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Title: Global research trends on the links between primary health care and diabetes from 1980 to 2024: a machine learning-based science mapping.

Short title: Global research trends on the links between PHC and diabetes.

Abstract

Purpose: A systematic and detailed examination of studies on diabetes can guide the evaluation of healthcare services, the identification of issues, and the implementation of preventive interventions. Therefore, this study aims to assess diabetes research in the primary health care (PHC) field using machine learning-based bibliometric methods.

Materials and methods: In this study, articles related to diabetes in the PHC field were obtained from the Web of Science Core Collection on March 15, 2024. These articles were analyzed using bibliometric methods and the Latent Dirichlet Allocation (LDA) topic modeling technique.

Results: The analysis of the studies revealed that 3.355 articles on diabetes in the PHC field were produced by researchers from 114 different countries, 4.226 institutions, and 12.426 individual researchers. Recent years have shown a growing interest in topics such as obesity, hypertension, chronic diseases, exercise, and physical activity within the PHC field. Topic modeling identified eight distinct latent topic clusters: (1) Diabetes management in PHC, (2) Risk factors and management of diabetes in PHC, (3) Acute and chronic complications of diabetes in PHC, (4) Gestational diabetes, (5) Prediabetes and Type 1 diabetes, (6) COVID-19 and diabetes, (7) Quality of life, awareness, and health education, (8) Current treatment methods and guideline resources.

Conclusion: Primary Care Diabetes and Journal of Family Medicine and Primary Care are the leading journals in PHC-related diabetes research. The studies show a significant overlap between diabetes research and topics such as hypertension and obesity. Future studies in the PHC field are recommended to focus on diabetic retinopathy and diabetic wound research.

Keywords: Primary health care, diabetes, data analysis, sience mapping, topic modeling.

Makale başlığı: 1980-2024 yılları arasında birincil sağlık hizmetleri ile diyabet arasındaki ilişkiler üzerine küresel araştırma eğilimleri: makine öğrenmesi tabanlı bilimsel haritalama çalışması.

Kısa başlık: Birincil sağlık hizmetleri'nde diyabet üzerine küresel araştırma eğilimleri.

Öz

Amaç: Diyabetle ilgili yapılan çalışmaların sistematik ve ayrıntılı olarak incelenmesi, sağlık hizmetlerinin değerlendirilmesine, sorunların belirlenmesine ve önleyici müdahalelere rehberlik edebilir. Bu nedenle çalışmamız kullanılan makine öğrenmesi destekli bibliyometrik yöntem ile birincil sağlık hizmetleri (BSH) araştırma alanındaki diyabet araştırmalarını değerlendirmeyi amaçlamıştır.

Gereç ve yöntem: Çalışmamızda 15 Mart 2024 tarihinde Web of Science Core Collection veri kaynağından elde edilen diabet konulu birinci basamak sağlık hizmetleri araştırma alanındaki makaleler bibliyometrik yöntemler ve Latent Dirichlet Allocation (LDA) konu modelleme yöntemi ile analiz etmektedir.

Bulgular: Çalışmalar incelendiğinde BSH alanındaki diyabet konusunda 3,355 makalenin 114 farklı ülkeden, 4,226 farklı kurum ve 12,426 farklı araştırmacı tarafından üretildiği görülmüştür. Son yıllarda birinci basamak sağlık hizmetleri alanında obezite, hipertansiyon, kronik hastalık, egzersiz, fiziksel aktivite konu başlıklarının yoğun ilgi gördüğü görülmüştür. Yapılan konu modellemesi ile sekiz farklı gizli konu kümesi bulunmuştur. Bunlar sırasıyla; (1) BSH'de diyabet yönetimi, (2) BSH'de diyabetin risk faktörleri ve yönetimi (3) BSH'de diyabetin akut ve kronik komplikasyonları (4) gestasyonel diyabet (5) prediyabet, tip 1 diyabet (6) COVID-19 ve diyabet (7) yaşam kalitesi, farkındalık ve sağlık eğitimi, (8) güncel tedavi yöntemleri ve rehber kaynaklar şeklindedir.

Sonuç: Primary Care Diabetes ve Journal of Family Medicine and Primary Care dergileri BSH alanında diyabet araştırmalarında öne çıkan dergilerdir. Diyabet araştırmaları ile hipertansiyon ve obezite konularının yoğun şekilde birlikte işlendiği görülmüştür. Gelecek çalışmalar için BSH alanında diyabetik retinopati ve diyabetik yara çalışmalarının yapılması önerilmektedir.

Anahtar kelimeler: Birinci basamak sağlık hizmetleri, diyabet, veri analizi, bilim haritalama, konu modelleme.

Introduction

Diabetes mellitus (DM), commonly referred to as diabetes, is a chronic and debilitating condition characterized by persistently elevated blood glucose levels due to insufficient insulin production or the body's inability to utilize the insulin it produces effectively [1]. Diabetes affects individuals across all ages, genders, and geographic locations, making it one of the leading global causes of mortality and morbidity. Both genetic and environmental factors contribute to the etiopathogenesis of Type 2 diabetes, which accounts for more than 90% of all cases [2, 3]. The global prevalence of diabetes has reached pandemic proportions, with the International Diabetes Federation (IDF) reporting a prevalence rate of 9% (463 million adults) in its 9th edition in 2019. According to IDF estimates, the number of people living with diabetes increased to 537 million worldwide in 2021, a trend largely attributed to the aging population [4].

In addition to its high prevalence, morbidity, and mortality, diabetes also poses a significant economic burden, making it a critical public health issue. It is observed that diabetes increases healthcare expenditures, imposing financial strains on national healthcare systems. Global healthcare expenditures related to diabetes reached $966 billion in 2021 for the 20-79 age group and are expected to rise to $1.05 trillion by 2045 [5, 6]. Without adequate glycemic control, diabetes may lead to complications that complicate treatment, increase healthcare costs, and result in higher mortality rates. Therefore, establishing a healthy lifestyle and achieving glycemic control through medical treatment are crucial.

Systematic and detailed examination of studies related to diabetes can guide the evaluation of healthcare services, identification of issues, and preventive interventions. For this purpose, bibliometric analyses can be utilized. Bibliometric analysis can assess the productivity trends of a research topic over time, as well as serve as a valuable tool for comparing research outputs of academics, leading institutions, countries, and journals in a specific field of interest [7-9]. Currently, the body of literature on diabetes research within the context of primary health care (PHC) remains limited in providing comprehensive and relevant information for traditional literature analysis. This article aims to reveal the overall structure of the scientific literature on diabetes—a significant topic in PHC research and one of the most common modifiable contributors to global morbidity and mortality—by analyzing publications indexed in the Web of Science (WoS).

Background

Primary healthcare services play a critical role in the provision of healthcare, encompassing preventive, promotive, and curative interventions. The primary goal of primary healthcare is not only to address diseases but also to intervene in and prevent the underlying risk factors that contribute to their development. Within a tiered healthcare system, the fundamental function of primary care institutions is to deliver preventive health services for all. Primary prevention focuses on preventing individuals from developing diseases [10]. However, many issues that could be resolved at the primary care level are often referred to secondary care, and problems manageable in secondary care are frequently transferred to tertiary care institutions. This practice leads to unnecessary overcrowding in institutions, reduces employee productivity, and diminishes service quality. Efforts to improve primary healthcare services significantly contribute to advancing public health. Stronger PHC will contribute significantly to health system performance and public health.

