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ABSTRACT

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OPTIMIZATION OF THE SCIENTIFIC SEARCH FOR LYME BORRELIOSIS SEVERITY DIAGNOSTICS

The article deals with the data of the use of analytical search capabilities for the optimization of the literature sources analysis in the Scopus scientometric database when studying the current state of Lyme borreliosis diagnosis and treatment in children.

Methods of examination: analytical requests and assessment were used to investigate the analytical data of the scientific search for Lyme Borreliosis diagnosis. The Scopus scientometric database gives the capabilities to make a relevant search of scientific literature on the studied issues. In particular, to assess the relevance of research on LB in infectious diseases field, the following analytical query was formulated in the Scopus database: (ALL("tick bites") OR ALL("endemic area in lyme borreliosis") OR ALL("questionnaire of parents of children with Lyme disease") OR ALL("affected by ticks") OR ALL("DNA to complex *B. burgdorferi* s.l. ") OR ALL("B. miyamotoi").

Research results. The use of the Scopus scientometric database optimizes the relevant search of scientific literature by the research topic; total number of papers and comparisons in Cite Score, SIR, SNIP; search results by authors, subject areas, country, among leading scientific institutions, types of publications, and the largest financial sponsors of the research topic.

Conclusions: the analytical review of publications on the use of artificial intelligence in medicine, in particular, infectology was presented in the article. The analysis of the papers in the Scopus scientometric database was carried out. The authors with the largest number of papers, taking into account countries and scientific institutions, were presented. Based on the data obtained from the analytical review of literature sources using Scopus, we can conclude that there is a growing scientific interest in the problem of studying the causes of the onset and progression of Lyme borreliosis. Thus, such research is extremely relevant for improving and maintaining patient health.

Keywords: Lyme borreliosis, children, technologies of medical diagnosis and treatment, Ixodes ticks, *Borrelia burgdorferi*.

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ОПТИМІЗАЦІЯ НАУКОВОГО ПОШУКУ ДЛЯ ДІАГНОСТИКИ ВАЖКОСТІ ПЕРЕБІГУ ЛАЙМ-БОРЕЛІОЗУ

Наведено дані використання можливостей аналітичного пошуку для оптимізації аналізу літературних джерел у наукометричній базі даних Scopus при дослідженні сучасного стану питань діагностики та лікування Лайм-бореліозу у дітей.

Мета дослідження: вдосконалити надання медичної допомоги дітям, що зазнали нападів кліщів; покращити діагностичний пошук наукової літератури з проблеми Лайм-бореліозу.

Методи дослідження: Використання наукометричної бази Scopus оптимізує релевантний пошук наукової літератури з досліджуваної проблематики. Зокрема, для оцінювання актуальності досліджень по ЛБ у інфектології в наукометричній базі Scopus було сформульовано аналітичний запит: (ALL("tick bites") OR ALL("endemic area in lyme borreliosis") OR ALL("questionnaire of parents of children with Lyme disease") OR ALL("affected by ticks") OR ALL("DNA to complex *B. burgdorferi* s.l. ") OR ALL("B. miyamotoi"))

Результати дослідження. Використання наукометричної бази Scopus оптимізує релевантний пошук наукової літератури за категоріями: досліджувана проблематика, загальна кількість праць і порівняння в Cite Score, SIR, SNIP, результати пошукового запиту по авторах, результати пошукового запиту (предметні галузі); в базі Scopus по країнах, серед ведучих наукових закладів, по видах публікацій, по найбільших фінансових спонсорах вивчення даної проблематики.

Висновки: У даній статті проведено аналітичний огляд публікацій по використанню штучного інтелекту в медицині, зокрема, інфектології. На основі отриманих даних аналітичного огляду літературних джерел з допомогою програми Scopus можна зробити висновок про зростаючий науковий інтерес до проблеми дослідження причин виникнення та прогресування Лайм-бореліозу, тому такі дослідження є надзвичайно актуальними для покращення та збереження здоров'я пацієнтів.

Ключові слова: Лайм-бореліоз, діти, технології медичної діагностики та лікування, іксодових кліщі, *Borrelia burgdorferi*.

