Diagnostic Analysis of Patients Qualified for Hip Replacement Using Multi-Criteria Methods: Clinical Decision Support System

Luiza Fabisiak, West Pomeranian University of Technology, Szczecin, Poland

<https://orcid.org/0000-0002-3378-9218>

Karina Szczypor-Piasecka, Pomeranian Medical University in Szczecin, Poland

ABSTRACT

Patients with advanced hip osteoarthritis are likely to suffer from biomechanical disorders. As many criteria inform how such patients are being qualified for alloplasty procedures, this article proposes a multi-criteria decisional framework in qualifying patients for treatment while undergoing diagnostic analysis for hip replacement surgery. In order to assess the patient's health condition, the competence of physicians and physiotherapists must first be checked. After creating the expert preference model and decision tree, the AHP method was applied followed by the Electre Tri method in the next stage of verification. Integrating these analytic procedures, a group of patients can be quickly evaluated and meaningfully profiled. Specifically, these patients can be classified in respect of their condition determined during hospitalisation as per the severity of degenerative disease and on the basis of their subjective feelings and diagnostics. The proposed methodology promises to allow optimal treatment to be assigned while enabling the appropriate classification and verification within group of patients targeted for hip replacement surgery.

KEYWORDS

AHP Method, Clinical Decision Support (CDS), Electre Tri, Hip Osteoarthritis, MCDA/MCDM Techniques, Orthopedics Surgery

1. INTRODUCTION

Degenerative diseases such as osteoarthritis and coxarthrosis affect about 60% of the elderly population over the age of sixty (60). Osteoarthritis includes mainly joint cartilage of hip joints (Leszczyński & Pawlak-Buś, 2008) whereas coxarthrosis will lead to biomechanical disorders that are caused by incorrect positioning or loading of various joint components. The results may be an impaired hip joint function and/or the wear of a joint cartilage for patients suffering from these degenerative diseases; over a period of time, their ligaments and joint capsules will thicken and become less flexible. In

DOI: 10.4018/IJHISI.2020100104

This article, published as an Open Access article on January 29, 2021 in the gold Open Access journal, International Journal of Healthcare Information Systems and Informatics (converted to gold Open Access January 1, 2021), is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>) which permits unrestricted use, distribution, and production in any medium, provided the author of the original work and original publication source are properly credited.

advanced stages of the disease, there is direct contact between the joint forming elements, thereby causing biomechanical disorders (Issa & Sharma, 2006; Marczyński, 2007).

The aetiology of a primary form of the hip coxarthrosis is unknown. What are known are the pre-conditional factors for the development of the osteoarthritis – these include, among others, those patients characterized as having: (i) a cardiac dysfunction in the joint area; (ii) changes in the joint fluid composition; (iii) abnormal nutrition of articular cartilage; (iv) age over 50; (v) female gender; (vi) obesity; and (vii) predisposing genetic factors. Secondary forms of the disease may occur as a result of injuries, diseases of joints and bones, hormonal and metabolic disorders, systemic diseases, nutritional disorders of femoral head, congenital and developmental joint deformations, obesity, lack of physical activity or abnormal forms of physical activity, certain categories of pursued profession, or more simply, the aging process (Ackerman et al., 2017).

A multitude of factors can affect the patient's clinical condition, complicating the decision on the optimal timing for a surgery. Advancing hip osteoarthritis, for example, can lead to biomechanical and motor dysfunctional disorders, resulting in increased disabilities and social isolation of the patient. Typical symptoms include complaints of increased pain; contractures and muscle atrophy; reduced joint mobility; and abnormal walking that may worsen over time along with the development of the degenerative disease. Often, the radiological image enables the detection of geodesy, osteophytes, sclerosis, narrowing or atrophy of the joint cavity, and the deformation of joint contours (Bennell & Hinman, 2011).

Additionally, a multitude of other criteria may have to be considered in qualifying patients for alloplasty of the hip joint. One such measure is the quality of walking and functional condition of patients waiting for alloplasty (Suetta et al., 2007; Srokowski et al., 2010). Another may be the size of decrease in muscle strength that is assessed using, for example, walking on stairs and muscle functioning tests (Arokoski et al., 2002; 2004). To date, no single functional test exists that includes the determination of impaired biomechanics for all joints' parameters.

In order to properly diagnose and prepare the patient for the needed surgery, the physician has to first examine the patient's clinical condition. With many influencing factors to be considered for the diagnosis, the methods used by physicians are often subjective, error-prone, and results largely dependant upon the experience of the investigator (Rodriquez et al., 1996; Guzik et al., 2019). Even so, the central challenge is the lack of uniformity of the patient's qualifications for the surgery and a lack of a suitable method to facilitate the doctor's decision on the treatment method. Development and verification of the appropriate method may improve the patient's classification for the surgery and/or the adjustment of an optimal conservative treatment.

