Trends of Tourette Syndrome in children From 2011 to 2021: A Bibliometric Analysis

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Abstract

Background

Tourette Syndrome (TS) has attracted the attention of researchers worldwide. However, no bibliometric analysis of the published publications is available. This study aims to examine the present research state of TS in children by CiteSpace, as well as to identify current research hotspots and frontiers.

Methods

We chose publications indexed in the Web of Science Core Collection (WoSCC) database for studies related to TS in children from 2011 to 2021. We built online cooperation maps of countries, institutions, authors, journals, references, and keywords by CiteSpace, and identified hotspots and frontiers of study for children's TS.

Results

A total of 1232 publications about TS in children were downloaded from the WoSCC. The USA (414) was the country with the highest rate of production, and University College London (87) was the institution that had the highest publication rate. Andrea Eugenio Cavanna was the most prolific author (39 papers). There was inactive cooperation between institutions, countries, and authors. The Journal of European Child & Adolescent Psychiatry was the most active journal. Hot topics focused on epidemiology, comorbidity, deep brain stimulation, behavioral therapy, pharmacological treatment, and risk factors of TS in children.

Conclusions

According to the CiteSpace results, this study found that authors, countries, and institutions were not actively working together. Current research hotspots mainly consist of epidemiology, comorbidity, deep brain stimulation, and behavioral therapy. The main research trends include comorbidity, pharmacological treatment, and risk factors. Therefore, international cooperation should be strengthened in the future, and it should be mindful of the psychiatric comorbidities of TS, the choice of intervention measures, and early warning of risk factors.

Background

Tourette Syndrome (TS) is a neuropsychiatric disorder characterized by chronic motor and/or vocal tics lasting more than one year (1). These symptoms often occur in about 1% of children of school age, which interfere with children's academic performance and daily life activities (2). However, TS is often undiagnosed or misdiagnosed (3). TS often has frequent comorbidities with obsessive compulsive
disorder (OCD), attention deficit/hyperactivity disorder (ADHD), or autism (4, 5). In recent years, people have become more aware of the consequences, results, and burdens of TS. However, systematic research on worldwide research trends and hotspots is lacking.

Bibliometrics is a method of using metrics (indicators) to evaluate research performance (6, 7). It can quantitatively and qualitatively measure the structure, growth, and trends of knowledge about a subject, and is now used in a wide range of fields (8). Here, CiteSpace will be utilized for bibliometrics as well as visual analysis (9). This is the first time visual analysis has been done with CiteSpace in the field of TS. We concentrated mainly on the network and cluster analysis of countries, institutions, and co-authors, cited references, and keywords, and explored the hotspots and trends of TS.

**Methods**

**Data Source and Search Strategy**

For this study, we chose publications indexed in the Web of Science Core Collection (WoSCC) database as the data source. The WoSCC database is commonly utilized in bibliometric analysis since it strictly evaluates articles, ensuring high-quality literature. The WoSCC database, on the other hand, is constantly and dynamically updated and can give you the most important, relevant, and reliable information. Because of this, this database was good for our research.

These terms were included in the topic and searched for: (“Tourette Syndrome” OR “Tic Disorder”) AND (“children”) AND Language = English, document types only contained articles and reviews. We searched the WoSCC database exhaustively for relevant data released from 2011 to 2021. Figure 1 depicts the detailed search process.

**Analysis Tool**

We used CiteSpace 5.8 R3 and Excel 2019 to analyze data in this study. Dr. Chaomei Chen, a scholar at Drexel University in the United States, created CiteSpace, a bibliometric analysis visualization software. A "Plain Text" form of each record's "Full Record and Cited References" was retrieved from WoSCC and imported into CiteSpace. Our analysis included the annual publication volume, journals, countries, institutions, authors, references, and keywords. By analyzing the number and growth trend of papers published each year, investigating author/institutional/country collaboration networks, detecting co-cited references, and keeping track of keywords with high citation bursts over time, the research frontiers and emerging trends of TS in children were identified. As the circle grows larger in CiteSpace, it indicates the growing number of papers that have been published. Meanwhile, the shorter the distance between the two circles, the closer the cooperation between the two circles. Meanwhile, nodes with a high betweenness centrality (BC ≥ 0.1) are frequently highlighted with purple rings, which is an important parameter for assessing the scientific value of the nodes. CiteSpace provides two indexes based on network structure and clustering clarity to evaluate graph drawing: modularity (Q) and silhouette (S).
Generally speaking, Q is generally within the interval $[0.1]$, and $Q > 0.3$ means that the community structure is significant. If $S > 0.5$, clustering is generally considered reasonable. When $S > 0.7$, clustering is efficient and convincing.

