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Jointly Organized By

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And

Indian Institute of Technology (IIT) Roorkee, India

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MEDITATION AND ITS UTILITIES IN OUR DAILY LIFE

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ABSTRACT

It is known to all that 'meditation' is an important part as the seventh step of eight-fold means of yoga. This step is just the previous step of Samadhi. Attainment of Samadhi is the highest goal to every yogi. But if we try to search its root, we must find that everybody follows it in their every fields of daily life consciously or unconsciously. We also know that it is too difficult to control our mind. Besides, it also is very true that nobody can complete any work in any field without controlling the mind. The great Indian sage Patanjali leads us to the way of eight-fold means of yoga. He defines the yoga as "Yogaschittavrittirnirodhah". Y.S.-1/2., That is to say, when a man can arrest his modifications of mind, he will be called a yogi. So, he is indicating here that our duty is to control the mind by the regular practice of meditation with respect. As a result, our mind will be calm, peaceful and enlighten. We shall try to see in this paper that has meditation or the power of concentration of mind helps us to do any work properly in our daily life by which we can achieve our goal?

GREAT CONTRIBUTON OF SUSRUTA SAMHITA IN MEDICAL SCIENCE

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ABSTRACT

Susrutasamhita is the part of Ayurveda Sastra. It is compiled by Susruta, and gave marvellous contribution to different types of surgery. For surgical purposes Susrutasamhita discussed about the surgical instruments, the description about the quality of instruments and the manufacturing methods too. Susrutasamhita altogether divided into two sections called Purvatantra and Uttaratantra. Purvatantra is also divided into five stanas.

We can see by the quality of the surgical instruments used in ancient India that, Indians were experts in metallurgy as in chemistry. The functions of surgical Instruments withdrawing a salya by moving it to and fro, injection or filling, binding, uplifting, stuffing the nose and cleansing. Many of these instruments had many similarities to the modem surgical instruments that are used in keyhole surgery at present. So, the contribution of this great Samhita in the light of this famous text will be highlighted in this paper.

CONVOLUTIONAL NEURAL NETWORK FRAMEWORK FOR IDENTIFYING SPATIAL BARRIERS TO HEALTHCARE IN LATEHAR DISTRICT, JHARKHAND, INDIA

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ABSTRACT

Tribes face difficulty accessing healthcare, as they live in remote and forested regions with rugged terrain, inadequate infrastructure and poor utilisation of healthcare services. This research applies Convolutional Neural Networks (CNNs) to detect and map these settlements within the Latehar district of Jharkhand, India. High-resolution satellite imagery is used to map terrain barriers, integrating it with health centre data obtained from the JSAC. CNN-based instance segmentation is applied to multispectral satellite data to program the identification of individual households. The model accurately captures the building footprints of each household, even in densely forested and hilly regions. Through Spatial Pattern Recognition, the CNN model optimises the extraction of topographic barriers, including dense forest cover and slopes, from Multispectral imagery and DEM. These outputs helped in generating a detailed terrain-corrected accessibility surface. The CNN model calculated the shortest distance and travel time for individual households to the health centre using the derived spatial layers and the OSM road network layer to identify critical gaps in healthcare service coverage within the district. Early studies have utilised the centroid of the villages to determine the mean distance and travel time, whereas this study, based on individual households, calculates the mean distance and travel time to the health centre of all the villages. The 2011 Census population data helped identify the tribal villages with high healthcare accessibility deficits. The results demonstrate that CNN-driven intelligence can enhance the detection of unrecorded tolas of tribal communities and understand the spatial constraints in accessing healthcare facilities. This approach provides a robust methodology for optimisation and allocation of targeted healthcare interventions and infrastructure improvements.

Keywords: Convolutional Neural Network Framework (CNN), Tribal Health, Tribal Healthcare Accessibility, Jharkhand, India

MATHEMATICAL STUDY OF PATHOPHYSIOLOGICAL PARAMETERS OF TYPE-2 DIABETES MELLITUS - A COMPARISON USING HYPOTHETICAL CLINICAL PARAMETERS

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ABSTRACT

The study concerns the computation of some pathophysiological parameters of Type-2 Diabetes Mellitus. Present model consists of coupled system of non-linear ordinary differential equations. An attempt is made to compare the computed pathophysiological parameter values with that of hypothetical clinical values which include the concentration of glucose, glycogen, glucagon and insulin in the blood plasma. Black and Red portions are introduced to define the protein, fat and carbohydrate inputs in a simple weighted diet for prescribing the calorie to type-2 diabetes mellitus cases. Comparisons of computed values are presented in the analysis.

Keywords: Diabetes Mellitus, Metabolism, Glucose, Insulin, Differential Equation.

AN INTEGRATIVE OBSERVATIONAL STUDY ON THE PHYSIOLOGICAL EFFECTS OF UDGEETH PRANAYAMA, YOGA NIDRA, AND SATTVIK AAHARA IN MENSTRUAL DISORDERS

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ABSTRACT

Background

In today's fast-moving world, women's daily routines have changed as well, which leads to a variety of menstrual illnesses including irregular periods, dysmenorrhea, and menorrhagia, severely impact the physical health of women. These illnesses are generally caused by sedentary lifestyle and nutritional inadequacies. Traditional yoga practices like om chanting, Yoga Nidra (guided meditation practice) and dietary changes (excluded junk food etc) have been proposed as comprehensive approaches to addressing these multiple difficulties. The combination of yoga Nidra (guided meditation practice), Sattvik aahara (a balanced diet), and Udgeeth pranayama (Om-chanting breathing method) are effective to reduce on physiological indicators (BMI & WHR) in women with menstrual problems.

Objectives

The primary objective of this research was to evaluate the efficacy of an integrated yogic and dietary intervention on physiological variables (BMI & WHR) in women with menstrual disorders. The specific aims were: Physiological Parameters - Assess changes in Body Mass Index (BMI), evaluate alterations in Waist-Hip Ratio (WHR).

Methodology

A randomized controlled trial was conducted out with two groups: an experimental group that received the integrated intervention and a control group who continued to live their normal lives. The intervention ran 8-weeks and included, Udgeeth pranayama is a 10-minute daily practice that focuses on chanting "Om" to create peace of mind. Yoga Nidra is a 40-minute guided meditation practice designed to induce deep relaxation. Sattvik Aahara is a diet that emphasizes fresh fruits, vegetables, and whole grains while avoiding processed foods, stimulants, and non-vegetarian goods. All participants completed pre- and post-intervention examinations, which measured the relevant physiological characteristic.

Results

Body Mass Index (BMI)- experimental group demonstrated a statistically significant reduction in BMI ($p = 0.018$), indicating improved metabolic health. control group also showed a significant change ($p =$

0.000), though the nature of this change requires further investigation to determine its clinical relevance. Waist-Hip Ratio (WHR)- experimental group, experienced a significant decrease in WHR ($p = 0.007$), suggesting a reduction in central adiposity. Control group, showed a significant change ($p = 0.000$) however, the implications of this change warrant additional analysis.

Conclusion

The study provides evidence supporting the efficacy of a holistic approach combining Udgeetha Pranayam, Yoga Nidra, and Sattvika Ahara in improving physiological aspects of health in women experiencing menstrual disorders. The intervention resulted in considerable increases in metabolic indices demonstrating its promise as a non-pharmacological technique for menstrual health management.

Keywords: Menstrual Disorders, Yoga Nidra, Deep relaxation technique, Sattvic diet, BMI, WHR

OPTIMIZING RESOURCES AND COSTS IN HEALTHCARE RETRIAL QUEUES WITH TRIADIC SERVICE CONTROL AND PATIENT IMPATIENCE

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ABSTRACT

Queue management is a critical component of healthcare operations, as inadequate control often leads to patient balking, refusing to join the queue or reneging, leaving before receiving service when waiting times become excessive. This paper presents a queueing model governed by a triadic control policy that regulates the service process by dynamically adjusting the number of active servers in response to system congestion. The model incorporates retrial behavior for urgent medical care patients, while non urgent patients may either balk or renege. Steady-state probabilities are derived using a matrix-analytic method, enabling the evaluation of key performance measures. Numerical experiments illustrate the effects of balking, reneging, and service rates on indicators such as the average number of patients in the system, the average number in orbit, waiting times, throughput, and the probability of patient rejection. To support operational decision-making, a cost function is formulated and optimized using Particle Swarm Optimization (PSO) to identify efficient resource-allocation strategies. The proposed model offers valuable insights for healthcare centers confronting patient impatience and capacity constraints. The findings provide practical guidance for improving system performance and supporting more effective allocation of limited healthcare resources.

IMPACT OF INTEGRATED YOGA MODULE ON SARCOPENIA: STUDY PROTOCOL FOR RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Sarcopenia is a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death. The prevalence ranges from 5% to 13% in people 60–70 years old and from 11% to 50% in people older than 80 years.

Method: This is a randomized controlled trial that will be conducted on 100 participants with sarcopenia aged 60 years and above randomly assigned to either the yoga group or wait-listed control group. The intervention will be in the form of group classes for 6 sessions per week for 90 days. For wait-listed control group intervention will be given for 30 days after the post-test secured as a control for 90 days. The outcomes include appendicular skeletal muscle mass using a Bioelectrical impedance (BIA) tool, Hand-grip strength by Camry dynamo-meter, leg strength by Manual Muscle Test- Quadriceps with knee extension, physical performance by Senior fitness test, Gait by Dynamic Gait Index (DGI) Quality of Life by SAR-QoL.

Discussion: The study outcomes will provide confirmatory evidence on the effects of integrated yoga module in managing sarcopenia as well as mental health in sarcopenic patients.

Ethics and dissemination: The study is approved by the Institutional Ethics Committee of University of Patanjali, Haridwar (ID: UoP/IEC/2025/08). Written informed consent will be obtained from each participant prior to inclusion. Results will be available through research articles and conferences.

Trial registration number: CTRI/2025/07/090429.

Keywords: Sarcopenia, Yoga, Ageing, Integrated Yoga Module

THE ROLE OF EMPLOYEE SILENCE IN SHAPING WORK CULTURE AND ITS EFFECT ON THE WELL-BEING OF WOMEN IN HEALTHCARE SECTOR

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ABSTRACT

This study investigates how employee silence influences workplace culture and ultimately affects the overall wellbeing of employees in healthcare settings. Using partial least squares structural equation modelling (PLS-SEM), the measurement model demonstrated strong reliability and validity, with Cronbach's alpha and composite reliability exceeding 0.7 and average variance extracted (AVE) values above 0.5, confirming convergent validity. Although the heterotrait–monotrait (HTMT) ratios between employee wellbeing and both employee silence (0.945) and workplace culture (0.943) were high, they remained within the acceptable threshold of 0.95, indicating that discriminant validity was not violated while reflecting the close practical connection of these constructs in healthcare environments. Structural model analysis revealed that employee silence significantly impacts both workplace culture ($\beta = 0.690$, $t = 29.5$, $p < 0.005$) and employee wellbeing ($\beta = 0.722$, $t = 30.247$, $p < 0.005$), while workplace culture itself positively affects employee wellbeing ($\beta = 0.503$, $t = 10.311$, $p < 0.005$). Mediation analysis confirmed that workplace culture partially mediates the relationship between employee silence and employee wellbeing ($\beta = 0.347$, $t = 9.489$, $p < 0.05$). The model's robustness is supported by R^2 values of 0.654 for employee wellbeing and 0.477 for workplace culture, along with moderate to large f^2 effect sizes.

The findings underscore that when employees remain unheard, workplace culture deteriorates and their overall wellbeing declines. For healthcare organizations, this highlights the need to integrate HR strategies that foster psychological safety, transparent communication, and participative decision-making. By actively reducing employee silence and strengthening workplace culture, healthcare institutions can safeguard staff wellbeing, improve job satisfaction, and enhance the quality of patient care. While the study provides sector-specific insights, its results are limited to healthcare settings; future research should examine these relationships across other service sectors to validate and extend the model.

EFFECT OF YOGA MODULE ON QUALITY OF SLEEP, ATTENTION & MOBILE PHONE ADDICTION IN SCHOOL STUDENTS

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ABSTRACT

Background: For students aged 11 to 16 years, the estimated daily exposure to smartphones is approximately 1.5 hours, indicating an increasing trend in the amount of time spent in front of screens. Increasing use of screen time is associated with reduced sleep quality, symptoms of mental health, impair cognitive, emotional and attention disorders, decrease academic performance, poor quality of life and smartphone addictions.

Aim: The aim of this study is to assess the effect of yoga module on sleep quality, attention and mobile phone addiction of school students who are frequent phone users.

Methodology: The present study is a parallel-group, randomized controlled trial (RCT). A total of 120 students were randomized into a yoga group (YG) (n=60) and control group (CG) (n=60) using an online randomizer. The YG received yoga practice, while the partially students of CG did daily routine. Students were assessed for screen time use, smartphone addiction (mobile phone dependence) (MPA), general health, sleep quality, symptoms of sleep and generalized attention deficit.

Results: The yoga group showed a significant reduction in the scores of generalized attention and sleep disturbance symptoms and excessive smartphone (screen time) use after the intervention ($p<0.005$, $p<0.000$ and $p<0.000$, respectively). Moreover, there was a statistically significant reduction in smartphone use for all modes of total weekdays and weekends. Additionally, in the yoga group, most of the sub-factors of smartphone use showed statistically significant changes; time spent on phone showed a consistent reduction across all modes such as weekdays and weekends. The control group showed a significant increase in the scores of poor attention and sleep disturbance symptoms and excessive smartphone (screen time) with daily activity ($p<0.005$, $p<0.000$ and $p<0.005$, respectively).

Conclusion: The results of the present study suggest that yoga practice has a positive impact on excessive smartphone use behaviour and sleep and attention deficit complications. More studies are needed to understand whether yoga practice can help reduce pleasure-seeking behaviour that leads to excessive smartphone use.

