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AI-driven solutions for low back pain: A pilot study on diagnosis and treatment planning

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ABSTRACT

Low back pain (LBP) mainly affects the working-age population, and few specific causes can be identified, making diagnosis difficult and rendering them nonspecific. Artificial intelligence (AI) can be a great ally for prognosis, diagnosis, and treatment plans in healthcare. To describe the development of software aimed at providing prognoses, diagnoses, and treatment suggestions for LBP with AI support, as well as to report the functionality and initial limitations through a pilot study. Fifty assessment records from a database of patients at the Physiotherapy School Clinic of the University of Gurupi-UnirG, who were treated for LBP, were analyzed. Using data mining, including information described by patients and post-processing of discovered anamnesis patterns (rules), it was possible to develop software for evaluation and intervention in this patient group. Subsequently, a pilot study was initiated with 34 patients residing in the city of Gurupi-TO to test the application's functionality. The software enabled more accurate treatments, diagnoses, and prognoses during the pilot study, directing the patient towards physiotherapeutic intervention based on the presented condition.

Keywords: low back pain, artificial intelligence, diagnosis, treatment, pilot study

INTRODUCTION

Low back pain (LBP) is one of the most common health problems and the number one cause of global disability [1]. LBP is the leading chronic health problem in the world [1]. Currently considered a public health issue, it is one of the leading causes of physical disability in active populations of industrialized countries, considering muscular, skeletal alterations, and economic and psychosocial disorders, making it necessary to adopt appropriate measures to control pain and improve the quality of life of these patients [1-5].

The prevalence of LBP in the adult population aged 18 years and older is 18.5%. LBP effects on average 80% of the world's population at some point in life, being the most common cause of activity limitation in individuals up to 45 years of age [1].

The increased incidence of LBP correlates with occupational activities, such as prolonged static postures and/or repetitive movements with mechanical stress, leading to metabolic damage to the components of the lumbar spine [3]. Physiotherapy emerges as an indispensable tool in promoting health and improving quality of life through the use of therapeutic techniques for the treatment of these patients [6].

The success of physiotherapeutic treatment for LBP depends on a thorough analysis of the individual and the variables assessed in the medical history, physical examination, goals, and proposed treatment techniques for the rehabilitation of these patients. Therefore, treatment success relies on a comprehensive physiotherapeutic assessment that involves multiple data and correct decision-making in the application of evidence-based techniques in the treatment of LBP [6, 7].

With the increasing amount of patient data obtained and stored in information systems, the possibility of obtaining critical information and successful knowledge to support decision-making processes by physiotherapy professionals is expanded. Physiotherapists are faced with a large number of variables that need to be managed so that they can make more assertive decisions regarding the treatment to be indicated for a patient [8].

Fortunately, technology is increasingly present in the daily lives of healthcare professionals, which supports professionals in extracting knowledge from a large amount of patient data and accompanying variables.

In this way, the use of artificial intelligence (AI) has shown significant potential in the applicability of physiotherapeutic treatment [6, 7, 9]. There are several precedents demonstrating its effectiveness. To enhance knowledge discovery in a database, one of the alternatives is the knowledge discovery in databases (KDD) process. KDD allows discovering relationships in data stored in a database more easily than with traditionally used techniques, such as statistics, for example. Researchers in the field of computing have researched and developed various methods and computer programs that are constantly incorporated into the KDD process [9].

The KDD process consists of several stages, which can be grouped into three main groups: data preparation, data mining, which stands out as a proper AI technique, and post-processing of the results obtained by mining [9].

Given the limited appropriation of the KDD process by physiotherapy, specifically for the diagnosis and treatment of LBP, this research project will exemplify and discuss the exploration of data from patient follow-ups using data mining and post-processing of discovered anamnesis patterns (rules).

The algorithm linked to an AI is an innovation that is likely to change the scenario of Physiotherapy in the coming decades, and to achieve the objective of this study, a team of developers, companies, and IT consulting professionals has been organized, in partnership with the Technological Park of the University of Fortaleza (TEC Unifor). Therefore, it is considered a major milestone for the definitive entry into the AI (machine learning) era with the development of software that can assist physiotherapists in assessing clinical and functional conditions of patients and collaborate in therapeutic decision-making. The software provides a more assertive understanding of the patient’s real needs regarding their clinical condition, suggesting to the physiotherapist what would be the most appropriate treatment.

