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Original Article

An Integrative Ayurvedic–Physiotherapy–IoT Model for the Management of Joubert Syndrome

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ABSTRACT

Joubert Syndrome (JS) is a rare genetic neurodevelopmental disorder characterized by cerebellar abnormalities, hypotonia, ataxia, developmental delay, and abnormal respiratory patterns. As no permanent cure is currently available, rehabilitation and supportive therapies play a crucial role in improving the functional abilities of affected children. This study proposes an integrative rehabilitation model that combines Ayurvedic therapy, physiotherapy, and Internet of Things (IoT) based monitoring for the management of Joubert Syndrome. The model integrates Ayurvedic neurotherapeutic interventions such as Abhyanga, Shirodhara, Nasya, and Medhya Rasayana with neurodevelopmental physiotherapy and sensory integration training. IoT-enabled wearable sensors and posture monitoring devices are used to track motor activity, posture stability, and breathing patterns in real time. The collected data can be analyzed through a cloud-based dashboard to support healthcare professionals in monitoring patient progress and adjusting rehabilitation strategies. The proposed hybrid framework aims to improve motor coordination, sensory processing, and overall quality of life of children with Joubert Syndrome.

Keywords: Joubert Syndrome(JS), Internet of Things(IOT), Smart Healthcare(SH)

INTRODUCTION

Joubert Syndrome (JS) is a rare genetic neurodevelopmental disorder that affects approximately 1 in 80,000–100,000 live births [6]. It is primarily associated with structural abnormalities in the cerebellum and brainstem and is commonly identified by the characteristic “molar tooth sign” on brain MRI [7]. The disorder occurs due to mutations affecting primary cilia, which play an important role in brain development and cellular signaling. As a result, children with Joubert Syndrome often experience hypotonia, ataxia, delayed motor milestones, abnormal eye movements, breathing irregularities, and varying levels of cognitive impairment [6]. Currently, there is no permanent cure available for Joubert Syndrome. Therefore, management mainly focuses on supportive and rehabilitative care. Physiotherapy plays a significant role in improving posture, balance, gait stability, muscle tone, and overall motor coordination in affected children [2]. Early and structured rehabilitation can help reduce functional limitations and support better daily living activities. In addition to modern rehabilitation practices, traditional systems such as Ayurveda describe neurological disorders under Vata-related conditions. Ayurvedic therapies, including Medhya Rasayana, are traditionally considered helpful in supporting cognitive function and maintaining nervous system balance [3,10]. Despite these available approaches, continuous monitoring and long-term tracking of rehabilitation progress remain challenging. Treatment outcomes often depend on regular assessment and timely adjustment of therapy plans. In this context, the use of Internet of Things (IoT) technology offers a practical solution. Wearable sensors and digital monitoring systems can record movement patterns, posture changes, and respiratory variations in real time [9]. Such technology allows better observation of patient progress and supports data-based decision making in rehabilitation. Therefore, this study proposes a structured hybrid model that integrates Ayurveda, physiotherapy, and IoT-based monitoring for comprehensive rehabilitation management of children with Joubert Syndrome. Figure 1 discusses the IOT system Architecture