The rest of this paper is organized as follows. Section II discusses materials and methods, more specifically, the form of disease, competence data and evaluation criteria applicable to the AHP (Analytic Hierarchy Process) and the Electre Tri process methods. Section III focuses on statistical results achieved from the application of these proposed methods while section IV offers suggestive insights from the interpretation of the evaluation results. Finally, section V closes the paper with potential limitations and future work in the associated study domain.

2. MATERIALS AND METHODS

2.1 Form of Disease, Competence Data and Evaluation Criteria

The evaluation criteria and vector of preferences of the examined patients are derived largely from the range of patient's responses to the survey questionnaire, a standard tool used for classifying and qualifying patients. Following a review of the knowledge base, expert preferences are created for physicians (and/or physiotherapists), where experts classify patients with osteoarthritis for the surgery and/or an optimal conservative treatment. Determining the vector of preference for selected criteria

Figure 1. Establishing the structure of specialized competence for source data. Legend: DZ – data acquisition source of the respondents (0 -10 points); KS – tuning parameters of local specific competencies (in % KS% = 100); KK parameters of global key competence tuning (in % of KK = 100)

requires the use of the appropriate AHP method (single v. group approach) identified in a dialogue mode vis-à-vis the fuzzy statements of a selected group of experts (Jaskowski et al., 2009).

This proposed work models and implements the competence of clinical experts in two stages, that is, (a) the defined competence stage; and (b) the assessment verification stage. The first stage comprises the establishing of key competence and the identification of the level of expertise (specialist v. professional competence). The second stage relates to the verification of their assessments and judgments accuracy. Additionally, the impact of decisions taken by experts is assessed (with their participation).

Here, competence is conceived as the application of knowledge, skills, and attitudes in the conduct of professional tasks at an appropriate level. Hence, the key competence (KK) is initially defined for each new expert being introduced into the decision-making process. Then, the expert competence (KS) is defined and specific grouping of selected competence are analysed in greater detail.

This work adopts a two-level model for the determination of competence. On the main level, sets of competence with accepted scales of importance are selected. On the secondary level, the details with determined significance are established. As a result, two indicators of competence assessment are created: KK – key competence with a nine-point value assessment, and KS – specialist competence with details of selected grouping of competence being evaluated. **Figure 1** depicts a model and template for experts' comparison vis-à-vis the structure of specialized competence for source data.

In building a knowledge base, it should be noted that patients with osteoarthritis might only be qualified for the joint replacement treatment on the basis of subjective, physical, and additional examinations. As such, the pain reported by the patient is an important qualifying factor for the surgery. However, pain in the buttock, thighs, cross-body joints or knee joints is not always caused by coxarthrosis. Some co-occurring dysfunctions or those resulting from coxarthrosis, such as spine complaints, sacroiliac joints or knee arthritis, may exacerbate pain and disturb the underlying disease. The severity of arthritis is also assessed via a radiological examination. In order to store these features in the knowledge base, a criteria tree (criteria – sub-criteria) is developed and guidelines are used on the basis of responses to the questionnaire. This allows for a thorough examination of patients' condition with coxarthrosis.

The structure of the decision tree model is based on proven methodological solutions. In order to replicate decisions made previously, it was necessary to create an appropriate decision-making tree

based on a full set of responses derived from the patient questionnaire. This represents an important stage in any causal analysis or multi-criteria optimization process. Accordingly, as shown in **Figure 2**, a set of criteria and sub-criteria is created, which in turn populates the “criteria tree” with an adaptation structure. The questionnaire is classified via seven (7) key features (criteria and sub-criteria). A scale of integer variable values within the range [0, ..., 5] are used throughout the study.

The data were characterized by the state of variables (D01 – Degenerative changes; D02 – Pain occurrence; D03 – Test of mobility of the hip joint; D04 – Walk analysis; D05 – Muscle strength assessment; D06 – Evaluation of muscle shortening; D07 – Other complaints).

Figure 2 models the decision-making tree used in the assessment of examined patient with coxarthrosis. It takes into account the specification of criteria and sub-criteria based on responses to the questionnaire of the examined patient and expert decision. The decision tree contains tuning of the parameters; that is, a determination of its significance for the purposes of interpretation and decision-making. Fragmentary criteria consist of sub-criteria that are subject to local alignment. Essentially, these fragmentary criteria must undergo relevance and impactful determination. Importantly, preferences for the fragmentary criteria are so-called parameters of the recipient’s preference, which are applied in cases of directing solutions linked to different preferences. In this work, by adopting a uniform evaluation scale (0-5), comparable cumulative measures in the assessment of experts’ competence and a quality level (in a form of criteria set) of evaluated patients can be achieved.

