

Leveraging digital health tools to improve early detection and management of developmental disorders in children

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Abstract

The early detection and management of developmental disorders in children are critical for mitigating long-term adverse effects and promoting optimal development. This paper explores the transformative potential of digital health tools in addressing the challenges associated with these disorders. We provide an overview of various developmental disorders, discussing their prevalence and impact on children, families, and society. The paper then examines the types of digital health tools available, including mobile applications, telemedicine, and wearable devices, highlighting recent technological innovations that enhance their efficacy. The benefits and limitations of these tools are evaluated to provide a balanced perspective. Furthermore, we explore strategies for effective management, emphasizing integrated care models that incorporate digital health tools, and the essential role of parental and caregiver involvement. Policy and ethical considerations, such as data privacy, equity of access, and the ethical use of artificial intelligence, are also discussed to ensure responsible deployment. The paper concludes with recommendations for healthcare providers, policymakers, and stakeholders on effectively leveraging digital health tools to improve early detection and management of developmental disorders in children. By addressing these factors, we aim to foster a more inclusive and responsive healthcare system that better supports the developmental needs of all children.

Keywords: Developmental Disorders; Early Detection; Digital Health Tools; Telemedicine; Integrated Care Models; Data Privacy

1 Introduction

Developmental disorders in children encompass a range of conditions that impair various aspects of development, including speech, motor skills, cognitive abilities, and social interactions. Disorders such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and speech and language disorders are prevalent and can significantly impact a child's life trajectory if not detected and managed early (Kamruzzaman, Islam, Siddique, Ahsan, & Azam, 2019). Early detection and management of these disorders are crucial because the earlier interventions are implemented, the better the outcomes for the child's development and overall quality of life. Early intervention can lead to improved cognitive and social skills, better academic performance, and enhanced adaptive behaviors, thereby reducing the long-term societal and economic burden (Sharma, Gonda, & Tarazi, 2018).

However, despite the known benefits of early detection, several barriers persist, including limited access to specialized healthcare, lack of awareness among parents and caregivers, and insufficient screening processes within routine

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pediatric care. These barriers can delay diagnosis and treatment, exacerbating the challenges faced by children with developmental disorders. As a result, there is a pressing need for innovative solutions that can overcome these barriers and facilitate timely and accurate detection and management (Lord et al., 2020).

The primary aim of this paper is to explore how digital health tools can be leveraged to improve the early detection and management of developmental disorders in children. Digital health tools, including mobile applications, telehealth services, wearable devices, and advanced data analytics, have shown promise in transforming healthcare delivery and enhancing patient outcomes. This paper seeks to examine the potential of these technologies to address the current challenges in diagnosing and managing developmental disorders.

Specifically, the paper will focus on several key objectives: First, to review the types of developmental disorders commonly found in children and the challenges associated with their early detection. Second, to analyze the various digital health tools available for early detection, highlighting their benefits and limitations. Third, to discuss strategies for integrating these tools into effective management plans, including the involvement of parents and caregivers. Finally, the paper will propose recommendations for healthcare providers, policymakers, and stakeholders on how to optimize the use of digital health tools to improve outcomes for children with developmental disorders.

The scope of this paper is to provide a comprehensive analysis of the role of digital health tools in the early detection and management of developmental disorders in children. The paper will begin with an overview of developmental disorders, discussing their prevalence, impact, and the challenges associated with their early detection. Following this, it will delve into the various digital health tools available for early detection, examining their technological capabilities, implementation strategies, and effectiveness.

The paper will also explore strategies for effective management using digital health tools, focusing on integrated care models that incorporate these technologies. This section will highlight the critical role of parental and caregiver involvement in utilizing digital health tools to support the child's development. Additionally, the paper will address policy and ethical considerations that need to be taken into account when deploying digital health tools in this context. The paper's final section will summarize the key findings and offer recommendations for practice, emphasizing the importance of a coordinated approach involving healthcare providers, parents, caregivers, and policymakers. It will also suggest future research and development directions, aimed at enhancing the capabilities and accessibility of digital health tools for early detection and management of developmental disorders.

2 Overview of Developmental Disorders in Children

2.1 Definition and Types

Developmental disorders are a group of psychiatric conditions originating in childhood that involve serious impairment in different areas. These disorders can affect language, learning, motor skills, and behavior, leading to challenges in a child's everyday functioning. Common developmental disorders include Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD), and speech and language disorders (Galiana-Simal et al., 2020).