The early diagnosis and treatment of DM are of critical importance due to several factors: Type 2 DM represents a significant public health issue, has an asymptomatic phase in its early stages, and is associated with progressive microvascular damage in undiagnosed patients. Additionally, it has been demonstrated that strict glycemic control can delay or prevent the development and progression of diabetic complications [11]. To reduce diabetes-related morbidity and mortality, primary care physicians must have a comprehensive understanding of how to manage diabetic patients effectively [12]. Consequently, primary care physicians should assess all patients for diabetes risk factors and implement preventive measures to reduce the likelihood of diabetes development. They should perform diabetes screening in at-risk individuals and, considering that prevention and treatment require a multidisciplinary approach, refer patients to nephrology, ophthalmology, cardiology, or other relevant specialties when necessary [13].

A review of the literature reveals that numerous bibliometric studies have been conducted on various aspects and topics related to diabetes. For instance, bibliometric studies have been performed on postoperative diabetes mellitus in kidney transplant recipients [7], the bibliometric analysis of experimental research on diabetic nephropathy [8], the bibliometric analysis of research on diabetic foot ulcer therapy [14], and gestational diabetes and long-term cardiovascular health [15]. Similarly, bibliometric analyses have been conducted on many diabetes-related topics. A Web of Science (WoS) search revealed that 55 bibliometric articles on diabetes were published in 2024, compared to 28 in 2023. This highlights that

diabetes is a highly prominent topic in the literature, and research analyses on this subject are conducted under a wide range of subtopics, drawing considerable interest. Additionally, diabetes is a significant public health issue, particularly for primary healthcare services [16, 17]. However, our detailed review of the literature did not identify any bibliometric studies that analyze discussions on diabetes within the context of primary healthcare research.

Materials and method

Data sources and search string

In our study, the Web of Science (WoS) Core Collection was selected as the data source, focusing on research articles and review articles that include the term "diabetes" in either the title or the author's keywords within the "primary health care" research area. All articles on diabetes published between 1980 and 2024 were included in our study. Document types such as book chapters, letters, and proceedings were excluded from the analysis. The primary reason for selecting Web of Science (WoS) as the bibliometric data source is the presence of a specific category named "primary health care" within WoS [9]. The existence of such a category defined by WoS allows us to conduct searches directly through journals explicitly associated with the primary health care category. A similar category is not available in the Scopus database. This ensures that publications unrelated to primary health care are included at a minimal level in the study.

Data for our analyses were collected on April 15, 2024. During data acquisition, we applied a sequential filtering process as shown in Figure 1 below, with the final dataset being retrieved using query number four. No ethics committee permission is required for the use of data obtained from such data sources. The relevant WoS data are publicly available and extracted from the journals indexed by such data sources. Therefore, ethics permission was not obtained in our study.

Statistical analysis and latent dirichlet allocation (LDA) topic modeling

The tools used for statistical analysis were Microsoft Office Excel, SQL, Hypertext Preprocessor (PHP) programming language, Python programming language, Oracle Database, R Bibliometrix package Biblioshiny program, and VOSviewer software. Microsoft Excel was used to quickly make modifications and revisions to the data. Additionally, SQL query language and the PHP programming language were employed to transfer the bibliometric data obtained from Web of Science (WoS) in Plain Text format into an Oracle database. Through the studies conducted using this setup, we were able to quickly access article content and

classify the articles, which proved particularly beneficial in the discussion section. VOSviewer and Biblioshiny programs were used to perform analyses such as co-authorship by country, co-authorship by institutions, co-authorship by authors, co-citation references, co-citation sources, trend topics, and co-occurrence of author keywords on the data obtained from WoS. Analyses were conducted using data obtained from the WoS bibliometric database in Plain Text and Excel formats. In some instances, the WoS reporting tool was also utilized during the analyses. The rationale for selecting two software packages was the observation that the different programs occasionally produced varying results in data analyses.

Also, we use Python programming language for machine learning based analyses. Additionally, for topic modeling, both Topics Analyses and LDA topic modeling were employed. LDA is a fundamental technique in text mining and natural language processing, representing words, documents, and corpora as mixtures of topics. Using LDA, topics within documents can be identified, providing a clear representation of their content [9]. In our study, LDA was applied to the abstracts and titles of research articles to perform topic modeling. This analysis was conducted using Python, with libraries such as Scikit-learn, Natural Language Toolkit (NLTK), Gensim, Matplotlib, and Wordcloud. NLTK (Natural Language Toolkit) is a Python library used for natural language processing. Scikit-learn is a Python library that integrates various machine learning algorithms, including classification, regression, clustering, and decision trees. Gensim is an open-source Python library focused on topic modeling for natural language processing. LDA analysis utilized all three libraries. Additionally, Matplotlib and Wordcloud libraries were used for the visualization of the results. Sometimes, the bibliometric data obtained may include copyright information or details about the journal in which the article was indexed. Therefore, researchers need to clean such expressions from the abstract section.

In the LDA analysis, the Perplexity and Coherence metrics were used to evaluate the model's performance. In this study, the Perplexity metric was calculated as 2875.808, while the Coherence score was determined to be 0.490. These scores indicate that the overall performance of the model is satisfactory; however, experimenting with different hyperparameter settings may further enhance coherence and topic interpretability. The obtained results demonstrate that clustering was successfully achieved in the eight-topic dataset. The Perplexity value indicates that the model effectively represents the text and aligns well with the test data, while the Coherence score suggests that the topics exhibit an adequate level of semantic meaning. However, the literature suggests that Coherence scores above 0.5

generally indicate stronger model consistency [18]. Therefore, based on the obtained scores, it can be inferred that the model is generally successful but could be further optimized. Additionally, elements such as copyright information and journal indexing details present in the bibliometric data were removed from the abstracts to achieve a more meaningful content analysis. In this context, experts refined the relevant word blocks to enhance the interpretability of the results.

Results

Since 1980, a total of 3.355 research and review articles on diabetes have been produced in the field of PHC research. These documents are indexed as follows: Science Citation Index Expanded (SCI-Expanded) with 2.533 articles, Emerging Sources Citation Index (ESCI) with 727 articles, and Social Sciences Citation Index (SSCI) with 571 articles. The total citation count for these documents is 41.866 (without self-citations: 39.633), with an average citation count of 12.48 per document and an h-index of 78 (Figure 2). Overall, interest in the topic of diabetes has increased over the years, with 2022 being the most productive year, contributing 336 articles (10.01%). The first article on this topic was published in 1980. Although it is early in 2024, six articles on diabetes have already been published.

