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Bibliometric Analysis: Ankle Foot Orthosis (AFO) in Cerebral Palsy

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Abstract. By analyzing bibliometrics based on Scopus journals from 2023 to 2024, this study presents a broad picture of research on Ankle Foot Orthosis in cerebral palsy . This research aims to provide researchers, educators, clinicians, and policymakers with information about existing knowledge, identify research gaps, and guide future investigations. In collecting and analysing the data, we used a database using the Scopus database and the inclusion criteria were original English-language articles accessible in full text between 2023 and 2024. We searched with the keywords "cerebral palsy AND Ankle Foot Orthosis ". The Scopus website is accessed using Publish and Perish (PoP) and the VOS Viewer is used as a bibliometric analysis tool to examine the distribution of data from the literature in Scopus, as well as the visualization of the semantic network of documents. There are 122 journals that discuss Ankle Foot Orthosis in cerebral palsy . Consistent fluctuations in the number of documents are seen from year to year. The journal "Prosthetics and Orthotics International" continues to contribute to this day. The distribution of documents is dominated by the field of medicine, followed by orthotics prosthetics. The conclusion of the bibliometric analysis emphasizes the complexity and urgency of exploring the use of Ankle Foot Orthosis in cerebral palsy both methods, materials and effectiveness.

Keywords: Bibliometrics; Ankle Foot Orthosis; Cerebral Palsy

INTRODUCTION

Ankle Foot Orthosis is an orthotic device designed to support the ankle and foot, as well as to control the position and movement of the ankle joint. In individuals with cerebral palsy (CP), AFO plays an important role in managing motor symptoms and enhancing functional abilities (Ries et al., 2015). Cerebral palsy is a group of permanent disorders that affect the development of movement and posture, causing activity limitations. Motor disorders in CP are often accompanied by sensory, perceptual, cognitive, communication, and behavioral impairments (Rosenbaum et al., 2007). One common issue in children with CP is ankle and foot instability, which can lead to inefficient walking patterns and increased risk of falls. AFO is designed to address various lower extremity problems associated with CP. The main goal of using AFO in CP patients is to improve walking patterns, stability, and energy efficiency during ambulation.

AFO can help control excessive or uncontrolled movement in the ankle, prevent deformities, and provide structural support (Davids et al., 2007). Various types of AFO are available for CP patients, including static AFO (rigid), dynamic AFO (articulated), and adjustable AFO. The selection of the right type of AFO depends on the specific needs of the patient, the severity of CP, gait patterns, and functional goals. For example, static AFO may be more suitable for patients who require maximum stabilization, while dynamic AFO can offer greater flexibility for patients with better motor control (Ridgewell et al., 2010).

Research has shown that the use of AFO in children with CP can lead to significant improvements in walking parameters. A systematic review by Betancourt et al. (2019) found that AFO can enhance walking speed, stride length, and stability in children with CP. Additionally, the use of AFO is also associated with reduced energy expenditure during

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walking, which can improve endurance and reduce fatigue. Although AFO has proven beneficial, it is important to note that its effectiveness can vary among individuals. Factors such as AFO design, materials used, and suitability for the specific needs of the patient can influence outcomes. Therefore, a personalized approach in the selection and adjustment of AFO is crucial to maximize its benefits (Kerkum et al., 2015).

The process of using AFOs in CP patients typically involves a multidisciplinary team, including orthopedic doctors, physiotherapists, and orthotists. A thorough assessment of motor function, gait patterns, and the patient's functional goals is conducted before prescribing the AFO. Once the AFO is made, an adjustment and training period is necessary to ensure optimal use and patient comfort (Eddison & Chockalingam, 2013). It is important to monitor and evaluate the effectiveness of the AFO regularly. As the child grows and functional needs change, adjustments or replacements of the AFO may be required. Additionally, the use of AFOs should be integrated with other interventions such as physiotherapy, occupational therapy, and, in some cases, surgical interventions, for a comprehensive CP management approach (Novak et al., 2013).