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INTRODUCTION

Lyme borreliosis (LB) is an important problem in pediatrics, as it belongs to the group of particularly dangerous infections caused by *Borrelia burgdorferi* [1]. This acute systemic disease is common among children,

and it is characterized by the presence of migratory erythema [2], and in some untreated patients, it is accompanied by nervous system damage [3], inflammatory arthritis [4], and carditis [5, 6, 7, 8]. The relevance of the topic of this thesis is due to the

increasing incidence of LB and its complications among the pediatric population of Ukraine. Untreated forms of the disease lead to disability. Studies of the patterns of tick infestation in children aged 1 month to 17 years inclusively have shown that children aged 3 to 11 years suffer the most from tick bites. This is due to their activity and lack of proper attention from their parents. The issue of improving the diagnosis and treatment of children with LB, raising awareness of parents of children about this vector-borne infection, and conducting a comprehensive study of Ixodes ticks to detect infection with their pathogens remains open.

Today, scientists require a lot of relevant, innovative, and qualitative research, which cannot be done without a detailed study of the state of the scientific issue [9, 10, 11, 12]. A full solution to this problem is impossible without a deep analytical review of the literature. Currently, this problem can be optimized by using information search engines. In science in general, and medicine in particular, there are a number of unresolved issues that have not yet been fully resolved, and scientists from around the world have been working on them for many years, but they remain relevant.

The aim of the study was to improve the provision of medical care to children exposed to tick attacks and to improve the diagnostic search of scientific literature on Lyme Borreliosis. In particular, to assess the relevance of the research on LB in infectious diseases, an analytical query was formulated in the Scopus scientometric database.

Research methods: analytical requests and assessment were used to investigate the analytical data of the scientific search of the diagnosis of Lyme Borreliosis. The use of the Scopus scientometric database optimizes the relevant search for scientific literature on the studied issues. In particular, an

analytical query was formulated in the Scopus scientometric database to assess the relevance of research on LB in infectious diseases: (ALL("tick bites") OR ALL("endemic area in lyme borreliosis") OR ALL("questionnaire of parents of children with Lyme disease") OR ALL("affected by ticks") OR ALL("DNA to complex B. burgdorferi s.l. ") OR ALL("B. miyamotoi"))

RESEARCH RESULTS

The information search revealed 1881 documents from 1991 to 2024. The total number of papers during some period was analyzed in dynamics. According to the results of the search in the Scopus scientometric database, we have seen an increase in the number of publications over the past twenty years. This also further confirms the high scientific interest in the topic under study, namely the application or use of medical, information, hospital, expert, and diagnostic systems in infectious diseases.

The information search revealed 1881 documents from 1991 to 2024.

Our search query on this topic in the Scopus scientific database returned 1,881 document results from 1991 to 2024, including 1,298 scientific papers from 2014 to 2023 over the past decade. The largest number of literary sources on the topic under study falls in the last 3 years. In particular, 210 publications were published in 2021, 196 in 2022, and 204 in 2023, which confirms the relevance of the study of this problem in medicine and the steady growth of interest in it around the world (Fig. 1).

A comparison of citations in the Cite Score, SIR, and SNIP databases shows an increase from 2021 to 2023, with the largest increase in the journals "Tick and Tick Borne Disease" and "Journal of Medical Entomology" (Fig. 2).

