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SPECIALTY SECTION

This article was submitted to
Children and Health,
a section of the journal
Frontiers in Public Health

RECEIVED 23 June 2022

ACCEPTED 29 July 2022

PUBLISHED 31 August 2022

CITATION

Zhao J, Lu Y, Wu X, Zhou F, Fei F, Wu X,
Ding X and Wang M (2022) Bibliometric
analysis of research themes and trends
in childhood autism spectrum
disorders from 2012 to 2021.
Front. Public Health 10:925475.
doi: 10.3389/fpubh.2022.925475

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Bibliometric analysis of research themes and trends in childhood autism spectrum disorders from 2012 to 2021

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Background: Autism spectrum disorders (ASD) are heterogeneous neurodevelopmental conditions that affect people worldwide. Early diagnosis and clinical support help achieve good outcomes. However, medical system structure and restricted resource availability create challenges that increase the risk of poor outcomes. Understanding the research progress of childhood ASD in recent years, based on clinical literature reports, can give relevant researchers and rehabilitation therapists more reasonable research guides.

Objective: This bibliometric study aimed to summarize themes and trends in research on childhood ASD and to suggest directions for future enquiry.

Methods: Citations were downloaded from the Web of Science Core Collection database on childhood ASD published from 1 January 2012, to 31 December 2021. The retrieved information was analyzed using CiteSpace 5.8.R3, and VOS viewer.

Results: A total of 7,611 papers were published across 103 areas. The United States was the leading source of publications. The clusters that have continued into 2020 include coronavirus disease 2019, gut microbiota, and physical activity, which represent key research topics. Keywords with frequency spikes during 2018–2021 were “disabilities monitoring network,” “United States,” and “caregiver.”

Conclusions: The Autism and Developmental Disabilities Monitoring Network in the United States can be used as a reference for relevant workers worldwide. An intelligent medical assistant system is being developed. Further studies are required to elucidate challenges associated with caring for a child with ASD.

KEYWORDS

autism spectrum disorders, children, bibliometrics, CiteSpace, VOSviewer

Introduction

Autism spectrum disorders (ASD) are heterogeneous neurodevelopmental conditions, characterized by early-onset difficulties in communication and restricted, repetitive behavior and interests (1). In 2020, the World Health Organization reported that 1 in 160 children worldwide presents with ASD (2). The United States National Center for Health Statistics reported in 2016 that the prevalence of ASD among children aged 3 to 17 years is 1 in 45 and that it is increasing, which is a cause for concern. ASD is a lifelong neurodevelopmental disorder with a profound impact on intellectual and general abilities and psychological functioning (3, 4). ASD was first described based on the characteristics of 11 children observed by child psychiatrist Kanner in 1943 (5). The definition of ASD continues to evolve (1, 6–8). The understanding of ASD is also evolving, and the number of related studies is increasing. Examining what currently constitutes research frontiers may help set directions for future research (9). This study aimed to examine the current evidence on childhood ASD, including research trends and leading topics, published over the past decade, and to propose directions for future research. These findings may be used as a reference for epidemiologists, pediatricians, rehabilitation therapists, and caregivers.

This study aimed to cover the following aspects. We analyzed Science Citation Index for childhood ASD studies using bibliometric methods. Countries, regions, institutions, and periodicals of study origin, study categories, keywords, and references per study were included in the dataset. Visual representation of findings was provided. Research influence of countries, regions, institutions, and journals was examined, and leading research topics were reported. We went over the hot spot trend in greater depth.

Materials and methods

On 24 March 2022, all citations published between 1 January 2012, and 31 December 2021, were retrieved from the Web of Science Core Collection (WoSCC). The search strategy was set as $TI = ("autistic*" OR "autism*" OR "ASD" OR "Kanner*" OR "Autism spectrum disorder") AND TI = (children OR Kid*)$, the document type was "ARTICLE," and the timeframe was from 1 January 2012 to 31 December 2021. A total of 8,160 papers were retrieved. After manual screening, 7,611 articles were included, and data on the following variables were extracted: title, publication year, country or region, institution, journal, references, and keywords (Figure 1).