ASD is characterized by persistent deficits in social communication and interaction across multiple contexts and restricted, repetitive patterns of behavior, interests, or activities. The spectrum nature of the disorder means symptoms and their severity can vary widely from person to person. ADHD is defined by a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. Speech and language disorders encompass a range of conditions, such as expressive language disorder, where a child has difficulty expressing themselves, and receptive language disorder, where understanding language is impaired (Hirota & King, 2023).

Each of these disorders can manifest differently. For example, ASD might present through challenges in social reciprocity, nonverbal communicative behaviors used for social interaction, and developing, maintaining, and understanding relationships. ADHD symptoms can include difficulties staying focused, hyperactivity, and impulsive behavior. Speech and language disorders might involve problems with articulation, fluency, voice, and the ability to understand and process language.

2.2 Prevalence and Impact

Developmental disorders are relatively common in childhood. According to the Centers for Disease Control and Prevention (CDC), approximately 1 in 44 children in the United States is diagnosed with ASD. ADHD affects about 9.4% of children aged 2-17 years, and speech and language disorders are present in about 7.7% of children aged 3-17 years.

These figures highlight the significant prevalence of these conditions and underscore the importance of addressing them effectively (Zablotsky et al., 2019). The impact of developmental disorders on children and their families can be profound and multifaceted. These disorders can lead to difficulties in academic achievement, social interactions, and daily functioning for children. They may struggle with building relationships, following instructions, and engaging in typical play activities. These challenges can contribute to feelings of frustration, isolation, and low self-esteem (Shaw, 2021).

Families of children with developmental disorders often experience considerable stress and burden. Parents may face challenges in managing their child's behaviors, accessing appropriate services, and balancing care with other responsibilities. The emotional and financial strain can be significant, affecting the overall well-being of the family unit. Moreover, society bears a considerable burden due to the increased need for educational support, healthcare services, and social interventions. Early and effective management of these disorders is crucial to mitigating these impacts and improving outcomes for affected children and their families (Hsiao, 2018).

2.3 Challenges in Early Detection

Despite the known benefits of early detection and intervention, several challenges hinder the timely identification and management of developmental disorders in children. One significant barrier is the variability in the presentation of symptoms. For instance, symptoms of ASD can be subtle in early childhood and may be mistaken for typical variations in development. Similarly, ADHD symptoms can sometimes be overlooked or attributed to normal childhood behavior, particularly in younger children (Iadarola, Pérez-Ramos, Smith, & Dozier, 2019).

Another challenge is the lack of standardized screening and assessment processes across healthcare settings. While there are established guidelines for developmental surveillance and screening, their implementation is often inconsistent. This inconsistency can result in delays in diagnosis, particularly for children from disadvantaged backgrounds who may have less access to regular healthcare services.

Additionally, there is a general lack of awareness and understanding of developmental disorders among parents and caregivers. This lack of awareness can delay seeking help, as early signs of developmental disorders may be missed or misinterpreted. Cultural factors and stigma associated with mental health and developmental conditions can further impede early detection and intervention.

Healthcare professionals also face challenges, including limited training in recognizing and managing developmental disorders. Pediatricians and general practitioners may have constrained time during consultations, limiting their ability to conduct thorough developmental assessments. Moreover, the availability of specialists such as developmental pediatricians, child psychologists, and speech and language therapists can be limited, resulting in long waiting times for diagnostic evaluations and intervention services (Bridgemohan et al., 2018).

The complexity of developmental disorders necessitates a comprehensive and multidisciplinary approach to assessment and management. However, coordinating care among various professionals and services can be challenging, particularly in systems with fragmented healthcare infrastructure. This fragmentation can lead to gaps in care and delays in initiating appropriate interventions (French, Sayal, & Daley, 2019).

Addressing these challenges requires concerted efforts to improve awareness, training, and resources for early detection and management of developmental disorders. Digital health tools present a promising avenue to enhance these efforts by providing accessible, scalable, and effective screening, assessment, and ongoing management solutions. By leveraging technology, it is possible to overcome some of the barriers to early detection and ensure that children with developmental disorders receive the support they need at the earliest possible stage.