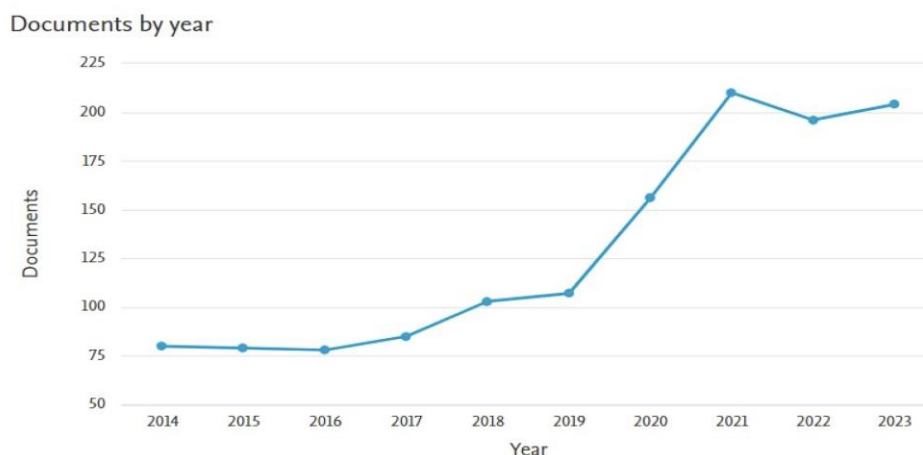


Figure 1 – Results of a search query in the Scopus scientometric database (total number of papers by year in dynamics)

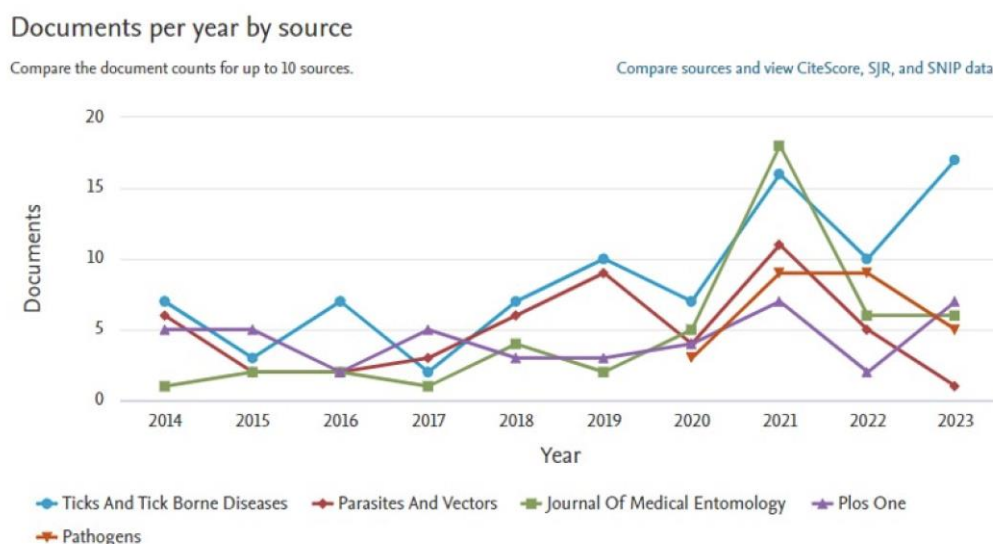


Figure 2 – The results of the search query in the Scopus scientometric database (total number of papers and comparison in Cite Score, SIR, SNIP)

In terms of the number of documents by source, the leading journals are Ticks and Tick Borne Disease – 86, Parasites and Vectors – 49, Journal Of Medical Entomology – 47, Plose One – 43, Pathogens – 26, Vector Borne and Zoonotic Disease – 25, Microorganisms – 24, Experimental and applied acarology – 19, BMG-Public Health Scientific Reports – 19 (Fig. 3).

Source ↓	Documents ↑
<input checked="" type="checkbox"/> Ticks And Tick Borne Diseases	86
<input checked="" type="checkbox"/> Parasites And Vectors	49
<input checked="" type="checkbox"/> Journal Of Medical Entomology	47
<input checked="" type="checkbox"/> Plos One	43
<input checked="" type="checkbox"/> Pathogens	26
<input type="checkbox"/> Vector Borne And Zoonotic Diseases	25
<input type="checkbox"/> Microorganisms	21
<input type="checkbox"/> Experimental And Applied Acarology	19
<input type="checkbox"/> Scientific Reports	19
<input type="checkbox"/> BMC Public Health	18

Figure 3 – Results of the search query by journals

As for the main authors, the leadership is held by such scientists as Sprong H., Ogden N.H., Hovius J.W., Eisen R.J., Fonville M., Moutailler S., Eisen L., Leighton P.A., Krause P.J. and Wormster G.P. (Fig. 4).