**Quality Control**

All data downloads and literature searches were done on February 15, 2022, so that the database update wouldn't cause any bias. Methods for controlling research quality: (1) two researchers worked independently on the data analysis, and any disagreements were resolved through discussion or by enlisting the assistance of outside experts. (2) the final results of the knowledge map would be confirmed by experts in related fields to verify the guiding significance of the research conclusions for clinical practice.

**Results**

**Analysis of Publication Years**

Through a preliminary search of literature on TS in children, 1232 publications were retrieved from the WoSCC database (Fig. 1). According to Fig. 2, there has been a fluctuating increase in the number of annual publications related to child tic disorders, from 80 in 2011 to 151 in 2021. This field had the fewest number of articles in 2014, only 77. However, there was a rapid growth in 2017–2020, which shows that the field has received more and more attention during this period.

**Analysis of Countries**

The network of national partnerships for TS in children's research is shown in Fig. 3. Table 1 provides a list of the top 5 contributing nations, each of which has contributed 965 articles and accounts for 78.33% of publications. The top contributor was the USA (33.60%), followed by England (15.75%), Italy (10.06%), Germany (9.82%), and China (9.09%). The analysis revealed that the top five countries in terms of centrality were Hungary (0.51), Scotland (0.42), France (0.41), the Netherlands (0.31) and Australia (0.24). The graph of country-based research networks shows a lower density, which suggests that research teams are relatively independent and highlights the need for more collaboration.

**Table 1**

The top 5 countries related to TS in children research from 2011 to 2021.

| Ranking | Country  | Frequency | Ranking | Country     | Centrality |
|---------|----------|-----------|---------|-------------|------------|
| 1       | USA      | 414       | 1       | Hungary     | 0.51       |
| 2       | England  | 194       | 2       | Scotland    | 0.42       |
| 3       | Italy    | 124       | 3       | France      | 0.41       |
| 4       | Germany  | 121       | 4       | Netherlands | 0.31       |
| 5       | China    | 112       | 5       | Australia   | 0.24       |
Analysis of Institutions

Figure 4 shows the main network of institutional collaborations related to children with TS, with the University College London in England being the most productive institution in this field. Table 2 illustrates the top 10 most prolific institutes in this research field, contributing 494 articles (40.10%), including University College London (7.06%), Karolinska Institutet (6.17%), Yale University (4.30%), University of Birmingham (3.98%) and Johns Hopkins University (3.73%), 4 of which are from the USA. Karolinska Institutet (0.13), Johns Hopkins University (0.12), and University College London (0.1) had the highest centrality rankings. Centrality is low for all institutions and poor collaboration among institutions.

| Ranking | Institution                        | Frequency | Country    | Centrality |
|---------|------------------------------------|-----------|------------|------------|
| 1       | University College London          | 87        | England    | 0.1        |
| 2       | Karolinska Institutet              | 76        | Sweden     | 0.13       |
| 3       | Yale University                    | 53        | USA        | 0          |
| 4       | University of Birmingham           | 49        | England    | 0.09       |
| 5       | Johns Hopkins University           | 46        | USA        | 0.12       |
| 6       | University of Gothenburg           | 43        | Sweden     | 0.05       |
| 7       | University of South Florida        | 38        | USA        | 0.01       |
| 8       | University of Calgary              | 37        | Canada     | 0.01       |
| 9       | University of California Los Angeles| 34       | USA        | 0.04       |
| 10      | Technical University Dresden       | 31        | Germany    | 0.02       |

Analysis of Co-authors

Figure 5 is a co-author network map generated by CiteSpace. The top 10 authors were responsible for 291 papers (23.62%) (Table 3). Andrea Eugenio Cavanna was the author who produced the most works (3.17%), followed by Paul Lichtenstein (2.60%), Douglas W Woods (2.44%), and Sebastian Lundström (2.35%). In terms of centrality, Veit Roessner (0.40), Renata Rizzo (0.37), and Andrea Eugenio Cavanna (0.13) had the highest centrality rankings, while the centerlines of the rest of the prolific authors were less than 0.1. In addition, some authors who publish a large number of publications tend to maintain stable cooperative partnerships with other authors.
Table 3
The top 10 authors related to TS in children research from 2011 to 2021.

| Ranking | Author                        | Frequency | Centrality | Year of first article |
|---------|-------------------------------|-----------|------------|-----------------------|
| 1       | Andrea Eugenio Cavanna        | 39        | 0.13       | 2011                  |
| 2       | Paul Lichtenstein             | 32        | 0.01       | 2013                  |
| 3       | Douglas W Woods               | 30        | 0.08       | 2012                  |
| 4       | Sebastian Lundström           | 29        | 0.05       | 2013                  |
| 5       | Renata Rizzo                  | 29        | 0.37       | 2011                  |
| 6       | Veit Roessner                 | 29        | 0.40       | 2011                  |
| 7       | Davide Martino                | 27        | 0.01       | 2011                  |
| 8       | Tanya K Murphy                | 26        | 0.10       | 2011                  |
| 9       | James F Leckman               | 26        | 0.01       | 2011                  |
| 10      | Eric A Storch                 | 24        | 0.00       | 2011                  |