Keywords: Mobile Phone Addiction, Quality of Sleep, Attention, School Students, Yoga

EFFECT OF A YOGA-BASED INTERVENTION ON PROPRIOCEPTION AND BALANCE IN ELDERLY INDIVIDUALS: A REVIEW

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ABSTRACT

This review aimed to evaluate the effect of yoga-based interventions on Proprioception and balance related outcomes among elderly individuals. Databases including PubMed/MEDMEDLINE, Cochrane Library, Science Direct, and Google Scholar were searched from 2015 to 2025. Randomized controlled trials (RCTs), quasi-experimental studies, pilot studies, and case reports involving yoga practices and outcomes related to proprioceptive function, postural stability, or fall risk in older adults were included. PRISMA guidelines were followed for screening and extraction of eligible articles. Primary outcomes assessed were joint position sense, static and dynamic balance scores, and postural sway measures. Secondary outcomes included flexibility, gait stability, muscle strength, and fear of falling indices. A total of 12 studies involving approximately 720 participants met the inclusion criteria, with an average sample size of about 60 participants per study. Intervention duration ranged from 4-week programs to 16-week protocols, with frequencies varying from 2 to 7 sessions per week. The findings indicate that yoga improves proprioceptive awareness, enhances balance performance, reduces postural instability, and lowers fall risk among older adults. Positive outcomes were observed across both shorter and longer intervention durations.

This review suggests that yoga is a safe, accessible, and cost-effective complementary approach for managing age-related motor and sensory decline in geriatric populations. However, further high-quality, large-scale RCTs are required to establish standardized clinical recommendations.

Keywords: Yoga, Proprioception, Balance, Elderly, Fall Risk, Geriatric Mobility.

EFFECT OF YOGIC SUKSHMA VYAYAMA ON UPPER & LOWER LIMBS STRENGTH, POSTURAL STABILITY AND SPINAL FLEXIBILITY AMONG ADOLESCENTS

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ABSTRACT

Background: Yogic Sukshma Vyayama (YSV) is a traditional, subtle yogic practice that involves gentle, sequential head-to-toe movements to enhance spinal flexibility, joint mobility, muscular strength, and postural balance. Adolescence is a critical stage for developing these physical attributes, yet WHO reports that over 80% of adolescents worldwide do not meet the recommended 60 minutes of daily physical activity, negatively affecting musculoskeletal health. Additionally, 20–30% of adolescents experience low back pain and reduced spinal flexibility due to weak core muscles, poor posture, sedentary habits, and excessive screen time. Although yoga-based practices have been shown to improve posture, balance, strength, and flexibility, controlled research specifically examining YSV in adolescents is limited. Therefore, this study protocol seeks to evaluate the effects of YSV on upper and lower limb strength, postural stability, and spinal flexibility in adolescents.

Methods: This study will involve 100 teenagers aged 13-19. All students will be tested twice: once at the beginning of the study and again 12 weeks later. Testing will take place on three separate days. On the first day, their upper body strength will be assessed using a hand-grip machine, lower body strength using a leg-strength device, and spinal flexibility using a sit-and-reach test. On the second day, their balance will be measured using a stopwatch, by observing how long they can stand on one leg. On the third day, students in the Yogic Sukshma Vyayam (YSV) group will be taught exercises, while the control group will simply continue their normal daily routine. After the first assessment, students will be randomly divided into two 50/50 groups using a computer-generated list: an experimental group that will practice the Yogic Sukshma Vyayam, and a control group that will receive no specific training and will simply follow their daily routine. The YSV group will practice for 45 minutes a day, six days a week, for 12 weeks. These exercises involve simple, gentle movements from head to toe. The control group will continue their daily activities without adding any new exercise routine.

Conclusion: Yogic Sukshma Vyayama is expected to significantly improve adolescents' limb strength, balance, and spinal flexibility compared to the control group. These positive effects likely result from enhanced muscle activation, joint mobility, and overall body coordination

Trial registration/IEC No.: Clinical Trial Number: ctri/2025/07/090546. Data of registration: 09/07/2025 and IEC no.: UOP/IEC/2025/10

Keyword: Yogic Sukshma Vyayama**,** Postural Stability**,** Spinal Flexibility, Adolescents Physical Fitness

A CONCEPTUAL FRAMEWORK ON DIGITAL WELLNESS AND MENTAL HEALTH: THE MEDIATING ROLE OF CAPACITY BUILDING IN MODERN WORKPLACES

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ABSTRACT

The way people work, learn, and connect has changed as a result of the growing incorporation of digital technologies into daily life. These developments have improved accessibility and efficiency, but they have also raised issues with digital overload, short attention spans, and increased mental stress. In order to provide a theoretical understanding of how balanced digital engagement might improve psychological well-being and long-term human development, this conceptual paper explores the interconnected fields of **digital wellness, mental health, and capacity building.**

The paper summarizes important ideas including digital mindfulness, cognitive load theory, mental wellness frameworks, and capacity-building models and is based on current literature. It contends that by controlling technology use, encouraging mindful digital practices, and lowering the likelihood of digital tiredness, digital wellness serves as a crucial mediator supporting mental health. Additionally, capacity building through organizational training, psychological skill development, and digital literacy emerges as a crucial facilitator that enables people to successfully handle technology demands.

This paper's conceptual approach emphasizes the dynamic connections between psychological resilience, personal development, and digital activity. It highlights how organizations and workplaces may foster supportive digital cultures that value mental health and promote ongoing skill development. This research adds to the growing conversation about encouraging better digital ecosystems by combining theoretical viewpoints from technology, psychology, and human development. Additionally, it lays the groundwork for upcoming empirical studies on the relationship between digital wellbeing and mental health outcomes.

Keywords: Digital Wellness, Mental Health, Capacity Building, Digital Mindfulness, Cognitive Load, Digital Literacy, Conceptual Framework

COMBATING FOOD ADULTERATION AND PROMOTING DIGITAL WELLNESS: AN ORGANIC FOOD MARKETPLACE WITH NUTRITIONAL TRACKING

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ABSTRACT

There is a growing demand to use digital interventions for the mental and physical well-being of young professionals. Currently apps are using self reporting systems, or integration with wearable technologies but often lack comprehensive nutritional guidance tied to verifiable food sources. However, due to growing food adulteration, the market is filled with harmful or cheaper substances used to alter quality and increase quantity for financial gain. To address this, the Healthy Wealthy app brings an honest and transparent system where organic food producers can connect with local consumers to provide authentic, organic fruits and vegetables. The produce listings will clearly display a sustainability score, including information about pesticides used during cultivation, sustainable practices employed, and allergen information (such as whether storage containers were used for peanuts, wheat or soy products). Food producers can share their sustainable practices through profile pages with blogging features, enhancing their visibility and credibility. Consumers can access personalized nutritional tracking and share their own recipes and wellness tips with other users, creating a collaborative platform for physical wellness. Consumers will have the option to pick up produce or have it delivered by the app's delivery partners. Thus, Healthy Wealthy will help connect local consumers with local organic producers through transparent produce information, promoting nutrition and physical fitness.

Keywords: Digital Health, Nutritional Tracking, User Experience Design, Sustainability, Organic Farming

A CRITICAL REVIEW OF MOVEMENT MECHANICS AND DISC PRESSURE DURING VARIOUS YOGIC PRACTICES IN LUMBAR DISC HERNIATION

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ABSTRACT

Lumbar Disc Herniation (LDH) is one of the most common causes of low back pain, with a global prevalence of about 1-3% in the adult population. LDH is a pathological condition in which the nucleus pulposus protrudes through the annulus fibrosus in intervertebral discs. This condition develops largely due to mechanical issues in the spine, including disc pressure and alignment. Yogic practices, especially asanas, are now widely used as a conservative and holistic approach in the management of LDH. Most of the research on LDH and Yoga focuses only on pain relief and functional improvements rather than on the biomechanical mechanism behind it. Since LDH is rooted in structural and mechanical changes, it's important to understand how specific yogic movements might influence disc pressure and spinal loading. Currently, no study has directly measured intradiscal pressure during yoga, leaving a noticeable gap in our understanding. This critical review aims to examine current lumbar biomechanics and relate them to common therapeutic yogic postures, outlining how movement patterns and alignment may influence disc pressure and spinal loading in lumbar disc herniation.

A HOLISTIC PERSPECTIVE ON HEALING THE PLANET AND SELF: INTEGRATING SMART TECHNOLOGIES IN WELLNESS TOURISM

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ABSTRACT

The discussion presents an actionable and evidence -based analysis of how wellness tourism can support both personal well-being and sustainable development, while smart technologies further enhance these outcomes through digital monitoring, personalized wellness tools, eco-efficient management systems. By embracing models like green retreats, fair trade practices, and community wellness centers, the tourism sector can significantly enhance its inclusivity and sustainability. It promotes policies and practices that blend tradition with innovation, ensuring that wellness tourism benefits individuals, communities, and the natural surroundings. Furthermore, inclusion of digital and smart technologies also plays a growing role by supporting efficient resource use and sustainable management. Ultimately, the framework envisions wellness tourism as a regenerative system that contributes to personal transformation, sustainability, community bonds and digital innovation. It supports a model of travel that nourishes the mind, body, and spirit while also healing the ecosystems that sustain life. Furthermore, these models show ethical entrepreneurship thriving with sustainable wellness outcomes. A comprehensive approach to wellness tourism promotes environmental restoration, cultural revitalization, and personal healing with digital innovations for the benefit of both visitors and local communities.

Keywords: Wellness Tourism, sustainability, Holistic Approach, Community Empowerment Regenerative Tourism, Digital Innovation.

IMPACT OF NON-NEWTONIAN BEHAVIOR ON BLOOD FLOW CHARACTERISTICS IN STENOSED ARTERIES: A MATHEMATICAL MODELING PERSPECTIVE

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ABSTARCT

The hemodynamics of blood flow within stenosed arteries plays a critical role in the onset and progression of cardiovascular diseases. While blood is often approximated as a Newtonian fluid under normal physiological conditions, its rheological behaviour exhibits strong non Newtonian characteristics in narrow or diseased arterial segments, particularly in the presence of stenosis. This study presents a comprehensive mathematical modeling framework to evaluate the impact of non-Newtonian behaviour on blood flow characteristics in stenosed arteries. The governing equations for unsteady, axisymmetric and incompressible flow are formulated using the Navier–Stokes model and solved under mild stenosis geometry by integrating multiple non-Newtonian constitutive equations, including Casson, Herschel Bulkley, Carreau and Power-law models. Hemodynamic indicators such as axial velocity profile, volumetric flow rate, pressure gradient and wall shear stress are examined across varying degrees of stenosis severity and viscosity parameters. The comparative analysis reveals that non-Newtonian rheology significantly alters arterial flow resistance and shear force distribution, with yield-stress-based models predicting the highest wall shear stress and pressure drop, whereas shear-thinning models demonstrate smoother velocity gradients and reduced flow resistance. Increased stenosis severity amplifies flow disturbance and wall shear stress peaks, which may contribute to plaque rupture and cellular injury. The findings underscore the importance of incorporating realistic non-Newtonian fluid models for accurate hemodynamic prediction and provide valuable insights for clinical diagnosis, stent design and computational cardiovascular research.

FINITE DIFFERENCE SIMULATION OF AIRFLOW IN THE HUMAN RESPIRATORY TRACT

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ABSTRACT

Airflow behaviour in the human respiratory tract is crucial for understanding normal pulmonary function and the development of respiratory diseases. This paper presents a mathematical formulation of airflow in the human airways based on the principles of fluid dynamics and realistic physiological geometry, along with a numerical solution using the finite difference method. The respiratory tract is idealized as a branching tubular system, and the governing equations are derived from the continuity and momentum equations for incompressible, viscous flow under laminar conditions. Appropriate assumptions are introduced regarding air properties, wall characteristics, and inlet–outlet boundary conditions to represent normal breathing. The resulting partial differential equations are discretized on a space–time grid using a finite difference scheme. Numerical results for velocity profile, pressure distribution, and wall shear stress are obtained for selected airway segments and breathing rates. The simulations demonstrate the strong influence of airway geometry on airflow patterns and pressure gradients. The proposed modeling and finite difference framework provides an effective basis for more detailed computational studies and for extending the analysis to pathological conditions and patient-specific airway geometries.

TRANSIENT MATHEMATICAL MODELING OF HEAT TRANSFER IN BIOLOGICAL TISSUES USING THE PENNES BIOHEAT EQUATION WITH TEMPERATURE-DEPENDENT PROPERTIES

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ABSTRACT

Heat transfer inside biological tissues is an important factor in many medical treatments such as hyperthermia, laser heating, cryotherapy, and thermal ablation. For predicting the time-dependent temperature changes in living tissues, mathematical modeling is widely used. In this study, we formulate a transient mathematical model of heat transfer in biological tissues using the Pennes bioheat equation and an extended version of it. The Pennes model considers heat conduction, blood perfusion, and metabolic heat generation, and is one of the most commonly used models in biomedical engineering. However, this model assumes constant thermal properties, which may not be accurate during heating or cooling because tissue properties change with temperature.

To improve the prediction of transient temperature fields, we present an extension of the Pennes bioheat equation in which the thermal conductivity and specific heat of the tissue depend on temperature. Both models are written as time-dependent partial differential equations along with corresponding initial and boundary conditions. The purpose of this study is to compare the mathematical formulations and highlight how the temperature-dependent extension can better represent real physiological behavior during thermal exposure. The study forms a theoretical basis for future numerical simulation and practical applications in medical thermal therapies.

MATHEMATICAL AND NUMERICAL SIMULATION OF BRAIN TUMOR DYNAMICS USING TIME-FRACTIONAL DERIVATIVES

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ABSTRACT

Understanding tumor growth in the brain is crucial and complex. This study explores a brain tumor model that integrates variable-order time-fractional derivatives within a two-dimensional irregular domain. The model's stability is demonstrated through Ulam-Hyers stability analysis, and the existence and uniqueness of the solution are established. The finite difference method is utilized for temporal discretization, while Gaussian radial basis functions are employed for spatial variables. Code verification is performed to confirm the accuracy and reliability of the computational approach. The study investigates the behavior of tumor cells, considering cell heterogeneity, the impact of the mutation rate, growth parameters along with various orders of time-fractional derivatives, including variable orders. The results and discussion provide a thorough analysis with graphical representations, highlighting novel behaviors induced by variable-order time-fractional effects on the brain tumor model.

