Towards Intelligent E-Health Educational Environment for Cerebral Palsy Children Rehabilitation.

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Abstract. We aim to find solutions to help children with cerebral palsy (CP) by providing different types of therapy and facilitating ways for rehabilitation. By the way, the importance of technology, as well as artificial intelligence and machine learning, towards providing an intelligent educational environment aimed to help patients by offering advanced learning methods for a personalized rehabilitation tailored to each patient's.

Keywords: Intelligent Educational Environment · Machine Learning · Personalized Rehabilitation · Cerebral Palsy · Therapy.

1 Introduction

Cerebral palsy (CP) can result from genetic or environmental factors acting alone. Nevertheless, it is important to note that single causal factors explain only a small proportion of cerebral palsy cases. The most likely explanation for most cases of cerebral palsy is a multifactorial model involving a combination of genetic and environmental influences. In this model, genetic and environmental determinants interact to contribute to the development of CP [22].

Physical rehabilitation seeks to enhance the physical function and independence of children with cerebral palsy, and to improve the quality of their lives as a result [11]. Rehabilitation has many effects on children with CP. Currently, hundreds of children with CP have been incorporated into schools. This integration provides opportunities for education and social development that might previously have been limited [29]. It also supports families by offering them the appropriate advice, and training to ensure effective care for their children.

Technological skills can improve the learning environment. Information and communication technologies are an important tool for enhancing the quality of health education by providing content through multiple modalities [25]. In this context, Artificial Intelligence (AI) is the core of intelligent systems. AI is applied widely in the fields of computing, healthcare, bioinformatics, etc., to facilitate analysis, reporting and decision-making. These AI applications have successfully revolutionized the domain of health and environmental informatics.

Various advanced applications involve different fields of healthcare, from e-health to personalized healthcare [1].

Our main object is to find a way to exploit the data's patients using machine learning techniques for an accurate result of cases. Further, our main issue is « **Can we propose an intelligent, personalized self-education environment for cerebral palsy patients** ? » To clarify our problem, we might focus on these points :

- What are the steps involved in creating an intelligent e-health environment, and what are the various machine learning techniques used in this context ?
- What's involved in designing an intelligent online tutoring system for cerebral palsy patients, using data analysis tools to adapt personalized self-education support ?
- How can machine learning be used to offer a range of personalized and alternative treatments, ultimately enhancing the efficiency of the healthcare system ?
- How can we develop a prediction model within our system that achieves high accuracy in personalized rehabilitation and delivering reliable results within our system ?

In this paper, we would like to initiate the potential of an intelligent tutoring system used for e-health educational environment and the various machine learning techniques involved in its development, emphasizing the revolutionary impact on the healthcare sector. For these reasons, we will focus on the importance of education and e-learning, and their importance in the field of e-health. Moreover, we look to help children with cerebral palsy to recover from their illnesses through exploiting the possibilities offered by education with artificial intelligence.

2 Literature review

Cerebral palsy (CP) is a group of neurodevelopmental disorders that affect movement and posture, usually involving the use of functional rehabilitation [21]. Recent research suggests that integrating educational environments and machine learning techniques has the potential to enhance treatment outcomes for children with cerebral palsy.

Many studies have recommended the reward of incorporating an educational setting into rehabilitation programs for cerebral palsy [15, 18]. Robust and inclusive educational environments provide opportunities for interactive learning, technique advancement, and social engagement, and certainly impact functional result [4]. Machine learning algorithms have been applied to develop accurate and objective functional assessment methods for children with CP. These tools enable real-time assessment of motor performance and progression, allowing the development of personalized rehabilitation schedules [10]. Techniques of ML, also, have been used to analyze gait, detecting specific patterns of walking in children with CP. This information can be used to design focused initiatives to enhance overall gait and mobility [6]. New technologies such as assistive wearable devices and augmented reality have shown promise in improving the learning environment for children with CP [23]. These technologies allow for interactive and attractive rehabilitation activities, promoting motivation and adherence. Machine learning models have been used to develop personalized rehabilitation programs based on the functional abilities of the patient, motor impairments and current progress [26]. These personalized approaches optimize rehabilitation results by adapting treatments to the needs of every child [13].