Statistical analysis

Citation features were analyzed using CiteSpace.5.8.R3 and VOSviewer. The H-index was used to estimate

the importance or impact of citations obtained from WoSCC.

Results

Annual distribution of publications

Both the retrieval result analyzer of Web of Science database and the duplicate removal function of CiteSpace software can obtain the number of documents issued each year. Over the past 10 years, the number of studies on childhood ASD has increased (Figure 2). The number of publications in this area increased from 2011 to 2018. More than 1,000 research papers were published in this area from 2018 to 2020. Finally, from 2020 to 2021, the number of documents decreased slightly.

Countries or regions

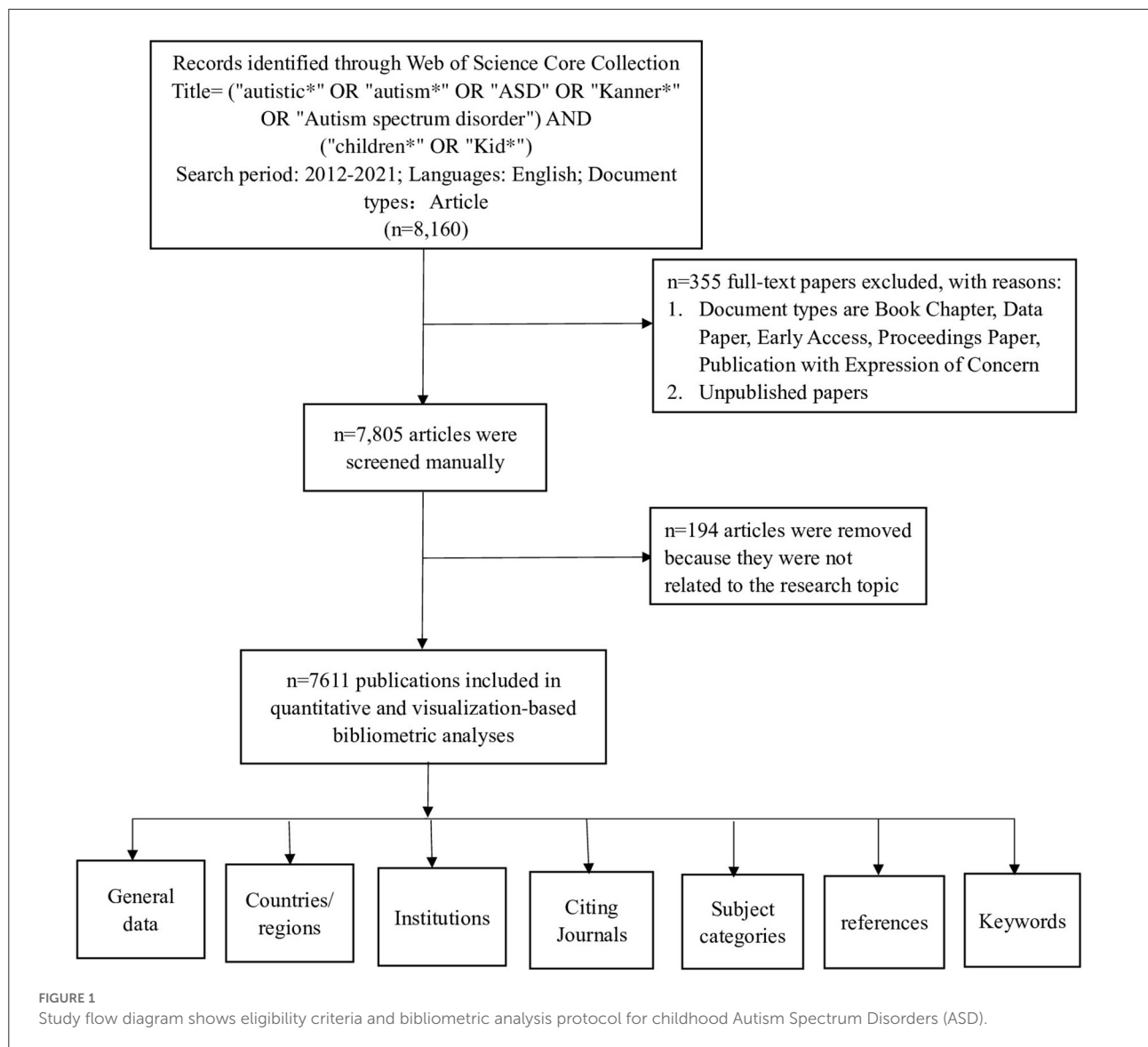
Using the country cooperation analysis function of CiteSpace, we can get the number of countries that have published articles and the influence of articles from a country. A total of 7,611 papers were published in 103 countries or regions. Collaborations among countries/regions are shown in Figure 3. The number of publications corresponds to the size of tags or nodes. Centrality can be ascertained from the purple ring area. Regions with the greatest number of citations included the United States ($n = 3,655$), Britain ($n = 653$), Australia ($n = 553$), China ($n = 478$), and Canada ($n = 472$). Among them, the United States (0.40) and Britain (0.17) have purple rings, representing articles from these regions have been cited more frequently than articles from other countries (Table 1). The H-index represents citation influence. The three countries with the highest h-index are the United States (102), England (58) and Canada (50).