PULSATILE NON-NEWTONIAN BLOOD FLOW IN AN ARTERIAL BYPASS WITH DISTAL STENOSIS: A NAVIER STOKES CARREAU MODEL USING MATLAB

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ABSTRACT

Arterial bypass surgery is commonly performed to restore blood flow when the native artery becomes severely narrowed due to atherosclerosis. The long-term success of the bypass depends strongly on the local hemodynamics, especially in the region of the distal anastomosis where abnormal flow patterns are known to trigger intimal hyperplasia and graft failure. In particular, the combined influence of pulsatile flow, non-Newtonian behaviour of blood and the presence of a distal stenosis is still not completely understood. In this study, we investigate the hemodynamics of blood flow in an arterial bypass with a distal stenosis using a mathematical and numerical approach. The flow is modeled by the two dimensional incompressible Navier–Stokes equations, and blood viscosity is represented by the shear-dependent Carreau model to account for its non-Newtonian nature. A time-periodic pulsatile velocity waveform is imposed at the inlet to simulate realistic physiological conditions. The governing equations are discretized using a finite difference method on a staggered grid, and the time integration is performed through a projection scheme for pressure velocity coupling. Simulations are implemented completely in MATLAB. The numerical results reveal the formation of recirculation zones at the distal anastomosis and within the stenotic region during different phases of the pulse. The non-Newtonian Carreau model predicts lower wall shear stress and larger areas of flow reversal compared with the Newtonian assumption. These discrepancies become more pronounced with increasing stenosis severity and during peak systole. The study concludes that non-Newtonian effects play a significant role in determining the hemodynamic environment in bypass grafts, particularly near the distal stenosis. Ignoring shear-dependent viscosity may underestimate regions of low and oscillatory wall shear stress that are associated with graft failure. The proposed study provides a useful tool for further investigations and can be extended to more realistic geometries and three-dimensional flow analysis.

HYBRID QUANTUM–CLASSICAL QCNN WITH VARIATIONAL QUANTUM CIRCUITS FOR COVID-19 RADIOGRAPHIC IMAGE CLASSIFICATION

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ABSTRACT

Quantum computing is increasingly recognized as a groundbreaking approach for medical image classification, providing notable benefits in enhanced model effectiveness and efficient feature extraction. In order to classify four-class COVID-19 radiographic images, this study presents an integrated hybrid methodology that blends a Quantum Convolutional Neural Network (QCNN) with traditional machine learning classifiers. Utilizing the concepts of quantum superposition and entanglement, the suggested system uses variational quantum circuits with trainable quantum gates to encode chest radiographs into high-dimensional quantum feature space. Classical models like Support Vector Machine (SVM), Random Forest (RF), and Multi-Layer Perceptron (MLP) are then used to classify the resulting quantum-derived features. The approach is then thoroughly tested against cutting-edge deep learning models such as VGG16, EfficientNet, CNN-EfficientNet-B0, and Vision Transformer (ViT-B/16).The incremental influence of individual quantum circuit parts is highlighted by a thorough ablation analysis. Strong classification performance, robust generalization, and excellent macro-AUC behavior are all displayed by the QCNN+SVM model. In comparison to typical deep learning architectures such as CNN, VGG16, and ViT, it delivers significantly higher parameter efficiency. These results assist the development of hybrid quantum-classical systems for clinical decision-making by positioning quantum convolutional neural networks as a workable and resource-efficient solution for medical image categorization on existing NISQ-era quantum hardware.

Keywords: Quantum convolutional neural network, Variational quantum circuits, Medical image classification, Vision Transformer, Quantum machine learning, ablation study, VGG16, EfficientNet, CNN.

A MATHEMATICAL MODEL FOR DRUG RELEASE AND DIFFUSION FROM POLYMER BASED CONTROLLED DELIVERY SYSTEMS

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ABSTRACT

Controlled drug delivery systems based on polymeric materials have become an important technology in modern therapeutics because they enable sustained, localized, and predictable drug release over extended periods of time. Such systems are used in diverse biomedical applications including implant coatings, transdermal patches, ocular inserts, and biodegradable nanoparticles, where precise regulation of drug diffusion is essential for maintaining optimal therapeutic levels and reducing dosing frequency and side effects. To understand and optimize these devices without relying solely on experimental trial-and-error, mathematical modeling plays a critical role in predicting the release behaviour of the drug from the polymer matrix. In this study, we develop and analyse a mechanistic mathematical model for drug release and diffusion from a polymer-based controlled delivery system. The delivery device is represented as a one-dimensional polymer slab with an initially uniform drug distribution, and drug transport within the matrix is assumed to follow Fickian diffusion. Interaction with the surrounding release medium is incorporated through a boundary condition that accounts for finite mass transfer at the polymer–medium interface. This formulation leads to a Partial Differential Equation problem that captures the essential physicochemical processes involved in controlled drug delivery. A finite difference numerical scheme is implemented to simulate the spatial and temporal evolution of drug concentration inside the polymer matrix, and the cumulative release profile is computed as a function of system parameters. Parametric studies demonstrate how diffusion coefficient, mass transfer coefficient, and polymer thickness influence the rate and extent of drug release. The results show that appropriate change of material and geometric properties can be used to achieve sustained and predictable release profiles, providing valuable insight for the design of polymer based therapeutic delivery devices.

BIOMECHANICAL IMPACT OF ATHEROSCLEROTIC PLAQUE DEPOSITION IN THE CAROTID ARTERY USING FLUID-STRUCTURE INTERACTION SIMULATION

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ABSTRACT

Atherosclerosis, often referred as the "silent killer", typically progresses unnoticed until significant arterial buildup has occurred, underscoring the critical need for early detection, prediction, and treatment. Especially around the carotid artery bifurcation, atherosclerotic plaque deposits frequently lead to disruptions in blood flow. Computational fluid dynamics (CFD) and fluid-structure interaction (FSI) models have been used to study the fluid dynamics of these disruptions in great detail. Yet, these numerical techniques have not been used to fully analyse the elastic response of plaques to haemodynamic stresses of the carotid artery. In order to examine the biomechanics of blood flow through calcified plaque deposits with elastic properties in an idealized three-dimensional carotid sinus model, this work uses a two-way FSI approach employing the Arbitrary Lagrangian-Eulerian technique. Total deformation, flow velocity, and WSS-based parameters were among the metrics that were examined and contrasted with a model of a healthy artery. The presence of atherosclerotic obstruction resulted in vessel deformation, an FSI-specific metric, close to the bifurcation apex. Around the carotid sinus, elevated concentrations of velocity, oscillatory shear index (OSI), and wall shear stress (WSS) were particularly prominent. These findings suggest a potential atherosclerotic expansion, with rising OSI reflecting an increased risk of further stenosis or thrombus formation. In the event of plaque rupture, the elevated velocity and WSS levels near the sinus could further amplify these risks.

NUMERICAL SOLUTION OF THE THREE-PHASE LAG BIOHEAT MODEL USING THE FINITE DIFFERENCE-COLLOCATION METHOD

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ABSTRACT

The rapid increase in cancer throughout recent decades has necessitated dedicated research into the development of effective methodologies and treatments. Among these treatments, Cryosurgery is an established, efficacious treatment for the destruction of cancerous and irregular tissues. During this process, the precise regulation of temperature within a biological system is critical for the selective destruction of unhealthy or abnormal tissues. Consequently, the development of bioheat transfer models is necessary for the accurate prediction and simulation of temperature distributions within biological tissues and organs throughout therapeutic interventions. This work investigates the simulation and mathematical modelling of the three-phase-lag (TPL) bioheat transfer model subjected to thermal boundary conditions during cryosurgery. In the present study, the temperature-dependent Laguerre Radial Basis Function with the Finite Difference method is used to obtain the temperature variation along with distance and time based on the TPL model. The phase lag of thermal displacement has a significant effect on the temperature distribution. Comparison of the TPL model with the (SPL) and (DPL) models of heat transfer is also done in the study. It is observed that among the TPL, DPL and SPL models total time required for complete tissue freezing is least for the single-phase lag model and largest for the three-phase lag model. This study attempts to provide the best mathematical results to obtain the freezing condition of tumour tissues in Cryosurgery.

NUMERICAL ANALYSIS OF TURBULENT FLOW DYNAMICS AND ARTERIAL STIFFNESS IN PATIENT-SPECIFIC CAROTID HEMODYNAMICS

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ABSTRACT

Cardiovascular diseases remain a leading global cause of mortality, with atherosclerosis strongly influenced by local hemodynamics in the carotid artery. This patient-specific computational study examines carotid blood flow at a Young's modulus of 0.9 MPa, using k-ε and k-ω turbulence models to assess hemodynamic behavior relevant to plaque development. Results show that the k-ω model generated larger flow recirculation zones in the carotid sinus, accompanied by lower Time-Averaged Wall Shear Stress (TAWSS) which indicating a higher risk of plaque deposition. In comparison, the k-ε model predicted comparatively higher TAWSS in the Common and External Carotid Arteries suggesting reduced susceptibility to endothelial damage. The highest Oscillatory Shear Index (OSI) appeared near the bifurcation and along the outer Internal Carotid wall which marking these locations as potential plaque-initiation regions. Overall, the k-ω model identified a broader disease-prone zone than the k-ε model that emphasizing the need for turbulence-aware and stiffness-sensitive simulations in atherosclerosis risk assessment.

Keywords: Turbulent Flow, Arterial Stiffness, Time-average Wall Shear stress, Oscillatory Shear Index

A STUDY ON THE PREVALENCE OF NOMOPHOBIA AMONG YOUNGSTERS AND ITS ASSOCIATION WITH SLEEP, ANXIETY, AND LIFESTYLE DISORDERS

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ABSTRACT

Nomophobia is defined as the fear or anxiety of being without a mobile phone which has emerged as a significant digital-age challenge, particularly among youngsters who rely heavily on smartphones for communication, education, entertainment, and social identity. This study examines the prevalence of nomophobia among young individuals and explores its association with sleep disturbances, anxiety symptoms, and lifestyle-related disorders such as irregular eating habits, reduced physical activity, and increased screen dependency. Contemporary research suggests that excessive mobile phone use disrupts sleep patterns through nighttime screen exposure, blue-light interference, and compulsive checking behaviour, leading to insomnia and daytime fatigue.1 Rising cases of digital anxiety and emotional dependence on smartphones further indicate a growing mental-health concern in this age group. Additionally, lifestyle imbalances such as sedentary routines and irregular meal schedules appear closely linked to prolonged smartphone engagement.

These abstract highlights the urgent need to understand how technology-driven behaviours impact public health and youth well-being. The proposed study aims to analyse these relationships through a mixed-method approach, enabling a comprehensive understanding of behavioural, psychological, and lifestyle variables.2 Findings from this research can support the development of digital wellness guidelines, school-level awareness programs, and public-health interventions to promote healthier technology use among youngsters.

Keywords: Nomophobia, Smartphone Addiction, Youngsters, Sleep Disturbance, Anxiety, Lifestyle Disorders, Digital Wellness, Public Health

DIGITAL WELLNESS AND DIGITAL INFRASTRUCTURE IN SCHOOL EDUCATION: AN URBAN–RURAL COMPARATIVE STUDY OF TECHNOLOGY ADOPTION, BARRIERS, AND LEARNING OUTCOMES

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ABSTRACT

The rapid expansion of digital infrastructure and smart technologies has transformed the school-learning environment, influencing not only academic outcomes but also students' digital wellness and cognitive behaviour. This study examines the urban–rural comparison of technology adoption among high-school learners through the lens of digital access, digital wellness, capacity building, and infrastructure readiness, thereby aligning educational technology with broader public-health and digital-development objectives.

Urban schools generally benefit from stronger digital ecosystems—reliable internet, availability of smart devices, and teacher training in digital tools. These factors enable personalized learning, faster information processing, and effective integration of e-content. However, concerns related to digital overload, mental fatigue, reduced attention span, and online distraction highlight critical digital-wellness challenges that require structured interventions.

In contrast, rural schools continue to experience gaps in connectivity, device availability, and digital literacy. Yet, even limited exposure to audio-visual learning and online platforms has demonstrated improvements in conceptual clarity, engagement, and student confidence. The study highlights structural barriers such as affordability, weak infrastructure, and insufficient teacher capacity, all of which restrict consistent adoption of smart learning technologies.

By analysing these disparities, the research provides insights for policymakers and institutions to develop equitable digital infrastructures, wellness-oriented technology guidelines, and targeted capacity-building initiatives.

Keywords: Digital Wellness, Technology Adoption, Digital Infrastructure, Urban–Rural Education Gap, Learning Outcomes, Capacity Building, Digital Literacy, Smart Education Technologies.

EFFECT OF PRANAYAMA ON ATHLETIC PERFORMANCE

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Background
Athletic performance is strongly influenced by the efficiency of the respiratory system, metabolic demands during training, and the level of psychological stress an athlete experiences. These factors collectively determine how well the body maintains aerobic and anaerobic output. Pranayama (Yogic Breathing) has been used traditionally to improve respiratory function and regulate autonomic balance. In recent years, it has attracted attention as a low cost, nonpharmacological technique that may support cardiorespiratory efficiency and recovery in athletes.

Purpose
The purpose of this review is to examine and synthesize findings from controlled clinical trials that have evaluated the acute and long term effects of various Pranayama practices on athletic performance. The focus is on objective performance markers, respiratory function, psychological resilience, and physiological indicators related to recovery.