In addition to the selection of meaningful criteria and sub-criteria for generating the decision-making tree, the work also assumed a means of determining preferences among the experts (i.e., physicians and physiotherapist). In this work, we propose an algorithmization of methods and verification of results as discussed with the application of the AHP (Analytic Hierarchy Process) and Electre Tri method.

2.2 Methods

The AHP process and Electre Tri process are part of the investigative research methodology being applied in the form of a clinical decision support (CDS). The study adopted criteria and vector of preferences of the examined patients are derived via the AHP method, which identifies fuzzy statements of a selected group of experts in the dialogue mode. Among the functional methods, the AHP is the most well known and widely used (Wei et al., 2005).

The relevance of the AHP method in the transformation of results obtained from the experts means that each criterion and factor in the hierarchical model is obtained from a paired comparison (Al-Harbi et al., 2001; Saaty, 2003; Socorro et al., 2007). The author sets 4 stages in the AHP method:

$$a_{ij} = \frac{1}{a_{ji}} \quad (1)$$

The interpretation of formula (1) is as follows: if the element a_{ij} contains a certain value a , then the element a_{ji} should contain the inverse value, as $1/a$. In addition, the elements on the main diagonal a_{ii} should contain unit values. The preferences are defined for all hierarchy levels. Evaluations are expressed in numerical values. Positivity of the matrix proposed by Saaty should contain integers ranging from 1 to 9 and values opposite to these (Saaty, 2005). The linguistic meanings of the numerical values of pairwise by Saaty comparisons are presented in **Table 1**. Each matrix is supplemented with one of 17 values: $1/9, 1/8, \dots, 1/2, 1, 2, \dots, 8, 9$.

For each pairing matrix, a preference vector $[w_1, w_2, \dots, w_n]^T$ is determined showing the strength of the variants or criteria compared in the matrix. Saaty (2005) recommends determining the preference vector by calculating the right-hand vector of the matrix. It is calculated by solving equation (2):

Figure 2. Model of criteria parameters in the evaluation of patient with coxarthrosis. Legend: C01 – parameters of the computational decision algorithm; DFn – calculation parameters of conditional algorithms; Dn – source data parameter sub-criteria (scale of 0-5 points); Kn – preferences of local tuning of sub-criteria (in% sum Dn = 100); Pn – preference of utility function (expert) (in% sum Sn = 100)

Table 1. The linguistic significance of the Saaty scale

Numerical Rating	Verbal evaluation
1	The compared objects (decision variants or criteria) are equivalent
2	The decision maker varies between the equivalence and the small advantage of the first of compared objects over the others
3	The small advantage of the first object over the second one
4	The decision maker fluctuates between a small advantage and a big advantage of the first of compared objects over the others
5	The advantage of the first object over the second one
6	The decision maker fluctuates between a large advantage and a significantly greater advantage of the first of compared objects over the others
7	The significant greater advantage of the first object over the second one
8	The decision maker fluctuates between a significantly greater advantage and a huge advantage of the first of compared objects over the others
9	The huge advantage of the first object over the second one

$$Aw = \lambda_{max} w \quad (2)$$

When the comparison matrix is consistent, there is only one non-zero eigenvalue of the matrix λ_{max} and it is equal to the size of the matrix. The vector w is a vector of preferences related to the value of λ_{max} . The matrix of comparisons from the side of the preference vector is shown in (3).

$$\begin{matrix} & A_1 & A_2 & \dots & A_n \\
 \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{matrix} & \begin{pmatrix} \frac{W_1}{W_1} & \frac{W_1}{W_2} & \dots & \frac{W_1}{W_n} \\ \frac{W_2}{W_1} & \frac{W_2}{W_2} & \dots & \frac{W_2}{W_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{W_n}{W_1} & \frac{W_n}{W_2} & \dots & \frac{W_n}{W_n} \end{pmatrix}
 \end{matrix} \quad (3)$$

Note that this scheme is true only when the matrix is consistent. The consistency of the matrix occurs when: $a_{ji} * a_{jk} = a_{ik}$ each i, j, k (Saaty, 1990; 2003), which in turn occurs when the elements of the preference vector are their mutual multiples (eg. $[1 \ 3 \ 6]^T$ or $[4 \ 2 \ 1 \ 8]^T$). It is noted that the pairwise pairing matrix is considered to be consistent when the value of the calculated coefficient of cohesion does not exceed 0.1 (Saaty, 2005).

Consistency of the comparison matrix can be calculated by determining the cohesion consistency index (CI), and then the consistency ratio (CR) according to formulae (4) and formulae (5):

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

$$CR = \frac{CI}{R} \quad (5)$$

where:

R - is a random index whose value depends on the size of the comparison matrix in pairs
 λ_{max} - the largest eigenvalue of the matrix, for a coherent matrix $\lambda_{max} = n$, n –size of the matrix.

In **Table 2**, the R -values depend on the dimension of the pairwise comparison matrix.