3 Digital Health Tools for Early Detection

3.1 Types of Digital Health Tools

Digital health tools encompass a wide range of technologies designed to improve health outcomes, and their application in early detection of developmental disorders in children has shown significant promise. Key types of digital health tools include mobile applications, telemedicine, and wearable devices (Abernethy et al., 2022). Mobile applications are increasingly used for screening and monitoring developmental disorders. These apps often feature interactive questionnaires, games, and activities that can assess a child's cognitive, linguistic, and motor skills. For instance, apps designed for autism screening might include activities that evaluate social engagement and communication skills.

Parents and caregivers can use these apps to monitor their child's development and receive alerts when potential developmental issues are detected (Senbekov et al., 2020).

Telemedicine has also revolutionized the early detection landscape by providing healthcare professionals with remote access. Through video consultations, parents can discuss their concerns with specialists, who can observe the child's behavior and provide initial assessments without the need for in-person visits. This approach is particularly beneficial for families in rural or underserved areas with limited access to specialists. Telemedicine can also facilitate follow-up consultations and ongoing monitoring, ensuring continuity of care (Khan & Khan, 2023).

Wearable devices, such as smartwatches and fitness trackers, have advanced capabilities for monitoring physiological and behavioral parameters. These devices can collect data on a child's activity levels, sleep patterns, and even heart rate variability, which can be indicative of developmental issues. For example, irregular sleep patterns and low activity levels might signal underlying developmental concerns. Wearable devices can provide continuous monitoring, offering a comprehensive view of the child's behaviors over time and allowing for early detection of anomalies (Ahuja, Sarkar, Chandra, & Kumar, 2022).

3.2 Technological Innovations

Recent technological innovations have significantly enhanced the capabilities of digital health tools for early detection of developmental disorders. One notable advancement is the integration of artificial intelligence (AI) and machine learning algorithms into these tools. AI can analyze large datasets from mobile applications, telemedicine sessions, and wearable devices to accurately identify patterns and predict developmental disorders. For instance, machine learning algorithms can be trained to recognize subtle behavioral cues from video recordings that may be indicative of autism spectrum disorder (Sahu, Gupta, Ambasta, & Kumar, 2022).

Another innovation is the use of natural language processing (NLP) to assess a child's speech and language development. NLP algorithms can analyze audio recordings of a child's speech to detect atypical patterns and provide insights into potential speech and language disorders. This technology allows for objective and precise assessments that can be conducted in real-world environments, enhancing the accuracy of early detection (Kamath, Liu, & Whitaker, 2019).

Advancements in sensor technology have also improved the functionality of wearable devices. Modern sensors can capture a wide range of biometric data with high precision, allowing for detailed physiological and behavioral indicators monitoring. These sensors are becoming smaller and more comfortable, making them suitable for use in young children (Rashidi, Tran, Betts, Howell, & Green, 2019).

Additionally, augmented reality (AR) and virtual reality (VR) are being explored as tools for developmental assessment. These technologies can create immersive environments where children's interactions with virtual objects and characters can be observed and analyzed. AR and VR can provide engaging and controlled settings for assessing social, cognitive, and motor skills, offering a novel approach to early detection (Araiza-Alba, Keane, Beaudry, & Kaufman, 2020).

3.3 Benefits and Limitations

The use of digital health tools for early detection of developmental disorders offers numerous benefits. One of the most significant advantages is accessibility. Mobile applications, telemedicine, and wearable devices can be used in the home environment, reducing the need for frequent visits to healthcare facilities. This accessibility is particularly important for families in remote or underserved areas, where access to specialized care may be limited (Senbekov et al., 2020).

Digital health tools also enable continuous monitoring and data collection, providing a comprehensive view of a child's development over time. This continuous data can help identify patterns and trends that might be missed in periodic assessments, allowing for earlier intervention. Furthermore, these tools can empower parents and caregivers by providing them with valuable insights and resources to support their child's development (Cerchione, Centobelli, Riccio, Abbate, & Oropallo, 2023).

The integration of AI and machine learning enhances the accuracy and reliability of early detection. These technologies can analyze vast amounts of data quickly and accurately, identifying subtle indicators of developmental disorders that human observers might overlook. AI-driven tools can also provide personalized recommendations for intervention, tailored to the child's specific needs (Rasool, Husnain, Saeed, Gill, & Hussain, 2023).