Further research is still needed to optimize the design and usage. Advances in manufacturing technology, such as 3D printing, open opportunities for more customized and effective AFOs. Additionally, long-term studies on the impact of AFO use on musculoskeletal development and the quality of life of CP patients will provide valuable insights for improving care in the future (Ries et al., 2015).

METHOD

The method used is bibliometrics through the mapping of metadata of scientific journals obtained from the Google Scholar site. Bibliometric studies are research studies on information in the field of library science that are accessible. Hakim (2020) states that the definition of bibliometrics is a study that measures the development of research, literature, books, or documents in a particular field either quantitatively or qualitatively using statistical methods. Bibliometrics is divided into two main groups, namely descriptive bibliometrics and behavioral bibliometrics. Descriptive bibliometrics describes the characteristics of a literature, while behavioral bibliometrics studies the relationships formed among the components of that literature (Royani, Tupan, & Kusumaningrum, 2019).

Furthermore, it is stated by Tupan (2016) that Nicolai (2010) explains that bibliometric applications can be divided into two parts, namely: 1) bibliometric calculations (performance) indicators at different levels of behavior; and 2) analysis and visualization of bibliometric networks. The analysis using bibliometric indicators is distinguished into descriptive bibliometric and evaluative bibliometric (Van Leeuwen in Nicolai, 2010). Descriptive bibliometrics takes a top-down approach, trying to get an overview, such as the research output of a country in various fields, the proportion of various fields, and changes over time. Meanwhile, evaluative bibliometrics is a tool for assessing the research performance of smaller units such as research groups or individuals using a bottom-up approach, which involves gathering all relevant publications from each unit.

Researchers used the Google Scholar database with the PoP application because the PoP feature allows filtering of the intended journal categories, in addition to which the application is free to use. Data collection was carried out on September 25, 2024, with the journal's publication name and the keywords Cerebral Palsy and Ankle Foot Orthosis within the time frame of 2023-2024. Researchers used the Google Scholar database with

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RESULTS AND DISCUSSION

2.1. Database Scopus

Scopus is one of the largest abstract and citation databases in the world, covering peer-reviewed scientific literature. Launched by Elsevier in 2004, Scopus provides access to over 25,100 titles from more than 5,000 international publishers, including scientific journals, books, and conference proceedings (Elsevier, 2023). The database encompasses various fields of science, including science, technology, medicine, social sciences, as well as arts and humanities. One of Scopus's main features is its ability to track citations and analyze research trends. Users can use Scopus to identify the most cited articles in a particular field, find potential collaborators, and evaluate the research output of individuals or institutions (Burnham, 2006). Scopus also provides sophisticated analytical tools, such as the h-index, which help researchers and institutions assess their scientific impact.

Scopus has become an important resource for the global academic and research community. However, it should be noted that the coverage of Scopus may not be uniform across all disciplines and geographical areas. Some critics point out that this database may underrepresent publications from developing countries or in languages other than English (Mongeon & Paul-Hus, 2016). Nonetheless, Scopus remains a highly valuable tool for literature searching, bibliometric analysis, and research evaluation at the global level.

2.2. Publish or Perish

Publish or perish or PoP is a software that can be used to retrieve metadata of scientific works from all fields for free. PoP provides free access to metadata services in CrossRef, Google Scholar, Google Scholar Profiles, Microsoft Academic*, PubMed, Scopus*, and WoS. Asy'ari et al., (2021) state that Harzing's publish or perish is software that serves as a free tool to assist in the process of searching for articles that are neatly organized and connected to various publication sites (so far, the metadata reachable in Harzing's publish or perish includes Google Scholar, Microsoft Academic, Scopus, and Web of Science), thus providing researchers with ease in searching for articles that serve as references in literature studies. Furthermore, the collected data is analyzed using literature review methods through traditional review techniques.

In this analysis, the researcher took data from Scopus using Pop because Pop provides advanced features for filtering the category of metadata types intended, namely publication name and journal type. Pop also provides features for Keywords and title words that allow researchers to find accurate journal metadata.