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

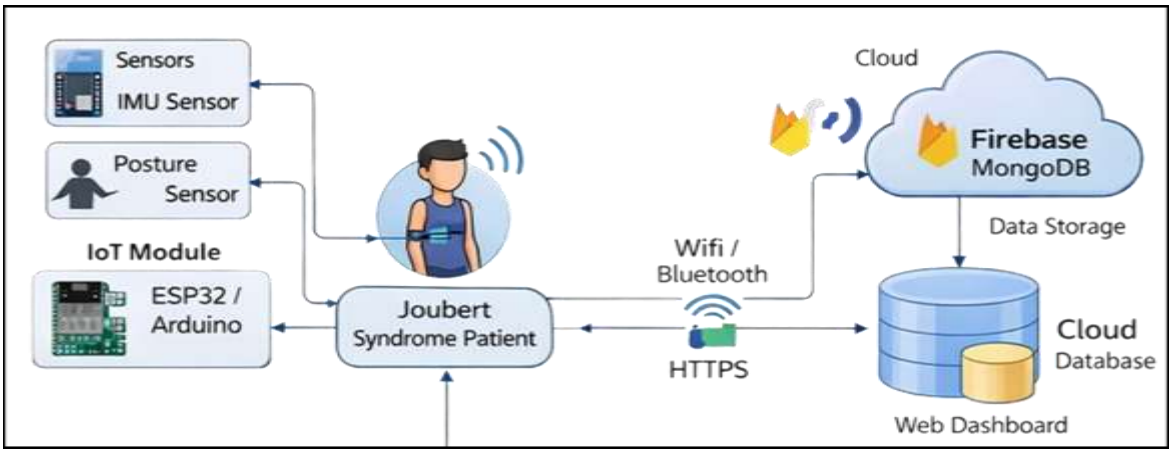

Figure 1: Iot System Architecture

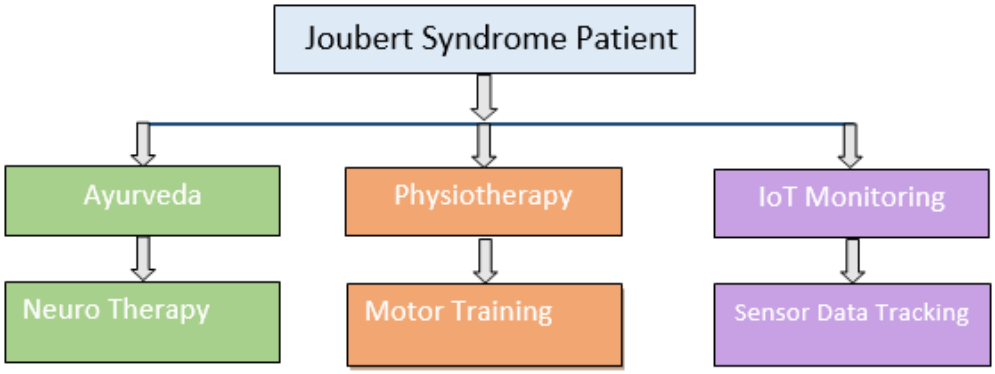

Figure 2: Conceptual Framework of Integrative Rehabilitation Model

Figure 2 discusses the Conceptual Framework of Integrative Rehabilitation Model

LITERATURE REVIEW

Joubert Syndrome is a rare genetic neurodevelopmental disorder caused by mutations that affect primary cilia and brain development, particularly in the cerebellum and brainstem [6,7]. The condition is often identified through the "molar tooth sign" on MRI. Because of these structural abnormalities, children commonly experience hypotonia, ataxia, delayed motor milestones, breathing irregularities, and cognitive delay [6]. Due to its long-term impact, continuous rehabilitation and supportive care are considered necessary. Physiotherapy is widely used to improve motor coordination, balance, posture, and muscle tone in children with cerebellar dysfunction [2]. Common rehabilitation methods include Neurodevelopmental Therapy (NDT), gait training, balance exercises, and sensory integration therapy. Occupational and speech therapy are also used to support daily functioning and communication skills. However, these approaches are generally applied as separate interventions. According to Ayurvedic principles, neurological disorders are associated with Vata imbalance [3,10]. Therapies such as Abhyanga, Shirodhara, Nasya, and Medhya Rasayana are traditionally recommended to support nervous system stability and cognitive function. These treatments are commonly practiced as supportive therapies alongside modern rehabilitation. Recent healthcare advancements have introduced IoT-based monitoring systems that use wearable sensors and digital platforms to track movement and physiological patterns in real time [9]. Similar technologies have shown positive outcomes in managing neuromotor disorders like cerebral palsy [8]. However, limited research has examined the integration of Ayurveda, physiotherapy, and IoT-based monitoring in a unified rehabilitation model for Joubert Syndrome.

3. Research Gap

Although physiotherapy and supportive rehabilitation strategies exist for Joubert Syndrome, limited research has explored the integration of traditional

Ayurvedic neurotherapeutics with modern IoT-based rehabilitation systems. Most current treatment approaches focus on isolated therapeutic methods rather than a unified hybrid framework. Therefore, there is a significant research gap in developing an integrative model that combines Ayurveda, Physiotherapy, and IoT-based continuous monitoring for comprehensive management of Joubert Syndrome.

3.1 Significance of the Study

This study is important because it attempts to combine traditional Ayurvedic therapy with modern physiotherapy and IoT technology in a single structured model. Such integration may help improve long-term rehabilitation planning for children with Joubert Syndrome.