Methods
A systematic search of major databases (PubMed, Cochrane Library, Web of Science, and others) was conducted to identify controlled trials involving Pranayama interventions in athletic or healthy adult populations. Studies assessing outcomes such as running performance at fixed Ratings of Perceived Exertion (RPE), anaerobic power tests, pulmonary function (FVC, respiratory endurance), Heart Rate Variability (HRV), cortisol levels, antioxidant status, and Perceived Stress Scores (PSS) were included.

Conclusions
The available studies suggests that regular Pranayama practice can improve pulmonary function such as increases in FVC and notable gains in respiratory endurance. Several studies also reported improvements in performance indicators, including faster running speeds at the same RPE and enhanced agility or power output. Psychological and recovery related benefits were also observed, particularly reductions in stress markers (cortisol, PSS) and increases in antioxidant activity.

Keywords: Pranayama, yogic breathing, controlled breathing, sports performance, exercise capacity, endurance, runners, cardiorespiratory fitness, heart rate variability, respiratory endurance.

ROLE OF SOCIAL MEDIA IN ENGAGING TRIBAL COMMUNITIES FOR HEALTH COMMUNICATION

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ABSTRACT

Tribal communities in remote areas often struggle for timely and reliable health information due to geographical isolation, limited healthcare infrastructure and low literacy levels. Social media can be used as digital communication platforms. Social media, particularly WhatsApp, have the potential to bridge this gap by enabling direct and real-time health communication. This study examines the effectiveness of WhatsApp in engaging tribal communities in Dharani, Maharashtra, for health awareness and information dissemination.

This research paper evaluates the role of WhatsApp as a medium for health communication among tribal communities and assess community engagement and responsiveness to health-related messages. It also identifies types of health content that generate the most interaction and participation.
A qualitative research approach was adopted, utilizing a WhatsApp group consisting of tribal members as the primary data source. Data were collected through participant monitoring, analysis of message interactions and selective interviews. Engagement was assessed based on response rates, user queries and the extent of message-sharing.

The findings indicate that WhatsApp is an effective platform for disseminating health information in tribal communities. Participants actively engaged with health messages, particularly those related to maternal health, hygiene and disease control. However, messages related to nutrition and diet received comparatively less attention. The accessibility of WhatsApp and its interactive nature facilitated real-time discussions, leading to increased awareness and information sharing within the group.

WhatsApp has emerged as a viable tool for health communication in tribal regions, offering an accessible and cost-effective medium for information exchange. The study highlights the potential of mobile-based interventions in addressing healthcare challenges in remote areas. Future research should focus on integrating digital health interventions into broader public health programs.

Keywords: Health communication, Tribal communities, WhatsApp engagement, Digital health interventions, Community health awareness.

IMPACT OF MINDFULNESS MEDITATION ON THE COGNITIVE ABILITY OF PREADOLESCENT: A REVIEW

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ABSTRACT

Mindfulness-Based Interventions (MBIs) represent an expanding domain of empirical inquiry within both positive psychology and clinical health care. Mindfulness meditation is fundamentally characterized by a non-reactive, focused awareness of present-moment internal and external experiences, coupled with an attitude of nonjudgmental acceptance. The preadolescent stage of human development, typically spanning the approximate ages of 9 to 12 years, is a crucial epoch marked by significant neurocognitive maturation. Given this developmental window, mindfulness practice has emerged as a promising, non-pharmacological strategy to foster cognitive and emotional growth in children. This systematic review critically examines the empirical evidence concerning the influence of structured mindfulness meditation on the cognitive abilities of preadolescents. The primary focus is placed on key domains of executive function, including attentional control, working memory capacity, cognitive flexibility, and advanced problem-solving skills. A synthesis of recent findings suggests that consistent engagement with mindfulness promotes enhanced attentional regulation and robust emotional self-regulation. By supporting self-awareness and cognitive stability during this critical growth phase, mindfulness-based programs appear to be particularly effective. The strategic integration of structured mindfulness interventions within educational settings holds potential to elevate both academic performance and psychological resilience. Collectively, the literature positions mindfulness meditation as a valuable, evidence-based approach for augmenting cognitive capacity and promoting overall psychological well-being in the preadolescent demographic.

Keywords: Mindfulness Meditation, Cognition, Preadolescence.

MINIMAL MODELS, MAXIMUM UNDERSTANDING: WHY BASIC COMPARTMENTAL MODELS ARE ENOUGH FOR EARLY EPIDEMIC BRN (R_0) CALCULATION

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ABSTRACT

The basic reproduction number (BRN) remains one of the most essential metrics in infectious disease epidemiology, providing a quantitative assessment of how efficiently a virus can spread in a population with no pre-existing immunity. Accurate estimation of the BRN is fundamental to guiding timely interventions and is crucial for making policies in health care, particularly during the early stages of an epidemic when rapid action is necessary. In this study, we analytically derive BRN expressions for five widely used epidemiological models—SIR, SAIR, SEIR, SIRD, and SEIRD—to investigate how changes in compartmental model structure influence BRN magnitude. These models incorporate different epidemiological features, including asymptomatic carriers, exposed but not yet infectious individuals, and disease induced mortality, resulting in structural variations that may affect disease transmission dynamics. Using the Next Generation Matrix (NGM) method, we systematically compute the BRN for each model and assess how the theoretical value responds to the addition or removal of compartments. To complement the analytical findings, we apply all five models to COVID 19 case data from India and estimate BRN empirically through statistical fitting and parameter optimization. Comparative analysis reveals that despite increased complexity in extended models, the overall BRN values remain largely consistent across frameworks. These results indicate that during the early phase of an outbreak, simpler models—such as the SIR model— which require fewer parameters and less data, can still yield reliable BRN estimates for informing urgent health care decisions. Consequently, public health authorities can act without waiting for more complex and data-intensive models to be calibrated. The study underscores the value of minimal epidemiological models for rapid policy support in health care, especially in resource-limited or time-sensitive epidemic settings, while also highlighting the relevance of more complex models in later stages of disease control planning.

STATISTICAL INFERENCE FOR TWO-PARAMETER CHRIS–JERRY LIFETIME MODEL IN CHRONIC DISEASE SURVIVAL ANALYSIS: CLASSICAL AND BAYESIAN APPROACHES WITH PROGRESSIVE TYPE-II CENSORING

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ABSTRACT

This study develops advanced statistical approaches for analyzing time-to-event outcomes in patients with chronic diseases, where incomplete follow-up and censoring frequently complicate clinical research. The Two-Parameter Chris–Jerry Distribution (TPCJD) is applied to model key survival outcomes—including complication onset, hospitalization, and mortality—providing a flexible and robust framework under progressive Type-II censoring. Four estimation techniques are investigated: Maximum Likelihood Estimation (MLE), Maximum Product Spacing (MPS), Bayesian estimation based on the likelihood function (BLE), and Bayesian estimation using product spacing (BPS). Bayesian estimators are constructed under a squared-error loss function using a conditional gamma prior for the shape parameter and a discrete prior for the scale parameter.

A comprehensive simulation study assesses the performance of these estimators and identifies efficient censoring schemes based on minimizing mean squared error (MSE). Applications to two real patient datasets—one involving diabetes and the other heart disease—demonstrate the practical relevance of the proposed framework.

Results indicate that the TPCJD, combined with both Bayesian and classical estimation methods, enhances accuracy in survival prediction and risk assessment even when patient data are partially censored. These findings support improved clinical decision-making, stronger public health planning, and more efficient allocation of healthcare resources for chronic disease management.

A CNN-BASED COMPUTATIONAL MODEL FOR MULTICLASS LUNG CANCER DIAGNOSIS USING CT SCAN IMAGES

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ABSTRACT

Early and timely diagnosis of lung cancer improves the survival rate; hence, timely diagnosis aids appropriate treatment planning. Deep learning techniques, especially CNNs, have emerged recently with outstanding performance in the analysis of medical images. The researchers have put forward a framework on computerized detection of lung cancer by employing high-resolution CT scan images obtained from the publicly available LungCancer4Types-ImageDataset. The proposed methodology integrates an improved ResNet50 architecture with dynamic regularization and hybrid loss optimization to enhance generalization and robustness against class variability. The model was trained end-to-end, including the fine-tuning of ResNet50 layers, global average pooling, dropout regularization, and a fully connected classification head. After 100 training epochs, the model attained a training accuracy of 98.84% and a validation accuracy of 85.42%, showing strong learning capability and stable convergence reflected in accuracy and loss curves. The confusion matrix and classification report further confirm robust classification, with particularly high recall for adenocarcinoma at 0.96 and squamous cell carcinoma at 0.93. The results have proved that the ResNet50-based framework is suitable for automated lung cancer detection and can thus support radiologists in the early identification of malignant lung abnormalities. The presented deep learning pipeline works effectively for multiclass lung cancer classification based on CT images with high diagnostic accuracy and promising clinical decision support systems.

Keywords: CNN, Lung Cancer Diagnosis, CT Scan Image, Machine Learning, Medical Imaging, Image Classification.

FUSING INTELLIGENCE WITH AGRICULTURE: IOT AND AI FOR FOOD SECURITY AND PUBLIC HEALTH

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ABSTRACT

The rapid integration of the Internet of Things (IoT) and Artificial Intelligence (AI) is reshaping agriculture with significant implications for public health and food security. As global populations grow and climate challenges intensify, reliable access to safe, nutritious food has become a critical component of public health systems. IoT-enabled sensing devices, smart monitoring platforms, and AI-driven analytics now support real-time assessment of crop conditions, soil health, water quality, and livestock well-being. These technologies not only enhance farm productivity but also enable early detection of contamination, disease outbreaks, and supply-chain disruptions, aligning agricultural innovation with the broader goals of connected health. This paper explores the role of IoT and AI as vital enablers in creating resilient, transparent, and health-focused agricultural ecosystems. It discusses how IoMT-inspired architectures, predictive analytics, and remote monitoring frameworks can ensure safer food production, reduce health risks, and contribute to sustainable public health outcomes.

Keywords: Smart farming, IoT in agriculture, AI-powered agriculture, Food security, Connected health, Real-time monitoring

A COMPARATIVE STUDY OF QUANTUM AND CLASSICAL MACHINE LEARNING MODELS FOR CERVICAL CANCER PREDICTION

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ABSTRACT

Cervical cancer (CC) remains a major global health concern, particularly in regions lacking reliable early diagnostic resources. Quantum machine learning (QML) offers a potential alternative computational framework, but its suitability for real-world clinical prediction requires systematic evaluation. This study presents a comprehensive benchmark comparing three QML methods: Quantum Support Vector Machine (QSVM), Quantum Neural Network (QNN), and Quantum k-Nearest Neighbors (QKNN) with classical algorithms, including SVM, KNN, and a multilayer Neural Network, for classifying cervical cancer biopsy specimens. To enable feasible quantum circuit implementation and reduce simulation overhead, Principal Component Analysis (PCA) was applied to reduce the dataset to four dimensions. The results show clear performance differences between classical and quantum approaches. Classical models consistently achieved superior accuracy (0.9401), with the Neural Network demonstrating the highest sensitivity (recall = 0.4545). Among QML models, QSVM performed best (accuracy = 0.9341, AUC = 0.8543), while QNN showed unstable behavior, low accuracy (0.3170), and significantly higher computation time (29.56 s). Although QML introduces promising research directions particularly quantum kernel-based methods: current QML techniques remain limited by Noisy Intermediate-Scale Quantum (NISQ) hardware. This work provides a foundational benchmark for QML-based cervical cancer prediction and defines a clear pathway toward more robust, clinically applicable quantum diagnostic methodologies.

APPLICATION OF QUEUEING THEORY IN HEALTHCARE SECTOR

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ABSTRACT

Managing queues in the healthcare sector is crucial to ensure timely patient check-ups, minimize patient waiting times, and make optimal use of limited medical resources. To analyse patient waiting times in a hospital in particular in a diagnostic centre, this study proposes a Markovian queueing model in which patients from three distinct age groups— young, adult, and elderly—arrive for MRI scan services. The diagnostic centre is equipped with a single MRI scan machine, which is subject to breakdowns. Services are provided to patients on a first-come, first-served (FCFS) basis. The proposed model incorporates several realistic queueing features, including patient balking behaviour and a triple-orbit retrial mechanism. In this mechanism, patients who are not immediately scanned are redirected to one of three retrial orbits, each corresponding to their respective age group. Patients in each retrial orbit attempt to access the MRI scan machine again after spending a random amount of time in the orbit. Upon successfully completing their scans, they exit the diagnostic centre. However, some arriving patients may observe a long queue and decide not to join it—this phenomenon, known as balking, reflects the tendency of patients to leave without waiting when the expected delay is too high. The mathematical model is developed by formulating the steady-state Chapman–Kolmogorov equations, which are subsequently solved to obtain explicit expressions for queue-size probabilities via probability generating functions (PGF). These probabilities enable the computation of key system performance metrics, such as the mean number of patients, their waiting times in the diagnostic service unit, and the operational state of the MRI scan machine, which are then used to perform a numerical analysis.

SUSTAINABLE MANAGEMENT OF DETERIORATING MEDICINES IN HEALTHCARE SUPPLY CHAINS WITH STOCHASTIC DEMAND

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ABSTRACT

Sustainable management of medicines is a major challenge for healthcare systems, where product deterioration, expiration and storage issues create significant waste, costs and carbon emissions. This paper examines a healthcare supply chain consisting of multiple hospitals, a distribution centre and two medicine suppliers: one regular and one outsourcing. These suppliers jointly serve the stochastic medicine demand at hospitals. We develop a multi-echelon inventory model that incorporates transportation and storage emissions, preservation investments to slow deterioration, and expiration costs for spoiled medicines. By analyzing the expected system costs using both continuous and discrete formulations, the model highlights key trade-offs among ordering decisions, storage quality and product shelf-life. The numerical results offer practical guidance for healthcare organizations aiming to reduce waste and enhance sustainable supply chain performance.

Keywords: Hospital Management, Multi-echelon inventory model, Deterioration, Stochastic demand, Cost Minimization.

