ARTIFICIAL INTELLIGENCE THEORY and APPLICATIONS

More information available at aita.bakircay.edu.tr

ISBN : 978-605-69730-2-4

Pre-Diagnosis of Osteoartritis Before DEXA with the Help of Artificial Neural Networks

Fadıma Gülsever AKSOY[1], Volkan AKDOĞAN [2,*], Murat KORKMAZ [3]

[1] *Cappadocia University School of Graduate Studies and Research, Department of Audiology*
[2] *İskenderun Technical University, Department of Electrical and Electronics Engineering*
[3] *Yozgat Bozok University Education and Research Hospital Department of Orthopedics and Traumatology*

* Corresponding Author: *İskenderun Technical University, Department of Electrical and Electronics Engineering*, Turkey. Tel.: +90 530 501 50 90. E-Mail: volkan.akdogan@iste.edu.tr

Publication Information

Keywords :
- Osteoarthritis;
- Artificial intelligence;
- Decision Support System;
- Lubricin.

Category : Full Research Article

Received : 01.04.2021
Accepted : 15.04.2021

A B S T R A C T

Osteoarthritis (OA) is a degenerative joint disease that increases in frequency with age and can significantly impair an individual's quality of life by causing pain and disability [1]. OA is the most common type of arthritis. In this study, due to the unnecessary exposure to radiation disadvantage of X-ray absorptiometry (DEXA) test used in the diagnosis of osteoarthritis, it was aimed to create an alternative and artificial intelligence-based decision support system with high accuracy. The system will be used as a pre-diagnosis method and decision support system. For this application, probabilistic artificial neural network designed with the help of a data set consisting of certain parameters taken from 200 patients. With its success rate, it has been observed that artificial neural networks can be used as a decision support system in the diagnosis of osteoarthritis. Thanks to this study, the possibility of applying the DEXA test to all patients who will come to the orthopedic and traumatology department with the suspicion of this disease will be minimized [2].

1. Introduction

Osteoarthritis is the most common form of arthritis in the world, which is frequently seen in the elderly population, causing erosion in the articular cartilage, osteophyte formations, subchondral sclerosis [3,4]. OA, which causes joint symptoms due to the impaired structuring of the joint cartilage, is a degenerative disease that occurs as a result of the disruption of the production and destruction processes with the effect of various traumatic, biomechanical, inflammatory and genetic factors [3]. It is not easy to diagnose patients in the early stages of the disease, and the disease progresses rapidly and patients cannot notice. The most important obstacle in its management is to identify and classify patients who will benefit from treatment. Comprehensive and patient-specific prediction models need to be developed. Age, gender, obesity,

presence of osteoporosis, occupational strains, sports activities, previous damage to the joint, proprioception disorder, genetic factors, calcium crystals, hypermobility, smoking, diabetes mellitus (DM) and hypertension (HT) are risk factors and in addition to these, osteoarthritis is more common in women. Repetitive minor traumas over the years disrupt the load-bearing ability of the joint and cause osteoarthritis by causing cartilage destruction. Especially in overweight people, the development of osteoarthritis in joints such as the knee is related to this condition [1].

In the advanced stages of the disease, it can reach levels that disrupt the daily life functions of the person. Although very rare, deformities can be seen. Osteoarthritis is a progressive disease. It may take a long time to be noticed and treatment may be delayed. Even if the complaints decrease or pass from time to time, problems caused by osteoarthritis may increase over the years and seriously reduce the quality of life. X-ray absorptiometry (DEXA), used in diagnosis and follow-up, is a widely used, highly sensitive and non-invasive method with proven accuracy in determining bone mineral density. Two X-rays with different energy levels are targeted to the patient's bones. When the amount absorbed by the soft tissue is subtracted from the total amount, the bone mineral density, the absorption of each beam by bone, can be determined. DEXA is the most widely used and most comprehensive bone density measurement technology [5].

It was observed that a protein named Lubricin, known as lubricant in ACL (anterior cruciate ligament) injuries in dogs as shown in Figure 1, may be a precursor of joint disease. Although research has been written about animals, it is thought that similar injuries in humans may have the same effect and this is an important development for early diagnosis. Injury of the anterior cruciate ligament can lead to severe osteoarthritis in both animal and human patients. In patients with joint injuries, Lubricin level increased significantly between the period of early injuries and before any signs of arthritis on radiological tests as shown in Figure 1 [6].