Institutions

The cooperation between institutions and the number of published articles of each institution can be achieved through CiteSpace software. Table 2 lists the top ten institutions with the largest number of documents, and their partnerships are shown in Figure 4. Eight of them are located in the United States, one in Canada, and one in the United Kingdom. The total link strength shows the influence of each institution.

Journals and research category

Using VOSviewer to analyze the citation source journals and co cited journals. The documents in the highest citing journals represent leading research topics. The research field of highly



cited journals are research basic knowledge. Tables 3, 4 show the top ten citing journals and cited journals, respectively. The leading research fields included psychology, special education, psychiatry, rehabilitation medicine, behavioral science, rehabilitation medicine, genetics, and neuroscience. Areas cited at increased frequencies included psychology, psychiatry, special education, rehabilitation medicine pediatrics, and behavioral science. The Journal of Autism and Developmental Disorders emerged as the most influential journal in this field (Figure 5).

Keywords

The default setting of CiteSpace is changed to the following mode: “Year Per Slice” = 2, “Top N%” = 30.0%, and “Minimum

Duration” = 2. Figure 6 summarizes the leading keywords, including the year of emergence. The red square in Figure 6 represents emerging keywords for the investigated timeline. The most frequently used keywords were “spectrum” (2012–2014), “deficit hyperactivity disorder” (2012–2014), “diagnostic interview” (2012–2015), “randomized controlled trial” (2016–2018), “typical development” (2016–2018), “technology” (2017–2019), “disabilities monitoring network” (2018–2021), “United States” (2018–2021), and “caregiver” (2018–2021).

References

Using the default setting of CiteSpace to cluster the co cited documents and choose label clusters with indexing terms.

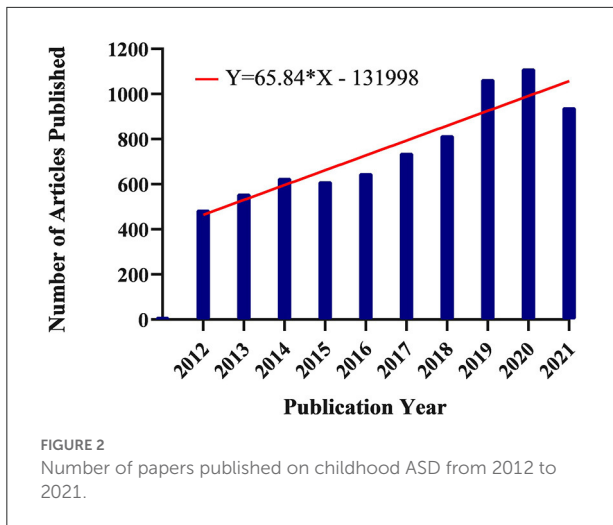


FIGURE 2 Number of papers published on childhood ASD from 2012 to 2021.