REGULATORY FRAMEWORK FOR DIGITAL HEALTHCARE REGULATING THE FUTURE OF HEALTHCARE IN A DIGITAL ERA

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ABSTRACT

Digital technologies such as mobile applications, teleconsultation services, wearable devices, digital therapeutics and precision clinical decision aids are rapidly changing the healthcare industry. These advancements have immense potential to increase accessibility, effectiveness in operations, and the promptness of decision-making in the field. Simultaneously, the increased use of these technologies raises questions about data privacy, patient safety, ethical responsibility, and the credibility of digital systems. In order to overcome these problems, sound regulatory systems are needed. The existing policies focus on the development of uniform data control, security measures, interoperability rules, and quality requirements of digital platforms. Such policies as the General Data Protection Regulation (GDPR), the Health Insurance Portability and Accountability Act (HIPAA) and many other national digital health initiatives offer directions to the consent, confidentiality, data privacy, and accountability between healthcare providers and technology developers. In most jurisdictions, computer-based diagnosis and treatment are considered a medical device, and require stringent clinical trials, risk management, and continuous monitoring. Due to the increased involvement of artificial intelligence in healthcare, new standards are being developed with transparency, reduction of bias, and intentional human supervision as priorities. In spite of these improvements, there are still issues of regulatory discrepancies, insufficient enforcement and the absence of international harmonization. It is necessary to enhance these frameworks so that they support innovation and the rights of the patients and make digital health ethical, equitable, and reliable. This study demonstrates the need to have flexible and future-oriented regulations that would be able to maintain trust and continue the development of digital health systems.

CAPACITY BUILDING OF HEALTH PROFESSIONALS THROUGH SAKSHAM: LMIS

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ABSTRACT

Strengthening the skills and competencies of health professionals is critical for improving the quality, efficiency, and equity of healthcare delivery in India. SAKSHAM: LMIS (Learning Management Information System), a digital learning & training platform of Ministry of Health & Family Welfare, Govt. of India developed by NIHFW, New Delhi to streamline online medical education, training, monitoring, and performance assessment of the health workforce and medical students in the country. The platform facilitates standardized e-learning modules, blended training approaches, competency-based assessments, and automated certification for diverse cadres including Medical Officers, Community Health Officers, ANMs, and frontline workers. Its integrated dashboards provide actionable insights for programme managers on training coverage, gaps, and outcomes, enabling timely interventions. SAKSHAM: LMIS also promotes accessibility and scalability by allowing health workers to learn at their own pace, improving retention and operational readiness. This study highlights the role of SAKSHAM: LMIS in enhancing structured learning, enabling real-time tracking of training progress, supporting data-driven decision-making and achieving SDG of Universal Health Coverage (UHC).

Keywords: SAKSHAM:LMIS, digital capacity building, UHC

REGULATORY GOVERNANCE AND ETHICAL CHALLENGES IN THE EVOLVING LANDSCAPE OF DIGITAL THERAPEUTICS

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ABSTRACT

Digital therapeutics (DTx) represent an emerging class of evidence-based medical interventions delivered through software, offering significant promise in managing chronic diseases, mental health disorders, and lifestyle-related conditions. As their clinical adoption accelerates, robust legal and ethical frameworks have become essential to ensure patient safety, data integrity, transparency, and accountability. The present work examines the evolving regulatory landscape governing digital therapeutics, highlighting the diverse approaches taken by agencies such as the U.S. Food and Drug Administration (FDA), European Medicines Agency (EMA), and India's CDSCO in defining standards for validation, risk classification, and post-market surveillance. Key ethical challenges are analyzed, including informed consent in digital environments, algorithmic transparency, equitable access, and the management of sensitive health data in an era of heightened cybersecurity threats. The integration of artificial intelligence and machine learning further complicates issues surrounding intellectual property, liability in cases of algorithmic harm, and continuous model updates that may blur regulatory boundaries. In low- and middle-income countries, ethical concerns intersect with infrastructural limitations, raising questions of digital literacy, inclusiveness, and cultural appropriateness. By synthesizing legal precedents, regulatory guidelines, and bioethical principles, the present work underscores the urgent need for harmonized global standards and multi-stakeholder governance models that balance innovation with patient rights and societal well-being. Strengthening legal accountability and ethical oversight will be pivotal in enabling digital therapeutics to realize their full potential as safe, trusted, and equitable components of future healthcare systems.

TRAJECTORY OF ECONOMIC EVOLUTION IN HEALTH-TECH PROGRAMMES: INTEGRATING COST-EFFECTIVENESS, ADOPTION PATTERNS, AND INNOVATION METRICS

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ABSTRACT

The rapid digital transformation of healthcare has catalyzed the emergence of health-technology (health-tech) programmes whose economic viability depends on a complex interplay of cost, value, and innovation dynamics. Empathetic the trajectory of economic evolution in this domain requires an integrated assessment framework that captures both the measurable and insubstantial determinants shaping technology adoption and long-term sustainability. This evaluation synthesizes empirical and theoretical evidence on cost-effectiveness analyses, diffusion and adoption patterns, and innovation performance metrics across diverse health-tech interventions, including digital therapeutics, AI-driven diagnostics, remote monitoring systems, and smart medical devices. This study highlighted how economic evaluation methodologies ranging from incremental cost-effectiveness ratios (ICERs) to budget impact models and real-world cost-utility assessments intersect with technology acceptance factors. These factors include usability, regulatory readiness, clinical trust, and socio-behavioural drivers. Additionally, this study examines innovation metrics, including R&D intensity, technology readiness levels (TRLs), scalability indices, and ecosystem maturity, as quantifiable indicators of developmental progress and market diffusion potential. The current study emphasizes the need for multidimensional economic frameworks that move beyond traditional financial assessments to incorporate adaptive learning, data-driven value generation, and health-system responsiveness. Through the integrating cost-effectiveness outcomes with adoption trajectories and innovation dynamics, this work provides a comprehensive perspective on how health-tech programmes evolve economically and identifies strategic levers for optimizing investment decisions, accelerating implementation, and maximizing health-system impact.

Keywords: Cost-effectiveness, Technology Adoption. Innovation Metrics, Health-Tech Programmes, Economic Evolution

GREEN HOSPITAL SUSTAINABILITY MODELS: EVIDENCE, IMPLEMENTATION CHALLENGES, AND FUTURE PATHWAYS FOR LOW-CARBON HEALTHCARE

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ABSTRACT

Hospitals are among the most resource-intensive public infrastructures, consuming two to three times more energy per square meter than commercial buildings and accounting for approximately 4.4% of global greenhouse gas emissions, as reported by the World Health Organization. Over the past two decades, sustainability in healthcare has evolved from isolated energy-saving measures to integrated sustainability models embedded within hospital design, operations, and governance. Large-scale studies from Europe and North America demonstrate that green building-certified hospitals achieve 25-40% reductions in energy consumption and 30-50% lower water use compared with conventional facilities. Implementation of renewable energy systems, high-efficiency HVAC, LED lighting, and building energy management systems has further been associated with 20-30% annual operational cost savings in tertiary care hospitals. Recent developments emphasize circular economy approaches, including biomedical waste reduction, sustainable procurement, and lifecycle assessment of medical devices. Studies highlight that digital health solutions, such as telemedicine and AI-enabled predictive maintenance, contribute to measurable reductions in hospital load, patient travel, and indirect carbon emissions. However, despite growing evidence, significant challenges remain, including high upfront capital requirements, fragmented regulatory frameworks, limited technical expertise, and difficulties in retrofitting aging hospital infrastructure without disrupting clinical services. Looking ahead, key pathways include AI-based energy optimization, smart microgrids, low-carbon medical technologies, and standardized sustainability metrics aligned with SDGs and ESG reporting. Stronger policy incentives, financing mechanisms, and institutional capacity are essential to scale green hospital models globally toward resilient, climate-aligned healthcare systems.

Keywords: Green Hospital, Sustainable Development Goals, Greenhouse gas emissions, AI-driven energy optimization, Low carbon technologies

MACHINE LEARNING TECHNIQUES FOR SECURING THE INTERNET OF MEDICAL THINGS (IOMT)

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ABSTRACT

The increasing integration of the Internet of Medical Things (IoMT) in healthcare systems improves patient monitoring, data analytics, and clinical decision support, but also exposes sensitive medical data to cybersecurity threats. Traditional protection methods are insufficient for addressing dynamic and evolving attack patterns across diverse and resource-constrained IoMT devices. This paper presents a machine learning-based security approach designed to detect abnormal device behavior and malicious network activities in IoMT environments. The proposed framework combines supervised and unsupervised learning techniques to classify traffic patterns, identify zero-day attacks, and reduce false alarms. Experimental results on benchmark IoMT datasets demonstrate high detection accuracy and improved resilience compared to static security systems. The work highlights the potential of machine learning to provide adaptive, scalable, and intelligent cybersecurity defense for future medical device networks. Future research includes implementing federated learning to enhance privacy and deploying lightweight models at the edge to support real-time protection.

Keywords: Machine Learning, Internet of Medical Things, IoMT Security, Anomaly Detection, Intrusion Detection, Healthcare Cybersecurity, Artificial Intelligence, Edge Intelligence, Dataset Evaluation, Zero-Day Attacks

THEME: INTEROPERABILITY OF HEALTH SYSTEMS AND DIGITAL RECORDS

INTEROPERABILITY IN HEALTHCARE: ADVANCES, CHALLENGES, AND FUTURE DIRECTIONS IN DIGITAL HEALTH RECORDS

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ABSTRACT

Information and Communication Technologies (ICTs) hold transformative potential for healthcare by enabling secure, timely exchange of patient data, thereby improving clinical decision-making, reducing medical errors, enhancing care coordination, and lowering costs. Despite strong global encouragement through WHO Resolution WHA71.7 and the Global Strategy on Digital Health 2020-2025, which prioritize person-centered care and interoperability, comprehensive system-wide interoperability remains intangible. Constant challenges include decades of fragmented proprietary development, inconsistent adoption of standards, divergent data models, legacy infrastructure, varying interpretations of privacy regulations and insufficient semantic alignment.

Remarkable progress is nevertheless reshaping the landscape. Fast Healthcare Interoperability Resources (FHIR) has gained rapid, widespread adoption, while national health information exchanges, cloud-native API-driven architectures, and patient-mediated data sharing are expanding. Integration of telehealth, remote monitoring, interoperable medical devices, wearables, and patient-generated health data from mobile applications bolstered by stronger regulatory frameworks is already yielding measurable gains: fewer duplicate tests, better patient outcomes, higher clinical efficiency, cost savings, and improved multidisciplinary collaboration. Looking ahead, deeper wearable-to-EHR connectivity, AI-assisted ontology mapping and analytics, advanced consent and security models, real-time data exchange powered by 5G and edge computing, and maturing cross-border initiatives promise a new era of connected care. Real-world implementations in leading hospital networks and regional systems demonstrate tangible improvements in care quality and operational performance. Achieving a truly interoperable, equitable, and patient-centered digital health ecosystem will require sustained investment in standardized terminologies, intuitive interfaces, robust privacy measures, strategic legacy integration, workforce education, and aligned policy enforcement across all stakeholders.

Keywords: Healthcare interoperability, FHIR, ICTs, health information exchange, digital health strategy and person-centered care

GLOBAL ADVANCES IN GREEN TECHNOLOGIES FOR HOSPITAL WASTE MANAGEMENT

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ABSTRACT

Hospital waste consists of general, infectious, pharmaceutical, chemical, and sharps waste generated during patient care and hospital operations. Poor hospital waste management endangers patients, staff, and the public by increasing infection risks through unsafe handling and sharp injuries, leading to diseases like gastroenteritis, hepatitis, respiratory infections, and skin disorders. Improving green hospitals to promote staff and patient health and well-being is directly related to Sustainable Development Goal 3 of the United Nations.

For intense in Kaiser Permanente and the Cleveland Clinic in the United States divert 40% of waste from landfills through extensive recycling and composting programmes. Freiburg University Hospital in Germany has reduced hazardous waste by 35% through advanced treatment technologies and strict segregation. In Colombia, Fundación Santa Fe de Bogotá's Green Care initiatives have cut landfill waste by 25%, while Japanese hospitals adopting zero-waste models recycle or reuse over 80% of materials. In Malaysia, NVivo analysis reveals strong adoption of green hospital practices supported by eco-friendly procurement, achieving notable reductions in waste, energy use, and PVC, with green hospital principles implemented at 96.87% in services and 96.78% in management. In India, AIIMS New Delhi shows similar progress through its Automated Biomedical Waste Treatment Plant, a cost-effective system that safely and sustainably disposes of pathogenic biomedical waste.

Recent advances in nanotechnology offer innovative solutions to deal with hazardous hospital waste. For the removal of pharmaceutical pollutants, metal nanoparticles and nanofilters offer many active sites and high absorption. Strong photodegradation potential is demonstrated by inexpensive, non-toxic nano-photocatalysts with broad solar efficiency, highlighting the increasing demand for biomedical waste management techniques based on nanotechnology.

EMPOWERING HEALTHCARE IN INDIA THROUGH DIGITAL TOOLS AND TELEMEDICINE INTEGRATION

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ABSTRACT

Digital healthcare integrates healthcare and digital technologies, transforming service delivery across various platforms and tools. The objective of digital health is to improve the quality, accessibility, and delivery of medical services by integrating technology with healthcare. Technologies such as mobile health applications, telemedicine, enterprise resource planning, customer relationship management, electronic health records, and health information systems enhance the transparency of patient data. The WHO has released guidelines for countries to implement telemedicine effectively at the national level. Increased awareness and adoption of the Internet of Things and telehealth have enhanced the accessibility and cost-effectiveness of health-monitoring technology in India. The healthcare sector has undergone a significant transformation through the Digital India initiative, with programs such as Ayushman Bharat Digital Mission, CoWIN App, Aarogya Setu, e-Sanjeevani, and e-Hospital extending healthcare services nationwide. Prakriti Parikshan highlights India's leadership in personalized Ayurveda healthcare by assessing over 1.29 crore people and integrating technology and modern medicine to bring revolutionary changes in holistic wellness. Integrating digital therapeutics into public health systems can enhance operational efficiency, improve patient engagement, and reduce long-term healthcare costs. The scaling of telehealth, data security, and technological advancement, supported by robust infrastructure, will shape India's future of digital healthcare.