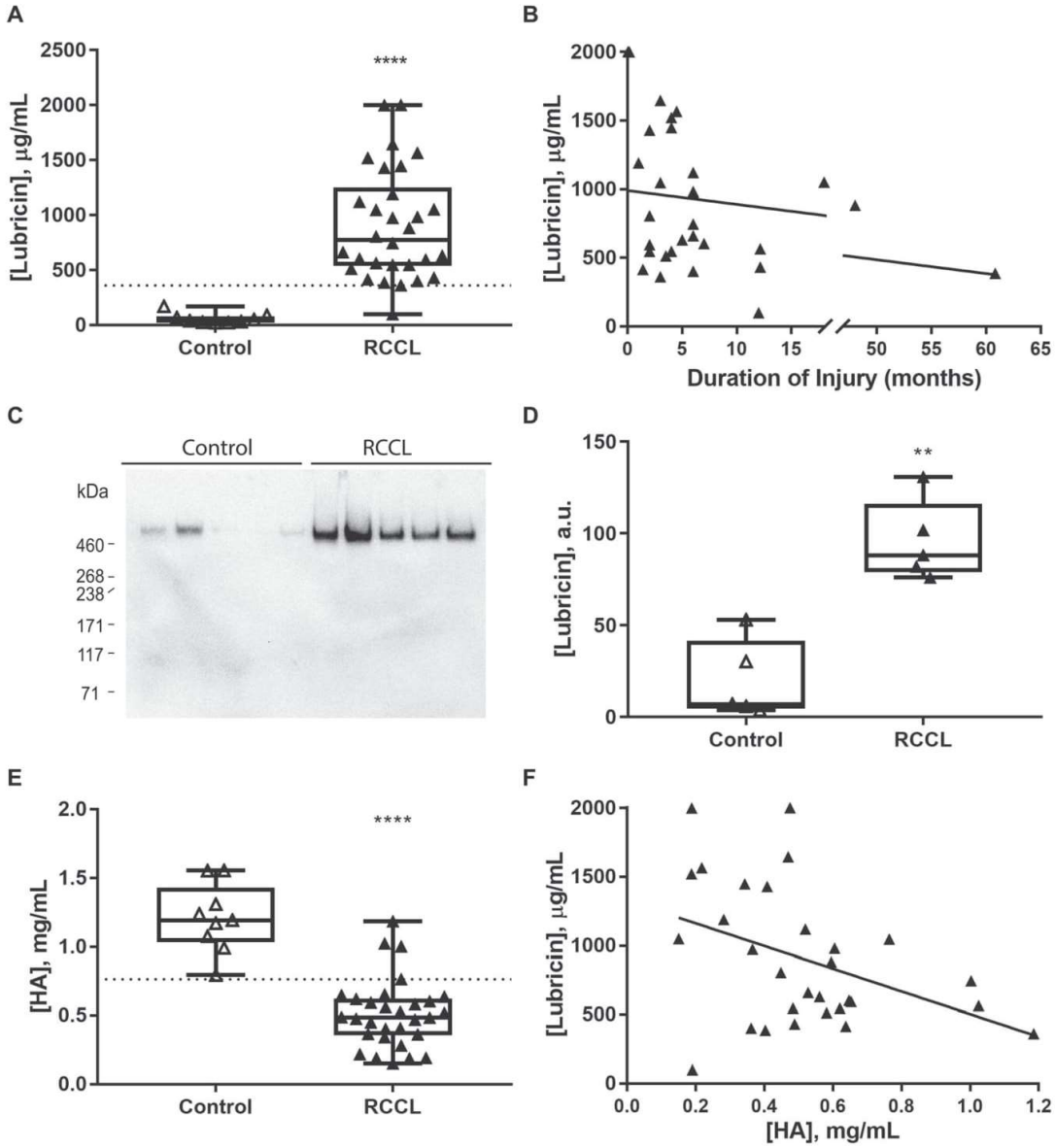

Figure 1. Canine synovial fluid lubricin and HA quantification. (A) Canine synovial fluid lubricin concentrations in control (n=9) and RCCL (n=30) joints. Dotted line: RCCL vs. control threshold (361.72 µg/mL) obtained by ROC curve. (B) Synovial fluid lubricin concentration plotted as a function of injury duration in dogs with RCCL (n=30), solid line: R2=0.07, Spearman's correlation test ρ=-0.35, n.s. C) Anti-lubricin (mAb 9G3, MABT401) western blots of synovial fluid from 5 randomly selected control and RCCL dogs. (D) Quantification of western blot in part C, reported as absorbance units (a.u.). (E) Synovial fluid HA concentration, dotted line: RCCL vs. control threshold (0.76 mg/mL) obtained by ROC curve. (F) Synovial fluid lubricin vs. HA concentrations for dogs with RCCL, R2=0.17, Spearman's correlation test ρ=-0.41, p=0.03. ** p<0.01, **** p<0.0001 for Wilcoxon test, α=0.05. [6]

Figure 1 illustrates that the mean synovial fluid lubricin concentration in the rupture of cranial cruciate ligament (RCCL) group was 905.2 ± 91.8 µg/mL (mean ± SEM), which was approximately 16 times greater than the control group (58.7 ± 16.1 µg/mL, mean ± SEM) (Fig. 2A, $p < 0.0001$). Reesink suggests that the increased presence of lubricant may actually be a biomarker for predicting future osteoarthritis [6].