Despite these benefits, there are several limitations to consider. One major challenge is the accuracy and reliability of digital health tools. While AI and machine learning algorithms have shown promise, they are not infallible and can produce false positives or negatives. Valuing these tools through rigorous clinical trials is crucial to ensure their effectiveness and accuracy.

Privacy and data security are also significant concerns. Digital health tools collect sensitive information about children's behaviors and health, and protecting this data from unauthorized access and breaches is essential. Ensuring robust data encryption and compliance with privacy regulations is critical to maintaining trust in these technologies (McGraw & Mandl, 2021). Additionally, there is the risk of over-reliance on digital tools at the expense of human judgment. While these tools can provide valuable insights, they should not replace professional assessments and interventions. It is essential to integrate digital health tools into a broader framework of care that includes healthcare professionals, ensuring a balanced approach to early detection and management.

4 Strategies for Effective Management Using Digital Health Tools

4.1 Integrated Care Models

Integrated care models represent a holistic approach to managing developmental disorders, combining traditional healthcare practices with innovative digital health tools. These models emphasize coordinated and continuous care, involving a team of healthcare professionals who collaborate to create and implement comprehensive care plans. The incorporation of digital health tools into these models can significantly enhance their effectiveness. One of the key components of integrated care models is the use of digital platforms that facilitate communication and information sharing among healthcare providers, parents, and caregivers. For instance, electronic health records (EHRs) that are accessible to all members of the care team ensure that everyone has up-to-date information about the child's developmental progress, treatments, and any changes in behavior or health status. This real-time access to information helps make timely and informed decisions, leading to better managing the child's condition.

Telemedicine is crucial in integrated care models by providing remote consultations and follow-ups. This is particularly beneficial for children with developmental disorders who may require frequent monitoring and adjustments in their care plans. Through telemedicine, specialists can conduct virtual assessments, guide parents, and collaborate with local healthcare providers, ensuring that the child receives continuous and coordinated care regardless of geographical barriers (Boppana, 2022).

Moreover, mobile applications designed to track developmental milestones and behaviors can be integrated into care plans. These apps allow parents and caregivers to log observations, complete screening questionnaires, and monitor their child's progress. The data collected can be shared with healthcare providers, enabling them to track trends and identify any emerging issues that may require intervention. This continuous monitoring helps identify changes that might otherwise be missed between regular clinic visits (DeWitt, Kientz, & Liljenquist, 2022).

4.2 Parental and Caregiver Involvement

Parents and caregivers play a vital role in effectively managing developmental disorders using digital health tools. Their involvement is essential for several reasons, including implementing care plans, monitoring progress, and providing emotional support to the child. Digital health tools empower parents and caregivers by providing them with the knowledge and resources they need to support their child's development. For example, educational apps and online platforms can offer tutorials, tips, and strategies for managing specific behaviors or developmental challenges. These resources can enhance parents' and caregivers' understanding of the disorder and equip them with practical skills to address everyday challenges.

Mobile applications and wearable devices enable parents and caregivers to actively participate in monitoring their child's development. By regularly inputting data and observations into these tools, they can provide healthcare providers with valuable information that can be used to tailor interventions and track progress. This active involvement fosters a sense of empowerment and confidence among parents and caregivers, as they become integral partners in their child's care (Zhai et al., 2023).

Moreover, digital health tools can facilitate peer support networks, connecting parents and caregivers with others who are experiencing similar challenges. These networks provide a platform for sharing experiences, advice, and emotional support, which can be invaluable for families managing developmental disorders. The sense of community and shared understanding can reduce feelings of isolation and stress, improving overall family well-being (Gruebner et al., 2022).

However, providing adequate training and support for parents and caregivers in using digital health tools is important. They need to understand how to use these tools effectively, interpret the data, and communicate their observations to healthcare providers. Ongoing support and education are crucial to ensure that they can fully utilize the potential of digital health tools in managing their child's condition (Tennant, Allana, Mercer, & Burns, 2022).

4.3 Policy and Ethical Considerations

The deployment of digital health tools for managing developmental disorders raises several policy and ethical considerations that must be addressed to ensure their effective and responsible use. These considerations include data privacy and security, equity of access, and the ethical implications of using advanced technologies in healthcare.