Thus, this project aims to describe the creation of the application with the purpose of proposing diagnosis, prognosis, treatment suggestions for LBP with AI support, as well as reporting the functionality and initial limitations through a pilot study.

METHODOLOGY

Methodologies Used for Analysis and Evaluation for Pilot Study

This study employed a descriptive developmental research approach, conducted through an application created by MEDME.CARE®, utilizing a preliminary database of patients presenting with LBP, along with information provided by physiotherapists through anamnesis conducted from August 2021 to August 2022. This study was approved by the Research Ethics Committee under opinion 4.644.995/21.

To demonstrate the application of each of the three data mining tasks, a dataset recording the follow-up of 50 patients at the physiotherapy school clinic with a clinical diagnosis of LBP was utilized.

For the experiment, the Weka Explorer program was adopted. According to [10], machine learning can be defined as an area that studies how computers can learn or improve their performance automatically. A key research area is to make computer programs learn to recognize complex patterns automatically and make intelligent decisions based on data.

This program was chosen to meet two recommendations: prediction and clarification of the relationship between variables and the predicted class. Through its graphical interface, it is possible to conduct data mining processes on small databases, evaluate the results obtained, and compare the various algorithms already incorporated into the tool. The algorithms are applied directly to a dataset and can be used for preprocessing, classification, regression, clustering, association rules; it also includes visualization tools to analyze which are the best algorithms to be applied in an experiment.

Three algorithms from this tool were used to work with this data, as follows:

1. The Naive Bayes algorithm, which is a classifier, uses data analysis to extract models that categorize the labels of a class. It assumes that all predictor elements are independent of each other, meaning they are uncorrelated and non-existent. Classification has numerous applications, including fraud detection, targeted marketing, performance forecasting, manufacturing, and medical diagnosis.
2. Another algorithm was used to demonstrate the task of discovering association rules, whose main objective is to discover strong relationships between data by relating the patterns in which they appear. Apriori is the algorithm that groups data with common characteristics. This choice is due to the fact that the collected data present several occurrences for the same variable, which facilitates machine learning for prediction. For example, the variable leg numbness may present one or more possible values for patients in the same group, which when analyzed may be associated with other variables, enabling different or non-different diagnoses. This association, regarding independent variables, is unfeasible for other computational programs due to its complexity.
3. The third algorithm used was J48, which generates a decision tree. Thus, the relationship between the values of the variables and the paths chosen by the machine when deciding on this dataset can be understood.

The Weka Explorer environment was chosen to exemplify this classification task, by class, grouping, and decision tree, as it is a widely used and easily operational environment. The use of different computational programs or algorithms allows for greater accuracy in developing solutions, based on efficiency, confidence, and thorough analysis, including incorrect data classification, which machine learning itself points out. Thus, the physiotherapist can use the tool more accurately, with decisions based on data science, seeking more effective treatments, the result of efficient diagnosis and prognosis.

Data and Associated Predictions

Naive Bayes algorithm

The objective of classification was to analyze the provided data according to their class, which in this case was to determine which patients need to undergo a preliminary evaluation, i.e., the need for an appointment with the physiotherapist before continuing the diagnosis.

The algorithm achieved an accuracy of 91.1765%, meaning it correctly predicted the class from the provided data (part A in **Figure 1**). It only made errors in 8.8235% of cases,