Based on the determined criteria preference, the aggregated preference vector is computed. The preference vector is the weighted sum of the individual criteria preferences. Elements of this vector indicate the global usefulness of individual decision variants in accordance with formula (6):

$$U_i = \sum_{k=1}^m s_k * u_{ik} \quad (6)$$

where,

U_i - the total usability of the i -th variant,

w_k - weight of the k -th attribute (criterion),

u_{jk} - normalized value of the utility of the i -th variant with terms of to the k -th attribute (criterion).

Interestingly, the AHP method creates a ranking. The highest quality value means the best-considered variant (Douplos, 2002; La Gauffre, 2007; Buyukozkan, et al., 2011). The result of the AHP method ranking of variants is further dependent on the comparative quality measure coming from each decision. This method is also used to determine the preferences of experts.

Electre Tri is used to qualify the patient for the hip joint surgery, vis-à-vis its application to the classification problem. Here, the ratio is used to estimate the degree of surpassing the decision-making variants a (objects) over b (profiles), which classifies separately from each other (Mousseau, 2002). This method deals with the issue of sorting. Pseudo-criteria, which determine conformity, reliability factors, and non-compliance rates, are applied. While determining these values, there are only minor differences in the equivalence thresholds, preferences, and vetoes of the different ranges. The conformity and reliability factors are described in formulae (7) and formulae (8):

$$c(a_i, b_j) = \frac{\sum_{k=1}^n w_k * \varphi_k(a_i, b_j)}{\sum_{k=1}^n w_k} \quad (7)$$

where the compliance indicators can take values:

Table 2. Values of conformity R for specific quality of criteria

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.51	1.54	1.56	1.57	1.58

$$\varphi_k(a_i, b_j) = 1, \text{ if } f_k(b_j) - f_k(a_i) < q_k$$

$$\varphi_k(a_i, b_j) = 0, \text{ if } f_k(b_j) - f_k(a_i) \geq p_k$$

$$\varphi_k(a_i, b_j) = \frac{f_k(a_i) + p_k - f_k(b_j)}{p_k - q_k}, \text{ if } q_k < f_k(b_j) - f_k(a_i) \leq p_k$$

and:

$$\sigma(a_i, b_j) = c(a_i, b_j) * \prod_{k \in D_c(a_i, b_j)} \frac{1 - d_k(a_i, b_j)}{1 - c(a_i, b_j)} \quad (8)$$

where non-compliance indicators d_k can take values:

$$d_k(a_i, b_j) = 1, \text{ if } f_k(b_j) - f_k(a_i) \geq v_k$$

$$d_k(a_i, b_j) = 0, \text{ if } f_k(b_j) - f_k(a_i) < p_k$$

$$d_k(a_i, b_j) = \frac{f_k(b_j) - f_k(a_i) - p_k}{v_k - p_k}, \text{ if } p_k \geq f_k(b_j) - f_k(a_i) < v_k$$

In the aforementioned formulas, the notation of variants includes a_i and b_j . This record indicates that in Electre Tri method, the decision-making variants (a_i) are compared with the profiles of variants (b_j). The profiles are “artificial variants” limiting individual quality classes. The decision-maker defines them at the time of establishing thresholds and scales of criteria. Importantly, profiles must be correctly defined, for example, the profile defined as the best profile should indeed be the optimal profile, and so on. Correctly defining profiles will enable the quality classes to be properly ranked. On the basis of the established reliability factor and the cut level defined by the decision-maker, the preference relations' λ between variants and profiles are determined.

Relations are determined according to the following rules:

$$a_i I b_j \leftrightarrow (a_i S b_j) \wedge (b_j S a_i)$$

$$a_i > b_j \leftrightarrow (a_i S b_j) \wedge \sim (b_j S a_i)$$

$$a_i < b_j \leftrightarrow \sim (a_i S b_j) \wedge (b_j S a_i)$$

$$a_i R b_j \leftrightarrow \sim (a_i S b_j) \wedge \sim (b_j S a_i)$$

Based on preference relations λ occurring between variants and profiles, assignments of variants to classes are typically conducted. Two procedures, which provide significantly different classification results, may be used for this purpose. These procedures are called optimistic v. pessimistic procedures.

The optimistic procedure comprises two steps:

- Compare the variant a_i with next profiles, b_j starting from the worst (b_0).
- Assign a_i to the class C_j , if b_j is the first encounter profile such as $b_j > a_i$.

The pessimistic procedure is built as follows:

- Compare the variant a_i with next profiles, b_j starting from the best.
- If b_j is the first encounter profile, for which $a_i \leq b_j$, then a_i assign to the class C_{j+1} (Mousseau, 1998).

In the current study, the Electre Tri method applies; indeed, it is used in situations where it is necessary to verify a very large number of decision-making variants. Decision variants and criteria cannot be compared pairwise; therefore, in Electre Tri, these elements should first be cross-referenced with the profiles proposed by the decision-maker. It allows for the removal of the worst variants from a decisive point of view and then to consider only those variants that are in the best quality classes (Lexer et al., 2007).