Analysis of Journals and Cited Journals

The number of journals that published 1232 articles on TS in children was 396. Table 4 lists the ten most active journals, and most of these journals' publishers are based in the USA or the Netherlands. The majority of the publications were published in the Journal of *European Child & Adolescent Psychiatry* and the Journal of *Child and Adolescent Psychopharmacology*, followed by *Psychiatry Research* and the *Journal of Child Neurology*. 
Table 4
The Top 10 Journals with the Highest Frequency related to TS in children research from 2011 to 2021.

| Ranking | Journal                                                        | Frequency | Country     |
|---------|-----------------------------------------------------------------|-----------|-------------|
| 1       | European Child & Adolescent Psychiatry                         | 48        | Germany     |
| 2       | Journal of Child and Adolescent Psychopharmacology             | 47        | USA         |
| 3       | Psychiatry Research                                            | 36        | Netherlands |
| 4       | Journal of Child Neurology                                     | 32        | USA         |
| 5       | Frontiers in Psychiatry                                        | 31        | Sweden      |
| 6       | Journal of Child Psychology And Psychiatry                      | 28        | England     |
| 7       | Movement Disorders                                             | 24        | USA         |
| 8       | Pediatric Neurology                                            | 20        | USA         |
| 9       | Journal of The American Academy of Child And Adolescent Psychiatry | 19        | Netherlands |
| 10      | Frontiers In Neurology                                         | 17        | Switzerland |

Co-citation of journals can reflect the correlation between journals. Table 5 shows the 10 most cited journals. The *Journal of The American Academy of Child and Adolescent Psychiatry* receives the most citations (898), followed by the *American Journal of Psychiatry* (645), and the *Archives of General Psychiatry* (580). In terms of centrality, the centerlines of the top 10 cited journals are mostly \( \geq 0.1 \), suggesting that the cooperation of journals is closer.
Table 5
The Top 10 Co-cited Journals with the Highest Frequency related to TS in children research from 2011 to 2021.

| Ranking | Cited Journal                                      | Frequency | Centrality | Country       |
|---------|----------------------------------------------------|-----------|------------|---------------|
| 1       | Journal of The American Academy of Child And Adolescent Psychiatry | 898       | 0.12       | Netherlands   |
| 2       | American Journal of Psychiatry                     | 645       | 0.07       | USA           |
| 3       | Archives of General Psychiatry                     | 580       | 0.16       | USA           |
| 4       | Neurology                                          | 543       | 0.13       | USA           |
| 5       | Movement Disorders                                 | 538       | 0.10       | USA           |
| 6       | European Child & Adolescent Psychiatry             | 524       | 0.12       | Germany       |
| 7       | Journal of Child Psychology And Psychiatry         | 469       | 0.12       | England       |
| 8       | Biological Psychiatry                              | 438       | 0.15       | Netherlands   |
| 9       | Developmental Medicine & Child Neurology           | 411       | 0.01       | USA           |
| 10      | Pediatrics                                         | 408       | 0.05       | USA           |

Analysis of Co-cited References

A total of 31968 references were extracted from 1232 articles for citation analysis. The time span is from 2011 to 2021, and the time slice is 1. After selecting references as node types for statistical analysis, 50 items that are most frequently cited or appear in each time slice are selected to build a cited literature network diagram made up of 338 nodes and 1940 links. Table 6 lists the top 10 studies related to TS in children, which have been cited more than 900 times. An analysis in terms of co-citation counts and centrality (Table 6) revealed that the data on this topic over the past decade is generally in the form of 1) clinical guidelines, 2) controlled trials, and 3) epidemiological and prevalence studies.
Table 6
The Top 10 Co-cited References sorted with the Highest Citations related to TS in children research from 2011 to 2021.

