An Integrated Digital Health Framework for Early Detection and Monitoring of Gynecomastia and Pseudo-Gynecomastia in Boys Post-COVID-19

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Abstract: Post-COVID-19 pediatric health surveillance has documented an increase in adolescent boys who develop gynecomastia and pseudo-gynecomastia. The conditions which usually show benign symptoms will cause psychological distress because they show signs of endocrine or metabolic disorders which resulted from COVID-19 infection or steroid use or changes in lifestyle or extended periods of inactivity. Current pediatric care systems do not provide hospitals with functional systems for monitoring patient conditions which would enable staff members to identify high-risk patients and provide them with necessary medical treatment. The use of digital health tools in post-COVID pediatric follow-up has not gained significant traction. The research presents a digital monitoring system which uses mobile health apps and wearable technology and artificial intelligence analytics to monitor risks associated with gynecomastia. The system helps clinicians and caregivers and public health officials to manage pediatric post-COVID care while decreasing the risk of long-term complications and psychosocial effects.

Keywords: Post-COVID Pediatrics; Gynecomastia; Pseudo-Gynecomastia; Digital Health; AI Monitoring; Child Health Surveillance

Introduction

The COVID-19 pandemic has caused deep and persistent effects on children's health which extend to multiple post-COVID conditions that develop after initial infection. The combination of lifestyle changes together with extended periods of inactivity and higher screen time and modified eating patterns and rising psychological stress and the common use of corticosteroids during medical treatment has created a negative impact on the growth and hormonal development of children and teenagers. The post-COVID period has shown a significant rise in diagnosed cases of gynecomastia and pseudo-gynecomastia among adolescent boys according to new clinical findings which reveal previously unknown pediatric health issues [1], [2].

Gynecomastia occurs when breast tissue becomes enlarged because of an estrogen-androgen hormonal imbalance while pseudo-gynecomastia develops when excessive body fat builds up in the chest area without any actual breast tissue development. Although most cases of pubertal gynecomastia resolve themselves after puberty, the post-COVID cases show an unusual pattern because they last longer and occur more frequently, which researchers believe relates to changes in metabolism and body weight and hormonal system disruptions and less physical exercise [3]. The conditions create physical health

problems for boys while also causing them social anxiety and psychological distress and lowering their self-worth.

Multiple research studies demonstrate that COVID-19 infection affects endocrine function through both its inflammatory pathways and its impact on lifestyle changes and treatment protocols [4]. The ongoing hormonal development process makes adolescents especially vulnerable to these types of disruptions. Although there has been a rise in anecdotal and clinical evidence, current practices for monitoring pediatric endocrine changes after COVID-19 remain insufficient because most cases are found during routine medical examinations at their later stages.

The current pediatric healthcare system needs continuous monitoring systems to track gynecomastia risk factors because no such systems currently exist. The existing healthcare system provides treatment which only responds to immediate patient needs and does not maintain continuous health monitoring outside of hospital visits. The existing gap between today's medical knowledge and established medical guidelines causes delays in diagnosis and restricts early lifestyle interventions while increasing the risk of unneeded medical procedures and surgical treatments [5].

Digital health technologies which include mobile health applications and wearable sensors and artificial intelligence-based analytics show effectiveness for chronic disease management yet they have low usage rates in pediatric post-COVID follow-up care. The absence of integrated digital systems which connect physiological and behavioral and clinical information hinders efforts to develop early detection methods for clinical decision-making. The study proposes an AI-enabled digital health framework to solve three main challenges which include increasing post-COVID gynecomastia cases in boys and lack of integrated monitoring systems for early intervention and insufficient use of digital tools in pediatric post-COVID care.

Related work

Existing literature on gynecomastia primarily studies its causes which occur during puberty and result from drug use while lacking sufficient research into post-viral and post-pandemic situations. Traditional studies identify obesity, hormonal imbalance, and endocrine disorders as primary contributors to gynecomastia and pseudo-gynecomastia in adolescents [6]. The studies took place before the COVID-19 pandemic started which resulted in changes to both lifestyle and physical health that they failed to consider.