In this section, we will deal with the relation between artificial intelligence and education, then we will study some cases that use technologies in rehabilitation for children affected by cerebral palsy.

2.1 Artificial Intelligence technologies for digital health education

AI technology is advancing rapidly, and its application in education is set to grow rapidly in the future. **Ke Zhang et al.** [30] focus on the current state of Artificial Intelligence Education (AIEd) research, identifies AIEd technologies and applications, examines their proven and potential benefits for education, connects the gap between AI technology innovations and their educational applications, and generates practical examples and sources of inspiration for both technology experts creating AIEd technologies and educators leading AI innovations in learning. **Chih-Pu et al.** [5] proposed a systematic mapping review and thematic synthesis of literature on the educational applications of AI in simulation-based learning. Simulation-based learning environments, such as intelligent systems, virtual reality, or medical simulations, refer to "*interactive digital learning environments that imitate a real-life process or situation ... allow learners to test their hypotheses of the effects of input variables on the intended outcomes* [16]."

Currently, we present intelligent technologies such as: multi-agent, machine learning, ontology, semantic and knowledge grid, autonomic computing, cognitive informatics, and neural computing. These recent developments have already produced huge changes in education, presenting new opportunities and challenges for teaching and learning anytime, anywhere. These technologies are driving forward new methods and systems that aim to stimulate creative pedagogical approaches and, eventually, enhance learning achievement [20].

2.2 Technologies used Rehabilitation for Children with Cerebral Palsy

Technologies used in the rehabilitation of children with cerebral palsy have been a revolution in therapeutic treatment. These innovative techniques and tools aim to improve the motor skills, independence, and overall quality of life. Through the integration of advanced technologies, especially machine learning, rehabilitation programs can provide personalized interventions that optimize these children's potential for functional improvement. **Den Hartog et al.** [6] proposed to use Inertial Measurement Units (IMUs) in combination with machine learning techniques to monitor and assess the severity of movement disorders, specifically dystonia and choreoathetosis, in children and young adults with dyskinetic cerebral palsy (CP). IMUs are wearable sensors that can measure inertial motion quantities such as accelerations and angular velocities. The feasibility study described in the text involved using four IMUs coupled with a smartphone to collect IMU data and time-synchronized video recordings in a natural environment, such as the participants' homes. **Yanxin Zhang et al.** [32] proposed a solution that involves evaluating seven supervised machine learning algorithms commonly used for the classification of sagittal gait patterns in children with spastic diplegia due to cerebral palsy. The study aims to compare the performance of these algorithms and determine the most suitable one for gait classification for children who suffer from cerebral palsy with spastic diplegia. Moreover, the rehabilitation engineering approach for children with cerebral palsy emphasizes the application of assistive and restorative technologies to support independence and integration into society. Assistive technologies improve interaction with the environment, while restorative technologies seek to accelerate skill training and increase performance without the use of assistive devices. The use of these technologies benefits healthcare providers by enhancing the impact of rehabilitation treatments, providing cost-effective services, and improving patients' quality of life. In this case, **Andrew et al.,** [28] describes the development of a home-based, inexpensive rehabilitation system that includes user feedback and involves children in the design process, outlining the methods used and their impact on the global design .

2.3 Motor skills Assessment

This below table contains detailed information and explanations about the assessment of different motor skills. It summarizes selected research studies into the use of technology to enhance rehabilitation and treatment for children with cerebral palsy (CP).

Table 1. Different reserchers based on motor skills assessment

Researcher	Method	Technologies	Methodology	Results
Tresser et al., 2021 [27]	The use of virtual games and novel input sensors for rehabilitation.	Personalized virtual gaming-based rehabilitation system (iVG4Rehab)	Intelligent personalized system.	Personalized system has great potential for upper extremity therapy for children with CP and contributes to a more comprehensive of their usability, and kinematics.
Lins et al., 2019 [14]	The use of a game played with a robot assisted therapy (lego-mindstorm).	Lego Mindstorms EV3 Kit / MindWave	Personalized and educational system (Therapeutic Learning)	The robot is an effective and very promising complementary tool to assist in the rehabilitation treatment.