It was found that 48.97% (n=1.643) of studies on diabetes were published as open access. The sustainability goals of these studies are as follows: good health and well-being (n=3.143, 93.68%), gender equality (n=168, 5.00%), zero hunger (n=21, 0.62%), quality education (n=18, 0.53%), no poverty (n=12, 0.35%), decent work and economic growth (n=4, 0.11%), sustainable cities and communities (n=4, 0.11%), life on land (n=2, 0.06%), reduced inequality (n=1, 0.03%), and peace, justice, and strong institutions (n=1, 0.03%).

Analysis of countries, institutions, and researchers

Upon reviewing the studies, it was found that the 3.355 articles were produced by 114 different countries, 4.226 different institutions, and 12.426 different researchers. The top five countries with the highest volume of research in this field were as follows: USA (n=951, 28.34%, Average Citation Per Article (ACPA): 17.56), England (n=325, 9.68%, ACPA: 19.69), Australia (n=229, 6.82%, ACPA: 12.36), India (n=225, 6.70%, ACPA: 4.34), and Spain (n=184, 5.48%, ACPA: 5.54) (Appendix 1). The five countries with the highest citation counts were USA, England, Australia, Canada, and the Netherlands. In the field of PHC research on diabetes, the top five institutions with the most contributions were: University of California System (USA, n=64), University of Leicester (England, n=58), University of London (England,

n=57), Utrecht University (Netherlands, n=53), and the US Department of Veterans Affairs (USA, n=46) (Appendix 2).

The most prominent researchers in the field, along with their average citation per article (ACPA) and number of articles, were as follows: Seidu S (University of Leicester, England, ACPA=14.45, n=20), Davies MJ (University of Leicester, England, ACPA=13.44, n=18), Kostev K (University Hospital of Giessen and Marburg, Germany, ACPA=13.50, n=16), Gorter KJ (Utrecht University, Netherlands, ACPA=16.07, n=15), Griffin SJ (University of Cambridge, England, ACPA=19.07, n=15), Lauritzen T (Aarhus University, Denmark, ACPA=18.87, n=15), and Kinmonth AL (University of Cambridge, England, ACPA=22.50, n=14). The countries of these researchers, as well as the keywords they frequently used in their articles, are shown in Figure 3.

Analysis of documents and references

A total of 3.355 documents were published in 62 different journals, with a total of 41.866 citations. The average citation count was 12.48, and the h-index was 78. The top five journals with the most publications in this field were as follows: Primary Care Diabetes (ACPI=10.28, C=9.970, n=970, 28.91%), Journal of Family Medicine and Primary Care (ACPI=3.07, C=864, n=281, 8.37%), BMC Family Practice (ACPI=20.96, C=3.584, n=171, 5.09%), Family Practice (ACPI=25.30, C=3.593, n=142, 4.23%), and Journal of Family Practice (ACPI=12.93, C=1.668, n=129, 3.84%) (Table 1).

Among the top 20 journals with the most diabetes-related publications in the PHC research area, it was observed that only five journals are indexed in ESCI, while the other 15 are indexed in SCIE. As seen in Table 1, the Annals of Family Medicine journal ranks 13th in terms of publication volume but has an exceptionally high average citation count of 58.61. This is also reflected in Appendix 3. Among the top 20 most cited papers in the relevant field, half of the journals were published in Annals of Family Medicine (Appendix 3). Additionally, Journal of The American Board of Family Medicine and Primary Care Diabetes each contributed two papers to the list.

According to Bradford's Law, the journals in the first zone are Primary Care Diabetes and Journal of Family Medicine and Primary Care. The second zone includes the following journals: BMC Family Practice, Family Practice, Journal of Family Practice, Family Medicine and Primary Care Review, American Family Physician, British Journal of General Practice, Journal of The American Board of Family Medicine, and Journal of Primary Care and Community Health. These

journals in the first zone can be considered core journals that researchers in the PHC research area, specifically those focused on diabetes, should prioritize. The increasing number of publications in these journals over the years further supports this conclusion.

The ten journals with the most citations in diabetes research are as follows: Diabetes Care (C=10,131), The New England Journal of Medicine (C=2.845), Diabetic Medicine (C=2.477), Lancet (C=2.269), Journal of the American Medical Association (C=1.773), Diabetologia (C=1.755), Diabetes Research and Clinical Practice (C=1.652), British Medical Journal (C=1.390), Diabetes (C=1.367), and Annals of Internal Medicine (C=1.073).

Emerging trends and research focus

In the 3.335 diabetes-related articles conducted in the PHC research area, a total of 4.568 author keywords, 3.559 keyword plus terms were used, and these articles were associated with 21 research areas outside of PHC. The ten most frequently associated research areas, in order of frequency, are as follows: medicine general and internal (n=1.393), endocrinology and metabolism (n=972), health care sciences and services (n=157), public environmental and occupational health (n=70), health policy and services (n=67), orthopedics (n=44), sport sciences (n=44), ophthalmology (n=19), respiratory system (n=5), and emergency medicine (n=4). The prominent topics in diabetes research within PHC over the years are shown in Figure 4a and Figure 4b ased on the author's keywords.

In our study, the eight topics obtained from the LDA topic modeling analysis conducted on the abstracts and titles of the relevant articles are presented in Table 2.

Discussion

In this study, a comprehensive bibliometric analysis and LDA topic modeling were conducted to visualize and evaluate the temporal dynamics and research trends of diabetes-related studies in the primary healthcare (PHC) research field. This study represents the first bibliometric assessment of research on diabetes and primary healthcare services and provides crucial data for future researchers in this area. A thorough analysis of the literature on diabetes mellitus and primary healthcare services was performed through bibliometric analysis. Furthermore, for diabetes, its complications, and clinicians and scientists working in primary care, the findings of this study will not only provide insights into research in this field but also offer a comprehensive overview and present key research directions. In this way, knowledge gaps will be identified, guiding future research directions, and acting as a catalyst to

promote informed decision-making in research and clinical practice. The focus of our study was on the existing and emerging research in the field, addressing discussions on diabetes management within PHC. Although many bibliometric analyses have been conducted on diabetes, it has been noted that no specific analysis has been conducted in the critical area of PHC, which plays a vital role in diabetes management. With the increasing life expectancy worldwide, diabetes will continue to be a significant health issue in primary care settings. In fact, the observed increase in the number of publications related to diabetes in PHC over the years supports this finding. In recent years, there has been a growing interest in topics such as obesity, hypertension, chronic diseases, exercise, and physical activity within the PHC field.

Primary healthcare services play a crucial role in the fight against diabetes by implementing various effective strategies. These include strengthening diagnostic and screening programs, expanding the use of digital health and telemedicine, providing personalized diabetes education, promoting healthy lifestyle programs and community engagement, utilizing motivational interviewing techniques, and effectively integrating community health centers into diabetes management. Through these initiatives, primary care can significantly enhance the effectiveness of preventive, protective, and therapeutic services for diabetes. The effectiveness of chronic disease management, particularly in primary care settings, is closely linked to a decrease in hospitalization rates [19]. As diabetes rates increase and hospital readmission rates remain high, hospitals will face challenges in assessing and addressing the educational needs of diabetic patients. This highlights the growing importance of PHC services. In the United States, 52.3% of all medical office visits were primary care visits in 2013, with diabetes ranking as the fifth most common primary diagnosis among these visits [20]. The prevalence of diabetes is expected to increase by 54% between 2015 and 2030, reaching over 54.9 million Americans. Annual deaths attributed to diabetes will rise by 38%, and the total annual medical and societal costs related to diabetes are projected to increase by 53%, surpassing $622 billion by 2030 [21]. The United States alone spends a staggering $294.5 billion annually on the diagnosis and treatment of diabetes and its complications, making it the country with the highest number of diabetes cases, followed by the People's Republic of China [22]. In Southeast Asia, it has been reported that 8.4% of total health expenditure is spent solely on diabetes treatment and medical care. India, as the hub of diabetes in the region, accounts for 87.8% of the diabetes patients in Southeast Asia. Health spending on diabetes in India ranks fourth, after the United States, China, and Germany [23].