By country, the number of publications is highest in the United States – 488, Germany – 105, the United Kingdom – 97, France – 95, the Netherlands – 91, Canada – 85, China – 62, Sweden – 57, Poland – 55. Thus, developed countries are mainly interested in studying the problems of Lyme borreliosis and its consequences (Fig. 5).

As for scientific institutions, the leading institutions by the number of documents by source are CDC – 45, Rijksinstituut voor Volksgezondheid-40, Public Health Agency of Canada-37, National Centre for Emerging and Zoon-32, John Hophins University School of Medicine-30, University of Montreal-30 (Fig. 6).

This problem was most often covered in research articles (73.4%), review articles (17.6%), conference abstracts (1.6%), and monograph chapters (1.2%) (Fig. 7).

The largest number of articles was published in the following fields: medicine – 891, immunology – 506, agriculture – 279, biochemistry – 158, veterinary medicine – 119, environment – 94, multidisciplinary sciences – 67, computer sciences – 57, engineering – 34. As for the field of knowledge, medicine comprises 891 articles, computer sciences – 57, which indicates a growing interest in the use of artificial intelligence algorithms in the problem under study. In terms of percentage, the largest share of scientific papers belonged to medicine (36.9%), immunology 21%, agriculture 11.6%, 36.9%, immunology 21%, agriculture 11.6%, biochemistry 6.5%, veterinary medicine 4.9%, environment 3.9%, multidisciplinary sciences 2.8%, computer science 2.4%, engineering 1.4%, pharmacology 1.2% (Fig. 8).

Documents by author

Compare the document counts for up to 15 authors.

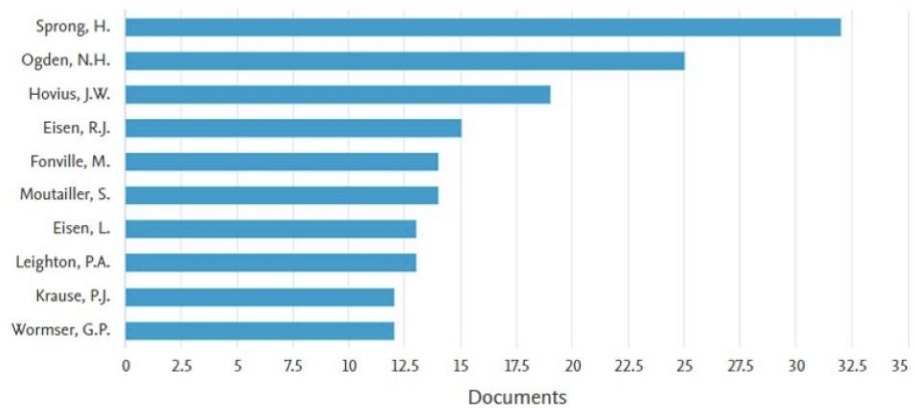


Figure 4 – Results of the search query by authors

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

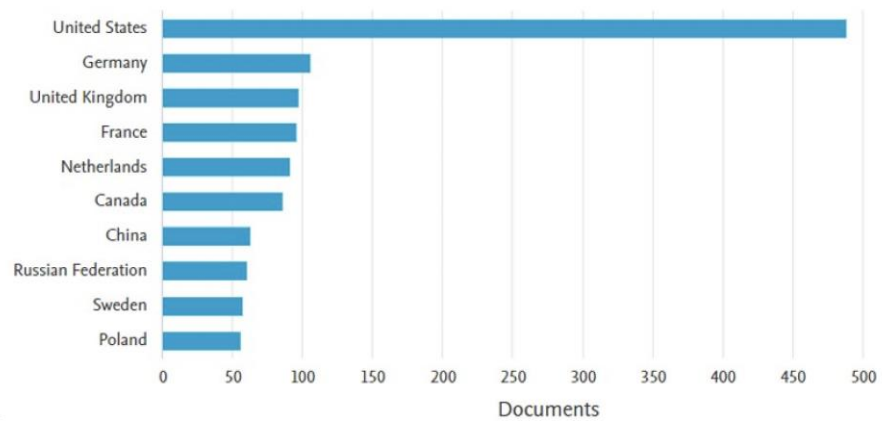


Figure 5 – Results of a search query in the Scopus database (countries)

Documents by affiliation

Compare the document counts for up to 15 affiliations.