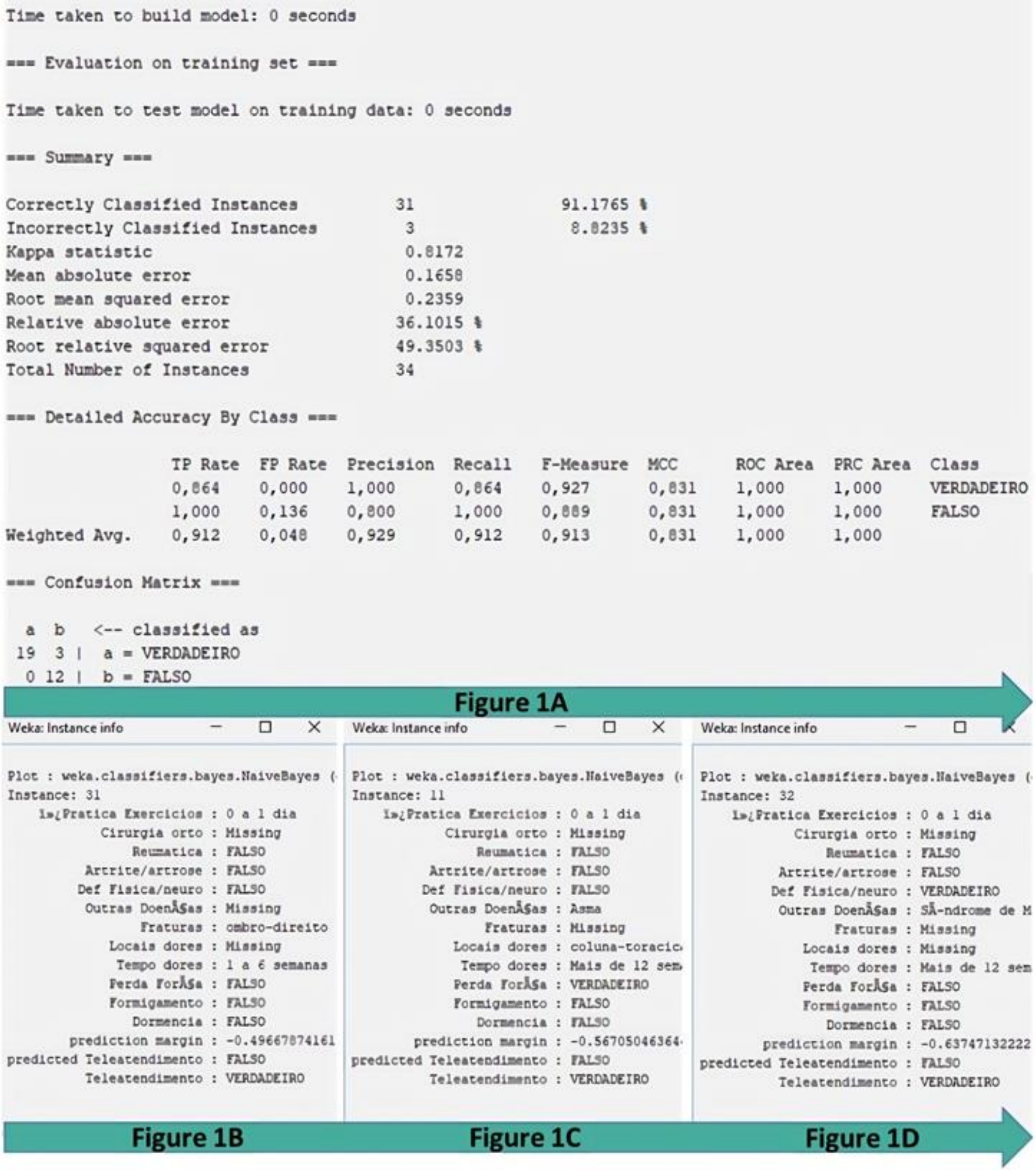

Figure 1. Accuracy assessment: The accuracy assessment of the Naive Bayes algorithm and its prediction analyses (A), variables "pain duration" and "fractures" (B); variable "weakness in the legs" (C), & variable "physical/neurological impairment" (D) (Source: Authors' own elaboration)

misclassifying 3 instances. Upon analyzing the algorithm's errors, it is concluded:

(1) The first error of the algorithm is related to the attributes "pain duration" and "fractures" (part B in **Figure 1**).

(2) The second error of the algorithm is related to the attribute "leg weakness" (part C in **Figure 1**).

(3) The third error of the algorithm is related to the attribute "physical/neurological deficiency" (part D in **Figure 1**).

Although other indicators do not suggest the need for physiotherapist intervention, studies and good clinical practices suggest further investigation as it may be related to "red flags".

Apriori algorithm

The objective of association was to group the best attributes that best identify and are most assertive in the physiotherapist's preliminary intervention. The parameters set were 20% support and 90% confidence. Only two attributes were not correctly associated: exercise practice/leg numbness and **"**physical/neurological deficiency/pain duration/leg numbness".