Post-COVID pediatric studies investigate metabolic and hormonal disturbances which affect children who are recovering from SARS-CoV-2 infection. Research demonstrates that changes in insulin resistance and lipid metabolism along with stress hormone levels lead to abnormal fat deposition and endocrine disorders [7]. The studies fail to establish monitoring systems and predictive models which would identify specific conditions like gynecomastia.

Digital health interventions in pediatrics have been successfully applied in monitoring obesity, diabetes, and asthma through the use of mobile applications and wearable devices [8]. The systems provide three benefits because they lead to better adherence rates and they allow for early detection of health problems and they support increased patient participation. The use of these systems for monitoring pediatric endocrine health conditions after COVID-19 remains limited.

Healthcare systems today use artificial intelligence and machine learning technologies to conduct risk assessments and identify diseases at their initial stages of development. AI-based models have demonstrated their ability to identify minor changes in human body functions which remain hidden during standard medical examinations [9]. The research study has identified a gap because scientists have not

yet used artificial intelligence to analyze pediatric wearable data for tracking post-COVID endocrine outcomes.

The existing research base demonstrates a distinct gap because researchers have examined gynecomastia pathology and post-COVID metabolic changes and digital health tools as separate elements while there exists no research on integrated digital monitoring systems which assess post-COVID gynecomastia and pseudo-gynecomastia conditions in boys. The study intends to close this research gap.

Proposed Work and System Architecture

The research presents a complete digital health system which enables early detection and ongoing monitoring and emergency treatment of gynecomastia and pseudo-gynecomastia in boys who have recovered from COVID-19. The design uses a three-tier system which integrates data collection with smart analytical tools and medical decision-making assistance to form a fully operational system. The system functions as a scalable solution which children can use in both urban areas and healthcare facilities with limited resources according to Fig1.