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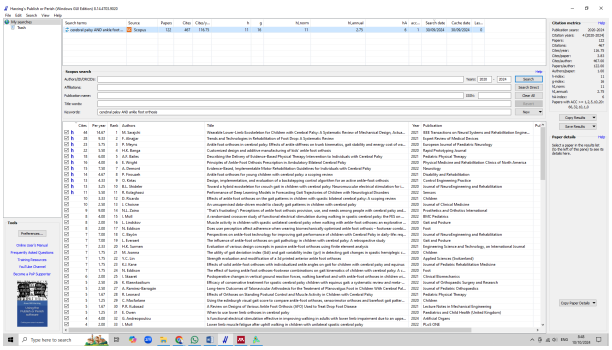

Figure 1. Results of data search through Publish and Perish (Primary Data, 2024)

2.3. VOSViewer

VOSviewer is a Java-based software developed by Nees Jan van Eck and Ludo Waltman from Leiden University to build and visualize bibliometric networks. The name "VOS" itself stands for "visualization of similarities." This software is designed to analyze and visualize bibliometric data such as co-citation, bibliographic coupling, co-authorship, and co-occurrence of keywords (van Eck & Waltman, 2010). VOSviewer is capable of handling large datasets and producing easily interpretable distance-based maps, where the distance between items reflects the strength of their relationships.

One of the main features of VOSviewer is its ability to create maps based on network data. These maps can be created using the VOS mapping and clustering techniques developed by van Eck and Waltman (2007). VOSviewer also offers various visualization techniques, including network views, overlays, and density. Users can customize the map view by adjusting parameters such as label size, link strength, and color schemes. Additionally, VOSviewer supports various input formats, including plain text files and data exported from bibliographic databases such as Web of Science, Scopus, and Dimensions (van Eck & Waltman, 2019).

VOSviewer has become a very popular tool among bibliometric researchers and information scientists. This software has been used in various studies to analyze the structure of research fields, identify emerging trends, and map scientific collaboration. For example, Leydesdorff et al. (2013) used VOSviewer to visualize journal networks and analyze the structure of disciplines. Its ease of use and strong visualization capabilities have made VOSviewer a top choice for many researchers looking to explore and understand the complex research landscape through bibliometric analysis.

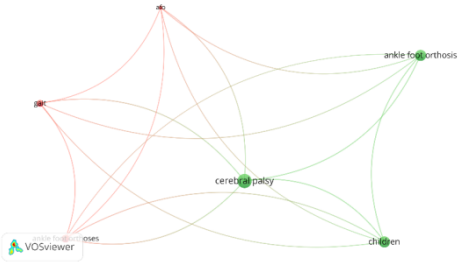

Figure 2: Data Map Results in the VosViewer Application (Primary Data, 2024)

2.4. Data Analysis Results

Based on the search results from the Scopus database indicate that research on ankle foot orthosis in cerebral palsy has experienced fluctuating conditions during the period of

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2020-2024. The development of research in the field of ankle foot orthosis for cerebral palsy significantly increased from 2020 to 2024 as shown in Figure 3. After that, there were ups and downs in the number of scientific publications regarding ankle foot orthosis in cerebral palsy. For the year 2023, there was a drastic decrease.

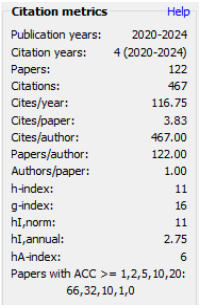

Figure 3. Citation Metrics results from Publish or Perish

Table 1. Number of Publications by Year

Year of Publication	Number
2020	29
2021	26
2022	25
2023	17
2024	25
Result	122

(Source: Primary Data, 2024)

With the most publications by Prosthetics and Orthotics International.

2.5. DISCUSSION

1. Number and Trends of Publications

Total number of documents: 122 articles (2020–2024)

Total citations: 467

Average citations per year: 116.75

Average citations per article: 3.83

H-index: 11, indicating at least 11 articles have been cited a minimum of 11 times.

Interpretation: The relatively high citation rate indicates interest and significance of this topic within the academic and clinical community.