J48 algorithm

The objective of the decision tree is to find the best path that could lead to the class result, following the attributes traversed. The algorithm correctly classified 88.2353%. It failed to find the correct paths in 11.7647%, i.e., 4 patients.

The algorithm was not accurate in placing the attribute "pain duration" before "rheumatic diseases", "arthritis/osteoarthritis", and "other diseases" in the decision tree, which do not even appear in the figure. If it had done the opposite, it would have been correct.

The items certified by the Weka tool, with the observations collected from the described analyses, were sent to MEDME.CARE® where an exclusive algorithm for the tool was created, focusing on supporting decision-making for clinical

Figure 2. Weka classifier visualize (Source: Authors' own elaboration)

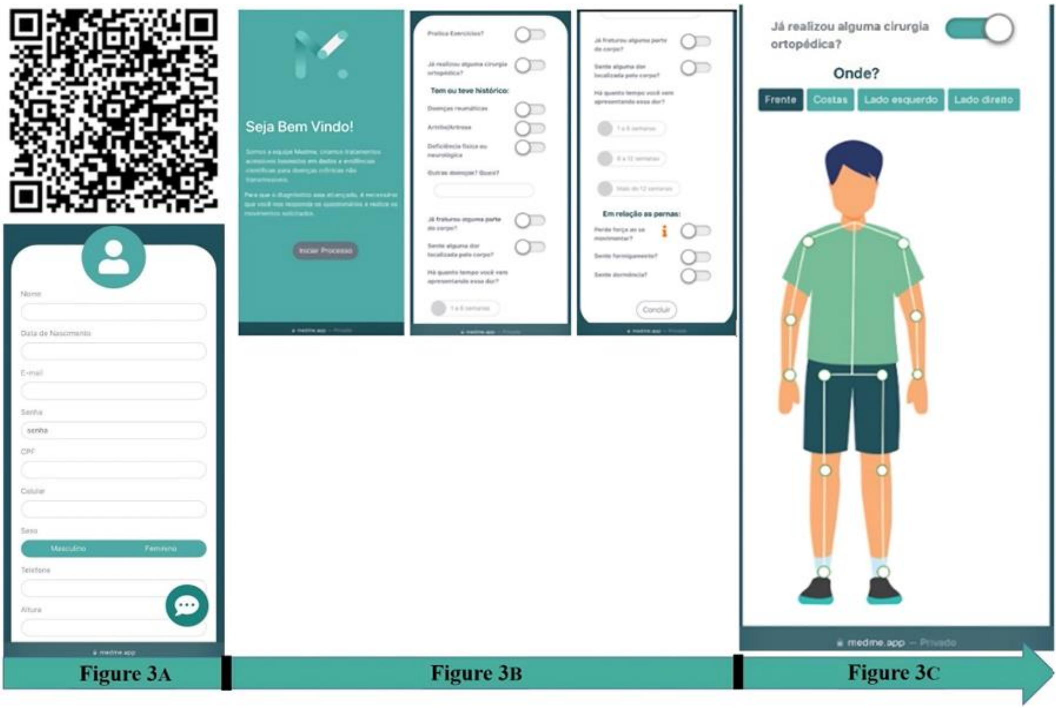

Figure 3. Initial description of the anamnesis in the application (A), information about the patient's clinical condition (B), & previously fractured area or correlated pains (C) (Source: Authors' own elaboration)

diagnosis, prognosis, and will be used for the prescription of treatment for patients with LBP in the future (**Figure 2**).

After this analysis, a platform was created, based on evaluative and interventional determinants for this group of patients. In the initial test, a pilot study was conducted with the same number of patients, residents of the city of Gurupi-TO, to identify the functionality and initial limitations of the solution.

The functionality of the application allows the patient to register in advance through a QR code provided by the physiotherapist to start the anamnesis: name, date of birth, email, password, CPF, cell phone, gender, telephone, height, weight, as well as the signature of the terms of use of MEDME.CARE® (part A in **Figure 3**).

The second stage of the patient registration process is the completion of data that complements the evaluative process, such as: physical exercise practice, history of orthopedic surgeries, rheumatic diseases, physical or neurological deficiency, other diseases, history of fractures, localized pain, how long they have been experiencing pain; in addition to a brief specific assessment for the legs: weakness when moving, tingling, and/or numbness (part B in **Figure 3**).