De Oliveira et al., 2020 [19]	The use of "REHAB FUN", an assistive technology in neurological motor disorders rehabilitation	Microsoft KinectT M / Web Platform (REHAB FUN)	Educational, personalized, and intelligent system.	It has recognized to be a motivating tool for patients, and the data collected enables doctor to personalize treatment plans to increase the effectiveness and efficiency of sports rehabilitation therapy.
Michel et al., 2016 [17]	The development of an innovative interactive virtual rehabilitation system.	Microsoft KinectT M / Virtual Reality (VR) System / Dynamic Difficulty Adjustment (DDA) capabilities	Educational, personalized, and intelligent system.	Good usability of the game and reveal a high ratio of acceptance and enjoyment from the children.
Bayon et al., 2016 [3]	The development of Robotic Platform for Gait Rehabilitation.	Robotic Trainer/ Inertial Measurement Units (IMUs)	Educational (support learning) , personalized (satisfy individual needs) , and intelligent rehabilitation (adjust and optimize therapy).	The pilot study proved the positive effects of using the CPWalker robotic platform for the rehabilitation of walking in children with cerebral palsy. The system enables patients to move freely, motivates them and incorporates physical and knowledge aspects in the therapy.
Zhang et al., 2021 [31]	The application of deep learning-based electronic computed tomography (CT) imaging information characteristics	Medical Imaging Modalities, Computer-Aided Diagnosis (CAD), Convolutional Neural Networks (CNN), 3D U-NET Model, Image Preprocessing	Intelligent rehabilitation	It can improve medical efficiency and accurately identify the patient's focus area, which had great application potential in helping to identify the rehabilitation training results of children with CP.
Ahmadi et al., 2018 [2]	Develop and test machine learning (ML) models for the automatic identification of physical activity (PA) type in ambulant children with CP.	Binary Decision Tree (BDT), Random Forest (RF), Support Vector Machine (SVM)	Intelligent and recommandation system	ML classification features trained on wrist, hip and joint-wrist accelerometers can efficiently identify physical activity patterns in ambulant children affected by (CP).

The studies employ personalized, educational, and intelligent systems to improve the effectiveness and efficiency of rehabilitation therapy. Technologies applied include virtual game-based rehabilitation systems, robotic platforms, assistive technologies, deep learning-based medical imaging and machine learning algorithms. Specifically, researchs have shown encouraging results in enhancing medical efficacy, personalizing treatment and improving the whole rehabilitation experience for children with cerebral palsy.

By building in exercises that promote optimal strength, mobility, balance and coordination, children with cerebral palsy can enhance their motor function and their ability to take part in daily activities. In addition, a sequence of activities promotes the brain's ability to reorganize itself and form new connections, known as neuroplasticity [12]. Through various regular exercises, children can further stimulate neural tracts and improve the brain's ability to adapt and learn new movements. This type of neuroplasticity plays a vital role in helping to promote improved function and the learning of motor skills in children with cerebral palsy. Furthermore, practising a wide range of physical exercises helps to avoid muscle disbalances and contractures, which are frequent problems in cerebral palsy. By focusing on particular muscle groups through a variety of exercises, children can achieve muscular balance, prevent contractures and reduce the risk of developing them [9]. Regular exercise also promotes joint flexibility and range of motion, which can improve overall.

3 Methods

We implemented a descriptive cross-sectional study conducted in the Physical and Rehabilitation Medicine (PRM) department at the University Hospital Center (CHU), over the period from June 2020 to June 2022.

3.1 Participants

A convenience sample of 42 participants with Cerebral Palsy was selected through appointments.
Participants were children and adolescents diagnosed with spastic or dyskinetic (CP), aged between 3 and 17 years old, in functional severity Gross Motor Function Classification System levels from I to V.
Patients transferred to another PRM department for follow-up and management, and patients with incomplete or unusable medical records, were excluded.