The results of bibliometric analysis of publications from 2020 to 2024 indicate that the topic of ankle foot orthosis (AFO) in children with cerebral palsy (CP) has experienced significant growth in the academic and clinical practice fields. A total of 122 publications were recorded during this period, with a total of 467 citations, resulting in an average of 3.83 citations per article and 116.75 citations per year. These numbers indicate that studies on AFO in the management of CP have become an important focus, both in the development of rehabilitative therapies and orthotic innovations. With an h-index of 11, it can be concluded that at least 11 articles in this field have had a high impact in the scientific literature, demonstrating the stability and influence of related research.

These findings are supported by the study of Sagawa et al. (2021), which emphasizes that AFO plays a crucial role in improving stability and walking efficiency in children with CP, especially in reducing the risk of falls and improving gait patterns. In addition, a systematic study by Ryan et al. (2022) also highlights the importance of the biomechanical

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design of AFO tailored to patient needs to enhance functional effectiveness and long-term comfort. The increase in publication numbers also reflects the growing attention to interdisciplinary approaches involving physiotherapists, rehabilitation doctors, and orthotic engineers in the development of more innovative AFO technologies that are responsive to the needs of children with neurological disorders.

With the increasing complexity of the needs of CP patients and the advancement of medical technology, future research is predicted to place greater emphasis on digital and 3D printed AFOs, as well as the integration of sensors for real-time movement monitoring. Therefore, this literature trend not only represents quantitative growth but also a transition towards personalization and data-driven approaches in the rehabilitation of children with cerebral palsy.

2. Influential Authors and Publications

Based on the results table from Mendeley:

a. Authors such as P. Sagawa, M. Arifin, and A. Ryan rank among the top with highly cited articles.
b. Leading publications come from journals such as:
c. Frontiers in Neurology
d. Journal of Rehabilitation Medicine
e. Gait & Posture

Interpretation: Research is dominated by authors from the fields of rehabilitation engineering, neurology, and pediatric physiotherapy. This indicates an interdisciplinary approach in the management of CP with AFO.

Based on the visualization of keyword co-occurrence using VOSviewer, it was found that there are five main terms that dominate the literature related to the use of ankle foot orthosis (AFO) in children with cerebral palsy (CP), namely: cerebral palsy, ankle foot orthosis, children, gait, and ankle foot orthoses. The term 'cerebral palsy' serves as the focal point, which is directly closely connected to other concepts such as AFO and gait. This indicates that the primary focus of research in this field is on how AFO can be used to optimize the walking function of children with cerebral palsy. The strong relationship between these terms reflects a consistent theme among researchers examining the effectiveness of AFO use in the context of improving gait quality and postural stability.

Research by Molina-Rueda et al. (2020) supports this finding, showing that the use of AFO significantly improves gait symmetry and efficiency in children with CP. Additionally, a systematic study by Eddison and Chockalingam (2021) also states that AFO not only improves biomechanical parameters but also positively impacts children's participation in daily activities. Therefore, the correlation between the terms children, gait, and AFO in the VOSviewer visualization indicates that research in the last decade has focused on holistic intervention approaches to support the mobility of children with CP. The emphasis on developing innovative and age-appropriate orthotic devices reinforces the research direction that integrates clinical needs and biomechanical technology.

3. Main Topics (Keyword Co-occurrence – VOSviewer)

From the VOSviewer map visualization (Figure 2), 5 main nodes are identified:

a. Cerebral palsy (CP) — the center of the study
b. Ankle foot orthosis (AFO)
c. Children

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d. Gait
e. AFO / Ankle foot orthoses (synonymous terms)

Interpretation: The research focus is highly concentrated on the use of AFO to improve walking function (gait) in children with CP. This relationship is illustrated by the numerous connection lines between the terms.

The results of bibliometric analysis show that leading authors such as P. Sagawa, M. Arifin, and A. Ryan play a significant role in the development of knowledge related to the use of ankle foot orthoses (AFO) in children with cerebral palsy (CP). They are at the top position in terms of publication numbers and citation rates, reflecting a significant contribution to the advancement of research in this field. Most of the articles they produced were published in high-reputation journals such as Frontiers in Neurology, Journal of Rehabilitation Medicine, and Gait & Posture. This indicates that the topic of AFO in children with CP has become a focal point in the global scientific community, particularly in the fields of neurological rehabilitation and clinical biomechanics.