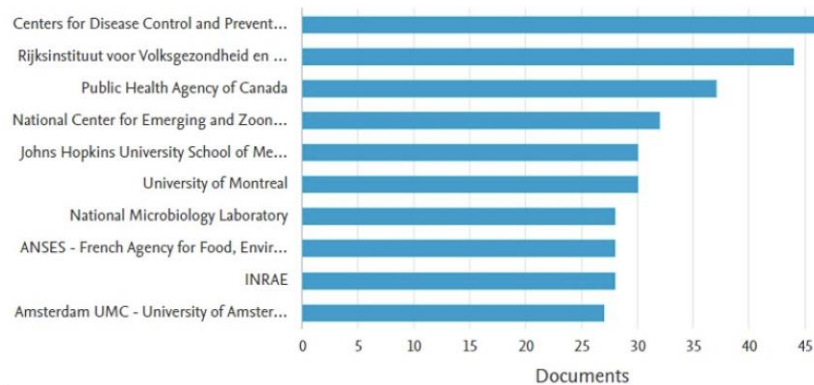


Figure 6 – Results of a search query in the Scopus scientometric database among scientific institutions

Documents by type

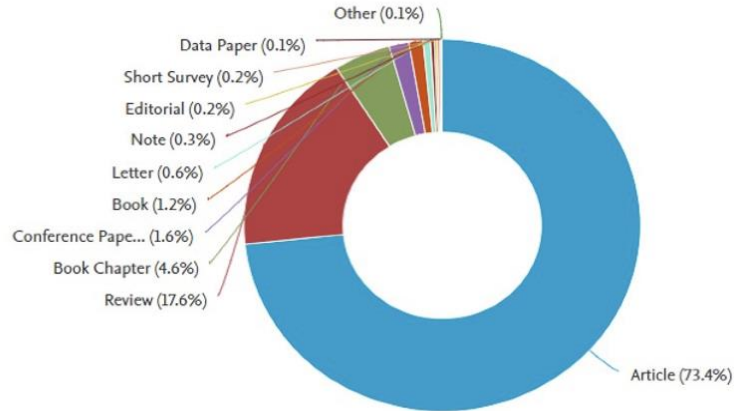


Figure 7 – Results of a search query in the Scopus scientometric database (types of publications)

Documents by subject area

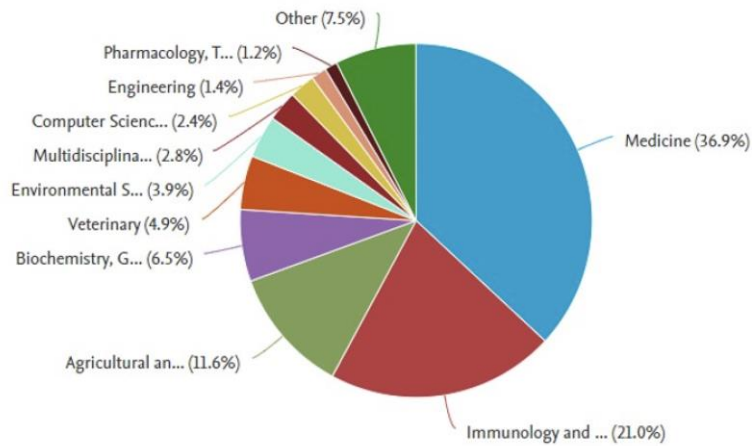


Figure 8 – Results of a search query in the Scopus scientometric database (subject areas)

Documents by funding sponsor

Compare the document counts for up to 15 funding sponsors.