FIGURE 3 Collaborations of countries or regions reporting studies on childhood ASD from 2012 to 2021.

TABLE 1 Top 10 countries or regions with publications on childhood ASD from 2012 to 2021.

| Rank | Country/region | Count | Centrality | H-index |
|------|---------------------------|-------|------------|---------|
| 1 | United States | 3,655 | 0.40 | 102 |
| 2 | England | 653 | 0.17 | 58 |
| 3 | Australia | 553 | 0.09 | 45 |
| 4 | Peoples Republic of China | 478 | 0.02 | 34 |
| 5 | Canada | 472 | 0.02 | 50 |
| 6 | Italy | 319 | 0.04 | 36 |
| 7 | Turkey | 222 | 0.04 | 20 |
| 8 | Netherlands | 206 | 0.03 | 39 |
| 9 | Japan | 172 | 0.00 | 22 |
| 10 | Iran | 165 | 0.00 | 22 |

The clustering labels of co-cited articles depend on citing and cited journals. The cited studies constitute knowledge base of research. The frequency of reference use represents its

TABLE 2 Top 10 institutions with publications on childhood ASD from 2012 to 2021.

| Rank | Institutions | Country | Count | Total link strength |
|------|--------------------------------------|---------------|-------|---------------------|
| 1 | Vanderbilt University | United States | 166 | 4,409 |
| 2 | University of Toronto | Canada | 139 | 4,198 |
| 3 | University of Pennsylvania | United States | 124 | 3,839 |
| 4 | University of California-Los Angeles | United States | 122 | 3,641 |
| 5 | University of California-Davis | United States | 121 | 3,373 |
| 6 | University of North Carolina | United States | 118 | 3,321 |
| 7 | University of Washington | United States | 112 | 3,290 |
| 8 | Ohio State University | United States | 104 | 3,201 |
| 9 | University of Wisconsin | United States | 104 | 3,148 |
| 10 | King's College London | England | 102 | 2,269 |



FIGURE 4 Collaborations of institutions reporting studies on childhood ASD from 2012 to 2021.

influence. Co-citations reveal research themes and development background. Table 5 lists the top 10 cited studies, which include research of diagnostic criteria, intervention methods, epidemiological findings, and ASD characteristics. Two of these studies examined ASD within families. The clustering labels of cited documents are obtained from the citing documents. Figure 7 presents clusters that continued into 2020, including #2 COVID-19, #4 gut microbiota, and #5 physical activity.

Discussion

Principal results

The number of studies on childhood ASD has increased likely due to a combination of educational and medical system

TABLE 3 The top 10 citing journals of publications on Childhood from ASD 2012 to 2021.

| Rank | Citing journals | Research fields | Count | Journal impact factor in 2020 |
|------|--|--|-------|-------------------------------|
| 1 | Journal of Autism and Developmental Disorders | Psychology: development | 1,070 | 4.291 |
| 2 | Research in Autism Spectrum Disorders | Special education/psychology: development/Psychiatry/rehabilitation medicine | 471 | 2.881 |
| 3 | Autism | Psychology: development | 348 | 5.689 |
| 4 | Autism research | Behavioral science/psychology | 319 | 5.216 |
| 5 | Research in Developmental Disabilities | Special education/rehabilitation medicine | 197 | 3.23 |
| 6 | Journal of Applied Behavior Analysis | Psychology | 135 | 3.695 |
| 7 | Frontiers in Psychology | Psychology | 93 | 2.988 |
| 8 | Plos One | Comprehensive journal | 88 | 3.24 |
| 9 | Journal of Developmental and Physical Disabilities | Special education/psychology: development/rehabilitation medicine | 86 | 1.71 |
| 10 | Molecular Autism | Genetics/neuroscience | 66 | 7.509 |