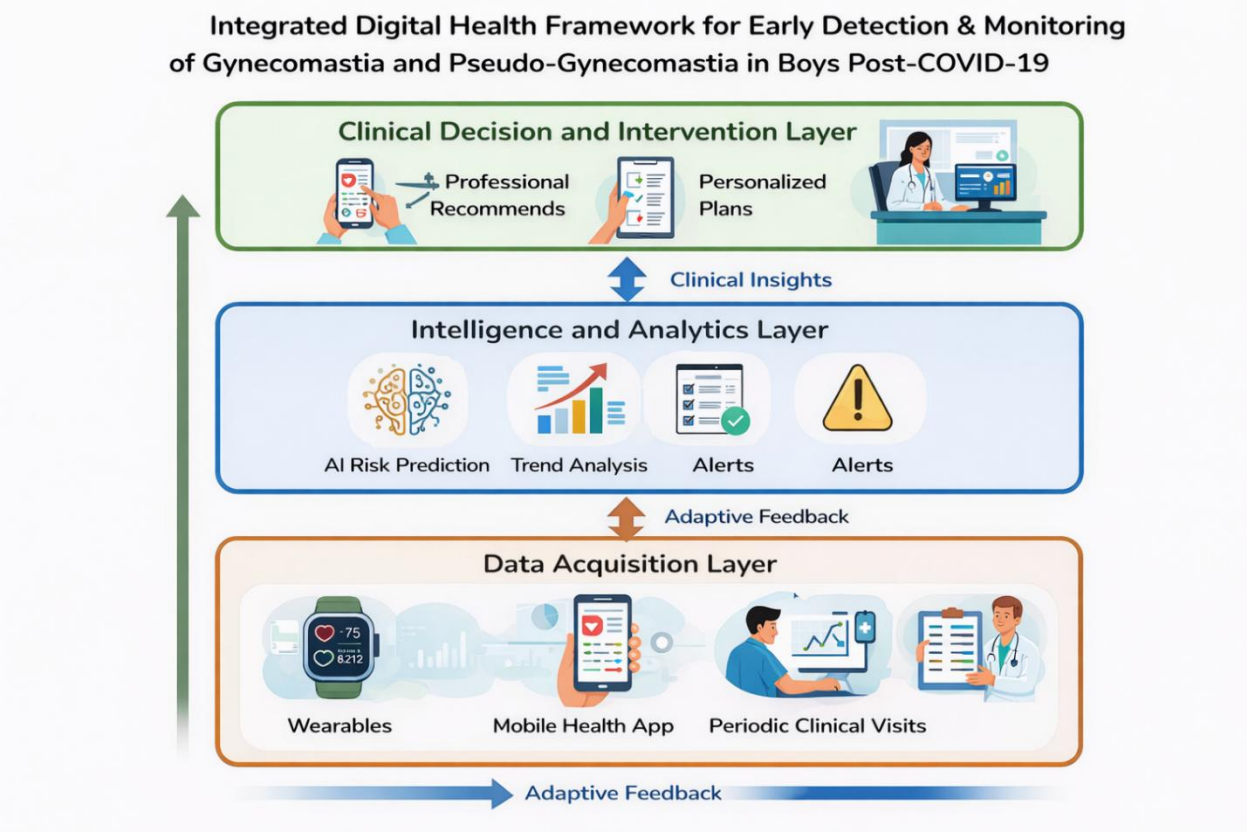

Figure 1. Proposed Framework

Data Acquisition Layer

The data acquisition layer functions to gather essential physiological data and behavioral data and clinical data through both continuous operations and scheduled data collection. Wearable sensors track physical

activity and sleep patterns and body mass index changes and sedentary behavior which serve as crucial markers for evaluating obesity and hormonal balance. A mobile health application enables caregivers to document their symptoms and dietary habits and complete their medication history which includes steroid use and their post-COVID recovery information. The system builds a comprehensive health profile for the child by using regular clinical data which consists of growth assessment results and basic hormonal testing information.

Intelligence and Analytics Layer

The intelligence layer operates its AI-based analytical system together with its machine learning models to process incoming data. The system conducts trend analysis to detect uncommon growth patterns and abnormal body fat development which occurs with changes in physical activity. The predictive models assess the transition risk from standard bodily functions to gynecomastia and pseudo-gynecomastia by evaluating lifestyle choices and post-COVID health indicators and clinical data. The system generates early warning signals when risk limits exceed actual value to support monitoring activities that occur before diagnostic tests start.

Clinical Decision and Intervention Layer

The clinical decision layer transforms analytical results into practical solutions which healthcare professionals can implement. The clinician dashboard displays visual summaries which show risk scores and track patient progress while providing alerts about individual patients. The system recommends early interventions through its risk assessment which identifies corresponding high-risk medical conditions that require lifestyle changes and dietary guidance and exercise programs and mental health assistance and pediatric endocrinologist consultations. The layer provides clinicians with essential medical treatment capabilities which enable them to treat urgent patient needs while they oversee all testing activities that require direct patient contact.

Methodology

The researchers employ design-based research methods to study healthcare systems together with their digital system development work. The researchers use a literature review and clinical consultation to identify post-COVID pediatric risk factors which affect gynecomastia development. The researchers develop and implement a digital monitoring system which functions with both simulated data and anonymized pediatric datasets. The machine learning models receive training to process longitudinal data while they develop capabilities to predict risk progression. The system evaluation process tests three different aspects which include detection accuracy and early alert response time and clinical usability to determine its real world usefulness and ability to expand.

Expected Outcomes

The system will enable early identification of boys who have a high risk of developing gynecomastia and pseudo-gynecomastia during the post-COVID period. The framework establishes continuous monitoring with AI risk prediction to decrease the occurrence of delayed diagnoses while stopping unnecessary medical and surgical procedures. The implementation of timely counseling together with lifestyle recommendations will enhance psychological health and overall life quality. The framework provides a digital model which can be expanded to support extended health monitoring of pediatric patients who have recovered from COVID-19.

Conclusions

The increasing cases of gynecomastia and pseudo-gynecomastia among boys after the COVID pandemic show a new pediatric health problem that needs urgent medical solutions. The existing pediatric healthcare system operates without constant patient observation while it depends on medical professionals to identify health problems at later stages. The research introduced a comprehensive digital health system which uses wearable technology and mobile health solutions together with AI analytical tools to provide early disease diagnosis and custom treatment solutions. The system architecture delivers useful information to medical professionals while it allows parents to monitor their children's health status throughout the day. The framework drives better pediatric post-COVID treatment by solving both technological and clinical problems. The future work will establish clinical validation through practical testing and national child health program integration.

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