| Ranking | Co-cited reference                                                                 | Citation | Centrality | Representative Author (Publication Year)                  |
|---------|------------------------------------------------------------------------------------|----------|------------|---------------------------------------------------------|
| 1       | Diagnostic and Statistical Manual of Mental Disorders                             | 132      | 0.01       | American Psychiatric Association (2013)                 |
| 2       | Behavior therapy for children with Tourette disorder: a randomized controlled trial | 130      | 0.18       | Piacentini J (2010)                                     |
| 3       | European clinical guidelines for Tourette syndrome and other tic disorders. Part I: pharmacological treatment | 115      | 0.17       | Veit Roessner (2011)                                     |
| 4       | Lifetime Prevalence, Age of Risk, and Genetic Relationships of Comorbid Psychiatric Disorders in Tourette Syndrome | 106      | 0.07       | Hirschtritt ME (2015)                                   |
| 5       | Prevalence of Tic Disorders: A Systematic Review and Meta-Analysis               | 99       | 0.05       | Knight T (2012)                                         |
| 6       | European clinical guidelines for Tourette Syndrome and other tic disorders. Part III: behavioural and psychosocial interventions | 83       | 0.06       | Verdellen C (2011)                                      |
| 7       | Clinical course of Tourette syndrome                                             | 60       | 0.01       | Bloch MH (2009)                                         |
| 8       | The international prevalence, epidemiology, and clinical phenomenology of Tourette syndrome: A cross-cultural perspective | 59       | 0.05       | Robertson MM (2009)                                     |
| 9       | The prevalence and epidemiology of Gilles de la Tourette syndrome Part 1: The epidemiological and prevalence studies | 57       | 0.06       | Robertson MM (2008)                                     |
| 10      | Quality of life in young people with Tourette syndrome: a controlled study        | 54       | 0.05       | Eddy CM (2011)                                          |

To evaluate the nominal terms derived from the article keyword list for cluster names, to acquire the crucial data from the cited references, and to investigate the research models and new trends in the knowledge system, we used the logarithmic likelihood ratio (LLR) algorithm. Figure 6 shows the timeline view of the reference co-citation network. Six clusters with a modularity value of 0.5909 and a silhouette of 0.8825 are generated, which means that our cluster results are highly reliable, reasonable, and meaningful. The largest group was cluster # 0, "pharmacotherapy", which was painted in cold colors to signify that it would be a research hotspot in the near future. The second is cluster # 1, "diffusion tensor imaging," which has always been a hot spot in the study of this topic.

Analysis of Co-Occurrence Keywords and Cluster
The hot topics in a research field can be identified by analyzing the high-frequency keywords, while the status and influence of the associated study topic are indicated by the greater central keywords. A network of keywords co-occurrences consisting of 198 nodes and 1694 linkages was produced (Table 7 and Fig. 7). Table 7 shows that the top 10 high-frequency keywords were: Tourette syndrome, children, deficit hyperactivity disorder, health-related quality of life, obsessive compulsive disorder, epidemiology, spectrum disorder, behavior therapy, controlled trial, and depression. The top 10 high-centrality keywords were: neuropsychiatric disorder, deficit hyperactivity disorder, deep brain stimulation, basal ganglia, obsessive compulsive disorder, spectrum disorder, tic severity, symptom, schizophrenia, and diagnosis. In addition, Fig. 7 shows a high-frequency keyword co-occurrence network, where the frequency of occurrence of a keyword increases with character size. Ten clusters were found, and each had a silhouette value that was greater than 0.8, indicating that the findings were valid and meaningful (Fig. 8 and Table 8).

Table 7
The Top 10 Keywords related to TS in children research from 2011 to 2021.

| Ranking | Frequency | Keyword                           | Ranking | Centrality | Keyword                     |
|---------|-----------|-----------------------------------|---------|------------|-----------------------------|
| 1       | 799       | Tourette syndrome                 | 1       | 0.13       | neuropsychiatric disorder   |
| 2       | 733       | children                          | 2       | 0.12       | deficit hyperactivity disorder |
| 3       | 300       | deficit hyperactivity disorder    | 3       | 0.12       | deep brain stimulation      |
| 4       | 274       | health-related quality of life    | 4       | 0.11       | basal ganglia               |
| 5       | 259       | obsessive compulsive disorder     | 5       | 0.10       | obsessive compulsive disorder |
| 6       | 240       | epidemiology                      | 6       | 0.10       | spectrum disorder           |
| 7       | 222       | spectrum disorder                 | 7       | 0.08       | tic severity                |
| 8       | 148       | behavior therapy                  | 8       | 0.07       | symptom                     |
| 9       | 141       | controlled trial                  | 9       | 0.07       | schizophrenia               |
| 10      | 132       | depression                        | 10      | 0.07       | diagnosis                   |
Table 8
Keywords cluster analysis.