Artificial neural networks are powerful and comparable computer systems that have the ability to learn from experience, adapt to new situations, and also work very quickly [8]. The artificial neural network can

be defined as a flexible mathematical model developed inspired by the working principles of the human brain. Artificial neural network consists of many nodes that are interconnected and can work in parallel. These nodes are connected to each other by weights [7]. The aim of this study on the use of artificial neural networks in the pre-diagnosis of osteoarthritis is to not apply the DEXA test to patients who have not been pre-diagnosed with osteoarthritis by the decision support system.

2. Methodology

The data set consists of patients who came to the Yozgat Bozok University Training and Research Hospital for diagnosis and treatment. The main purpose is to create a pre-Dexa decision support system to avoid direct Dexa in patients who are thought to have osteoarthritis. AI structure contains 24 input and an output. Probabilistic neural network (PNN) consists of the input layer, two hidden layers and the output layer. In the first hidden layer, the distance of the input from the training data is found, in the second hidden layer, the previous values are collected and the output data is obtained. Hidden layers act like a black box at the connection between the input layer and the output layer, providing the relationship between the two layers. If there is a nonlinear relationship between the input layer and the output layer, the hidden layer makes it easy to generalize from outputs [9]. PNN is a feed forward network frequently used in classification and pattern networks; it consists of the input, sampling, addition and output layer. In the PNN algorithm, the probability function of each class is approximated by a Parzen window and a nonparametric function. The output of each class is used as the input of the other class. A given input vector produces a forward output vector. The difference between the output vector produced by the network and the target output vector is propagated backward in the network and the weights are corrected. This process is called the learning process [10]. The Parzen window is used in Bayes' Theorem, the error is minimized with the Parzen window and the naive bayes method. Result takes a value of 1 for targeted values and 0 for non-target values. Osteoarthritis pre-diagnosis can be made according to this value at the exit of the network.

The information to be learned for the preliminary diagnosis of osteoarthritis is given below.

A- General Information

1. Year
2. Gender
3. Menopause status
4. Number of pregnancies
5. Osteoporosis in the family

B- 10 Question Test

6. Has any of your family members had hip fractures after a slight bump or fall? (Yes No)
7. Have any of your bones fractured after a slight impact or fall? (Yes No)
8. Have you used corticosteroids (cortisone, prednisone etc.) for more than three months? (Yes No)
9. Have you ever been shortened by more than three centimeters? (Yes No)
10. Do you regularly drink alcohol (more than 2 glasses a day)? (Yes No

11. Do you smoke more than 20 cigarettes a day? (Yes No)
12. Do you often have diarrhea? (Yes - No) (For women)
13. Have you entered menopause before the age of 45? (Yes No)
14. Has your period been interrupted for 12 months or longer due to reasons other than pregnancy or menopause? (Yes - No) For men
15. Have you ever had impotence or loss of libido due to a decrease in testosterone level? (Yes No)

C- Blood Test

16. Calcium
17. Phosphor
18. Alkaline Phosphatase
19.Vitamin D
20. Parathormone
21. TSH
22. Estrogen
23. Testosterone
24. Lubricin

Osteoarthritis Preliminary Diagnosis with Probabilistic Neural Network (OSA);

ANNs are logical software developed to perform the basic functions of the brain such as learning and generating new information by generalizing recall by imitating the working mechanism of the human brain. ANN are synthetic structures that mimic biological neural networks [11]. With machine learning, the mistakes made by people are reduced, they can solve complex problems, they can be retrained, they can learn and weigh owing to the examples they processed, and they can produce solutions to the problems they do not encounter. When an input is available, the distance from the input vector to the training vector is calculated in the first layer. This produces a vector that shows how close its elements are to the training input. In the second layer, the results are summed for each input and produces the net output as a probability vector. Finally, a competition transfer function in the output of the second layer selects the maximum of these possibilities and produces a 1 (positive definition) for this class and a 0 (negative definition) for non-target classes. Artificial neural networks are used to solve problems that are difficult to program and difficult to code. The brain has features such as learning, creating solutions, exploring, and creating new solutions. A machine learning-based Decision Support System, which was intended to be used before DEXA in disease diagnosis, is structured. Clinical decision support systems; are computer programs that provide support to healthcare personnel in their clinical decisions. These systems help physicians to make decisions by taking into account patients' specific clinical information. Clinical decision support systems; can provide great benefits in improving the quality of healthcare services, detecting diseases early, preventing medical errors, providing appropriate treatment to patients and reducing costs.