To identify the location of the human body where the patient feels pain or has already suffered a fracture, a playful method was developed, in which the patient can report the location. This allows for easy understanding by the potential professional who may attend to them (part C in **Figure 3**).

Based on the responses, the software can guide the best approach for the patient, which may include scheduling a preliminary assessment and physiotherapeutic follow-up via teleconsultation, or prescribing exercises that the patient can perform at home. A pilot study was conducted with 34 patients from the city of Gurupi-TO, with 22 females and 12 males, average age ≅ 25 years, all with complaints of LBP correlated with work activity, who responded to the application questionnaire.

RESULTS AND DISCUSSION

The patients' pain was characterized in weeks, with 4 patients reporting that the pain started around 1 to 6 weeks, 9 patients from 6 to 12 weeks, and 21 patients > 12 months, indicating the chronicity of the condition logical during evaluation.

Regarding the lower limbs (LL), some patients reported experiencing weakness, numbness, and/or tingling sensations in their legs. Of the analyzed patients, 23 did not experience any complaints related to the LL, 5 experienced leg weakness, 1 felt tingling sensations, and 5 felt numbness.

Based on the algorithmic analysis, 23 out of 34 studied patients were directly referred for evaluation and management with the physiotherapist, based on clinical history and prognosis, and 11 were able to proceed with the second part of the anamnesis, which is related to postural evaluative exercises.

This was because the algorithm understood, based on the clinical picture reported by the patient, that there is a higher probability of signifying a more serious pathology (red flag) when: "The patient is over 60 years old", "The patient has undergone orthopedic surgeries", "They have had rheumatic diseases, arthritis, osteoarthritis", "They have a physical or neurological deficiency", "They are experiencing pain for 1 to 6 weeks associated with the other factors described" above and when they present the symptoms described in aforesaid.

For these reasons, the algorithm recommended the intervention of a physiotherapist before continuing with possible remote treatment.

The software also allows movement analysis for postural assessment. Through AI, via human body recognition using the patient's own smartphone camera, they can perform the movement based on model videos. Computational vision mapped through the program assists both the patient in performing and accurately measuring real-time movements and the physiotherapist. Factors such as pain intensity, range of motion, repetitions, isometric holding, and other information can be measured in the professional's assessment. However, this study demonstrated limitations in this evaluative parameter due to the patient's difficulty in understanding to execute such activity. This can affect the accuracy of the assessment and, consequently, treatment planning. To overcome these limitations, healthcare professionals may need to use alternative assessment approaches, simplify instructions, and involve caregivers or family members when necessary.

This development in the field of artificial neural networks has sparked significant interest in its application in human movement modeling through video analysis. With this tool, it is possible to provide more accurate screening, diagnoses, prognoses, as well as treatment monitoring and follow-up, being an important ally for adherence and management of health conditions [11]. Systematic review studies point to the same direction of the information exposed about AI to improve back pain outcomes and lessons learned from clinical classification approaches. Artificial neural networks can also be used to predict the recurrence of lumbar disc herniation [12].

Following current scientific evidence-based premises for treatment, it is important that patients are protagonists in their rehabilitation plan, along with the physiotherapy professional, for effective pain control, improvement of physical function, and quality of life, becoming indispensable for teleconsultation.

After patient improvement and education, the created algorithm will contribute to modeling the demonstrated movement and evaluating the patient's performance during rehabilitation, to conclude if the movements performed by the patient correspond to those prescribed by the physiotherapist. Assessing how consistent the patient's movement is in reference to the set of prescribed movements, and thus evolving during the functional progression process in treatment.

CONCLUSION

After creating the software and conducting a pilot study, it was possible to make adjustments to the algorithm to improve diagnosis/prognosis through data analysis in the Weka Explorer, identify the main limitations, and possible improvements to demonstrate the impacts of the program on the treatment of LBP. Science and technology continue to direct complementary actions and adjustments, focusing on optimizing physiotherapeutic action, effective and resolute care for patients with LBP. Being a disease of high prevalence, with symptoms self-reported by patients, with numerous evaluative parameters ranging from postural alterations, spinal pathologies, and movements that trigger muscular injuries, the MEDME.CARE® solution becomes an evaluative and interventional tool that, through AI, seeks to optimize these processes.