In our study, we examined chronic disease management topics in PHC settings across various countries. Socioeconomic and demographic changes, along with the aging population, are factors influencing the prevalence of diabetes and other related health conditions [24]. Furthermore, urbanization and access to starch-based foods, coupled with sedentary lifestyles, have a significant impact on diabetes statistics in these countries [25]. Germany follows an integrated approach to disease management through its German Disease Management Program, which emphasizes coordination of care based on general practice and has reported positive outcomes [26]. In Korea, cardiovascular disease (CVD) is among the leading causes of mortality, and the government has implemented various policies since 2007 to facilitate the management of hypertension and diabetes and to encourage doctors and patients [27]. The burden created by the rise of non-communicable chronic conditions is expected to be more significant in low- and middle-income countries, where resources are limited [28].

Among the findings from our topic analyses, the management and risk factors of diabetes have emerged as a major focus. The challenge here lies in the increasing complexity of diabetes management, which results from the need to avoid hyperglycemia and hypoglycemia, the availability of multiple medication combinations, the variety of medical device options for diabetes management, and the need to facilitate lifestyle changes for patients. In Australia, significant budgets are allocated for the coordination and management of chronic diseases in primary care settings [29]. It is known that the development of an integrated clinical decision support system for the early detection and management of chronic diseases, which focuses on regular screening of at-risk individuals, early interventions, timely referrals to specialist services, and adherence to evidence-based guidelines, improves diabetes management. More importantly, the inclusion of care in primary health services and patient participation is crucial [30].

Acute and chronic complications of diabetes in PHC have been heavily discussed in the literature. Globally, it is reported that 6.7 million people aged 20-79 died due to diabetes and diabetes-related causes in 2021. This represents 12.2% of all deaths in this age group [4]. Previous studies have highlighted the high prevalence of comorbidities in diabetic patients and the challenges in managing these multiple conditions [31]. Elevated blood glucose levels can lead to acute complications and chronic macrovascular and microvascular complications. These may include retinopathy, nephropathy, neuropathy, cardiovascular events, diabetic foot, cerebrovascular events, and cancer [32]. Diabetes is also the leading cause of

vision loss and kidney failure in adults, as well as the most common cause of amputations [33]. Among patients with acute coronary syndrome, 20-30% have type 2 diabetes, and 40% of these have impaired glucose tolerance. Evidence suggests that mortality rates following acute myocardial infarction are twice as high in diabetic patients [34]. Diabetic foot ulcers are among the most common complications in poorly controlled diabetic patients. They are typically the result of poor glycemic control, underlying neuropathy, peripheral vascular disease, or inadequate foot care. Diabetic foot ulcers account for more healthcare visits than other diabetes-related complications. The annual incidence of diabetic foot ulcers worldwide ranges from 9.1 million to 26.1 million [35]. Studies show that the prevalence of foot ulcers in diabetic patients ranges from 4% to 10%, with a lifetime occurrence rate as high as 25% [36].

Diabetic retinopathy is one of the significant neurovascular complications of diabetes and is a leading cause of blindness in working-age adults. Worldwide, 93 million people are affected by diabetic retinopathy [37]. Diabetic kidney disease, especially in developed countries like the USA, is a leading cause of end-stage renal disease, and 30-40% of diabetes mellitus patients develop diabetic nephropathy [38]. The most common type of diabetic neuropathy, peripheral neuropathy, primarily affects the nerves in the extremities, especially the feet [39]. This condition primarily disrupts sensory function, leading to gradual numbness, which increases the risk of ulcers due to external injuries [40]. Other systemic disorders, such as hypertension, dyslipidemia, hypoproteinemia, anemia, nephropathy, neuropathy, and heart conditions, also need to be treated through appropriate medications and interdisciplinary collaboration. Therefore, the interdisciplinary clinical team is crucial in reducing risk factors, maintaining glycemic control, and mitigating complication risks [41]. Educating the patient about complications and the need for proper medical care can reduce complication risks and improve treatment adherence.

Gestational diabetes (GDM), which is defined as the onset of diabetes during the second or third trimester of pregnancy, is a common pregnancy-related condition [42]. In 2020, it was estimated that 20.9 million pregnant women and their newborns worldwide were affected by GDM. GDM is significantly associated with an increased risk of various adverse outcomes, including postpartum hemorrhage, preeclampsia, neonatal hypoglycemia, macrosomia, cesarean delivery, and maternal and neonatal mortality. Furthermore, GDM increases the likelihood of type II diabetes, obesity, and metabolic syndrome in both the women and their children later in life.

Our study reveals that prediabetes and type 1 diabetes are heavily researched topics in PHC studies on diabetes. The prevalence of prediabetes is increasing worldwide, and it is predicted that by 2030, more than 470 million people will have prediabetes. Lifestyle changes are a cornerstone in preventing diabetes for prediabetic individuals, potentially reducing relative risk by 40-70% [43]. To slow the growth of new diabetes cases, efforts to increase awareness of prediabetes, encourage healthy behaviors, and improve the availability of evidence-based lifestyle programs are essential [44]. Type 1 diabetes mellitus is one of the most common chronic diseases in children but can occur at any age [45]. Monitoring prediabetes and type 1 diabetes is critical in preventing complications, which is effectively managed through strong PHC services.

Another important topic addressed in our study is the relationship between the COVID-19 pandemic and diabetes. Diabetes Mellitus not only predisposes individuals to more severe disease but also doubles the risk of death from COVID-19 due to lung and heart involvement [46]. The treatment of COVID-19 in diabetic patients requires an integrated team approach to minimize medical complications and the risk of death. Numerous studies suggest an increased risk of Type 1 diabetes mellitus after COVID-19 infection, although there is no conclusive evidence linking causality [47].