3. RESULTS

After the expert preference model and the decision tree are generated, the AHP method is applied.

In the assessment verification stage, the Electre Tri grouping method is used. The Electre Tri method is used to select the best actions from a given set of criteria and sub-criteria and to create the ranking. The Electre Tri grouping model does not impose any preference on the passer-by and allows for a situation of incomparability (Murata, 1989). The implementation of a developed IT (information technology) solution enables one to discover a “fuller” knowledge about patients. The result is a gradation of profiles and linguistic rules that categorized patients into individual groups.

One of the study assumptions is to identify the patient who meets the postulate of qualification for the surgery. This relates to a *a priori* determined five-level scale of proportional profiling.

Linguistic names of profiles and their meanings include:

- Highest profile - qualifying the patient for the immediate surgery;
- High/Medium profile - use of pharmacotherapy or suitably designed physiotherapy;
- Low/Lowest profile - use of appropriately planned physiotherapy.

The presented summary (Table 3) shows that the group of patients as characterised by high values (72%).

Table 3. Statistics of obtained linguistic profiles in Electre Tri modeling

PROFILES	Group	%	C01	D01	D02	D03	D04	D05	D06	D07
The highest	17	17	17	85	76	69.499	34.75	55.501	63	52
On the object	1	1	1	5	4.471	4.088	2.044	3.265	3.706	3.059
High	72	72	53	319	283.00	255.166	177	268.828	118	186
On the object	1	1	0.736	4.431	3.931	3.544	2.458	3.734	1.639	2.583
Medium	11	11	0.364	3.273	2.788	2.773	2.727	3.682	0.909	1.727
On the object	1	1	0.033	0.298	0.253	0.252	0.248	0.335	0.083	0.157

In the case of the *Highest* linguistic profile, the profile equals 17%, which means that the patient requires emergency surgery. If the profile is *High* or *Medium*, it is possible to apply pharmacotherapy or appropriately planned physiotherapy, which can delay the surgery by reducing unpleasant complaints such as pain. Results of studied patient's analyses in a hierarchical ranking are presented in **Table 4**.

4. DISCUSSION

This article verifies the evaluation of functional condition of patients with coxarthrosis. It categorizes these patients for surgical procedure using the relation of exceeding (Electre Tri). The study combines the necessary information on subjective sensations of the patient with functional examination. Hence, doctors and/or physiotherapists can be aided via CDS in their decision-making by means of measurements and tests, as well as the use of appropriate decision-making tools and methodologies that can be implemented via IT solutions.

Notably, the prerequisite for doctors and/or physiotherapists is to have knowledge about preferences of the indicated group of patients and to adjust the description of methods to the reality of the situation. The Electre Tri method omits the decision-making attribute in the classifications, i.e. no dependent variable is implemented, which, in turn, allows "non-dominated" knowledge about considered decision-making processes to be discovered.

With the conducted survey, a ranking of patient's classification for surgery can also be obtained. The article objectively presents the actual physical condition of the examined patient through the selection of appropriate criteria, the preferences of a group of doctors, physiotherapists, and the physical condition of the patient. The patient's examination according to the proposed tool enables the classification and verification of the patients for the treatment.

Moreover, the costs of medical treatment incurred by national budgets should also be considered. These costs are enormous and ever increasing, even accelerating. Such costs are related to the diagnosis, treatment, rehabilitation, professional absenteeism, and pension benefits of patients with hip osteoarthritis. Imperfections of the healthcare systems, incorrect diagnosis, and standard rehabilitation programs increase the treatment duration. All factors mentioned above can increase joint degradation, disability and prolonged pain. Hence, it is necessary to search for tools, including automated CDS that will not only improve the decision-making process of the caregivers, but also assist in efficiently and effectively identifying the best directions for the delivery of treatment to specific patients via the use of appropriate e-technology to support recommended solutions from the different specialties, including physiotherapy or pharmacotherapy.

5. CONCLUSION

Medical research should, generally, be reliable and credible; that is, the studies are carried out in accordance with the principles of evidence-based medicine (EBM). Not only would results of such studies lead to better clinical decisions, but patients would also benefit in term of therapeutic decisions being made on past research evidence (Plaszewski, 2006; Gluck et al., 2008).

To date, the extant EBM literature includes papers on Clinical Decision Support (CDS) with particular emphasis on contextual information on patients, practitioners and services, decision support technologies, user interface considerations, and diseases evaluation (Fraccaro et al., 2015). Kaplan (2001) notes a general consensus on CDS improving the quality of medical care.