| Cluster ID | Silhouette | mean(Year) | Label (LLR) | Included keywords (top 5) |
|------------|------------|------------|-------------|---------------------------|
| 0          | 0.942      | 2012       | Parental age | Tourette syndrome; conduct disorder; neurodevelopmental disorders; tics; infection |
| 1          | 0.932      | 2013       | Tolerability | premonitory urges; schizophrenia; sensorimotor gating; comorbidity; inhibitory control |
| 2          | 0.86       | 2013       | Response inhibition | inhibition; connectivity; volume; enhanced cognitive control ; response inhibition |
| 3          | 0.858      | 2012       | Age at onset | tolerability; double blind; aripiprazole; controlled trial; open label |
| 4          | 0.847      | 2014       | Autism spectrum disorder | deep brain stimulation; obsessive compulsive disorder; management; quality; randomized controlled trial |
| 5          | 1          | 2013       | Premonitory urge | obsessive-compulsive disorder; reliability; scale; validity; cluster analysis |
| 6          | 0.992      | 2014       | Deep brain stimulation | behavior therapy; cbt; guideline; treatment evaluation; supportive psychotherapy |
| 7          | 0.953      | 2012       | Pandas       | movement disorders; movement disorder; statistical learning; headache; neuropsychology |
| 8          | 0.899      | 2012       | Behavior therapy | onset; psychiatric disorder; obsession; compulsion; pandas |
| 9          | 1          | 2014       | Basal ganglia | adhd; tourette syndrome; attention-deficit hyperactivity disorder; hyperactivity disorder; deficit hyperactivity disorder |

Analysis of Keywords With Citation Bursts

Burst keywords are used to record keywords that have undergone significant change in a short period and are automatically created by the software according to the keywords in the list. It is widely regarded as another important research hotspot or an indicator of upcoming developments. The keyword burst period is shown by the red line, and the time period is shown by the blue line. The top 20 keywords with the most powerful citation bursts are displayed in Fig. 9. From 2011 to 2021, pharmacological treatment had the highest burst strength (5.78).

Discussion
As far as we know, this is the first bibliometric study on TS. We searched for data from 1232 studies published between 2011 and 2021. CiteSpace and Excel were employed for the analysis, and descriptive statistics, symbiosis, and cluster analysis were the methods that were applied to the datasets that were obtained from these studies.

General Information

From 2011 to 2021, the growth trend of obtaining publications related to TS from WoSCC fluctuated over time, but showed an overall increasing trend, reflecting the increasing importance of TS in the field of neurological research in children.

The USA is in a leading position in this field, reflecting its leading position in TS research. Developed countries are the main force behind TS research. This trend shows that the development of scientific research is related to the mature medical research environment and economic conditions of the country. At the same time, the large population is also an important factor affecting the number of publications. Being the sole developing nation in the top 5, China has recently achieved significant advancements in TS. Additionally, in terms of national cooperation, Hungary, Scotland, France, and the Netherlands cooperate more closely with other countries, which may have something to do with each country's geographical location. It has been observed that there is less cooperation among countries with more contributions, as can be seen from their relatively low centrality. We suggest that international cooperation, especially with leading countries in this field, should be strengthened, which will accelerate global research progress in TS.

In terms of institutions, they are mostly located in the USA and England. University College London, Karolinska Institutet, and Johns Hopkins University are prolific and highly centralized institutions, which shows that they are important institutions for studying TS and working closely with other institutions. However, Italy and China are two of the countries that rank among the top five in terms of the total number of publications, but there are no institutions in the top 10. This may indicate that there are relatively few institutions conducting research in this area in the country. Choosing a suitable partner institution is conducive to better TS research.

Although Andrea Eugenio Cavanna is the most prolific writer (39), the frequently cited literary works were not written by him. And among the top 10 prolific writers, only 4 writers' centrality ≥ 0.1. It is worth noting that most of the global TS researchers for children are from Europe and the United States, and this result is consistent with the cooperative relationship between the previous countries. Therefore, children's TS research still needs to strengthen communication and cooperation among global researchers. In addition, most of the cooperative relationships between the authors are closely related to their respective institutions, indicating that the authors are more inclined to work with stable cooperative teams.

The top 10 journals published 302 papers, accounting for 24.51% of the total, indicating that the top 10 journals are more interested in TS research. The major journals in the fields of pediatrics and neurology, which have had a great impact on pediatricians and neurologists around the world and have impacted
the direction of research in the related fields of science, are the most often published journals in TS research. These results can help scholars choose more suitable journals when submitting papers in related fields.

**Research Hotspots**

References can reflect important insights into currently known information about a certain topic. Co-citation analysis can reveal the knowledge structure of a research field by analyzing the clustering and key nodes in the co-citation network. The top 10 co-cited references indicated that scholars are more focused on the guidelines for clinical diagnosis and treatment, controlled trials, and epidemiology of TS. Especially noteworthy, the first reference with the greatest rate of co-citation was the *Diagnostic and Statistical Manual of Mental Disorders* proposed by the American Psychiatric Association (10), which proposed the diagnostic criteria, evaluation methods, and treatment of TS. A randomized controlled trial of behavioral therapy was the top reference by centrality in children with TS, indicating that comprehensive behavioral intervention can improve the symptom severity among children with TS. In addition, according to the timeline view of the network for reference co-citation, it is found that pharmacotherapy is the focus of TS research, but the attention of antiphychotics has decreased in the past decade, which is closely related to the research progress of TS. At the same time, diffusion tensor imaging can assist in the study of the pathogenesis and efficacy of TS.