4. Objective of the Study

The main objective of this study is to develop and analyze a hybrid model that integrates Ayurveda, physiotherapy, and IoT-based monitoring for the management of Joubert Syndrome. The model aims to improve motor coordination, posture, muscle tone, and gait of affected children. It also focuses on enhancing sensory integration, monitoring sleep and respiratory irregularities, and tracking rehabilitation progress through smart devices. Overall, the study intends to improve the quality of life of patients by providing a structured and personalized rehabilitation framework.

4.1 Hypothesis

H_0 (Null Hypothesis): The integrative Ayurvedic–Physiotherapy–IoT model does not produce significant improvement in motor and sensory functions in children with Joubert Syndrome.

H_1 (Alternative Hypothesis): The integrative Ayurvedic–Physiotherapy–IoT model produces significant improvement in motor and sensory functions in children with Joubert Syndrome.

METHODOLOGY

This study is planned as a conceptual framework to examine how a combined Ayurvedic, physiotherapy, and IoT-based rehabilitation approach may support children with Joubert Syndrome. For the proposed implementation, around 15 to 20 children in the age group of 1 to 10 years, diagnosed with Joubert Syndrome, would be included. The intervention is expected to continue for a period of 16 to 24 weeks. During this time, the children would undergo selected Ayurvedic therapies along with regular neurodevelopmental physiotherapy sessions. Wearable devices and simple posture monitoring sensors would be used to observe movement patterns, balance, sleep habits, and breathing irregularities. Before starting the intervention, an initial assessment would be carried out using standard evaluation tools such as GMFM, PDMS-2, and Sensory Profile 2. After completing the intervention period, the same assessments would be conducted again to understand the level of improvement. The results would be compared on the basis of pre- and post-intervention performance. Basic statistical methods, including percentage improvement and paired sample t-test, would be applied to interpret the findings. All collected information would be kept confidential and used strictly for academic and research purposes. This study follows a pre-test and post-test single group research design as shown in Fig 3.

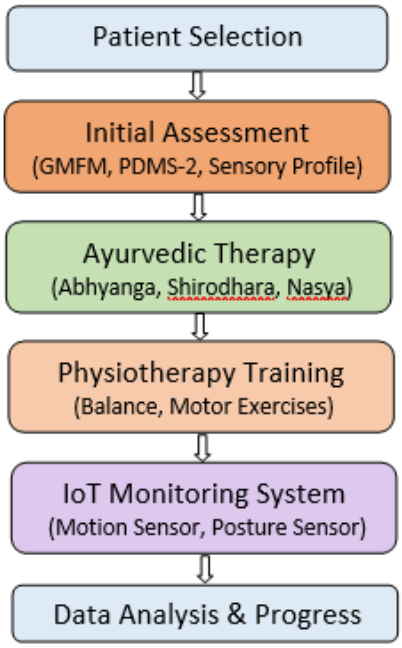

Figure 3: Flowchart of Hybrid Rehabilitation Process

5.1 Ethical Considerations

Any future clinical implementation of the proposed hybrid model would require prior approval from an institutional ethics committee. The study would follow established ethical guidelines to ensure the safety and well-being of participants. Informed consent would be obtained from parents or legal guardians before including children in the study. Participation would be voluntary, and they would have the right to withdraw at any time. All data collected through IoT-based monitoring systems would be securely stored and kept confidential. The information would be used only for research and rehabilitation purposes.

Formula 1 (Percentage Improvement)

$$\text{Improvement\%} = \frac{\text{PreTestPostTest} - \text{PreTest}}{\text{PreTest}} * 100$$

Percentage Improvement (%) = (Post Test Score – Pre-Test Score) / Pre Test Score × 100

6. Ayurvedic Component

The Ayurvedic component of the model includes therapies such as Abhyanga using medicated oils like Ksheerabala Taila and Dhanwantaram Taila to improve muscle tone and calm neurological imbalance. Shirodhara is administered to promote relaxation and better sleep patterns. Nasya therapy helps stimulate cranial nerve activity, while Medhya Rasayana herbs such as Brahmi and Ashwagandha support cognitive development.

6.1 Physiotherapy Component

The physiotherapy component includes neurodevelopmental treatment focusing on postural reactions, controlled mobility, and trunk strengthening. Sensory integration therapy provides vestibular stimulation, proprioceptive input, and visual–motor coordination exercises. Gait and balance training is performed using gait trainers, balance boards, and Swiss balls. Fine motor training includes grip strengthening and hand–eye coordination tasks. Respiratory physiotherapy involves diaphragmatic breathing and chest mobility exercises to improve breathing stability.