Diabetic patients often live with a reduced quality of life due to complications. Emerging epidemiological studies have shown that patient education on lifestyle changes, such as balanced nutrition, weight loss, smoking cessation, and regular exercise, is effective in controlling glucose balance and improving quality of life [48]. Today, the PHC system plays a significant role in disease prevention, especially by promoting a healthy lifestyle that includes physical activity. There is a need to increase awareness of complications among primary care physicians at the forefront of diabetes care [49]. The treatment of chronic diseases like Type 2 diabetes is challenging because it requires continuous screening and follow-up. Despite new guidelines, clinical inertia from doctors, patients, or the healthcare system can lead to ineffective management of Type 2 diabetes [50]. Therefore, in the healthcare system, updates should be made through in-service training plans and the creation of working groups to keep information up to date. For future studies, it may be suggested to focus on more specific topics within PHC research, such as diabetic retinopathy and diabetic wounds. Additionally, it is recommended that health policymakers implement public awareness campaigns, develop healthy nutrition policies, and revise existing regulations. Strengthening primary healthcare services and promoting policies that encourage urban planning initiatives to facilitate physical activity should also be

prioritized. Public health experts should support diabetes prevention by implementing healthy lifestyle programs in schools, workplaces, and communities. Furthermore, primary care physicians are advised to enhance counseling and educational services while closely monitoring patients' metabolic risk factors.

This study represents the first bibliometric analysis conducted in the PHC research area on diabetes, and it is the first bibliometric analysis in PHC using machine learning techniques. In our research, we identified the current state of the field, created visual maps, and used LDA topic modeling analysis to describe the general situation of the field under eight different topics. By examining trends and current issues, we provided references for future research. However, there are some limitations in our study. Firstly, all data was obtained from the WoS Core Collection. Although WoS indexes the most important journals in the field, some journals may not be indexed. Secondly, our study only analyzed articles and review articles. The primary reason for this is that these types of documents are the most suitable for capturing the essence of the field and provide the richest bibliometric data in terms of metrics such as abstracts, titles, keywords, and references. Thirdly, LDA cannot directly assign meaning to the topics it identifies; the interpretation of these topics relies on the researcher's judgment. Consequently, the generated topics may sometimes appear ambiguous or meaningless. However, this limitation has been mitigated through the expertise of primary care physicians specializing in diabetes. Additionally, LDA performs better with longer documents, as a larger sample of words enhances the model's ability to identify topics more accurately. In this regard, our study benefits from an ideal dataset.

Author contributions: The authors participated sufficiently in the study design, interpretation of the data and/or the writing of the manuscript.

G.Y.: Conception, Design, Supervision, Materials, Literature Review, Writing.

M.D.: Conception, Design, Supervision, Literature Review, Writing, Materials, Data Collection and/or Processing, Literature Review, Writing.

S.A.: Materials, Data Collection and/or Processing, Analysis and/or Interpretation.

Conflict of interest: No conflict of interest was declared by the authors.

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Table 1. Top 20 Most Published Journals on Diabetes in the PHC Research Area

Rank	Journal	JIF	Research Domain	SCIE/ SSCI/ ESCI	ACPI	C	N	%
1	Primary Care Diabetes	2.90	Endocrinology & Metabolism; Primary Health Care	SCIE, SSCI	10.28	9.970	970	28.91
2	Journal of Family Medicine And Primary Care	1.40	Primary Health Care	ESCI	3.07	864	281	8.37
3	BMC Family Practice	2.90	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	20.96	3.584	171	5.09
4	Family Practice	2.20	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	25.30	3.593	142	4.23
5	Journal of Family Practice	0.60	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	12.93	1.668	129	3.84
6	Family Medicine and Primary Care Review	0.70	Primary Health Care	ESCI	0.90	111	123	3.66
7	American Family Physician	4.00	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	20.92	2.510	120	3.57
8	British Journal of General Practice	5.90	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	25.49	2.855	112	3.33
9	Journal of The American Board of Family Medicine	2.90	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	19.84	2.182	110	3.27
10	Journal of Primary Care and Community Health	3.60	Primary Health Care	ESCI	4.41	428	97	2.89
11	Primary Care	1.90	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	11.11	1.067	96	2.86
12	Canadian Family Physician	3.10	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	13.64	1.241	91	2.71
13	Annals of Family Medicine	4.40	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	58.61	5.275	90	2.68
14	Scandinavian Journal of Primary Health Care	2.10	Health Care Sciences & Services; Medicine, General & Internal; Primary Health Care	SCIE, SSCI	18.30	1.647	90	2.68
15	Atencion Primaria	2.50	Medicine, General & Internal; Primary Health Care	SCIE, SSCI	4.66	340	73	2.17
16	Australian Family Physician	1.22	Medicine, General & Internal; Primary Health Care	SCIE	11.03	728	66	1.96
17	Australian Journal of Primary Health	1.30	Health Care Sciences & Services; Health Policy & Services; Primary Health Care; Public, Environmental & Occupational Health; Public, Environmental & Occupational Health	SCIE, SSCI	9.24	610	66	1.96
18	Korean Journal of Family Medicine	2.30	Primary Health Care	ESCI	6.47	401	62	1.84
19	African Journal of Primary Health Care Family Medicine	0.91	Primary Health Care	ESCI	6.86	391	56	1.66
20	Primary Health Care Research and Development	1.60	Primary Health Care	SCIE, SSCI	8.04	450	56	1.66

N: Record Count, JIF: Journal Impact Factor for 2022 years, C: Citation

Table 2. Cluster Title and Description of LDA Topic Modeling Findings for Abstracts and Titles