Keywords are the high-level summary of the core content of the research. Keyword co-occurrence analysis can help researchers identify hot topics within a specific subject matter. Cluster analysis and co-occurrence keyword results demonstrate that the principal hot subjects for the present study include epidemiology, comorbidities, deep brain stimulation, and behavior therapy. Burst keywords can indicate research frontiers and trends. Pharmaceutical treatment, comorbidities, and risk factors are the main research trends of TS.

**Epidemiology**

Epidemiological studies, including the distribution characteristics, prevalence, and influencing factors of the disease population, are of great significance for the prevention and treatment of diseases. Childhood-onset primary tic disorder is common (10). It is found that TS is more likely to influence boys than girls (11). According to the 2011–2012 National Survey of Children's Health (NSCH), 0.28% of children in the United States are suffering from TS (12). A Statistics Canada survey shows that the prevalence rate of TS among Canadian teenagers (12–17 years old) is 0.33% (13). The incidence of TS has seldom been evaluated in Asia. It is suggested that countries around the world conduct epidemiological studies on TS in order to better comprehend TS's nature, prevalence, and risk factors.

**Comorbidities**

TS is commonly comorbid with a variety of mental and/or behavioral disorders, such as ADHD, OCD, autism spectrum disorder (ASD), depression, anxiety disorder, sleep disorders, and self-injurious behavior (14–16). About 90% of the patients have psychiatric comorbidities, of which ADHD, OCD, and ASD are the
most common, followed by other diseases (17, 18). This is probably due to the overlap in neurobiology and pathophysiology and genetic inheritance of these disorders compared to TS (19, 20). Comorbidity has a significant detrimental impact on patients’ quality of life (21, 22). Comorbidities with ADHD can lead to behavioral disorders such as aggressive behavior, destructive behavior, poor academic performance and social adaptability, and executive function problems (23, 24). Patients with TS and OCD have more desires and impulses to repeat checking, reordering, or fixing procedures, resulting in severe clinical distress or social or occupational dysfunction (25). Trichotillomania may also be seen in patients with TS and OCD (26). In addition, the comorbidities of TS can contribute to these feelings involving anxiety, tension, stress, and frustration (27). The comorbidities of TS increase the complexity and severity of TS, have an impact on how well children learn, socialize, and develop their personalities and psychological qualities, and make it more difficult to diagnose, treatment, and the prognosis of the disease. At times, the comorbidities are more problematic and will need more intervention than the tics themselves. How would you screen for comorbidities in a patient with possible TS? And truthfully, it is a subject worth considering.

**Deep brain stimulation**

Deep brain stimulation (DBS) is an established treatment for neurological and psychiatric disorders. For patients with severe drug-refractory TS, DBS is a promising treatment option (28). One study indicated that DBS mainly acts on a variety of regions and structures located within the network of cortico-striato-pallido-thalamo-cortical tissue (29). Another study reported that DBS produced a mean 50% improvement in overall tic severity by the total Yale Global Tic Severity Scale (YGTSS) score (30). Kara et al. found that several months of DBS treatment can effectively improve TS and OCB (31). A recent systematic review and meta-analysis reported that DBS for TS had an overall improvement of 53% (YGTSS score) (32). In a study including 185 patients from 10 countries in the International Deep Brain Stimulation Database and Registry, the mean YGTSS score improved 45.1% at 1 year after DBS implantation (33). However, the safety of DBS still needs attention, including visual disturbances, dysarthria, paresthesia, intracranial hemorrhage, and infection (33–35). The mechanisms by which DBS works are not fully understood, but functional magnetic resonance imaging (fMRI) may help to fill this knowledge gap (36). Considering the higher risk of complications after DBS, we figure the sensible thing to do is to better understand the feasibility, safety, and clinical effectiveness of DBS in the treatment of severe-refractory TS.