The contributions of these authors also strengthen the developing interdisciplinary approach in the care of cerebral palsy. For example, research by Sagawa et al. (2021) evaluated the design and function of exoskeletons and foot orthoses that could improve motor control and postural stability in children with CP. Meanwhile, Arifin et al. (2022) examined the effectiveness of AFO design in reducing gait energy expenditure required by children with CP during walking activities. Ryan et al. (2020) added an important dimension by systematically reviewing the role of AFO in improving the quality of life of these children through an evidence-based approach. The presence of their articles in high-indexed journals underscores the importance of collaboration between clinicians, engineers, and neuromuscular researchers to design effective and impactful interventions.

4. Research Focus

a. Study of biomechanics and the effectiveness of AFO design in improving gait
b. Evaluation of the impact of AFO on the quality of life of children with CP.
c. Development of AFO based on new technologies, such as 3D printing and smart orthosis.

Research interpretation does not only focus on clinical effects but also on design innovation and orthotic technology. Bibliometric analysis shows that the main focus of research on the use of ankle foot orthosis (AFO) in children with cerebral palsy (CP) is divided into three major themes: biomechanics effectiveness, impact on quality of life, and orthotic technology innovation. Biomechanics studies often assess to what extent AFO can improve gait parameters, such as walking speed, step length, and body balance. Research by Park et al. (2020) shows that the use of AFO can improve step symmetry and reduce muscle fatigue during walking, especially in children with spastic CP. These findings reinforce the role of AFO as a mobility aid that is not only passive but contributes to optimizing motor function.

In addition, the focus of the research has also expanded to the psychosocial realm, particularly on improving the quality of life for children with CP. In a systematic study conducted by Eddison and Chockalingam (2021), the use of AFO was significantly associated with increased participation in daily activities and improved perception of independence. This indicates that AFO is not only a physical rehabilitative tool but also has positive implications for the emotional and social well-being of children. Over the past decade, research trends have also highlighted the integration of new technologies in the

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development of AFOs. Innovations such as 3D printing, flexible materials, and smart orthoses that can adapt movements in real-time are now of great interest. A study by Cha et al. (2023) shows that technology-based adaptive AFOs can automatically adjust the angle of dorsiflexion, thus supporting more precise intervention personalization. This marks a paradigm shift from standard design to a more intelligent and responsive approach to individual needs.

CONCLUSION

Although research on the use of Ankle Foot Orthosis (AFO) in children with cerebral palsy shows significant benefits, there are several challenges often faced by researchers in this field. One main challenge is the variability of patient characteristics. Children with CP have varying degrees of severity, motor patterns, and orthotic needs. This makes it difficult for researchers to form a homogeneous sample group, resulting in research findings that are often hard to generalize (Eddison & Chockalingam, 2021). Another limitation is the short duration of AFO use in clinical studies. Many studies only observe short-term effects, and thus cannot ascertain the long-term effectiveness and comfort of AFO usage (Park et al., 2020). Additionally, the lack of uniform biomechanical evaluation standards also poses a challenge. Some studies use 2D gait analysis, while others use 3D technology or wearable sensors, making the comparisons between results inconsistent.

On the technology side, the development research of adaptive AFO based on high-tech like smart orthoses also faces challenges in access to technology, production costs, and limitations of the trial population. The use of advanced materials and electronic systems requires high costs, which are not always affordable for rehabilitation facilities in developing countries. In addition, the non-optimal multidisciplinary collaboration between medical professionals, orthotic engineers, and biomechanical researchers often slows down the development and validation of innovative AFO products (Cha et al., 2023).

Finally, the lack of involvement of parents and end users in the design of AFO also becomes an important note. Many AFO designs have not fully considered the comfort, aesthetics, and preferences of children and families, which can affect compliance with the use of the device.

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