6.2 IoT-Based Smart Rehabilitation System

The IoT-based smart rehabilitation system includes wearable motion sensors that track limb movement, tremors, gait symmetry, and overall motor patterns using IMU technology consisting of accelerometers and gyroscopes. Smart posture sensors monitor trunk control and detect sway patterns associated with ataxic gait. Respiratory monitoring devices help identify apnea-like episodes and send alerts through a mobile application. A cloud-connected dashboard allows physiotherapists and Ayurvedic physicians to review progress and adjust treatment plans remotely. The collected data from wearable sensors is transmitted to a cloud database through wireless communication modules. A web-based dashboard developed using technologies such as PHP or Node.js can be used to visualize patient data, monitor rehabilitation progress, and generate analytical reports. This dashboard allows doctors and physiotherapists to remotely track patient performance and make necessary adjustments to therapy plans as shown in Table 1.

Table 1: Technology Stack for IoT Rehabilitation System

Component	Technology
Sensors	IMU Motion Sensor, Posture Sensor
Microcontroller	ESP32 / Arduino
Communication	WiFi / Bluetooth
Database	Firebase / MongoDB
Dashboard	Web Dashboard (PHP / Node.js)

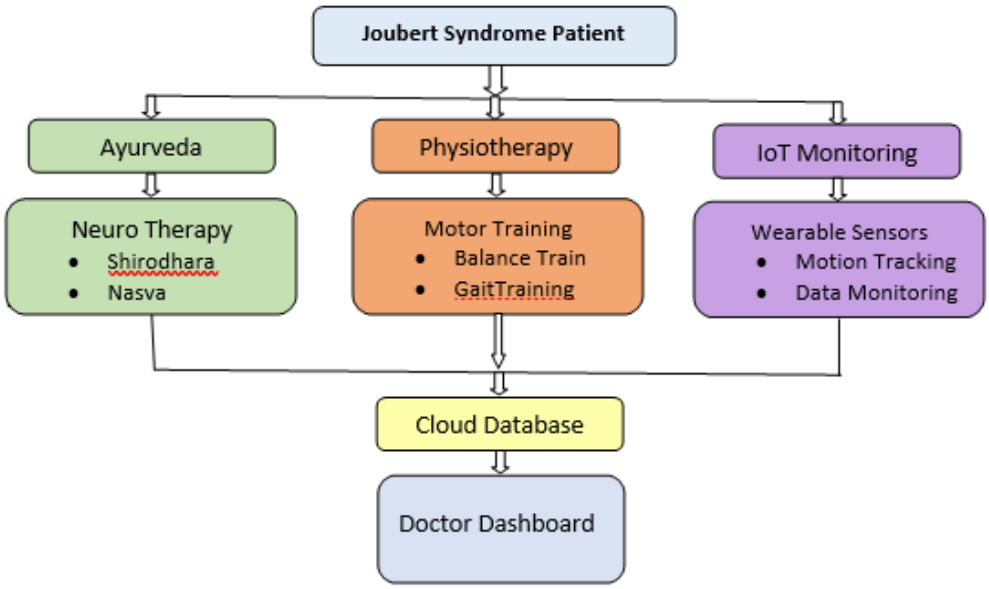

Figure 4: Hybrid Ayurvedic–Physiotherapy–IoT Rehabilitation Model

Figure 4 discusses the Hybrid Ayurvedic–Physiotherapy–IoT Rehabilitation Model.

7. Expected Results

The expected outcomes of the hybrid model include improvement in muscle tone, balance, and motor coordination. Children may show better milestone achievement and enhanced visual–motor integration. Sensory irregularities are expected to reduce over time. Stable breathing patterns and improved sleep quality are also anticipated. The IoT-based system may help in early detection of abnormal patterns and allow timely modification of therapy, thereby reducing caregiver burden as shown in Figure 5.