3. Results and Conclusion

At the end of this study, 1-fold and 3-fold cross-validation method is applied. In the 1-fold technique, 30% of the data is used as test data and 70% of the data is used as training data, while in the 3-fold technique, the data is divided into three, each data is used as both test and training data. Cross Validation is used to evaluate the performance of machine learning models. Cross Validation allows to know how to generalize the machine learning model to an independent data set and to understand how accurate its predictions are in practice. Machine learning has known data (training data set) and unknown data (test data set). In the K-fold technique, the machine learning model is checked for compliance and allows the machine learning model to be tested while still in the training phase to get an idea of how to interpret the independent data. Then, with the confusion matrix, the data are divided into False Positive (False Positive), False Negative (False Negative), True Positive (True Positive) and True Negative (True Negative). It can be used if there is sufficient accuracy.

$$\text{Accuracy} = (TP + TN) / (TP + TN + FP + FN) \quad (1)$$

$$\text{Precision} = TP / (TP + FP) \quad (2)$$

In our country, it has been observed that there is no study to establish a decision support system for the early diagnosis of osteoarthritis. In addition, it is very difficult to obtain the data sets required for the development of these systems. This study stands out as an alternative research in order not to apply the DEXA test, which is widely used for the diagnosis of osteoarthritis, to every patient and to reduce unnecessary radiation exposure.

In this study, the idea of looking at the glycoprotein named Lubricin and applying a decision support mechanism before using DEXA for patients with a diagnosis of osteoarthritis was proposed for the first time, and the study will be carried out by training artificial neural networks. With this study, it is thought that it can help physicians in their decisions in terms of providing a decision support system for the pre-diagnosis of osteoarthritis.

References

1. Koca NT, Sepici V, Tosun AK, Koca G. Diz Osteoartritli Hastalarımızda Risk Faktörleri ve Osteoartrit-Osteoporoz İlişkisi. Turk J Osteoporos 2011;17.
2. Alakoç, Y., Akdoğan, V., Korkmaz, M., & Orhan, E. R. (2018). Osteoporoz Ön Tanısının Olasılıksal Sinir Ağları (OSA) Yardımıyla Gerçekleştirilmesi. Sakarya University Journal of Computer and Information Sciences, 1(3), 1-6.
3. Hedbom, E., & Häuselmann, H. J. (2002). Molecular aspects of pathogenesis in osteoarthritis: the role of inflammation. Cellular and Molecular Life Sciences CMLS, 59(1), 45-53.
4. Cesare Paul, E., & Abramson, S. B. (2006). Osteoartrit Patogenezi; İç: Dinçer F, editör. Kelley Romatoloji. Ankara: Güneş Kitapevi, 1493-1513.
5. Choi, Y. J. (2016). Dual-energy X-ray absorptiometry: beyond bone mineral density determination. Endocrinology and Metabolism, 31(1), 25.
6. Wang, Y., Gludish, D.W., Hayashi, K. et al. Synovial fluid lubricin increases in spontaneous canine cruciate ligament rupture. Sci Rep 10, 16725 (2020). https://doi.org/10.1038/s41598-020-73270-2
7. Wang, S., Dong, X., & Sun, R. (2010). Predicting saturates of sour vacuum gas oil using artificial neural networks and genetic algorithms. Expert Systems with Applications, 37(7), 4768-4771.
8. Takefuji, Y., & Wang, J. (Eds.). (1993). Neural networks in design and manufacturing. World Scientific.

9. Efendigil, T., Önüt, S., & Kahraman, C. (2009). A decision support system for demand forecasting with artificial neural networks and neuro-fuzzy models: A comparative analysis. Expert Systems with Applications, 36(3), 6697-6707.

10. Koskivaara, E. (2000). Artificial neural network models for predicting patterns in auditing monthly balances. Journal of the operational research society, 51(9), 1060-1069.

11. Egrioglu, E., Aladag, C. H., Yolcu, U., Uslu, V. R., & Basaran, M. A. (2009). A new approach based on artificial neural networks for high order multivariate fuzzy time series. Expert Systems with Applications, 36(7), 10589-10594.