TABLE 4 Journal titles of the top 10 cited publications on childhood ASD from 2012 to 2021.

| Rank | Cited journals | Research field | Count | Journal impact factor in 2020 |
|------|--|--|-------|-------------------------------|
| 1 | Journal of Autism and Developmental Disorders | Psychology: development | 6,342 | 4.291 |
| 2 | Autism | Psychology: development | 3,733 | 5.689 |
| 3 | Journal of Child Psychology and Psychiatry | Psychology/psychiatry | 3,261 | 8.982 |
| 4 | Research in Autism Spectrum Disorders | Special education/psychology: development/psychiatry/rehabilitation medicine | 3,233 | 2.881 |
| 5 | Pediatrics | Medicine/pediatrics | 2,378 | 7.125 |
| 6 | Journal of the American Academy of Child and Adolescent Psychiatry | Pediatrics/psychiatry | 2,334 | 8.829 |
| 7 | Research in Developmental Disabilities | Special education/rehabilitation medicine | 2,312 | 3.23 |
| 8 | Autism Research | Behavioral science/psychology | 2,224 | 5.216 |
| 9 | PLoS One | Comprehensive journal | 1,572 | 3.24 |
| 10 | Child Development | Psychology: education | 1,295 | 5.899 |

changes, which increased disease awareness. The number of published studies decreased from 2020 to 2021 likely due to restrictions associated with the coronavirus disease 2019 pandemic. The United States is the leading source of studies, suggesting policies and regulations in this country are more responsive to the needs of autism patients than those in other countries. The most influential journal in this field is the Journal of Autism and Developmental Disorders. This field includes disciplines such as psychology, psychiatry, special education, rehabilitation, medicine, pediatrics, and behavioral science. Meanwhile, keyword co-occurrence and reference cluster analysis revealed changes in research focus over time. From the emerging keywords from 2012 to 2015, the diagnosis of ASD and its comorbidity were the research hotspots of that year. In 2016 and 2017, we tend to establish randomized controlled trials within ASD groups and the differences between ASD and typical development groups. Based on previous research

findings, researchers began looking for more appropriate technologies to establish disability monitoring networks and strengthen attention to ASD caregivers from 2017 to 2021.

Research focus

Disability monitoring networks

Centers for Disease Control and Prevention (CDC) began monitoring the prevalence of ASD in 1996. The Children's Health Act of 2000 authorized CDC to establish the Autism and Developmental Disabilities Monitoring (ADDM) Network, which aims to assess ASD prevalence and diagnosis timing in children aged 4 and 8 years (19). The ADDM Network has established ASD and developmental disorder monitoring sites across the United States, starting with six sites in 2000 to 14 sites in 2002, and then to 8 sites in 2004 (20). Eleven and 14

TABLE 5 Top 10 most cited publications on childhood ASD from 2012 to 2021.