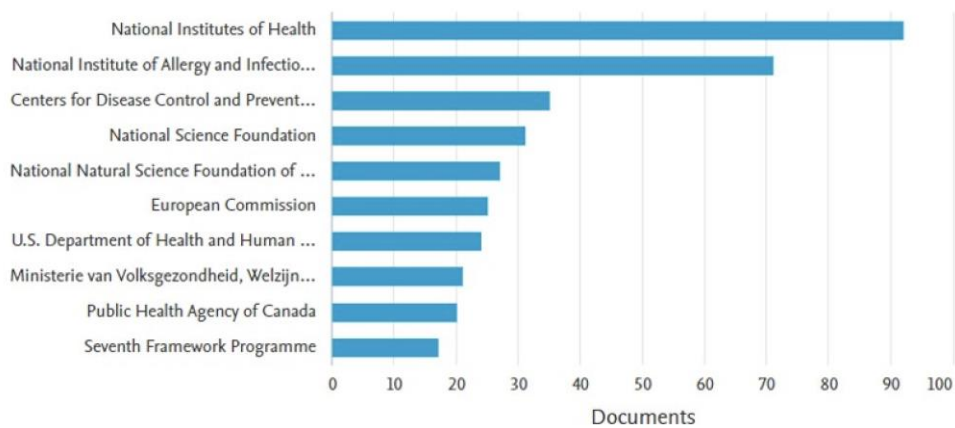


Figure 9 – The results of a search query in the Scopus scientometric database (financial sponsors)

Among the most important financial sponsors of the study of this problem are the National Institute of Health – 92, National Institute of Allergy and Infection Disease – 71, CDC – 35, National Science Foundation – 31, National Natural Science Foundation Of China – 27, European Commission – 25, US Department of Health and Human Services – 24, Ministerie van Volksgezondheid, Welzijn en Sport – 21 (Fig. 9).

The study presents machine learning methods for assessing and predicting the severe course and damage to organs and systems in Lyme borreliosis in children, as well as its development and evaluation of

effectiveness. Development of a multifactorial model for predicting the severe course of Lyme borreliosis in children: "ROC analysis"; use of Data Mining technologies to predict the course of Lyme disease in children for computerized diagnostic systems. The final result was that significant factors were obtained for predicting the course of LB in multivariate regression analysis in Statistica 10.0 without taking into account insignificant criteria. To build a multivariate regression model for predicting the severe course of Lyme borreliosis, a number of probable factors (occurrence and progression) were selected (Table 1).

Table 1 – Identification of potential risk factors for localized and disseminated forms of LB

Variable of the model	Name of factor
X ₁	Age
X ₂	Sex
X ₃	Causative agent of infection
X ₄	Number of ticks
X ₅	Affected system
X ₆	IgM (RU/ml)
X ₇	IgG (RU/ml)
X ₈	Ig G (in dynamics)
X ₉	VLsE IgM
X ₁₀	P41 IgM
X ₁₁	P39 IgM
X ₁₂	OspC Ba (<i>Borrelia afzelii</i>)
X ₁₃	OspC Bb (<i>Borrelia burgdorferi</i>)
X ₁₄	OspC Bg (<i>Borrelia garinii</i>)
X ₁₅	IgM
X ₁₆	VLsE (<i>Borrelia afzelii</i>) IgG
X ₁₇	VLsE (<i>Borrelia burgdorferi</i>) IgG
X ₁₈	VLsE (<i>Borrelia garinii</i>) IgG
X ₁₉	Lipid Ba (<i>Borrelia afzelii</i>) IgG
X ₂₀	Lipid Bb (<i>Borrelia burgdorferi</i>) IgG
X ₂₁	P83 IgG
X ₂₂	P41
X ₂₃	P39 IgG
X ₂₄	OspC (<i>B. afzelii</i>) IgG
X ₂₅	P58IgG
X ₂₆	P21IgG
X ₂₇	P20IgG
X ₂₈	P19IgG
X ₂₉	P18IgG
X ₃₀	IgG

A mathematical model for determining the risk factor for the development of the disseminated form of Lyme disease.

