	4
15	5	30	40	15	15	2.2	7
16	3	62	54	30	33	3.5	2
17	4	60	54	30	30	2.8	1
18	4	60	55	28	25	2.8	1
19	4	63	58	20	18	3	2
20	4	43	33	20	15	3	3
21	6	17	40	10	12	2	5
22	8	20	30	12	12	2	5
23	4	64	48	15	15	2.5	4
24	4	54	49	20	18	3	2
25	3	72	55	28	30	3.5	1

While taking decisions about the treatment process we have applied ICrA of the data received from the observation of the patient's state in order to find the subordination between the restorations of the separate movements in the cervical partition of the spine. As input data for the ICrA an IM with 25 objects (patients) and 7 criteria (functional indicators) with certain individual scores was constructed. The ICrA results, presented in Table 4 and Table 5, are visualized onto the intuitionistic fuzzy interpretational triangle (Fig. 1).

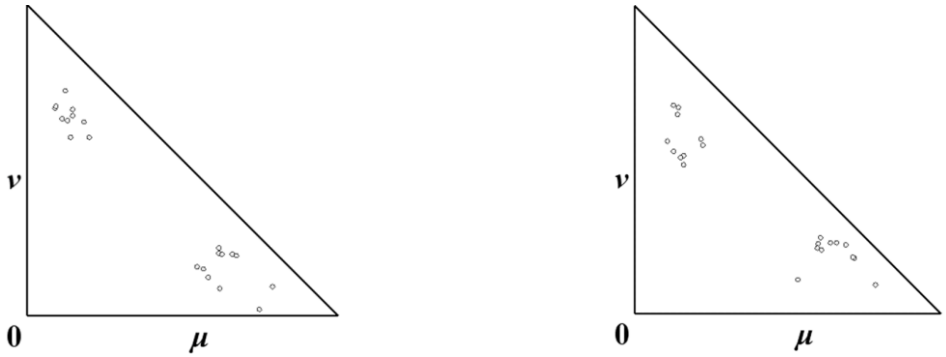
The analysis of the results showed a week positive consonance in two of the indicators – head flexion and lateral inclinations. These results come to confirm the well-known fact that the main muscle performing head flexion (m.sternocleidomastoideus) is also auxiliary in performing lateral inclinations. On the other hand, the main muscles performing lateral inclinations are auxiliary in performing flexion. This means that improving one of these movements will lead to corresponding improvement of the other movement. All other indicators are in dissonance or week dissonance which means that the evaluation of the patients condition during the kinsetherapy examination is a complex process. And to establish a final conclusion about the results from the kinesitherapy treatment is extremely important to perform all of the presented above functional tests.

Table 4. Membership degrees of the criteria pairs at the beginning of the observation

μ	Pain	Fl. H.	Ext. H.	L. L.	H. R.	Ott	Forestie
Pain	1.00	0.09	0.11	0.09	0.13	0.14	0.75
Fl. H.	0.09	1.00	0.62	0.63	0.62	0.57	0.15
Ext. H.	0.11	0.62	1.00	0.67	0.66	0.58	0.18
L. L.	0.09	0.63	0.67	1.00	0.79	0.62	0.12
H. R.	0.13	0.62	0.66	0.79	1.00	0.55	0.15
Ott	0.14	0.57	0.58	0.62	0.55	1.00	0.20
Forestier	0.75	0.15	0.18	0.12	0.15	0.20	1.00

Table 5. Membership degrees of the criteria pairs at the end of the observation

μ	Pain	Fl. H.	Ext. H.	L. L.	H. R.	Ott	Forestie
Pain	1.00	0.13	0.16	0.16	0.15	0.11	0.53
Fl. H.	0.13	1.00	0.69	0.72	0.71	0.61	0.13
Ext. H.	0.16	0.69	1.00	0.66	0.64	0.60	0.22
L. L.	0.16	0.72	0.66	1.00	0.79	0.61	0.14
H. R.	0.15	0.71	0.64	0.79	1.00	0.60	0.14
Ott	0.11	0.61	0.60	0.61	0.60	1.00	0.22
Forestier	0.53	0.13	0.22	0.14	0.14	0.22	1.00



a) b)

Fig. 1 Geometrical visualization of the InterCriteria correlations onto the intuitionistic fuzzy interpretational triangle:
a) at the beginning of the observation; b) at the end of the observation.

Conclusions

The article describes a novel approach of analyzing the treatment results of patients with Behterev's disease in order to improve the process of taking decisions about the treatment course – with the application of InterCriteria Analyses. The results from ICrA confirm the already known results from previous research, showing that the muscles in the human body are closely connected and improving one movement will lead to improving another one. Moreover, the results are showing that to evaluate the physical and functional condition of patients with Behterev's disease, before and after kinesitherapy course of treatment all of the tests are required. The obtained results also prove applicability of ICrA approach to the researched problem; give grounds for extending its application and potential of further in-depth study.

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References

1. Atanassov K. (1986). Intuitionistic Fuzzy Sets, Fuzzy Sets and Systems, 20(1), 87-96.
2. Atanassov K. (1999). Intuitionistic Fuzzy Sets: Theory and Applications, Physica-Verlag, Heidelberg.
3. Atanassov K. (2012). On Intuitionistic Fuzzy Sets Theory, Springer, Berlin.
4. Atanassov K. (2016). Intuitionistic Fuzzy Sets, VII ITKR Session, Sofia, 20-23 June 1983, Int J Bioautomation, 20(S1), S1-S6.
5. Atanassov K., D. Mavrov, V. Atanassova (2014). InterCriteria Decision Making. A New Approach for Multicriteria Decision Making, Based on Index Matrices and Intuitionistic Fuzzy Sets, Issues in Intuitionistic Fuzzy Sets and Generalized Nets, 11, 1-8.
6. Atanassova V., D. Mavrov, L. Doukovska, K. Atanassov (2014). Discussion on the Threshold Values in the InterCriteria Decision Making Approach, Notes on Intuitionistic Fuzzy Sets, 20(2), 94-99.
7. Ball J. (1971). Enthesopathy in Rheumatoid Ankylosing Spondylitis, Ann Rheum Dis, 30, 213-223.
8. Goldman L., A. Schafer (2011). Goldman's Cecil Medicine, 24th Ed., Philadelphia, PA, Elsevier Saunders.
9. http://www.healthcentral.com/encyclopedia/hc/bechterews-disease-3168676/ (Last access March 18, 2020)
10. InterCriteria Research Portal, http://www.intercriteria.net/publications (Last access March 18, 2020)
11. Rudwaleit M., A. Metter, J. Listing, J. Sieper, J. Braun (2006). Inflammatory Back Pain in Ankylosing Spondylitis: A Reassessment of the Clinical History for Application as Classification and Diagnostic Criteria, Arthritis Rheum, 54(2), 569-578.
12. Todinova S., D. Mavrov, S. Krumova, P. Marinov, V. Atanassova, K. Atanassov, S. G. Taneva (2016). Blood Plasma Thermograms Dataset Analysis by Means of InterCriteria and Correlation Analyses for the Case of Colorectal Cancer, Int J Bioautomation, 20(1), 115-124.
13. Ware J., C. Sherbourne (1992). The MOS 36-Item Short-form Health Survey (SF-36®): I. Conceptual Framework and Item Selection, Med Care, 30(6), 473-483.
14. Ware J., K. Snow, M. Kosinski, B. Gandek (1993). SF-36® Health Survey Manual and Interpretation Guide, Boston, MA: New England Medical Center, The Health Institute.

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