In clinical practice, the quantitative and objective analysis of diagnosis is often applied. Essentially, those analyses consist of measuring, describing, and evaluating the patient's classification for the surgery. Treatment of coxarthrosis is based mainly on pharmacotherapy and physiotherapy. In advanced stages of the disease, joint replacement is a preferred method. One key approach is prevention, which comprises mainly the elimination of predisposing factors that promote the degenerative disease, for example, weight reduction, increased physical activity, the correction of dysfunctions in the

Table 4. Ranking of the classification of examined patients with coxarthrosis

	Common name	C01	D01	D02	D03	D04	D05	D06	D07	OPTIMISM
1	W_64_58_156_P12	1	5	5	3.333	2.5	3.667	5	4	The highest
2	W_83_67_167_P13	1	5	4.333	3.833	1.5	3.5	5	4	The highest
3	W_78_82_163_P 21	1	5	4.333	3.833	1.75	3.167	5	4	The highest
4	M_63_99_170_P84	1	5	5	4.167	1.75	2.167	5	4	The highest
5	W_74_60_163_P25	1	5	4.333	4.667	1.75	3.167	5	3	The highest
6	M_62_123_176_P99	1	5	4.667	3.833	1.25	3.333	3	5	The highest
7	W_67_83_164_P51	1	5	3.333	4.333	1.75	3	5	3	The highest
8	W_80_68_162_P20	1	5	5	4.167	1.5	2.5	5	3	The highest
9	M_77_65_164_P77	1	5	5	4.667	2	2.833	5	2	The highest
10	W_75_50_156_P26	1	5	4.667	3.5	2.5	3	5	2	The highest
11	M_59_75_177_P64	1	5	4	4.333	2.5	5	1	4	The highest
12	M_64_103_185_P69	1	5	4.667	3.833	2	2.833	5	2	The highest
13	W_30_83_173_P27	1	5	5	3.5	2.5	3.667	1	5	The highest
14	W_68_86_164_P56	1	5	5	5	1.75	2.333	3	3	The highest
15	W_89_80_155_P44	1	5	4.667	3.5	2	2.667	5	0	The highest
16	M_77_89_175_P83	1	5	2	4.667	3.75	5	0	2	The highest
17	W_71_68_164_P07	1	5	5	4.333	2	3.667	0	2	The highest
18	M_58_72_176_P87	1	5	4	3.5	3.25	4	5	4	High
19	W_67_64_160_P35	0	3	4.667	3.833	2.5	4	3	5	High
20	M_49_80_181_P93	1	5	4.667	3	2.5	4.167	3	4	High
21	W_80_65_165_P09	0	3	4	3	2	3.833	3	5	High
22	W_78_65_154_P32	1	5	4.333	4.167	1.75	3.833	3	4	High
23	W_78_66_158_P03	1	5	4.667	3.167	2.5	3.833	3	4	High
24	M_77_93_180_P95	1	5	4.667	3.5	2	3.667	3	4	High
...	...	...	...	...	...	...	...	...	...	...
84	W_75_55_162_P34	1	5	3.667	3.333	2.5	3.833	0	2	High
85	W_54_65_157_P39	1	5	4	3.167	3.25	4.833	0	0	High
86	M_60_93_176_P78	0	3	4.667	2.833	2.5	4.333	1	0	High
87	M_79_98_172_P89	1	5	2.667	2	2.5	5	0	0	High
88	M_54_50_172_P72	1	5	3.333	3	3.75	4.333	0	0	High
89	W_70_50_163_P19	1	5	3.333	4	2	2.667	0	0	High
90	W_71_72_163_P43	0	3	3.667	3.5	2.5	5	3	3	Medium
91	M_53_107_186_P91	0	3	3.333	3	3.25	5	3	2	Medium
92	M_66_65_175_P62	1	5	2.333	3.5	2.5	3.667	3	2	Medium
93	W_73_73_156_P46	1	5	3	3.667	2	3.333	3	2	Medium
94	W_74_67_156_P10	0	3	3	3.333	3.75	5	0	2	Medium
95	M_65_88_166_P100	1	5	2.667	2.167	2	3.833	1	2	Medium
96	W_30_66_170_P49	0	3	3.333	3.833	3.25	4.333	0	2	Medium
97	M_60_88_173_P71	1	5	3.333	3.167	3.75	3.333	0	2	Medium
98	W_60_62_160_P22	0	3	2.667	4.333	2.5	3	0	3	Medium
99	W_68_73_158_P23	0	1	3.333	1	3.75	4.667	0	2	Medium
100	M_62_92_172_P74	0	3	3.667	2.5	3.25	4.333	0	0	Medium

Note that the final stage of osteoarthritis treatment is the joint replacement (Greene, 2007).

musculoskeletal system, an avoidance of overloads and injuries, and the elimination of posture defects in knee and foot joints (Arokoski et al. 2002, Wójcik et al., 2012, Walash et al., 2006).