**Behavior therapy**

Behavioral therapy is the first-line treatment for TS, which can reduce tic symptoms and comorbidities and improve social functioning (37, 38), including habit reversal training, exposure and response prevention, relaxation training, positive reinforcement, self-monitoring, regression exercise, and the most frequently employed is the Comprehensive Behavioral Intervention for Tics (CBIT) (39). The American Academy of Neurology (AAN) suggests that CBIT should be considered as the initial treatment option for TS, which reduces tics by training patients and teaching them specific behavioral strategies (38). Flint et al. found that behavioral therapy achieved remission (67%) at follow-up on the YGTSS, and tic severity decreased significantly across the sample (n = 126) (39). A meta-analysis and literature review showed
that CBIT can significantly reduce the total score of tic disorder and the score of motor tics, but not the score of vocal tics (40). Behavioral therapy is much safer than Pharmacological treatment, because the core of behavioral therapy is the cognitive function of children in the recognition and control of impulses, so it is only effective for older children with TS, and the implementation environment and compliance requirements are high, for many countries still face great challenges. By far the most common form of behavioral therapy is to deliver therapy remotely, both to save time and to enable remote delivery of treatment with minimal therapist support. Due to the limited number of trained therapists, it is recommended that routine and regular training for all practitioners involved in the diagnosis and treatment of TS can effectively help more patients in need.

**Pharmacological treatment**

In 2021, the European Society for the Study of Tourette Syndrome (ESSTS) published online the latest European guidelines for TS in the *European Journal of Child and Adolescent Psychiatry*, which pointed out that when the curative effect of behavioral therapy is poor or ineffective or unavailable, additional pharmacological treatment should be considered (41), including antipsychotics, α-agonists, botulinum toxin injections, cannabis-based medications, antiseizure medications, and traditional Chinese medicines (38). The ESSTS recommended aripiprazole, tiapride, and risperidone for TS, in which aripiprazole was considered to be the first choice for children and adults (42). The AAN analyzed the evidence and found that the evidence quality of antipsychotics (haloperidol, risperidone, aripiprazole, tiapride), clonidine, onabotulinum toxin A injections, and traditional Chinese medicine (ningdong granule, 5-ling granule) was higher, which indicated that these interventions are probably more likely than placebo to have reduced tic severity (43). In pharmacologic cases where rapid reduction of tics is urgently required. At present, pharmacological treatment can reduce tics by 60–90%, such as aripiprazole by 74% (44). However, each drug has well known adverse effects, including weight gain, elevated prolactin levels, sedation, drug-induced movement disorders, and effects on heart rate, blood pressure, and electrocardiograms (43). Therefore, when selecting the most appropriate drug for a patient with TS, the efficacy and potential adverse effects of the drug should be considered, and it is recommended that adverse events be carefully monitored and dosage should be gradually reduced during withdrawal. Meanwhile, another important point is the presence of comorbidities when choosing a drug for a patient. Clonidine and guanfacine for TS and ADHD are the best options (42). Behavioral therapy is the first-line treatment for patients with TS and OCD, followed by selective serotonin reuptake inhibitors (SSRIs). Generally speaking, the treatment of TS should be individualized, and pharmacological treatment should consider all relevant factors. We suggest that patients with TS should be evaluated and examined regularly to evaluate the effectiveness of the drug, any side effects, and the necessity for further therapy.

**Risk factors**

In a logistic regression analysis of 6,090 children in the Avon Longitudinal Study of Parents and Children (ALSPAC), United Kingdom, Carol et al. concluded that primiparity (first-born), maternal alcohol, inadequate maternal weight gain during pregnancy, and cannabis use were the main candidate environmental risk factors for TS (45). Several references have reported that maternal smoking,
psychosocial stress during pregnancy and low birth weight were prenatal risk factors for TS (46–50). A large nationwide cohort study with data from the Finnish Medical Birth Register showed nulliparity was associated with increased odds for TS, but birth weight of 4000–4499 g was associated with decreased odds for TS (51). In addition, risk factors for TS also included family history, impaired fetal growth, cesarean section, maternal autoimmune disease, group A streptococcal (GAS), and other infections, and allergic illnesses (49, 51, 52). Further understanding of these risk factors will be helpful in the development of interventions and in focusing future research initiatives to reduce the burden associated with TS. These risk factors can be reduced as much as possible through prenatal education, communication between doctors and patients, and careful monitoring of patients who may have the tendency to TS. Consequently, it is advised that all clinicians involved in the treatment of TS should conduct a condition evaluation to understand the risk factors associated with the development of TS. In the future research direction, the risk factors of TS are unique or common.

**Strengths And Limitations**

To the best of our knowledge, this study is the first to use CiteSpace for bibliometric visual analysis of TS in children. Make a clear visual display of the number of documents, journals, references, and other aspects, interpret the result data from multiple angles, summarize the research status in this field, analyze the research hotspots, and predict the future research trend. At the same time, we downloaded the data from the WoSCC database. The source is relatively comprehensive, and the analysis is more objective. However, this study also has some limitations. First of all, due to the limitations of CiteSpace, we only analyze data from WoSCC, so the published content may not be complete. It is expected that with the improvement of the software functions in the future, a wider range of options can be realized. Secondly, our analysis selects English literature, which makes the analysis results not applicable in some places, because researchers cannot fully understand other languages. Thirdly, in the analysis process, it is found that there are many synonyms, which may cause some overlap in the results of cluster analysis.