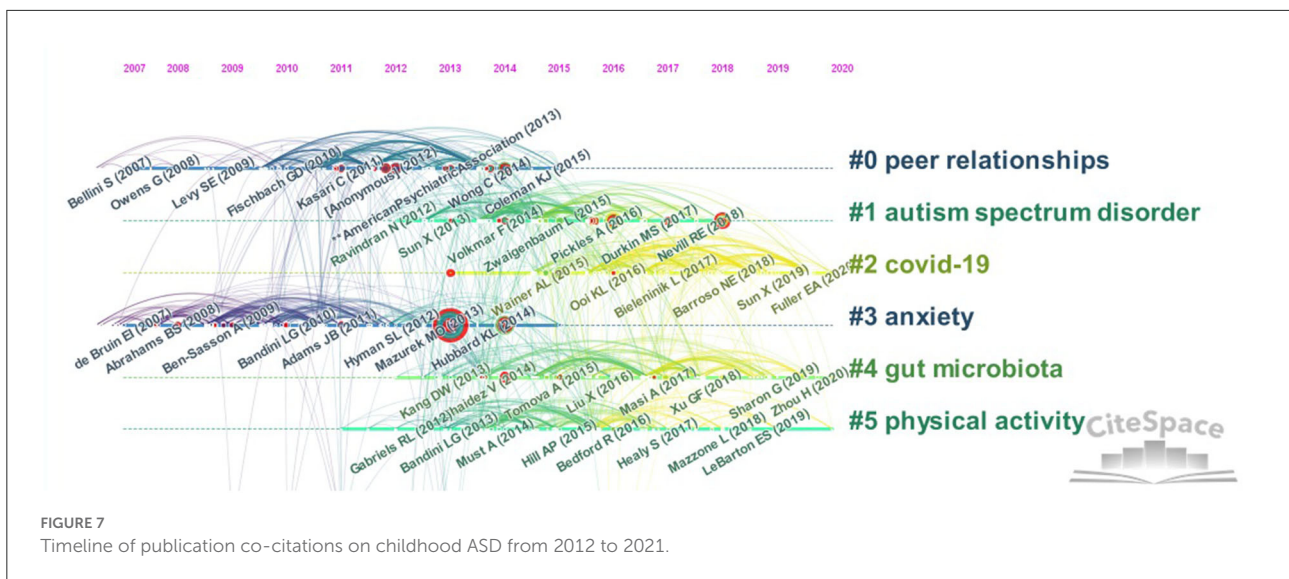
| Rank | Title of cited document | DOI | Count | Interpretation of findings |
|------|---|---------------------------------------|-------|--|
| 1 | Diagnostic and statistical manual of mental disorders, fifth edition, DSM V (10) | doi: 10.1176/appi.books.9780890425596 | 928 | Provides diagnostic criteria of ASD |
| 2 | Prevalence of autism spectrum disorder among children aged 8 years- autism and developmental disabilities monitoring network, 11 sites, United States, 2014 (11) | doi: 10.15585/mmwr.ss6706a1 | 298 | Provides the latest ASD prevalence estimates provided by the Autism and Developmental Disabilities Monitoring (ADDM) network according to DSMIV-TR and DSM-5 standards and asserts the need to monitor prevalence trends in ASD and to improve early diagnosis |
| 3 | The impact of parenting stress: a meta-analysis of studies comparing the experience of parenting stress in parents of children with and without autism spectrum disorder (12) | doi: 10.1007/s10803-012-1604-y | 107 | Reports that family stress associated with raising ASD children is higher than that associated with raising children with other types of disabilities or those with typical development |
| 4 | Autism (9) | doi: 10.1016/S0140-6736(13)61539-1 | 92 | Provides ASD definition, epidemiology, prognosis, outcomes, early symptoms and screening characteristics, clinical evaluation criteria, cognitive and neuroscience findings, and neurobiological, genetic, and intervention characteristics |
| 5 | Randomized, controlled trial of an intervention for toddlers with autism: the early start denver model (13) | doi: 10.1542/peds.2009-0958 | 86 | Presents evidence that comprehensive development behavior intervention for children with ASD helps improve cognitive and adaptive behavior and reduce ASD severity |
| 6 | Global prevalence of autism and other pervasive developmental disorders (14) | doi: 10.1007/s10803-014-2351-z | 78 | Systematically reviews global epidemiological findings on ASD and pervasive developmental disorders |
| 7 | Evidence-based practices for children, youth, and young adults with autism spectrum disorder: a comprehensive review (15) | doi: 10.1007/s10803-014-2351-z | 77 | Presents evidence-based and targeted interventions for children and adolescents with autism spectrum disorders |
| 8 | Naturalistic developmental behavioral interventions: empirically validated treatments for autism spectrum disorder (16) | doi: 10.1007/s10803-015-2407-8 | 75 | Summarized the theoretical and empirical evidence for the naturalistic developmental behavior intervention and suggests directions for further research |
| 9 | What is the male-to-female ratio in autism spectrum disorder? A systematic review and meta-analysis (17) | doi: 10.1016/j.jaac.2017.03.013 | 71 | Presents evidence that girls who meet the ASD criteria are at a high risk of not receiving a clinical diagnosis |
| 10 | Prevalence and characteristics of autism spectrum disorder among 4-year-old children in the autism and developmental disabilities monitoring network (18) | doi: 10.1097/DBP.0000000000000235 | 67 | Provides evidence relevant to early identification of children with ASD, suggesting that assessment age should be reduced in in communities participating in autism and developmental disorder monitoring |