3.2 Study Design

The study design is a controlled trial. The main objective was to determine the therapeutic efficacy of the rehabilitation program by applying the training activities. If children dedicated to this program have participated, we will make a personalization sheet to check the effectiveness of the exercises practiced.

3.3 Statistical analysis

The study analyzed the symptoms of a group of patients with motor function disorders.

Table 2. Patient distribution characteristics

Clinical features	Number	Percentage
Genre		
Masculine	23	54,80%
Female	19	45,20%
Semiological form		
Spastic	38	90,50%
Dyskinetic	4	9,5%
Topographical form		
Hemiplegia	8	19%
Diplegia	11	26,20%
Triplegia	1	2,40%
Quadriplegia	22	52,40%

It underlines the dominance of spastic semiological and topographical forms of quadriplegia within patients suffering from CP. It is an important consideration for health professionals to consider these results when developing personalized treatment planning and support patients with diverse clinical features. The distribution of genders in the study revealed no meaningful difference between males 54,80%) and females (45,20%) in terms of the type of motor function disability. However, more detailed research and higher sizes could be required to examine potential gender related differences in motor function impairment.

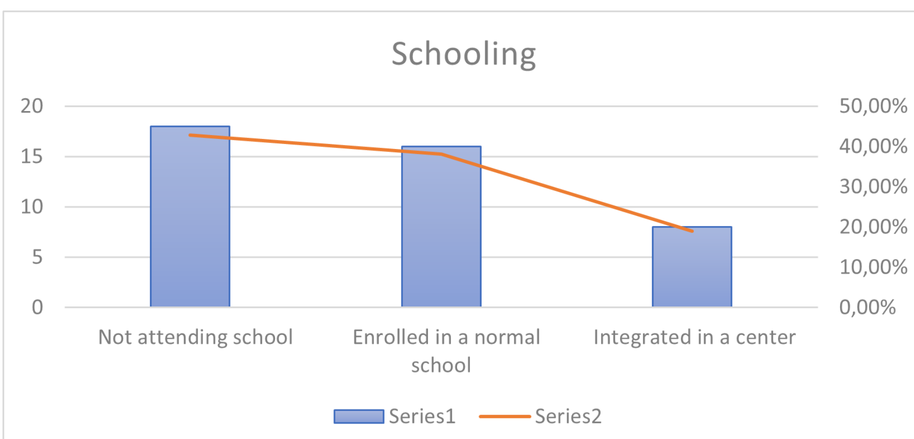

Fig. 1. The distribution of patients according to the level of education.

The figure 1 shows an overview of the education level of a group of individuals studied. Based on the information collected, the survey indicates a highly diverse educational environment for the patients. Whereas a considerable percentage of them attend ordinary schools, a significant number are not registered in any formal educational institutions at all. In addition, a more limited but important group benefit from specialized educational centers, perhaps tailored to their needs. The results underline the importance of education and providing accessible educational opportunities for all individuals. Enhancing access to education for out-of-school patients could lead to better social and personal development opportunities.

The following figure 2 shows the distribution of patients according to GMFCS.