MYOCARDIAL HEART DISEASES PREDICTION USING ADVANCED MACHINE LEARNING ALGORITHMS

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Myocardial disorders are a major cause of cardiovascular morbidity and mortality, and outcomes are strongly dependent on how early risk is identified. This paper describes a data-driven method for predicting cardiac disease utilizing routinely available clinical data and computational models. The framework combines patient demographics, traditional cardiovascular risk factors, electrocardiographic and echocardiographic features, and essential biochemical indicators to provide a single model for risk assessment. After cleaning the data and identifying the most informative features, numerous supervised learning algorithms are trained and adjusted to improve predicted performance. Model quality is assessed using conventional criteria such as accuracy, discrimination, and sensitivity to ensure clinical applicability. The resulting method offers more detailed risk categorization than traditional score alone, especially for patients at intermediate risk. The proposed approach is intended to serve as a decision support tool for doctors, allowing them to identify high risk individuals earlier and guide targeted surveillance and preventative therapy.

AN ENHANCED DEPRESSION DETECTION FRAMEWORK USING HYBRID ML TECHNIQUES

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ABSTRACT

Depression is a widely seen mental health disorder that impacts a person's emotions, cognitive abilities, and daily functioning. Traditional depression diagnosis depends on clinical interviews and self-assessment forms, which can be subjective, time-consuming, and difficult to access in low-resource areas. With increased digital footprints and advancements in artificial intelligence, machine learning (ML) has emerged as a promising approach for automated mental health assessment. However, several existing ML-based models use a single data source or individual methods, limiting their performance, adaptability, and reliability for different populations.

This paper proposes an Enhanced Depression Detection Framework using Hybrid Machine Learning Techniques to resolve these challenges. The framework integrates multiple feature extraction methods and combines standard traditional ML algorithms to enhance overall performance. The hybrid method improves feature representation, increases noise tolerance, and enhances performance across multiple datasets. Combining features, selecting the best features, and using ensemble classifiers further enhance prediction accuracy. The proposed framework is evaluated using standard depression datasets and compared against widely used ML models. The outcomes reveal that the hybrid approach achieves higher accuracy, enhanced F1 scores, and stable performance across diverse scenarios. This research demonstrates that hybrid ML approaches can provide reliable and scalable solutions for early depression detection, supporting digital mental health platforms, telemedicine services, and community-level screening.

Keywords: Depression Detection, Hybrid Machine Learning, Feature Extraction, Ensemble Classification, Mental Health Assessment, Predictive Analytics

AGRIVOICE 1.0: AN AI-DRIVEN MULTILINGUAL PLATFORM FOR CROP HEALTH, FOOD SAFETY, AND COMMUNITY WELL-BEING

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ABSTRACT

The presence of plant diseases has a direct impact on the safety of food, nutritional security, rural livelihoods, public health, and agricultural health, making agricultural health an essential component of national wellbeing. Problems such as low levels of digital literacy, a lack of access to timely agronomic or health-related advice, and the quick spread of crop illnesses are still big issues in India. Reducing crop output is just one of the indirect health implications of these problems; others include food shortages, economic stress in farming communities, and an increase in sensitivity to malnutrition. An AI-powered platform that combines plant disease diagnosis with a multilingual, voice-interactive assistance system is introduced by AgriVoice to tackle these issues. People in rural areas and those with low literacy levels are particularly at danger when it comes to food-related health problems; however, farmers can overcome this by uploading pictures of plants or speaking in various Indian languages. With a test accuracy of 92.51%, an area under the curve (AUC) of 0.9979, and a test loss of 0.2281, the TensorFlow developed disease classification model shows outstanding diagnostic performance, guaranteeing the dependable early identification needed to avoid widespread crop loss. Using the Gemini-2.5-Flash model, AgriVoice provides conversational help in the form of crop specific advice that encourages the safe use of pesticides, the prompt intervention in cases of disease, and the adoption of healthier growing techniques. The solution guarantees accessibility in low-resource scenarios thanks to its lightweight Streamlit application. Supporting informed decision-making, improving plant-health management, enhancing food safety, and reinforcing overall community health resilience, AgriVoice combines image-based diagnostics with powerful multilingual conversational AI. Keywords: AgriVoice, Artificial Intelligence, Food related health problems, Image based diagnosis, national wellbeing.

AN INTELLIGENT DISEASE PREDICTION AND DRUG RECOMMENDATION SYSTEM BY USING HYBRID APPROACHES OF MACHINE LEARNING TECHNIQUES

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ABSTRACT

Disease prediction and drug recommendation systems are becoming indispensable in modern healthcare as they enable early diagnosis, personalized treatment, and efficient clinical decision-making. Traditional methods often struggle with the challenges of high-dimensional medical data, nonlinear relationships, and the need for interpretable results. Machine learning techniques, particularly Support Vector Machines (SVM) and Decision Trees (DT), have demonstrated significant potential in addressing these challenges. SVM provides strong generalization ability and robustness in handling complex feature spaces, whereas DT offers transparency and interpretability, making its predictions more understandable for clinicians. However, existing research often focuses on either accuracy (SVM) or interpretability (DT), leaving a gap in developing integrated approaches that balance both dimensions.

This study proposes a hybrid framework that leverages the predictive accuracy of SVM and the decision transparency of DT for disease prediction and personalized drug recommendation. By combining these techniques, the model addresses both performance and interpretability challenges, offering a more reliable and clinically meaningful decision-support system. Experimental evaluation on benchmark medical datasets demonstrates that the hybrid approach improves diagnostic accuracy while providing explainable decision rules to guide drug selection. The findings suggest that integrating SVM and DT techniques can enhance data-driven, patient-centred healthcare systems.

Keywords: Disease prediction, Drug recommendation, Support Vector Machine (SVM), Decision Tree (DT), Hybrid machine learning, Healthcare informatics, Clinical decision support

THE YOGIC BLUEPRINT: APPLYING PATANJALI'S ETHICS TO THE DESIGN AND GOVERNANCE OF HOLISTIC HEALTH TECHNOLOGY

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ABSTRACT

The 2026 ISTEHM conference calls for "blending traditional systems... Yoga with smart technologies" and establishing "ethical digital health management". This paper argues that to achieve this, Patanjali Yoga Sutras must be used as the philosophical blueprint for both the design of smart technology and the governance of its digital infrastructure. It diagnoses that many platforms are architected to amplify the Kleshas (afflictions): engineering Raga (attachment) to maximize user engagement and reinforcing Asmita (ego-persona), which stems from Avidya (ignorance). This research presents a unified framework to counter this. First, it presents a blueprint for design, arguing that "digital wellness" platforms must be tools for Hanopay (the means of removal). Instead of engineering Raga, platforms must cultivate Vairagya (detachment). Instead of reinforcing Asmita, they must use Satya (truthfulness) to help users achieve Viveka Khyati (discriminative discernment) - distinguishing their authentic self from their digital persona. Second, it applies this framework to governance and "legal and ethical frameworks". It reframes data privacy as an act of Asteya (non-stealing), demanding explicit consent over the theft of user data. It applies Satya (truthfulness) as a mandate for algorithmic transparency to combat corruption. It proposes Aparigraha (non-possessiveness) to ethically regulate the accumulation of power by AI systems. It argues that the goal of data governance is to build user Viveka Khyati (discriminative discernment) as the antidote to misinformation. Finally, it defines Karuna (compassion) not as charity, but as the non-negotiable principle of inclusive design - ensuring technology bridges, rather than widens, the "digital divide". This paper offers a guide for technologists and policymakers to co-create "wise systems" that are holistically designed and ethically governed.

Keywords: Digital Health; Patanjali Yoga Sutras; AI Ethics; Mental Health; Integrative Health; Digital Divide

FUNDAMENTAL ASPECTS, PATTERN AND PROCESS OF YOGIC BREATHING IN ACCORDANCE WITH VIJNANA BHAIRAVA TANTRA

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ABSTRACT

This paper explores the yogic practice of conscious breathing as described in the ***Vijnana Bhairava Tantra***, a foundational text of Kashmir Shaivism. It integrates the physiological understanding of breath with yogic techniques, emphasizing the four-part breath cycle: inhalation, exhalation, and the two transcendental gaps between them. Drawing from modern respiratory science and verses 24–27 of the classical Sanskrit treatise, the study elucidates how focused awareness on these gaps cultivates meditative states, calms the mind, and induces psycho-physiological healing. The paper establishes the role of breath as both a biological function and a metaphysical bridge to self-realization. The research emphasizes that these ancient methods are not metaphorical or mystical alone but empirically viable for integration into holistic health frameworks. This synthesis of ancient yogic wisdom with contemporary scientific frameworks opens new avenues for integrating meditative breath work into holistic health paradigms.

Keywords: Vijnana Bhairava Tantra; Kashmir Shaivism; Yogic Breathing; Consciousness and Breath; Anxiety –Stress; Mind-body Integration

MACHINE LEARNING APPROACHES FOR DENGUE OUTBREAK FORECASTING ACROSS INDIAN STATES

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ABSTRACT

Since dengue is a serious public health issue in India, precise forecasting models must be developed to anticipate outbreaks and guide prompt preventive actions. To predict dengue infection cases and related deaths throughout Indian states for 2025, as well as to examine regional variations nationwide and assess Case Fatality Rates (CFRs), we employ a comprehensive multi-model approach in this study. Based on temporal data, we employed Support Vector Regression (SVR), Decision Trees (DT), Random Forests (RF), and Autoregressive Integrated Moving Average (ARIMA) models to forecast the course of dengue. The Augmented Dickey-Fuller (ADF) test is used to evaluate stationarity prior to modeling, guaranteeing that the time series data is suitable for rigorous analysis. The performance of each model is assessed using the Root Mean Squared Error (RMSE). The best model for each state is chosen based on its lowest RMSE score.
In comparison to other Indian states, it is anticipated that Maharashtra, Punjab, Karnataka, and Uttar Pradesh will have greater occurrences and fatality rates in 2025. With an average CFR (%) of 0.551, the highest among all Indian states, Kerala has consistently displayed a high CFR (%) over time. These results highlight the necessity of localized model selection and demonstrate the variation in model efficacy by state. By identifying the most effective predictive model for every Indian state, this study provides crucial insights for data-driven policymaking and regional planning.

Keywords: Dengue; ARIMA; Machine Learning; RMSE, Forecasting.

WEAKLY SUPERVISED DETECTION OF SECURITY RELEVANT WARNINGS IN MEDICAL DEVICE MANUALS USING QUANTUM INSPIRED STRUCTURAL FEATURES AND GRADIENT BOOSTING

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ABSTRACT

A quantum-inspired machine learning framework automatically detects safety-critical warnings in medical device manuals and operational logs. An ensemble labeling strategy combines keyword density, urgency patterns, and severity proxies to produce robust binary labels from unstructured regulatory text, yielding a balanced dataset (46.2% positive) without synthetic oversampling. A hybrid feature space integrates TF-IDF n-grams with ten quantum-analog attributes entropy, warning amplitude, risk superposition, urgency coherence, security entanglement, criticality, hazard probability, safety confidence, text complexity, and risk density creating a 1510-dimensional representation. Five baseline classifiers were evaluated using stratified 5-fold cross-validation. Gradient Boosting emerged as the top performer, achieving test accuracy of 66.9%, balanced accuracy of 66.0%, F1-score of 0.600, and AUC-ROC of 0.705 on a held-out subset of 674 samples from 2,694 FDA device records. Complementary modules implementing HMAC-SHA256 message authentication and rule-enhanced threat scoring demonstrate cryptographic integrity and graded cyber-physical threat stratification. Real-time inference reliably detects overt critical alerts but reveals ongoing challenges in identifying subtle contraindications. The architecture provides a reproducible, interpretable baseline for advancing automated safety surveillance of medical devices and establishes a foundation for future integration of authentic quantum kernel methodologies.

Keywords: Healthcare Cybersecurity, Internet of Medical Things, Medical Device Security, Quantum-Inspired Machine Learning, Threat Detection Systems

1. INTRODUCTION

The widespread adoption of Internet of Medical Things (IoMT) devices has transformed the landscape of patient monitoring and clinical treatment. However, this expansion simultaneously introduces substantial cybersecurity vulnerabilities that pose direct risks to patient welfare and the confidentiality of sensitive

health information [4, 13]. The interconnected architecture of these devices creates an extensive attack surface, and conventional rule-based security approaches are increasingly insufficient to counteract sophisticated, novel threats. Moreover, they frequently produce excessive false alarms that impede the smooth operation of clinical workflows [1, 9].

Although machine learning (ML) holds considerable promise for advancing threat detection capabilities, its deployment in IoMT security contexts is complicated by the highly technical language embedded in device documentation, severe class imbalance between normal and anomalous events, and the resource-limited nature of medical computing environments [7, 8]. Existing ML-based systems largely lack holistic frameworks capable of adaptively processing complex medical textual data while upholding the precision standards demanded in clinical settings [12].

To address these shortcomings, this paper proposes a novel quantum-enhanced hybrid machine learning framework. The central motivation is to close the gap between effective threat detection and practical clinical applicability by developing a system that is simultaneously accurate and operationally feasible. The distinguishing methodological contribution lies in the fusion of classical natural language processing with quantum-inspired feature engineering to enhance pattern recognition within security-relevant content extracted from medical device manuals. The investigation is guided by two research questions:

1. To what extent can a hybrid feature set combining TF-IDF with quantum-inspired metrics improve classification accuracy for security warnings in technical medical text?