The main aim of this study was to create a test procedure for the diagnostic of osteoarthritis of hip joints and then, where needed, to suggest CDS for generating the computation needed to aid decision making for the caregivers. Such a procedure will then permit a logical determination of the patient's qualification and readiness for the appropriate clinical intervention and procedure.

Initially, the patient's condition is determined while during the hospitalization process on the basis of his or her subjective feelings, diagnostics and preferences of doctors and physiotherapists. Next, in order to characterize the preferences of physicians, an analytical methodology was adopted. This is the most important criterion for basic examinations, which are performed on the patient before being added to the proposed procedure. Importantly, the examination based on the proposed tool enables the classification and verification of patients with coxartrosis for the surgery and the adaptation of optimal prophylactic medical therapy by a doctor or physiotherapist.

Following this, during the results verification process, the same group of patients qualified for the surgery by a team of doctors and physiotherapists from Department of Orthopedics, Traumatology and Oncology of the Pomeranian Medical University in Poland were screened to verify results of the procedure. The verification confirmed the compatibility and relevance of the study methods and results.

Altogether, the conceptualization and verification of an appropriate procedure may facilitate the work of physicians and physiotherapists, reduce costs, reduce waiting time for surgery and provide mental comfort to the patient. Taken together, all of these steps could help to develop the electronic decision-making models for CDS as part of the larger health information systems (HIS) to speed up and improve health services. It could enable the development and sharing of knowledge across multiple disciplines while tending to the needs of both caregivers and patients.

REFERENCES

- Ackerman, I. N., Kemp, J. L., Crossley, K. M., Culvenor, A. G., & Hinman, R. S. J. (2017). Hip and Knee Osteoarthritis Affects Younger People, Too. *Orthop Sports Phys Ther*, 47(2), 67–79. doi:10.2519/jospt.2017.7286 PMID:28142365
- Al-Harbi, K. M. (2001). Application of the AHP in project management. *International Journal of Project Management*, 19(1), 19–27. doi:10.1016/S0263-7863(99)00038-1
- Arokoski, H. (2002). Hip muscle strength and cross-sectional area in men with and without hip osteoarthritis. *The Journal of Rheumatology*, 29(10), 2185–2195. PMID:12375331
- Arokoski, M., Haara, M., Helminen, H., & Arokoski, J. (2004). Physical function in men with and without hip osteoarthritis. *Archives of Physical Medicine and Rehabilitation*, 85(4), 574–581. doi:10.1016/j.apmr.2003.07.011 PMID:15083432
- Bennell, L., & Hinman, S. (2011). A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. *Journal of Science and Medicine in Sport*, 14(1), 4–9. doi:10.1016/j.jsams.2010.08.002 PMID:20851051
- Buyukozkan, G., Cifci, G., & Guleryuz, S. (2011). Strategic analysis of healthcare service quality using fuzzy AHP methodology. *Expert Systems with Applications*, 33(8), 9407–9424. doi:10.1016/j.eswa.2011.01.103
- Doumpos, M., & Zopounidis, C. (2002). Multi-criteria classification methods in financial and banking decision. *International Transactions in Operational Research*, 9(5), 568–571. doi:10.1111/1475-3995.00374
- Fracaro, P., Casteleiro, M. A., Ainsworth, J., & Buchan, J. (2015). Adoption of Clinical Decision Support in Multimorbidity: A Systematic Review. *JMIR Medical Informatics*, 3(1), e4. doi:10.2196/medinform.3503 PMID:25785897
- Gluck, J. (2008). Metodyka badań naukowych w rehabilitacji neurologicznej. *Przegląd Medyczny Uniwersytetu Rzeszowskiego*, 3, 214–219.
- Greene, W. B. (2007). *Ortopedia Nettera*. Elsevier Urban & Partner.
- Guzik, A., Drużbicki, M., & Maistrello, L. (2019). Relationship Between Observational Wisconsin Gait Scale, Gait Deviation Index, and Gait Variability Index in Individuals Poststroke. *Arch Phys Med Rehabil*. 10.1016/j.apmr.2018.12.031
- Issa, S., & Sharma, L. (2006). Epidemiology of osteoarthritis: An update. *Curr Rheumatol Rep. Current Rheumatology Reports*, 8(1), 7–15. doi:10.1007/s11926-006-0019-1 PMID:16515759
- Jaskowski, P., Biruk, S., & Bucon, R. (2009). Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment. *Automation in Construction*, 19(2), 120–126. 10.1016/j.autcon.2009.12.014
- Kaplan, B. (2001). Evaluating informatics applications—Clinical decision support systems literature review. *International Journal of Medical Informatics*, 64(1), 15–37. doi:10.1016/S1386-5056(01)00183-6 PMID:11673100
- La Gauffre, P., Haidar, H., & Poinard, D. (2007). A multicriteria decision support methodology for annual rehabilitation programs for water networks. *Computer-Aided Civil and Infrastructure Engineering*, 22(7), 478–488. doi:10.1111/j.1467-8667.2007.00504.x
- Leszczyński, P., & Pawlak-Buś, K. (2008). Choroba zwyrodnieniowa stawów - epidemia XXI wieku. Osteoarthritis – the epidemic of the 21st century. *Farmacja Współczesna*, 1, 79–87.
- Lexer, M., & Vakić, H. (2007). *Multiple Criteria Decision Making in Natural Resource Management*. Lecture Notes, Universität für Bodenkultur.
- Marczyński, W. (2007). Patologia chrząstki stawowej – dynamika zmian, zapobieganie. *Wiadomości Lekarskie (Warsaw, Poland)*, 60, 1–2, 53–58.
- Mousseau V. & Słowiński R. (1998). Inferring an Electre Tri Model from Assignment Examples. *Journal of Global Optimization*, 12(2), 157–174.