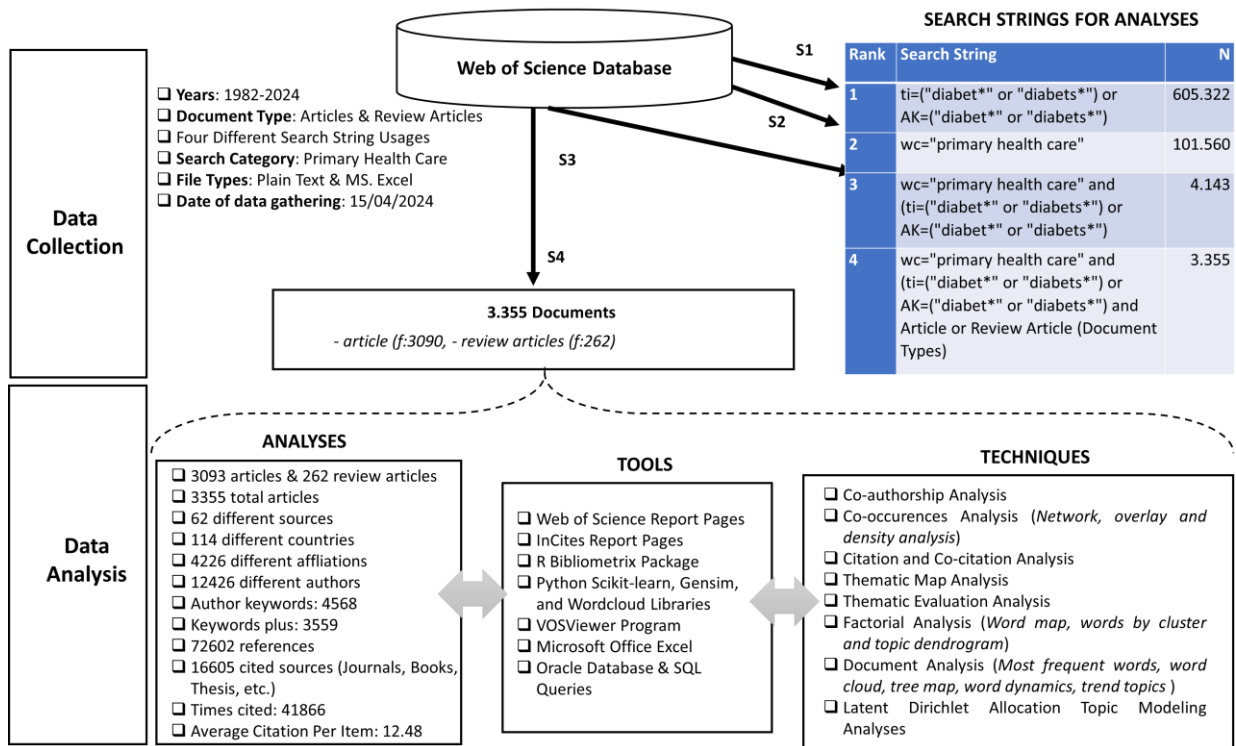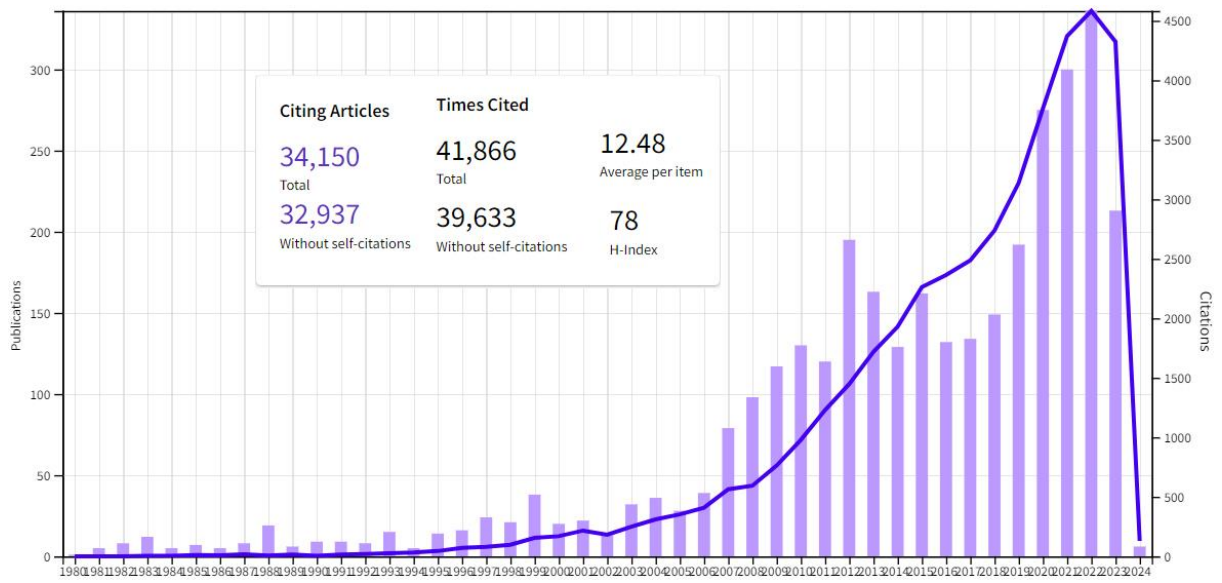| Rank	Cluster Title	Narrative Description of Content
1	Diabetes management at PHC	Studies evaluating diabetes management in primary care are grouped under this heading.
2	Risk factors and management of diabetes in PHC	The words in this cluster describe the risk factors of diabetes and issues related to the management of risk factors (obesity, lifestyle, diet, body mass index) and are grouped under this heading.
3	Acute and chronic complications of diabetes in PHC	Topics such as retinopathy, nephropathy, neuropathy, diabetic foot ulcers, amputation, cardiovascular risk factors are grouped under this heading.
4	Gestational diabetes	Under this heading, the definition of diabetes in pregnant women, risk factors, diagnostic methods, the effect of drugs used during pregnancy on diabetes and research on referral situations are grouped.
5	Prediabetes, Type 1 diabetes	The definition of prediabetes and Type 1 diabetes are grouped under this heading.
6	COVID-19 and diabetes	Studies conducted to learn the relationship between the prevalence of diabetes and the interaction with diseases in patients with COVID-19 pneumonia are grouped under this heading.
7	Quality of life, awareness and health education	Studies evaluating the relationship between behavioral risk factors for diabetes and awareness are grouped under this heading.
8	Current treatment methods and guiding resources	Approaches to hypertension treatment, health management, types of medication, PHC guidelines, and hypertension control are grouped under this heading.

Figure 1. Research Methodology and Study Design

SEARCH STRINGS FOR ANALYSES

Rank	Search String	N
1	ti=("diabet*" or "diabets*") or AK=("diabet*" or "diabets*")	605.322
2	wc="primary health care"	101.560
3	wc="primary health care" and (ti=("diabet*" or "diabets*") or AK=("diabet*" or "diabets*")	4.143
4	wc="primary health care" and (ti=("diabet*" or "diabets*") or AK=("diabet*" or "diabets*") and Article or Review Article (Document Types)	3.355

Data Collection

Web of Science Database

❑ **Years**: 1982-2024
❑ **Document Type**: Articles & Review Articles
❑ Four Different Search String Usages
❑ **Search Category**: Primary Health Care
❑ **File Types**: Plain Text & MS. Excel
❑ **Date of data gathering**: 15/04/2024

S1
S2
S3
S4

3.355 Documents
- article (f:3090, - review articles (f:262)

Data Analysis

ANALYSES

❑ 3093 articles & 262 review articles
❑ 3355 total articles
❑ 62 different sources
❑ 114 different countries
❑ 4226 different affiliations
❑ 12426 different authors
❑ Author keywords: 4568
❑ Keywords plus: 3559
❑ 72602 references
❑ 16605 cited sources (Journals, Books, Thesis, etc.)
❑ Times cited: 41866
❑ Average Citation Per Item: 12.48

TOOLS

❑ Web of Science Report Pages
❑ InCites Report Pages
❑ R Bibliometrix Package
❑ Python Scikit-learn, Gensim, and Wordcloud Libraries
❑ VOSViewer Program
❑ Microsoft Office Excel
❑ Oracle Database & SQL Queries

TECHNIQUES

❑ Co-authorship Analysis
❑ Co-occurences Analysis (*Network, overlay and density analysis*)
❑ Citation and Co-citation Analysis
❑ Thematic Map Analysis
❑ Thematic Evaluation Analysis
❑ Factorial Analysis (*Word map, words by cluster and topic dendrogram*)
❑ Document Analysis (*Most frequent words, word cloud, tree map, word dynamics, trend topics*)
❑ Latent Dirichlet Allocation Topic Modeling Analyses