Author contributions: AGNN: conductiNG the pilot test in Gurupi, Tocantins, Brazil; **SDSCH:** practical execution and logistics in Gurupi, Tocantins, Brazil & text writing; **RM:** practical execution of the pilot experiment & identifying specific movements for analysis by the advanced AI machine; **GMC:** enhancing the methodology with insights on AI and the intricate mechanisms of data mining; **FP:** discussion & results; **VFL:** text writing by offering important directions for a multidisciplinary approach; **MJMP:** providing valuable insights from both pharmacological and non-pharmacological perspectives & playing a key role in contextualizing the study; **CGSR:** analysis of results and writing of the discussion; **RCA:** text composition & providing essential insights for a multidisciplinary approach; & **WBD:** refining the writing & organizing ideas throughout the entire text. All authors have agreed with the results and conclusions.

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Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

1. WHO. Low back pain. Word Health Organization; 2023. Available at: https://www.who.int/news-room/fact-sheets/detail/low-back-pain (Accessed: 5 May 2024).
2. GBD. GBD 2019: Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: A systematic analysis for the global burden of disease study 2019. GBD; 2019. Available at: https://vizhub.healthdata.org/gbd-results/ (Accessed: 5 May 2024).
3. GBD 2021 Low Back Pain Collaborators. Global, regional, and national burden of low back pain, 1990-2020, its attributable risk factors, and projections to 2050: A systematic analysis of the global burden of disease study 2021. Lancet Rheumatol. 2023:5(6):e316-29. https://doi.org/10.1016/S2665-9913(23)00098-X PMid:37273833
4. Dzakpasu FQS, Carver A, Brakenridge CJ, et al. Musculoskeletal pain and sedentary behaviour in occupational and non-occupational settings: A systematic review with meta-analysis. Int J Behav Nutr Phys Act. 2021;18(1):159. https://doi.org/10.1186/s12966-021-01191-y PMid:34895248 PMCid:PMC8666269
5. Dziedzinski AT, Johnston C, Zardo E. Perfil epidemiológico dos pacientes com dor lombar que procuram o serviço de traumatologia e ortopedia do Hsl-PUC-RS [Perfil epidemiológico dos pacientes com dor lombar que procuram o serviço de traumatologia e ortopedia do Hsl-PUC- RS]. Rio Grande Sul. 2005;13(12):453-8.
6. Zsarnoczky-Dulhazi F, Agod S, Szarka S, Tuza K, Kopper B. AI based motion analysis software for sport and physical therapy assessment. Rev Bras Med Esporte. 2024;30:1-5. https://doi.org/10.1590/1517-8692202430012022_0020p
7. Priebe JA, Haas KK, Moreno Sanchez LF, et al. Digital treatment of back pain versus standard of care: The cluster-randomized controlled trial, Rise-uP. J Pain Res. 2020;13:1823-38. https://doi.10.2147/JPR.S260761 PMid:32765057 PMCid:PMC7381830
8. Miranda BS, Pontes SS. Physiotherapy in the age of big data: A systematic review. Braz J Funct Health. 2022;10(2):98-114.
9. Carvalho DR, Moser AD, Silva VA, Dallagassa MR. Mineração de dados aplicada à fisioterapia [Data mining applied to physiotherapy]. Fisioter Mov. 2012;25(3):595-605. https://doi.org/10.1590/S0103-51502012000300015
10. Han J, Kamber M, Pei, J. Data mining: Concepts and techniques. Cambridge: Morgan Kaufmann; 2006.
11. Li M, Jiang Y, Zhang Y, Zhu H. Medical image analysis using deep learning algorithms. Front Public Health. 2023;11: 1273253. https://doi.org/10.3389/fpubh.2023.1273253 PMid:38026291 PMCid:PMC10662291
12. Azimi P, Mohammadi HR, Benzel EC, Shahzadi S, Azhari S. Use of artificial neural networks to predict recurrent lumbar disk herniation. J Spinal Disord Tech. 2015;28(3): E161-5. https://doi.org/10.1097/BSD.0000000000000200 PMid:25353200