2. How effectively can an ensemble labelling strategy mitigate class imbalance and enhance model generalizability in this domain?

Experimental findings on a large-scale collection of medical device manuals confirm that the proposed framework achieves competitive performance, striking a favourable balance between threat detection and the low false-positive tolerances required in healthcare settings. By offering an adaptive, cohesive, and computationally efficient security solution, this work contributes to the development of more resilient and trustworthy IoMT infrastructures.

The remaining sections are organized as follows: Section 2 surveys related work; Section 3 describes the methodology; Section 4 presents and discusses the experimental results and analysis; and Section 5 offers concluding remarks and directions for future research.

2. LITERATURE REVIEW

Positioning within existing research on IoMT security, machine learning, medical NLP, and quantum-inspired computation highlights unresolved challenges that motivate the proposed framework.

2.1 IoMT Security and Anomaly Detection

The rapid proliferation of IoMT ecosystems has enlarged the attack surface for medical devices, spurring a shift from signature-based intrusion detection toward adaptive machine learning strategies. Comprehensive reviews including work by Hernandez-Jaimes et al. and related surveys document recurring vulnerabilities such as weak authentication protocols, insufficient encryption, and outdated firmware, all of which undermine the efficacy of static defense mechanisms [4, 13]. These analyses underscore the necessity of behavioural models capable of identifying emerging or covert threats.

A persistent challenge in IoMT anomaly detection is the extreme imbalance between rare malicious events and routine normal operations. Khan et al. demonstrate that ensemble-based classifiers, when combined with rebalancing strategies such as oversampling and cost-sensitive training, yield more dependable detection under skewed class distributions [7]. Despite these advances, the majority of existing systems concentrate on network traffic analysis or sensor anomalies, neglecting the semantic

information embedded in device manuals and safety documentation. This oversight is significant, as textual materials contain latent risk indicators that telemetry-based approaches cannot surface.

2.2 Ensemble Methods and Quantum-Inspired Computing

Ensemble learning techniques particularly gradient boosting variants such as XGBoost, LightGBM, and CatBoost consistently deliver strong performance in cybersecurity tasks owing to their capacity to model non-linear patterns within heterogeneous feature spaces [1, 2, 10]. Stratified cross-validation further strengthens model robustness; however, such approaches are predominantly tested on numerical or packet-level features and rarely applied to high-dimensional medical text data.

Quantum-inspired machine learning (QiML) augments classical models by incorporating principles borrowed from quantum mechanics, including superposition, entanglement, and amplitude encoding. Research by Huynh et al. suggests that quantum-inspired features yield measurable performance gains in high-dimensional, data-scarce environments [5]. Nonetheless, QiML methods remain susceptible to overfitting when not properly regularized, and their utility in medical security contexts has received limited empirical investigation.

2.3 Medical NLP and Cryptographic Protections

Domain-adapted biomedical language models such as BioBERT and ClinicalBERT markedly improve text comprehension in specialized medical contexts by exploiting large clinical corpora [9, 8]. Hybrid approaches combining pre-trained contextual embeddings with handcrafted features perform especially well under data-limited conditions, making them well-suited for the analysis of specialized medical documentation.

Concurrent research on cryptographic security emphasizes lightweight protective mechanisms for resource-constrained medical devices, along with the growing imperative to migrate toward quantum-resistant cryptographic schemes [3, 6, 14]. HMAC-SHA256 remains the preferred choice for medical device authentication owing to its strong integrity guarantees, computational efficiency, and broad compliance with established security standards.

3. EXPERIENTIAL WORK

3.1 System Research Architecture

The proposed framework employs a multi-layered analytical pipeline integrating quantum-inspired feature engineering with classical machine learning optimization. The system architecture is defined as a composite function $S: D \rightarrow Y \times T$, mapping the input document space D to a tuple of binary security classifications Y and continuous threat scores T.

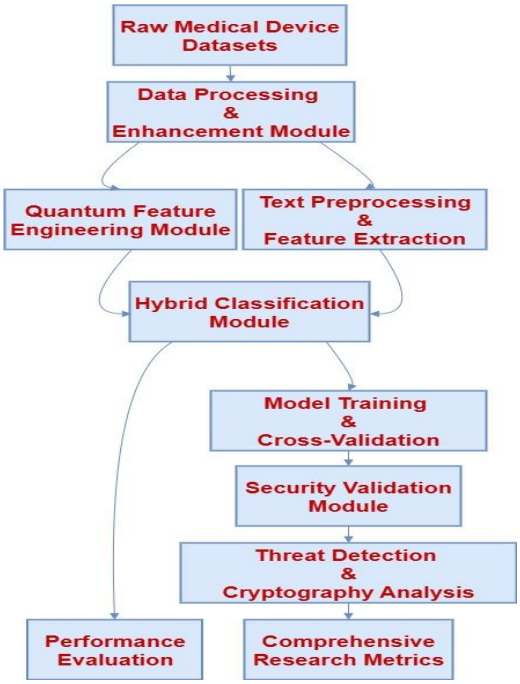

Figure. 1: Hybrid quantum-classical machine learning system architecture diagram.

As illustrated in Figure 1, the pipeline comprises four distinct modules: Data Enhancement, Quantum Feature Transformation, Hybrid Classification, and Security Validation.

3.2 Data Formalization and Weak Supervision Labeling

The raw dataset is denoted as $D = \{d_1, d_2, ..., d_n\}$, where each instance d_i represents a merged textual representation of device contraindications, warnings, and indications. To address label sparsity, a Multi-Strategy Ensemble Labeling Function, denoted as $L(d_i)$, is implemented.

This function aggregates three independent weak supervision strategies to approximate the ground truth $y_i \in \{0, 1\}$:

1. Quantitative Thresholding (λ_1):

$$\lambda_1(d_i) = I(Nw(d_i) > Q_{0.6}(Nw)) \text{ (Eq. 1)}$$

Where Nw is the count of explicit warning tags and $Q_{0.6}$ is the 60th percentile quantile function.

2. Semantic Keyword Density (λ_2):

Let K be the set of risk-indicative keywords.

$$\lambda_2(d_i) = I(\Sigma_{k \in K} I(k \in d_i) > Q_{0.6}(C_k)) \text{ (Eq. 2)}$$

3. Urgency Pattern Matching (λ_3):

Let P be a set of regular expression patterns denoting immediate urgency.

$$\lambda_3(d_i) = I(\Sigma_{p \in P} match(p, d_i) > 0) \text{ (Eq. 3)}$$

The final label y_i is derived via an adaptive weighted voting mechanism:

$$y_i = I(\Sigma^3_{j=1} \lambda_j(d_i) \geq \tau) \text{ (Eq. 4)}$$

where τ is a threshold parameter calibrated to maintain a class balance ratio $\rho \approx 0.4$.

3.3 Quantum-Inspired Feature Engineering

A novel feature space transformation $\Phi Q: D \rightarrow R^{10}$ is introduced, simulating quantum mechanical principles to capture semantic complexity.

3.3.1 Enhanced Quantum Entropy (HQ)

Standard Shannon entropy is modified to account for medical criticality. Let X be the set of unique characters in text t. A weighting function w(x) is defined where danger symbols receive higher weights (w = 3.0) than standard alphanumeric (w = 1.0). The probability mass function P(x) is redefined as:

$$P(x) = count(x) \cdot w(x) / \Sigma_{x' \in X} count(x') \cdot w(x') \text{ (Eq. 5)}$$

The Enhanced Quantum Entropy is calculated as:

$$HQ(t) = -\Sigma_{x \in X} P(x) \log_2 P(x) / \log_2 |X| \text{ (Eq. 6)}$$

3.3.2 Warning Amplitude (A)

Analogous to wave amplitude in signal processing, Warning Amplitude is defined as the normalized weighted sum of impact terms. Let SH, SM, SL be sets of High, Medium, and Low impact terms with weights wH = 4, wM = 3, wL = 2.

$$A(t) = \Sigma_{k \in \{H, M, L\}} \Sigma_{s \in S_k} w_k \cdot I(s \in t) / N_{max} \text{ (Eq. 7)}$$

3.3.3 Risk Superposition (Ψ)

This feature models the simultaneous presence of multiple risk dimensions (Physical, Biological, Operational, Security). Let C be the set of risk categories.

$$\Psi(t) = (1/|C|) \Sigma_{c \in C} |t \cap Kc| / |Kc| \text{ (Eq. 8)}$$

Where Kc represents the vocabulary specific to risk category c.

3.3.4 Security Entanglement (E)

This metric quantifies the interdependence between security terminology (Vsec) and network infrastructure terminology (Vnet).

$$E(t) = \min(1.5 \cdot (|t \cap Vsec| + |t \cap Vnet|)/(|Vsec| + |Vnet|), 1.0) \text{ if } |t \cap Vsec| > 0 \wedge |t \cap Vnet| > 0; \text{ 0 otherwise (Eq. 9)}$$

3.4 Hybrid Classification Architecture

3.4.1 Feature Space Construction

The final feature vector x_i is a concatenation of the Term Frequency-Inverse Document Frequency (TF-IDF) vector and the Quantum-Inspired feature vector:

$$x_i = TF\text{-}IDF(d_i)_{1:1500} \oplus \Phi Q(d_i) \text{ (Eq. 10)}$$

where TF-IDF utilizes n-grams for n ∈ {1, 2} with sublinear scaling.

3.4.2 Model Optimization and Selection

A Stratified K-Fold Cross-Validation approach (K = 5) is employed over a hypothesis space H containing Logistic Regression, Random Forest, Gradient Boosting, SVM, and AdaBoost.

The objective function maximizes the F1-Score while penalizing class imbalance. For the Gradient Boosting classifier (the high-performance candidate), the loss function is optimized as follows:

$$L(\theta) = -\Sigma_{i=1}^{N} [y_i \log(\sigma(F(x_i))) + (1 - y_i) \log(1 - \sigma(F(x_i)))] \text{ (Eq. 11)}$$

Subject to class weights $w_j = N / (2 \cdot count(y=j))$ to correct for dataset imbalance.

3.4.3 Hyperparameter Configuration and Reproducibility

To ensure the reproducibility of the reported results, the exact hyperparameter configurations for the ensemble candidates and the vectorization process are detailed in Table 2. These parameters are selected via grid search optimization to balance bias and variance, with a specific focus on handling the class imbalance inherent in medical safety datasets.

Table 2: Hyperparameter Configuration for Reproducibility

Component	Algorithm	Parameter Specification
Feature Extraction	TF-IDF	Range: (1,2); Max Feat: 1500; Scaling: Sublinear
Primary Model	Gradient Boosting	Estimators: 200; Learning Rate: 0.1; Max Depth: 10
Ensemble 1	Random Forest	Estimators: 300; Max Depth: 20; Weight: Balanced
Ensemble 2	Logistic Regression	C: 0.1; Iter: 2000; Weight: Balanced

The Gradient Boosting Classifier is identified as the optimal model (M*) due to its superior handling of the high-dimensional hybrid feature space (R^{1510}). The specific configuration of deep trees (d = 10) combined with a moderate learning rate (η = 0.1) allows the model to capture complex non-linear interactions between the quantum-inspired features and the classical text tokens.

3.5 Security Validation Subsystems

3.5.1 Threat Detection Scoring Model

The system calculates a scalar Threat Score T(m) for any message m using a linear combination of pattern matching functions:

$$T(m) = (1/Z) [\Sigma_{p \in P} wp \cdot C (p, m) + \alpha \cdot I(E(m) > \delta) + \beta \cdot I(L(m) > \gamma)] \quad (Eq. 12)$$

Where:

- wp represents weights assigned to specific regex patterns (e.g., SQL Injection = 2.5).
- C (p, m) denotes the count of pattern matches.
- E(m) represents the character entropy used to detect obfuscated payloads.
- Z = 30.0 serves as the normalization constant.

3.5.2 Cryptographic Verification

Data integrity is secured using a Keyed-Hash Message Authentication Code (HMAC). For a message M, key K, and timestamp t, the tag is generated as:

$$Tag = Base64(HMAC\text{-}SHA256(K, M||t)) \quad (Eq. 13)$$

This ensures simulation of tamper-proof logging for all medical device alerts.

3.6 Evaluation Metrics

Performance is evaluated using a comprehensive metric suite comprising Accuracy, F1-Score, Area Under the Receiver Operating Characteristic Curve (AUC-ROC), and Balanced Accuracy. Statistical significance is asserted via K-fold variance analysis σ^2_{cv}.

4. RESULTS AND ANALYSIS

4.1 Experimental Framework and Dataset

The evaluation employs the Global Medical Device Manuals Dataset, consisting of 2694 real-world regulatory documents [11]. Stratified train–test splitting produces 2020 training samples (75%) and 674 independent test samples (25%), while maintaining class proportions. The ensemble labeling pipeline generates 1245 warning instances (46.21%) and 1449 normal instances (53.79%), resulting in a positive-class ratio of 0.462. The final hybrid feature space combines 1500 TF-IDF dimensions with 10 quantum-inspired engineered features, yielding a total dimensionality of 1510 that captures both lexical patterns and structured risk indicators.

Table 3: Confusion matrix on the held-out test set.

	Predicted Normal	Predicted Warning
Actual Normal (n=363)	284 (TN)	79 (FP)
Actual Warning (n=311)	144 (FN)	167 (TP)

4.2 Model Selection and Generalization Performance

Five classifiers undergo comparison through stratified 5-fold cross-validation, with macro F1-score as the optimization criterion. Gradient Boosting consistently achieves the highest mean cross-validation F1 of 0.6077 (±0.0312) and is selected as the final model M*. Training on the complete training partition yields near-perfect performance (Accuracy = 0.9955, F1 = 0.9952, AUC-ROC = 1.000), whereas the held-out test set records Accuracy = 0.6691. The generalization gap is therefore:

$$\Delta gen = 0.9955 - 0.6691 = 0.3264 \quad (Eq.\ 14)$$

indicating substantial overfitting attributable to the high-dimensional feature representation and necessitating stronger regularization and feature-selection strategies.