Data privacy and security are paramount when using digital health tools, particularly when they involve sensitive information about children's health and development. Robust measures must be in place to protect this data from unauthorized access and breaches. This includes using encryption, secure data storage solutions, and compliance with the Health Insurance Portability and Accountability Act (HIPAA) regulations in the United States. Ensuring data privacy and security builds trust among users and encourages the adoption of digital health tools.

Equity of access is another critical consideration. While digital health tools have the potential to enhance care, there is a risk that they could exacerbate existing disparities if not implemented thoughtfully. Children from low-income families or rural areas may have limited access to the necessary technology and internet connectivity. Policymakers and healthcare providers must work to ensure that these tools are accessible to all, regardless of socioeconomic status or geographic location. This could involve providing subsidies for technology, investing in broadband infrastructure, and developing low-cost or free digital health solutions (Richardson, Lawrence, Schoenthaler, & Mann, 2022).

The ethical implications of using advanced technologies such as artificial intelligence in digital health tools must also be considered. AI algorithms can provide powerful insights and predictions but can also perpetuate biases if not properly designed and validated. It is essential to ensure that these technologies are developed and used in a manner that is transparent, fair, and accountable. This includes involving diverse stakeholders in the development process, continuously monitoring the performance of AI tools, and being transparent about their capabilities and limitations.

Furthermore, informed consent is a key ethical consideration. Parents and caregivers must be fully informed about how digital health tools work, what data is collected, and how it will be used. They should be able to opt-in or out of using these tools and control their data. Clear communication and education about the benefits and risks associated with digital health tools are essential to ensure informed decision-making (Wies, Landers, & Ienca, 2021).

5 Conclusion

In this paper, we have explored the critical role of digital health tools in detecting and managing developmental disorders in children. We began by defining various developmental disorders, highlighting their prevalence and their profound impact on children, families, and society. Early detection of these disorders is paramount to mitigate long-term consequences, yet numerous challenges impede timely identification and intervention. Addressing these challenges through innovative digital solutions is crucial for improving outcomes and providing timely support to affected children and their families.

We then examined the landscape of digital health tools, including mobile applications, telemedicine, and wearable devices, revolutionizing how developmental disorders are detected and managed. Technological innovations such as artificial intelligence (AI), natural language processing (NLP), and advanced sensors have significantly enhanced these tools' capabilities, providing more accurate and timely assessments. These technologies offer new possibilities for early intervention by enabling continuous monitoring and real-time data analysis, which are essential for identifying developmental issues at the earliest stages.

Furthermore, we discussed integrated care models that incorporate digital health tools, emphasizing the importance of coordinated and continuous care involving a team of healthcare professionals. Parental and caregiver involvement was highlighted as essential for successfully utilizing these tools, with digital platforms empowering them through education and support networks. Finally, we addressed the critical policy and ethical considerations, such as data privacy, equity of access, and the ethical use of AI, that must be navigated to ensure the responsible deployment of digital health tools. These considerations are vital to fostering trust and ensuring that all families benefit from technological advancements.

To effectively leverage digital health tools in the early detection and management of developmental disorders, several key recommendations for healthcare providers, policymakers, and stakeholders are essential. Firstly, healthcare providers and technology developers must ensure that digital health tools are user-friendly and accessible to all families, regardless of socioeconomic status or geographic location. This includes designing intuitive interfaces for mobile and wearable applications and providing multilingual support to cater to diverse populations. Policymakers should support initiatives that reduce technology costs and improve internet connectivity in underserved areas, ensuring equitable access to these vital tools.

Secondly, healthcare providers should integrate digital health tools into routine pediatric care, using them as complementary resources alongside traditional assessment methods. This integration requires training healthcare professionals to use these tools and effectively interpret the data they generate. By embedding digital health tools within standard care practices, healthcare providers can enhance early detection and intervention efforts. Additionally, engaging parents and caregivers is crucial for the success of digital health tools. Healthcare providers should educate families on the importance of early detection and using digital tools effectively. Resources such as tutorials and support groups can empower parents and caregivers to monitor their child's development and collaborate with healthcare professionals. Regular feedback and communication channels between families and providers can further strengthen this partnership.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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