Mousseau, V., Słowiński, R., & Zielniewicz, P. (2002). *Electre Tri 2.0a Methodological guide and user's manual*. Université Paris Dauphine.

Murata, T. (1989). Petri nets: Properties, analysis and applications. *Proceedings of the IEEE*, 77(4), 541–580. doi:10.1109/5.24143

Płaszewski, M. (2006). Praktyka oparta na dowodach – zasady i kierunki rozwoju Evidence Based Practice w fizjoterapii. *Rehabilitacja Medyczna*, 10(1), 9–14.

Rodriguez, A. A., Black, P. O., Kile, K. A., Sherman, J., Stellberg, B., McCormick, J., Roszkowski, J., & Swiggum, E. (1996). Gait training efficacy using a home-based practice model in chronic hemiplegia. *Archives of Physical Medicine and Rehabilitation*, 77(8), 801–805. doi:10.1016/S0003-9993(96)90260-9 PMID:8702375

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, 48(1), 9–26. doi:10.1016/0377-2217(90)90057-I

Saaty, T. L. (2003). Decision-making with the AHP: Why is the principal eigenvector necessary? *European Journal of Operational Research*, 145(1), 85–91. doi:10.1016/S0377-2217(02)00227-8

Saaty, T. L. (2005). The Analytic Hierarchy and Analytic Network Processes for the Measurement of Intangible Criteria and for Decision-Making. In *Multiple criteria decision analysis: State of the art surveys*. Springer.

Socorro, G.-C.M., & Lamata, T.M. (2007). Solving a decision problem with linguistic information. *Pattern Recognition Letters*, 28(16), 2284–2294. doi:10.1016/j.patrec.2007.07.010

Srokowski, G., Bułatowicz, I., Kaźmierczak, U., Tyma, R., Radzimińska, A., Strojek, K., & Srokowska, A. (2010). Ocena jakościowa chodu oraz badanie funkcji biodra pacjentów zakwalifikowanych do zabiegu endoprotezoplastyki stawu biodrowego. *Now Lekarskie*, 79(3), 183–190.

Suetta, C., Aagaard, P., Magnusson, S. P., Andersen, L. L., Sipilä, S., Rosted, A., Jakobsen, A. K., Duus, B., & Kjaer, M. (2007). Muscle size, neuromuscular activation, and rapid force characteristics in elderly men and women: Effects of unilateral longterm disuse due to hiposteoarthritis. *Journal of Applied Physiology (Bethesda, Md.)*, 102(3), 942–948. doi:10.1152/jappphysiol.00067.2006 PMID:17122381

Walash, N., Mitchell, H., Reeves, B., & Hurley, M. (2006). Integrated exercise and self-management programmes in osteoarthritis of the hip and knee: A systematic review of effectiveness. *Rehabil Med.*, 10(4), 57–65. doi:10.1179/108331906X163432

Wei, C. C., Chien, C. F., & Wang, M. J. J. (2005). An AHP-based approach to ERP system selection. *International Journal of Production Economics*, 96(1), 47–62. doi:10.1016/j.ijpe.2004.03.004

Wójcik B., Jabłoński M., Gębala E. & Drelich M. (2012). Porównanie efektów klasycznego usprawniania pacjentów po aloplastyce stawu biodrowego we wczesnym okresie pooperacyjnym z dodatkowym zastosowaniem techniki rozluźniania powięziowego. *OrtopTraumatolReha*, 2(6), 161–178.

Luiza Fabisiak is Assistant Professor in the West Pomeranian University of Technology, Faculty of Computer Science and Information Technology, Department of Software Engineering, Information Security Research Group. She is Ph.D. technology in the area of Internet services and security. She is working as a researcher in the web usability area. Her main researches topic concerns the usefulness of the Internet, with particular emphasis on new methods of usability and functionality. Currently, She is working on the safety of Electronic Health Records (EHR) and improvement of the quality of health care in Poland.