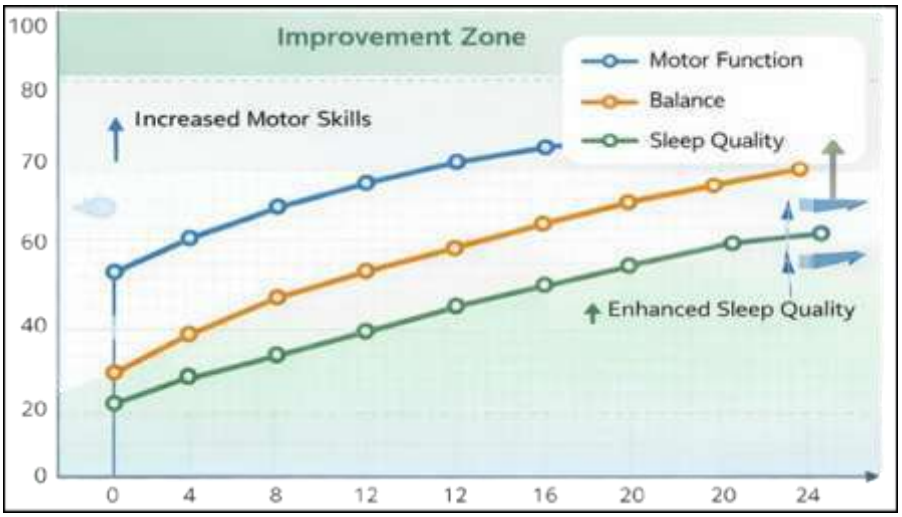

Figure 5: Rehabilitation Monitoring Graph of Hybrid Therapy Progress

Example:

The graph illustrates the gradual improvement in motor function, balance, and sleep quality during the 24-week hybrid rehabilitation therapy program as shown in Table 1.

Table 1: Comparative Rehabilitation Outcomes Before and After Hybrid Intervention

Parameter	Pre-Treatment	Post-Treatment	Improvement
Muscle Tone	Low	Moderate	Improved
Balance	Poor	Better	Improved
Motor Coordination	Delayed	Improved	Significant
Sleep Pattern	Irregular	Stable	Improved

DISCUSSION

The hybrid approach creates a synergistic effect, Together, they form a closed-loop rehabilitation ecosystem, enabling long-term improvement and better predictive outcomes for JS patients. The hybrid model combines Ayurveda, physiotherapy, and IoT technology into a unified rehabilitation framework. Ayurveda supports neurorestoration and regulation of muscle tone, physiotherapy enhances motor learning and sensory integration, and IoT enables continuous monitoring and remote supervision. Together, these components create a structured rehabilitation system that supports sustained functional improvement in children with Joubert Syndrome.

CONCLUSION

This study suggests a rehabilitation model that combines Ayurveda, physiotherapy, and IoT-based monitoring for managing Joubert Syndrome. As there is no permanent cure for this condition, supportive treatment and regular rehabilitation are important for improving daily functioning and overall development in affected children. In this model, Ayurvedic therapies are used to support muscle tone and cognitive balance, while physiotherapy focuses on improving posture, coordination, and movement control. IoT-based devices such as wearable sensors are included to monitor motor activity, posture, and breathing patterns. This may help doctors and therapists understand the child's progress more clearly and make changes in therapy when required. The model is theoretical at present and has not yet been tested in real clinical settings. However, it provides a clear direction for combining traditional and modern approaches in a structured way. With proper clinical studies and practical implementation, this approach may help in better rehabilitation planning for children with Joubert Syndrome. Further research is needed to test this model through clinical trials and long-term follow-up studies. This will help determine how useful and effective the model is in real clinical practice.

LIMITATIONS

This study is conceptual in nature and does not include real-time clinical testing. The proposed hybrid model has not yet been implemented on actual patients. Therefore, the effectiveness of the model is based on theoretical understanding rather than direct experimental results. Another limitation is that the study does not include a fixed sample size or a control group for comparison. Without randomized clinical trials, it is difficult to measure the exact impact of the intervention. Long-term follow-up studies would also be necessary to understand whether the improvements are sustainable over time. The use of IoT-based monitoring systems may face practical challenges such as device accuracy, data storage issues, internet dependency, and technical maintenance. Ensuring patient data privacy and security is also an important concern when using cloud-based systems. Financial constraints and lack of technical infrastructure may limit the practical implementation of this model, especially in rural or low-resource areas. Additionally, trained professionals who understand both Ayurvedic therapies and physiotherapy may not be easily available in all settings. Despite these limitations, the proposed model provides a useful foundation for future clinical research and structured rehabilitation planning.

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