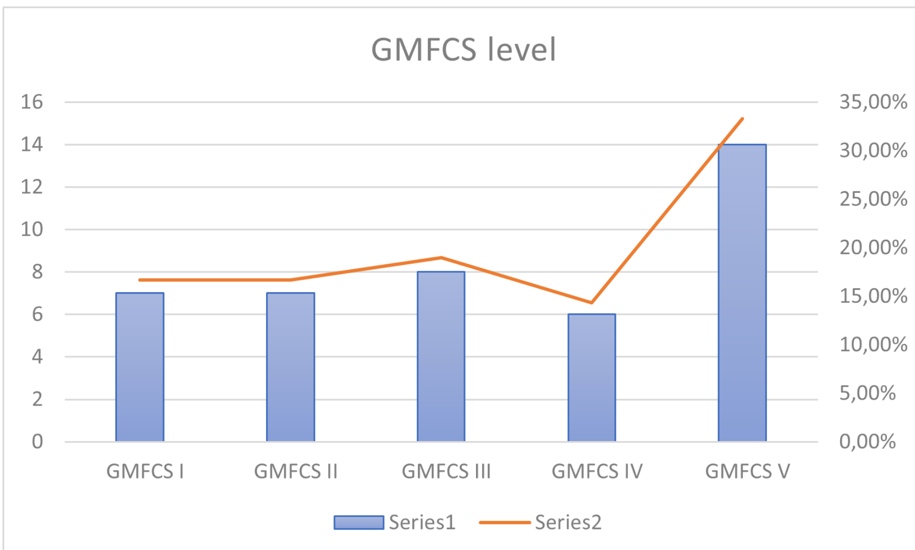

Fig. 2. The distribution of patients according to GMFCS.

The level of GMFCS V dominates with a percentage of 33.30%. It suggests that a proportion of patients in the study have serious mobility limitations and require assistance with motor activities. Next, GMFCS III follows with a percentage of 19.00%. Generally includes people with moderate motor function disabilities, which indicates that there are a number of patients with severe mobility limitations for GMFCS II and GMFCS I in the same stage with percentage 16.70%. It also suggests that there is an equally close distribution of patients with motor limitations (GMFCS II) and patients with minimal disabilities (GMFCS I). Finally GMFCS IV reaches 14.30 and reveals a marked presence of patients with serious impairments but with some ability to perform motor function activities.%.

3.4 Therapeutic treatment

11 patients did not attend physiotherapy sessions (26.20%). Physiotherapy was not accessible for 16.70% of patients. A problem of social support was reported by two patients (Table 3).
The data indicates the importance of improving the dissemination of information on available health services. Lack of access and information can have a significant effect on a patient's health results and quality of life.

Table 3. Distribution of non-physiotherapy patients based on cause (n=11)

	Number	Percentage[1]	Percentage[2]
No indication	2	18.20%	4.8%
No access	7	63.60%	16.7%
Problem of care	2	18,20%	4,8%

In the table 4 below, the results emphasize the critical role of nurses in the rehabilitation process. Lack of cooperation or information from doctors can have a significant impact on a patient's ability to self-educate.

Table 4. Distribution of patients who do not undergo self-rehabilitation, by cause (n=15)

	Number	Percentage[3]	Percentage[2]
Uncooperative caregiver	12	80.0%	28.6%
Uncooperative child	2	13.3%	4.8%
Uninformed caregiver	1	6.7%	2.4%

To overcome this problem, it is absolutely necessary to educate and support both therapists and patients. Doctors need to be aware of the importance of self-rehabilitation and trained in effective methods of helping and guiding patients through their rehabilitation journey. In addition, patients need to be educated about the benefits of self-rehabilitation and motivated to take an active part in their own health care.

3.5 Observations

In this survey, 42 children with cerebral palsy (CP), mainly boys, quadriplegia was the most common form (52.40%). **Dziri et al.** [7] reported a frequency of

[1]Percentage in relation to children who do not receive physiotherapy.
[2]Percentage in relation to the study population.
[3]Percentage of children who do not self-rehabilitate.

65.70% of quadriplegia among children consulting for CP in the PRM department of the Institut national d'orthopédie.
Some 42.90% were not enrolled in school, and 19% had access problems. The French National Authority for Health (HAS) considers solarization and social participation of children with CP to be a right. In the UK [24], the National Institute for Health and Care Excellence (NICE) recommends that children with CP be referred to specialized facilities that can provide both care and schooling for this population.
Some 26.20% did not receive physiotherapy, mainly because of access problems (16.70%). Average weekly physiotherapy sessions were 2.84 ± 0.35. Home self-education was practised in 64.30% of cases, with non-cooperation of primary caregivers being the main reason for discontinuation. **Ben Salah Frih et al.** [8] noted that 10.2% of children with CP consulting the Monastir PRM service were not doing physiotherapy.
Specific recommendations include specialized training and care facilities, early referral to physiotherapists and integration of self-education into daily activities.

CP is one of the most frequent causes of disability in childhood. The decision to manage this condition is a complex one. It depends not only on therapeutic objectives and treatment efficacy, but also on family preferences, the availability of a dedicated service, and health and social insurance policies.