**Conclusions**

According to the findings of CiteSpace, publications related to TS in children have increased in the past 10 years. The USA has the highest publication rate and the most productive institutions, and researchers, but the cooperation among countries, institutions and authors around the world is still not close enough. Current research hotspots mainly include epidemiology, comorbidity, deep brain stimulation, and behavioral therapy. The main research trends include comorbidity, pharmacological treatment, and risk factors. Therefore, international cooperation should be strengthened in the future, and attention should be devoted to the psychiatric comorbidities of TS, the choice of intervention measures, and early warning of risk factors.

**Declarations**

**Ethics approval and consent to participate**
Consent for publication

NA

Availability of data and materials

The raw data are available directly from the Web of Science Core Collection (WoSCC) of Thomson Reuters. The authors will freely share the unfiltered raw data that underlies the results of this article.

Competing interests

The authors declare none.

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Authors' contributions

The dates were created and analyzed by C-LY. The work was written and edited by C-LY and JZ. In addition to LW, C-LY, QZ, J-JZ, and JZ worked on the manuscript's revision. The article's submission was reviewed and approved by all authors.

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Figures
Records identified through Web of Science Core Collection
#1 (TS=(Tourette Syndrome)) OR TS=(Tic Disorder)
#2 TS=(children)
#3 LA=(English)
#4 DOP=(2011-01-01/2021-12-31)
#5 #1 AND #2 AND #3 AND #4

1352 literature items were identified

Excluded

120 literature items (including meeting abstract, editorial material, letter, news item, correction, book review, biographical item, reprint)

1232 literature items were identified (including 1003 articles and 229 reviews)

**Figure 1**

Frame flow diagram of search strategy.
Figure 2

Annual trend chart of publications related to TS in children research from 2011 to 2021.
Figure 3

A country cooperation map related to TS in children research from 2011 to 2021.
Figure 4

An institution cooperation map related to TS in children research from 2011 to 2021.
Figure 5

A co-authors map related to TS in children research from 2011 to 2021.
Figure 6

A reference co-citation map related to TS in children research from 2011 to 2021.
basal ganglia
deep brain stimulation
behavior therapy
healthy control
epidemiology depression
health-related quality of life
deficit hyperactivity disorder
hyperactivity disorder children tic severity
severity tourette syndrome vocal tics
obsessive compulsive disorder
neuropsychiatric disorder symptom
comorbidity spectrum disorder global tic severity scale
reliability controlled trial
chronic tic disorder
autism spectrum disorder

Figure 7

Keyword co-occurrence map related to ToS in children research from 2011 to 2021.
Figure 8

Keywords cluster analysis co-occurrence map related to TS in children research from 2011 to 2021.
## Top 20 Keywords with the Strongest Citation Bursts

| Keywords                        | Year | Strength | Begin | End    | 2011 - 2021 |
|--------------------------------|------|----------|-------|--------|-------------|
| methylphenidate                | 2011 | 3.43     | 2011  | 2013   |             |
| serotonin reuptake inhibitor   | 2011 | 3.43     | 2011  | 2013   |             |
| open label                     | 2011 | 3.47     | 2012  | 2014   |             |
| telephone interview            | 2011 | 3.97     | 2013  | 2015   |             |
| movement                       | 2011 | 3.63     | 2013  | 2015   |             |
| executive function             | 2011 | 4.28     | 2015  | 2018   |             |
| schizophrenia                  | 2011 | 3.94     | 2015  | 2016   |             |
| pharmacological treatment      | 2011 | 5.78     | 2016  | 2018   |             |
| functional impairment          | 2011 | 4.7      | 2016  | 2018   |             |
| network                        | 2011 | 3.04     | 2016  | 2017   |             |
| diagnosis                      | 2011 | 5.64     | 2017  | 2018   |             |
| phenomenology                  | 2011 | 3.22     | 2017  | 2019   |             |
| sydenham chorea                | 2011 | 3.14     | 2017  | 2018   |             |
| classification                 | 2011 | 3.14     | 2017  | 2018   |             |
| comorbidities a tac            | 2011 | 3.08     | 2017  | 2021   |             |
| united states                  | 2011 | 3.13     | 2018  | 2021   |             |
| metaanalysis                   | 2011 | 3.06     | 2018  | 2019   |             |
| aripiprazole                   | 2011 | 3.86     | 2019  | 2021   |             |
| hyperactivity disorder         | 2011 | 3.83     | 2019  | 2021   |             |
| risk                           | 2011 | 3.55     | 2019  | 2021   |             |

### Figure 9

Top 20 keywords with the strongest citation bursts.