Figure 2. Total Cited and Publications Over Time

Figure 3. Three Field of Author Country, Author, and Author Keywords for Diabates Articles
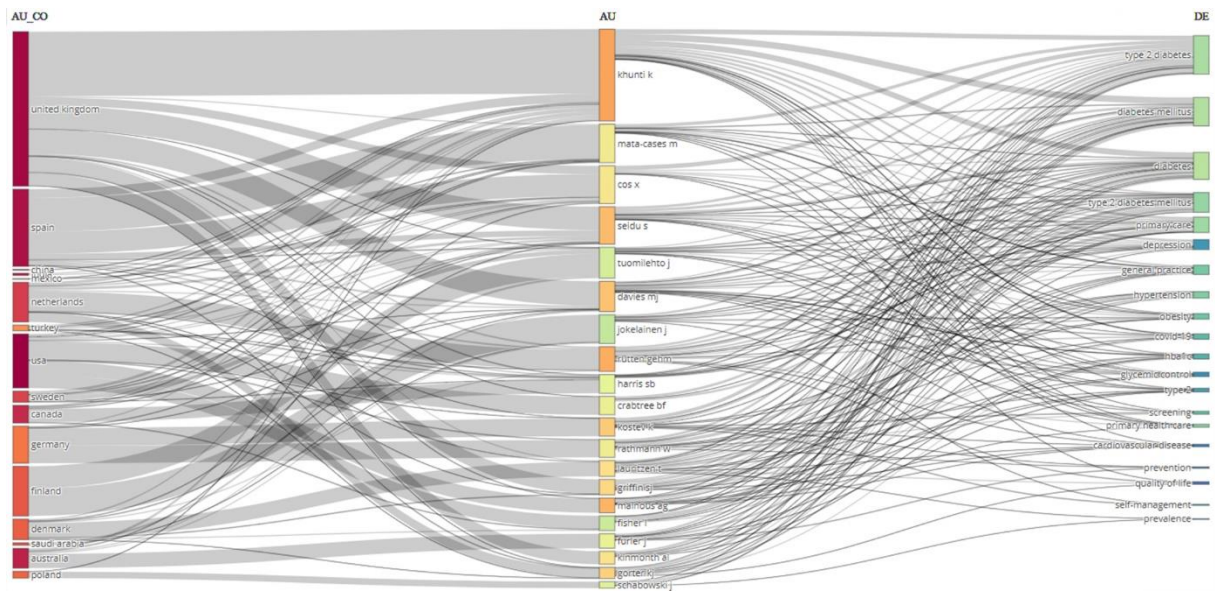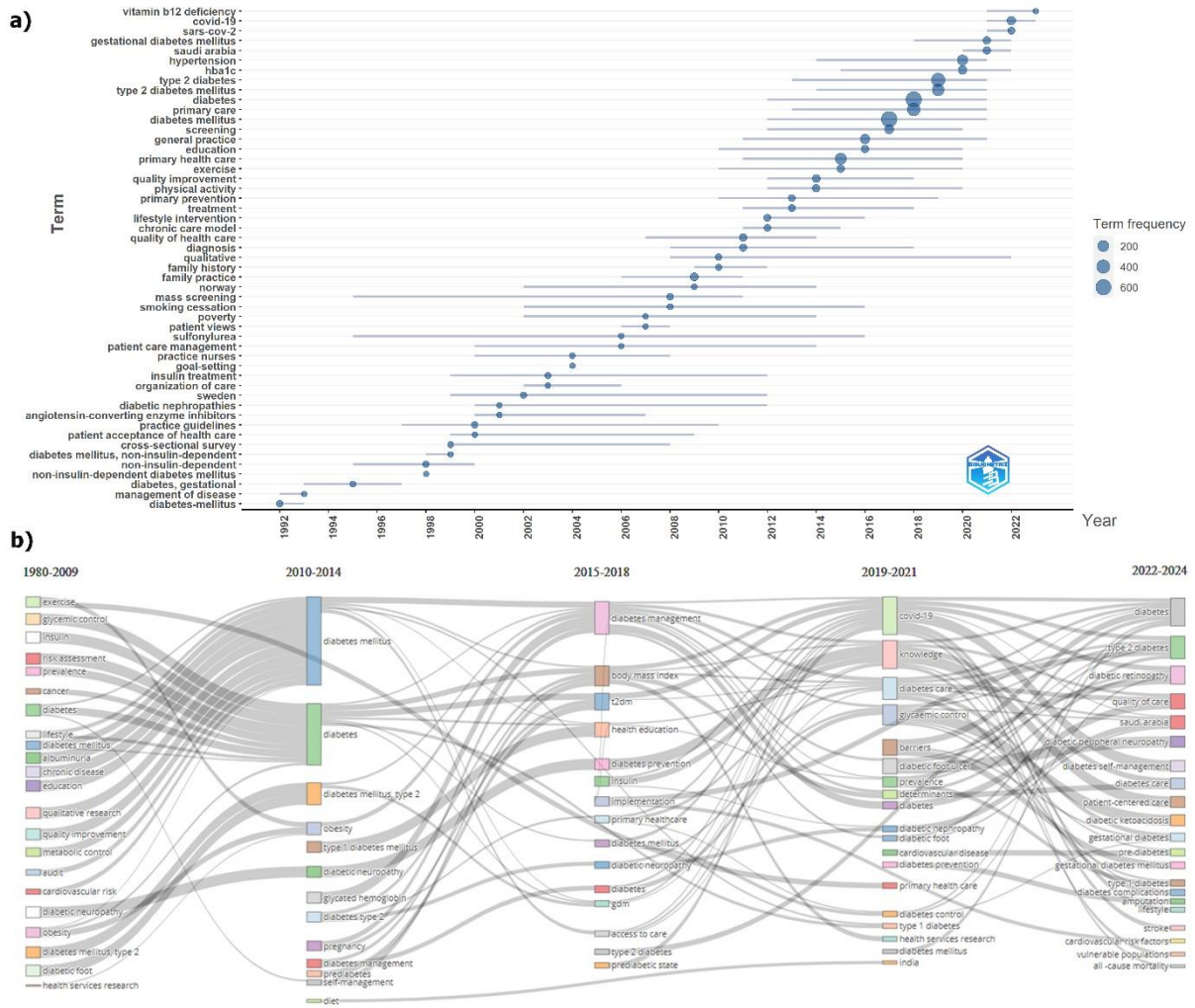
Figure 4. Author's Keywords Trend Topic Analyses (4a) and Thematic Evaluation for Author's Keywords (4b)

APPENDIX

Appendix 1. Top 30 Countries with the Most Publications on Diabetes in the PHC Research Field

Rank	Countries	HI	ACPA	N	%	Rank	Countries	HI	ACPA	N	%
1	USA	67	17.56	951	28.34	16	Germany	15	13.46	70	2.08
2	England	42	19.69	325	9.68	17	New Zealand	13	7.74	58	1.72
3	Australia	28	12.36	229	6.82	18	Finland	14	12.35	57	1.69
4	India	16	4.34	225	6.70	19	Turkey	13	11.14	50	1.49
5	Spain	16	5.54	184	5.48	20	Belgium	13	10.74	42	1.25
6	Canada	31	16.69	172	5.12	21	Italy	10	9.08	38	1.13
7	Netherlands	29	16.76	151	4.50	22	Wales	16	25.76	37	1.10
8	Saudi Arabia	12	6.03	110	3.27	23	France	11	8.83	36	1.07
9	Poland	4	1.72	108	3.21	24	Norway	11	10.37	35	1.04
10	China	19	11.72	101	3.01	25	Scotland	15	24.00	34	1.01
11	Sweden	21	14.89	101	3.01	26	Malaysia	9	12.39	33	0.98
12	Denmark	18	12.05	84	2.50	27	Mexico	8	8.76	33	0.98
13	Iran	16	12.86	74	2.20	28	Israel	10	14.93	30	0.89
14	South Africa	14	8.68	74	2.20	29	Japan	7	5.82	28	0.83
15	South Korea	9	5.63	73	2.17	30	Brazil	7	8.00	25	0.74