Caregivers

Research into caregivers of children with ASD covers aspects such as caregiver demographic characteristics and views on treatment, nursing training, and health problem, quality of life, and family cohesion surveys, as well as input into specialist nursing and intelligent care system development.

Demographic characteristics of patients, caregivers, and communities affect the perception of patients with ASD. The mothers of 396 children from Singapore completed a quantitative checklist for autism in adults, revealing that child sex, cognitive function, birth order, mother age, and ethnicity

were not characteristics of autism reported by caregivers. Delayed or impaired language development in the child and depressive symptoms and low education level in the mother were associated with social autism (29). Caregivers able to predict child problematic behavior may take action to minimize this risk. However, such predictions are challenging for caregivers that do not receive BCBA support, in which case the use of artificial intelligence technologies may be useful. Zheng et al. proposed a machine learning-based framework that helps predict problem behavior (30). Following an early diagnosis, caregivers of children with ASD need specialist education



to help meet child needs. This approach also encourages social interaction among caregivers (31), which helps improve caregiver physical and psychological health and quality of life (32, 33). In 2021, Nie et al. proposed an immersive interaction system based on augmented reality to help autistic children practice social attention skills (34).

Limitations

There are some limitations to this study. First, we downloaded only citations from the WoSCC database. The findings may differ if citations from other databases are included. Second, despite efforts to reduce bias in this study, no study method can reduce bias present in the original studies. Third, this study only included research findings published between 2012 and 2021. Some relevant studies are on-going, precluding inclusion in the present study, which may subject these results to the effects of time lag. Some of the most recent research hotspots require manual reading to be discovered. The use of artificial intelligence in medicine is increasing, providing novel opportunities to codify existing bias and change practice (35); the use of these technologies in ASD research and care is particularly promising (36).

Conclusions

Disability monitoring networks and caregiver-focused questions are the leading areas of research in childhood ASD, aiming to improve diagnosis, interventions, and outcomes. Many questions in this field remain unanswered. Eleven

sites across the United States provide ASD prevalence data, which may support policy development and clinical practice. These data may help establish rehabilitation intervention systems for caregivers, supporting disease management. The use of artificial intelligence-based technologies may support research and clinical practice, including studies aimed at elucidating neurobiomarkers of ASD. Remote assessment and intervention guidance is required in the time of pandemics (37, 38).

Data availability statement

The original contributions presented in the study are included in the article/supplementary files, further inquiries can be directed to the corresponding author.

Author contributions

JZ, YL, and FZ acquired, analyzed the data, and drafted the manuscript. FF, XD, and XingW analyzed the data. MW and XiaoW designed the research, acquired the article information, and revised the manuscript. All authors agreed to be accountable for the content of the work. All authors contributed to the article and approved the submitted version.

Funding

The work was financially supported the Key R&D and Promotion Projects in Henan Province (222102310615) and Henan Province Medical Science and Technology

Key Project Jointly Constructed by Province and Ministry (SBGJ202102189).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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