$$\begin{aligned} \text{KRRDFLB} = & X1 \times 0.195006 + X2 \times 1.054402 + \\ & X4 \times 1.099619 + X5 \times 1.066334 + \\ & + X6 \times 0.096539 + X7 \times 0.119710 + X8 \times 0.808857 + \\ & X9 \times 1.359550 + X10 \times 1.193117 + \\ & + X11 \times 1.178243 + X12 \times 0.979160 + X13 \times 0.923724 + \\ & X14 \times 1.251910 + X15 \times 1.565490 + X16 \times 1.089057 + \\ & X17 \times 1.509904 + X19 \times 1.111819 + X20 \times 0.854634 + \\ & X22 \times 0.949557 + X23 \times 1.248157 + X24 \times 1.435077 + \\ & X26 \times 1.548784 + X27 \times 1.519191 + X28 \times 0.661533 - \\ & 0,762931. \end{aligned}$$

Thus, among the 30 analysed factors, 24 most significant risk factors were selected that have the greatest impact on the development of severe pathology: X1 – age; X2 – sex; X4 – pathogen of LB; X5 – affected system; X6 – IgM (IU/ml); X7 – IgG (IU/ml); X8 – P41; X9 – P39; X10 – OspC Ba (*B. afzelii*); X11 – OspC Bb (*B. burgdorferi*); X12 – OspC Bg (*B. garinii*); X13 – IgM; X14 – VLsE (*B. afzelii*); X15 – VLsE (*B. burgdorferi*); X16 – VLsE (*B. garinii*); X17 – Lipid Ba

(*B. afzelii*); X19 – P83; X20 – P41; X22 – OspC (*B. afzelii*); X23 – P58; X24 – P21; X26 – P19; X27 – P18; X28 – IgG.

ROC-analysis and PCA method were carried out in children to identify the level of difficulty of Lyme Borreliosis.

Figure 10 shows the visualization results of the PCA method for the analysis of localized (black dots) and disseminated (gray dots) forms of Lyme Borreliosis.

In Figure 1, 30 factors are shown in different directions, which have different effects on the severity of the course of LB. In particular, the increase in factors x_{10} , x_{12} , x_{16} , x_{17} , x_{18} , x_{21} , x_{22} , x_{23} , x_{24} , x_{30} and a decrease in the x_3 factor will contribute to an increase in the severity of the course of LB, namely the occurrence of a disseminated form (class 1).

Conversely, a decrease in the factors x_{10} , x_{12} , x_{16} , x_{17} , x_{18} , x_{21} , x_{22} , x_{23} , x_{24} , x_{30} and increasing the factor x_3 will help to reduce the severity of the course of LB, namely the occurrence of a localized form (class 0).

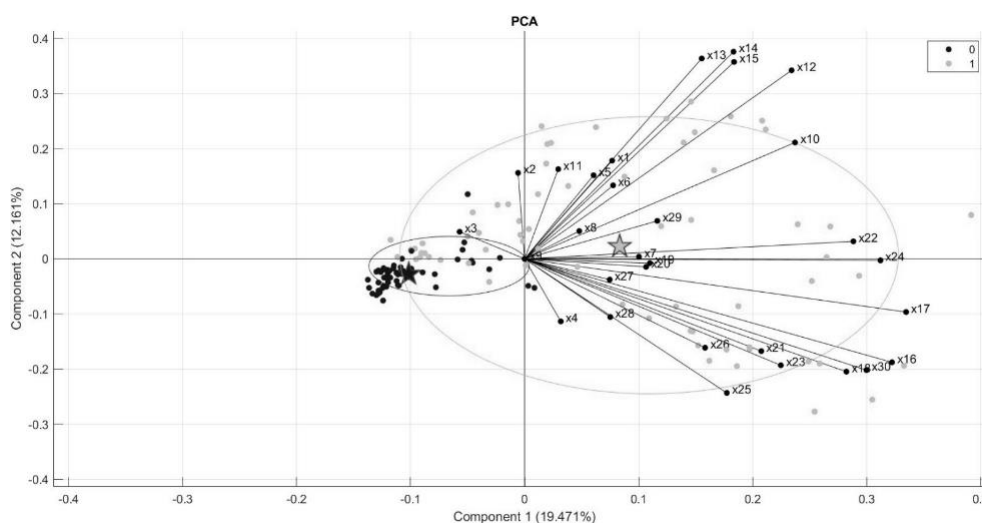


Figure 10 – Visualization of the results of the PCA method for the analysis of Lyme Borreliosis forms