ACPA: Average Citation per Articles, N= Document Count, HI: H-index

Appendix 2. Top 15 Institutions with the Most Publications on Diabetes in PHC Research Area

Rank	Afliations	Country	TC	HI	ACPA	N	%
1	University of California System	USA	1.628	23	25.44	64	1.90
2	University of Leicester	England	1.340	20	23.10	58	1.72
3	University of London	England	1.208	20	21.19	57	1.69
4	Utrecht University	Netherlands	753	17	14.21	53	1.58
5	US Department of Veterans Affairs	USA	1.668	20	36.26	46	1.37
6	Veterans Health Administration	USA	1.668	20	36.26	46	1.37
7	Utrecht University Medical Center	Netherlands	649	16	14.42	45	1.34
8	University Hospitals of Leicester NHS Trust	England	1.019	18	23.70	43	1.28
9	University System of Ohio	USA	432	11	10.80	40	1.19
10	State University System of Florida	USA	454	11	11.64	39	1.16
11	Aarhus University	Denmark	540	13	14.21	38	1.13
12	University of Toronto	Canada	547	13	14.78	37	1.10
13	University of Cambridge	England	915	16	25.42	36	1.07
14	Leicester General Hospital	England	784	15	22.40	35	1.04
15	Maastricht University	Netherlands	555	14	16.32	34	1.01

ACPA: Average Citation per Articles, N= Document Count, HI: H-index, TC: Times Cited

Appendix 3. Top 20 Most Cited Studies on Diabetes in PHC Research Area

Rank	Title	Journal	JIF	Authors	Year	C
1	Development of a brief diabetes distress screening instrument	Annals of Family Medicine	4.4	Fisher, L; Glasgow, RE; (...); Polonsky, WH	2008	277
2	Impact of Peer Health Coaching on Glycemic Control in Low-Income Patients With Diabetes: A Randomized Controlled Trial	Annals of Family Medicine	4.4	Thom, DH; Ghorob, A; (...); Bodenheimer, TA	2013	215
3	Lay understanding of familial risk of common chronic diseases: A systematic review and synthesis of qualitative research	Annals of Family Medicine	4.4	Walter, FM; Emery, J; (...); Marteau, TM	2004	200
4	A systematic review of chronic disease management interventions in primary care	BMC Family Practice	2.9	Reynolds, R; Dennis, S; (...); Zwar, N	2018	191
5	Changes in age at diagnosis of type 2 diabetes mellitus in the United States, 1988 to 2000	Annals of Family Medicine	4.4	Koopman, RJ; Mainous, AG; (...); Geesey, ME	2005	184
6	Quality of life of patients with diabetes mellitus -: An overview of research in primary health care in the Nordic countries	Scandinavian Journal of Primary Health Care	2.1	Wändell, PE	2005	182
7	Diabetic foot ulcers: Prevention, diagnosis and classification	American Family Physician	4.0	Armstrong, DG and Lavery, LA	2005	180
8	Participatory Decision Making, Patient Activation, Medication Adherence, and Intermediate Clinical Outcomes in Type 2 Diabetes: A STARNet Study	Annals of Family Medicine	4.4	Parchman, ML; Zeber, JE and Palmer, RF	2010	174
9	Dietary Fiber for the Treatment of Type 2 Diabetes Mellitus: A Meta-Analysis	Journal of The American Board of Family Medicine	2.9	Post, RE; Mainous, AG; (...); Simpson, KN	2012	170
10	Depression and Increased Mortality in Diabetes: Unexpected Causes of Death	Annals of Family Medicine	4.4	Lin, EHB; Heckbert, SR; (...); Von Korff, M	2009	168
11	Impact of Electronic Health Record Clinical Decision Support on Diabetes Care: A Randomized Trial	Annals of Family Medicine	4.4	O'Connor, PJ; Sperl-Hillen, JM; (...); Gilmer, TP	2011	162
12	Competing demands or clinical inertia: The case of elevated glycosylated hemoglobin	Annals of Family Medicine	4.4	Parchman, ML; Pugh, JA; (...); Bowers, KW	2007	160
13	Effectiveness of Cinnamon for Lowering Hemoglobin A1C in Patients with Type 2 Diabetes: A Randomized, Controlled Trial	Journal of The American Board of Family Medicine	2.9	Crawford, P	2009	152
14	Management of Blood Glucose in Type 2 Diabetes Mellitus	Annals of Family Medicine	4.4	Ripsin, CM; Kang, H and Urban, RJ	2009	150
15	Integrated Management of Type 2 Diabetes Mellitus and Depression Treatment to Improve Medication Adherence: A Randomized Controlled Trial	Annals of Family Medicine	4.4	Bogner, HR; Morales, KH; (...); Cappola, AR	2012	147
16	Type 2 diabetes and cardiovascular disease in South Asians	Primary Care Diabetes	2.9	Gholap, N; Davies, M; (...); Khunti, K	2011	145
17	Barriers to effective management of type 2 diabetes in primary care: qualitative systematic review	British Journal of General Practice	5.9	Rushforth, B; McCrorie, C; (...); Foy, R	2016	144
18	Cinnamon Use in Type 2 Diabetes: An Updated Systematic Review and Meta-Analysis	Annals of Family Medicine	4.4	Allen, RW; Schwartzman, E; (...); Phung, OJ	2013	144
19	Clinical inertia to insulin initiation and intensification in the UK: A focused literature review	Primary Care Diabetes	2.9	Khunti, K and Millar-Jones, D	2017	143
20	Diabetic Retinopathy	Primary Care	1.9	Hendrick, AM; Gibson, MV and Kulshreshtha, A	2015	142

JIF: Journal Impact Factor for 2022 years, C: Citation

Gökben Yaslı, PhD. Department of Public Health, İzmir Health Directorate, İzmir, Türkiye, e-mail: gokben.yasli@gmail.com (https://orcid.org/0000-0003-2464-2238)

Serkan Alıcı, Msc. Faculty of Economics and Administrative Sciences, Dokuz Eylul University, İzmir, Türkiye, e-mail: serkan.alici@deu.edu.tr (https://orcid.org/0000-0001-8684-4180)

Muhammet Damar, PhD. Information Center, Dokuz Eylul University, İzmir, Türkiye and Upstream Lab, MAP, Li Ka Shing Knowledge Institute, Unity Health Toronto, Toronto Ontario, Canada, e-mail: damarmuhammet@gmail.com (https://orcid.org/0000-0002-3985-3073) (Corresponding Author)