3.6 Strengths and limitations of the study

We are aware of the fact that our study is the first to take stock of CP management in Tunisia, with the aim of highlighting discrepancies with international recommendations. This study could be the first step towards a continuous assessment tool that could be used in our departments to improve the quality of care provided to our patients.
However, our study has a number of limitations, mainly linked to the small sample size. Indeed, the problem of archiving outpatient records limited our data collection to inpatients. Our study remains mono-centric, and cannot describe the quality of care in other PRM departments in Tunisia. Further multicenter studies are needed to make recommendations and ensure optimal care for our patients.

4 Proposed architecture

The assessment involves evaluation of the educational framework existing in healthcare facilities, identifying its forces and faibles, and understanding the main issues and challenges faced by patients. It incorporates aspects such as availability, personalized learning, relevancy of content and engagement. To achieve this, we have proposed the following architecture, which will help eliminate the problems identified in the experimental study, by providing a framework for self-education presented in figure 3. The framework should include features such as adaptive and responsive learning elements, feedback mechanisms and personalized learning paths to support different learning skills and styles. In addition, it should consider the integration of multimedia resources, user-friendly interfaces, and secure data processing to enhance the educational experience while maintaining patient privacy and safety. Through a complete evaluation of the educational system, the proposed architecture can be designed to enhance learning outputs and improve the overall educational experience of patients in the online tutoring system.

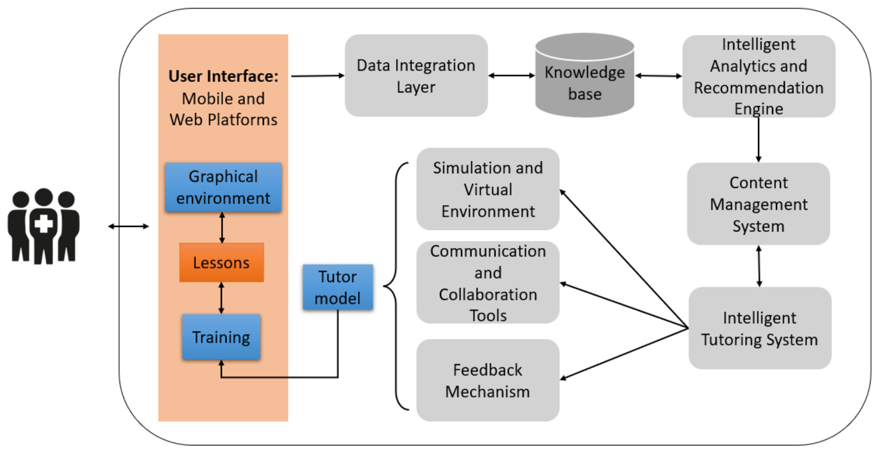

Fig. 3. Proposed architecture for e-health tutoring system.

It uses advanced technologies such as AI, ML, VR, and simulations to create personalized, responsive, and interactive educational experiences. The framework includes patient data from a diversity of sources, analyzes it using an intelligent analytics engine, and provides personalized recommendations. It also offers a content management system for generating and publishing educational content customized to individual needs. The intelligent tutor system offers personalized support and monitors patient progress. The simulation and virtual environment element provide patients with the ability to practice clinical skills, decision-making and patient interactions in a safe virtual scenario. Communication and collaboration features support interaction with healthcare specialists and trainers. A feedback mechanism assures ongoing monitoring of patient status and provides more timely feedback. The environment is accessible via mobile and web platforms, with flexibility and simplicity at hand. As a result, our system gives patients empowerment by offering personalized learning experiences, practical skills development, and support along their e-health education path.

5 Conclusion

The results of this study suggest that rehabilitation treatment is a promising program for children with CP, as it improves their quality of life. For these, we proposed to integrate AI technology into education, which could provide some solutions and offer potential benefits for the rehabilitation of children who affected cerebral palsy.

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This work is copyrighted under privacy policy constraints. We are in the process of developing this project for use and evaluated by children who suffer from cerebral palsy.

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