DISCUSSION

Lyme Borreliosis (LB) is a zoonotic multisystem disease. Lyme disease (LD) is caused by three species of *Borrelia burgdorferi*: (*Borrelia afzelii*, *B. garinii* and *B. burgdorferi sensu stricto*) and has different stages, including localized, early disseminated. Various computer diagnostic systems are used to diagnose Lyme disease in people [9, 10, 11, 12], which are implemented in mathematical methods of biomedical signal processing [13, 14, 15], algorithmic support and software to diagnostic acute and late disseminated forms

(joint, neurological, cardiac). Having made the analytical review a high actuality of the development of mathematical models to predict a difficult period of Lyme Borreliosis in children, it was proved to be used. Limited evidence of infected cases with tick-borne pathogens in patients tested for Lyme neuroborreliosis in the Netherlands [11].

Therefore, prospective studies on humans with tick exposure are necessary to describe the prevalence, etiology, and clinical symptoms of tick-borne diseases rather than Lyme borreliosis and tick-borne

encephalitis. In particular, a multifactor progressive model to predict localized and disseminated forms of Lyme Borreliosis was proposed in the article. The proposed model can be used for previous investigations in neuroborreliosis [11].

Using linear logistic and multivariate regression analysis, factors were identified for constructing a compartmental mathematical model for constructing a multivariate regression model for predicting the severe course of Lyme borreliosis in children.

According to the PCA algorithm described above, a model-free factor analysis is used to assess the severity of the course of LB in the form of localized and disseminated forms.

To study localized and disseminated forms of Lyme borreliosis in children, cluster analysis and decision tree were used. A multifactorial regression model for predicting the severe course of Lyme borreliosis in children was developed and implemented. New methods for organizing and optimizing the processes of predicting the severity of Lyme borreliosis using standardized scales of Lyme disease severity, possible organ and system damage are proposed.

The severity of LB is assessed in the form of localized and disseminated forms. On the basis of the obtained results, the features of the diagnosis of various forms of Lyme disease have been established in the Phython and MatLab programs, which will facilitate the prognostic stage of providing medical care [16]. There is still a need to improve the diagnosis and treatment of children with Lyme Borreliosis, to find out the awareness of parents of children about this vector-borne infection; to conduct a comprehensive study of Ixodes ticks to detect infection with their pathogens in bitten children with clinical suspicion of LB in Ternopil region and other regions of Ukraine.

A simple but interpretable probabilistic model for predicting the number of registered cases of infectious diseases was proposed in the research. The applied Bayesian Monte Carlo regression system is easily extensible and allows the inclusion of prior knowledge about the subject area, making it suitable for use on limited but complex data sets often encountered in epidemiology [17].

CONCLUSIONS

Having made an analytical review of publications on the use of artificial intelligence in medicine, in particular, infectology and the analysis of papers by years in the Scopus scientometric database, the following conclusions were made: there is a growing scientific interest in the problem of studying the causes of the onset and progression of Lyme Borreliosis, so such studies are extremely relevant for improving and maintaining patient health. A mathematical model for predicting the severity of the form of Lyme borreliosis based on multivariate regression analysis was developed, on the basis of which a medical calculator for practitioners with a prediction accuracy of 95% was developed.

Prospects for further research. We would like to emphasize that it is necessary to expand the existing database of patients with existing research methods, add the non-erythematous form of Lyme borreliosis. Conducting a comprehensive use of various machine learning methods, using cluster analysis, regression analysis, decision trees, and the PCA method, for a more complete diagnostic assessment of the course of Lyme borreliosis in children is very perspective and should be taken into consideration making future investigations. Taking into account modern approaches [18], we are going to use the example of a virtual globe in the analysis of the spread of Lyme borreliosis.

AUTHOR CONTRIBUTIONS

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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