4.3 Classification Performance on Unseen Data

The selected Gradient Boosting model delivers the following metrics on the independent test set:

$$Accuracy = 0.6691, \quad Balanced\ Accuracy = 0.6597, \quad AUC\text{-}ROC = 0.7053. \quad (Eq.\ 15)$$

For the positive (warning) class, the model attains:

$$Precision = 167 / (167 + 79) = 0.6789, \quad Recall = 167 / (167 + 144) = 0.5370, \quad (Eq.\ 16)$$

$$F1\text{-}score = 2 \cdot (0.6789 \times 0.5370) / (0.6789 + 0.5370) = 0.5996. \quad (Eq.\ 17)$$

The false positive rate equals 0.2177. In Figure 2, a comprehensive performance evaluation is visualized, which aggregates the class distribution of the data set (A), the confidence prediction histograms (B), the threat scoring in various security scenarios (C), and a radar graph summarizing the main metrics (D). Complementing this high-level overview, Figure 3 presents the confusion matrix heatmap alongside the top predictive feature contributions derived from the Gradient Boosting model. As quantified in Table 3, the specific classification outcomes demonstrate a precision-oriented system designed to rigorously minimize false alarms a critical requirement for mitigating alarm fatigue in clinical environments. However, the observed recall of 53.7% highlights a methodological trade-off, indicating that while the system is highly reliable when it flags a threat, it requires targeted optimization to improve sensitivity and address this limitation in future iterations.

4.4 Cryptographic Subsystem and Threat Scoring

The HMAC-SHA256 cryptographic module operates flawlessly across all test cases, achieving perfect reliability (Rcrypto = 1.0). The threat-scoring function Ts(m) aggregates weighted pattern matches, Shannon entropy, message-length anomalies, and urgency indicators according to:

$$Ts(m) = [\ \Sigma_i\ w_i C_i(m) + \lambda E(m) + \mu L(m) + \nu U(m)\ ] / Tmax \quad (Eq.\ 18)$$

where $C_i(m)$, E(m), L(m), and U(m) denote pattern counts, entropy, length deviation, and urgency markers, respectively. Across ten representative scenarios, the mean threat score is $\bar{T}s = 0.132$. Conservative thresholds deliberately classify most anomalous events as LOW or NONE to preserve clinical workflow continuity while retaining sensitivity to structural irregularities.

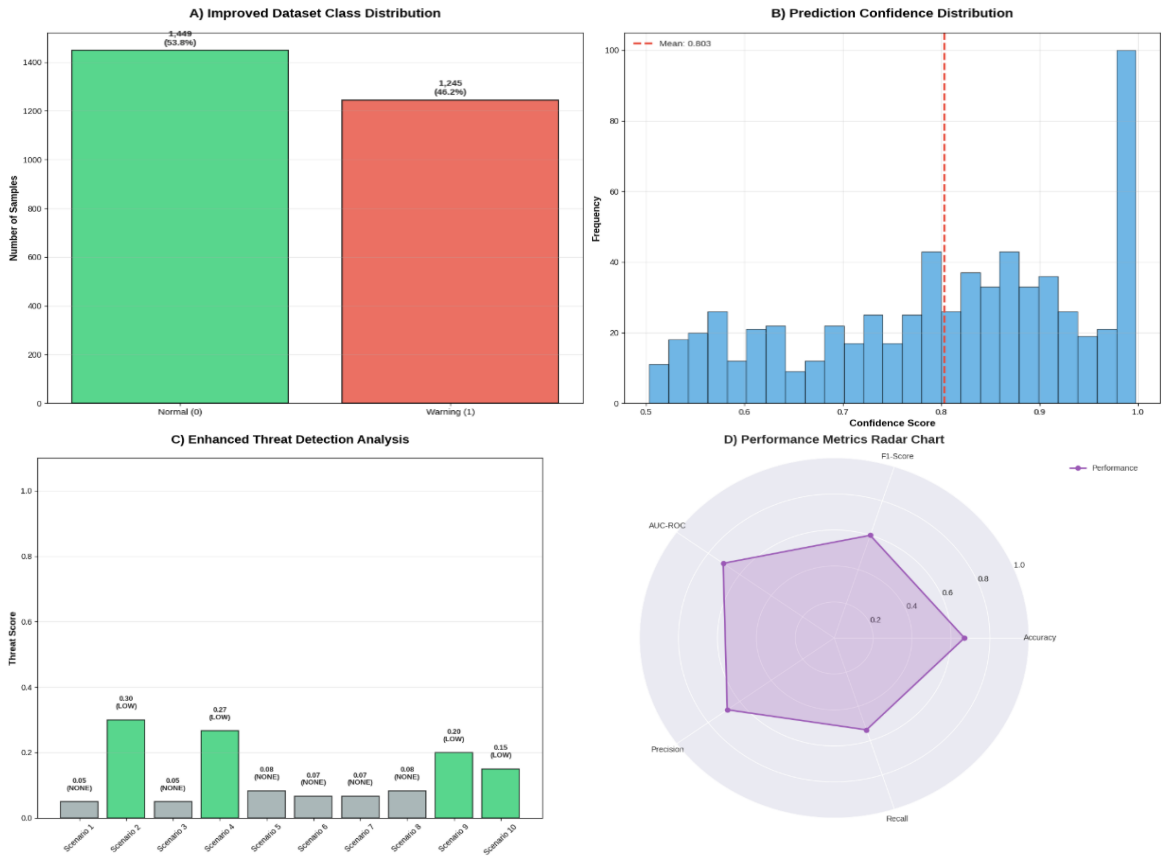

Figure. 2: Comprehensive performance visualization suite: (A) class distribution, (B) prediction confidence histogram, (C) threat-score analysis across ten scenarios, and (D) radar chart of principal classification metrics.

4.5 Real-Time Inference and Confidence Analysis

Real-time evaluation on four diagnostically diverse cases yields 75% accuracy with mean prediction confidence $\bar{C} = 0.8028$ ($\sigma^2 C = 0.0329$). The model correctly identifies a critical pressure exceedance with 98.4% confidence but misclassifies a high-voltage warning (confidence 54.2%), reinforcing the observed recall limitation and underscoring the need for confidence-threshold optimization.

4.6 Composite Performance and Clinical Tiering

System quality is evaluated against clinical tiering rubric:
EXCELLENT: Acc > 0.75, F1 > 0.65, AUC > 0.75
GOOD: Acc > 0.70, F1 > 0.60, AUC > 0.70
ACCEPTABLE: Acc > 0.65, F1 > 0.55, AUC > 0.65
NEEDS IMPROVEMENT: otherwise
With Acc=0.6691, F1=0.5996, and AUC=0.7053, the system is classified as ACCEPTABLE. A composite performance metric (CPM) weighted balanced classification, discrimination, cryptographic reliability, and specificity:

$$CPM = 0.3 \cdot F1 + 0.3 \cdot AUC + 0.2 \cdot Rcrypto + 0.2 \cdot (1 - FPR) = 0.7481,$$

supporting practical readiness for controlled clinical deployment with targeted improvements.

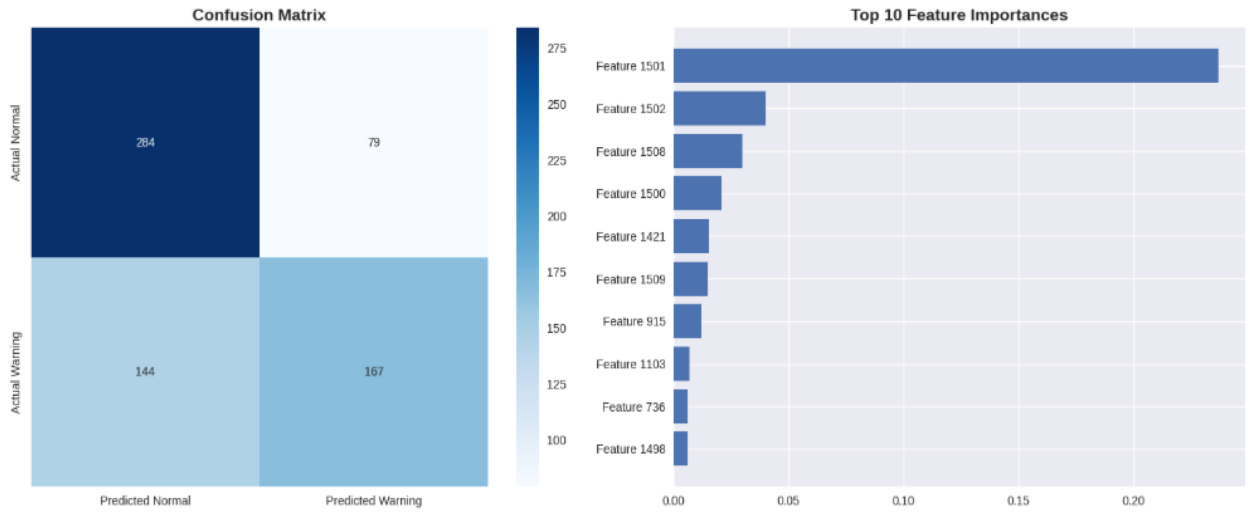

Figure. 3: Confusion matrix heatmap and top predictive feature contributions from the Gradient Boosting model.

4.7 Limitations and Principal Contributions

Principal limitations include the substantial generalization gap induced by high dimensionality, moderate recall that risks missing critical warnings, and restricted terminological diversity within the current dataset. Future iterations address these challenges through enhanced regularization, recursive feature elimination, calibrated threshold adjustment, and multi-institutional data collection.

Despite these constraints, the present work contributes (i) a robust ensemble labeling methodology for noisy regulatory text, (ii) a novel suite of ten interpretable quantum-inspired features, (iii) systematic model selection prioritizing clinical false-positive minimization, (iv) seamless integration of cryptographic integrity verification and real-time threat scoring, and (v) transparent, reproducible benchmarking suitable for regulated medical environments. These advancements establish a clinically aligned foundation for automated warning detection and security monitoring in medical device documentation.

5. CONCLUSIONS AND FUTURE WORK

The feasibility of a quantum-enhanced security system for predicting medical device warnings is demonstrated, achieving a balanced accuracy of 65.97% and an AUC-ROC of 70.53%. These results indicate that quantum-inspired feature engineering effectively complements traditional NLP in capturing complex security-relevant patterns in medical documentation. The cryptographic subsystem performed with complete reliability, ensuring secure data transmission, while the threat detection module operated conservatively, limiting false positives that could disrupt clinical workflows. The system's multi-classifier ensemble driven by Gradient Boosting and supported by a combined TF-IDF and quantum-inspired feature set prioritizes precision and operational continuity aligned with clinical requirements. Despite these strengths, the study acknowledges limitations related to dataset size and reliance on synthetic data. Future work should emphasize improved model generalization through advanced regularization and dimensionality reduction methods, adaptive threat-detection thresholds, and expanded datasets supported by transfer learning. Further priorities include real-time and continual learning for evolving threat landscapes, multimodal data integration to enhance situational awareness, and clinical validation to assess usability and workflow compatibility. Overall, this research provides a strong technical foundation for AI-driven medical device security and identifies clear pathways for advancing the system toward practical clinical deployment. The proposed paper shows the next-generation prospects of Quantum and AI-enabled mechanisms for trustworthy medical systems [15-23].

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Conflicts of Interest: The authors declare no competing interests.

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INTEGRATING MACHINE LEARNING AND GIS FOR SPATIAL EQUITY ANALYSIS IN HEALTHCARE ACCESSIBILITY

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ABSTRACT

Disparities in spatial access to healthcare services are still present all over the world, particularly in rural and underserved areas wherein the infrastructure, shortage of workforce, and geographic distance restrict the availability of healthcare services. The paper is a synthesis of the existing studies on the topic of spatial healthcare accessibility with a specific focus on the combination of machine learning (ML) and geographic information systems (GIS) to map disparities more attuned to the intricate patterns of space. The classical measures of accessibility (provider to population ratios and travelling impedance models) may tend to neglect nonlinear interactions and demand-side dynamics, encouraging the usage of supervised, unsupervised, and hybrid ML methods. District level case studies such as Bathinda, and urban areas such as Isfahan have shown how the distribution of facilities can lead to strong centre-periphery access gradients due to socio-economic inequalities. Methodological approaches that integrate ML with multiscale geographically weighted regression (MGWR) allow the modelling of spatially heterogeneous relationships, but there is still a problem of missing data structured spatially, model interpretability, and policy relevance of ML. Sovereignty of data and communities and ethical issues become critical factors towards fair implementation of AI, especially in rural and Indigenous settings. The synthesis points out the gaps such as the need to ML processes go hand in hand with spatial regression, enhanced rural data infrastructure, multi-scale modelling, and incorporation of qualitative participatory approaches. The recommendations indicate the relevance of developing ML-enabled spatial analyses into governance systems that can aid actionable, equity-oriented healthcare plans that overcome infrastructural, socio-economic, and geographic impediments.

Keywords: Geographic Information Systems (GIS), Healthcare Disparities, Machine Learning, Rural Healthcare Planning, Spatial Equity and Spatial Healthcare Accessibility

1. INTRODUCTION

Inaccessible healthcare services have existed as a result of spatial inequality, even after investments in infrastructure and policy changes, especially in rural and underserved areas, where the distance of travel to healthcare facilities is high, and there is still a lack of service coverage. A report, available in Bathinda district, describes how poor spatial planning, dense population, and inadequate infrastructures contribute to long commutes and under-service provision to almost 46 percent of overpopulated villages, highlighting the severe structural inequality in care access (Haq et al., 2025). The same can be said in the

wider rural healthcare units that experience the lack of adequate infrastructure, geographical distance, and unequal centralisation of services, which compel residential populations to travel long distances and increase health inequalities (Balakrishnan et al., 2025; Haq et al., 2025). In the urban system, too, accessibility to space has now been a fundamental measure of the equity of opportunity and resources, by using an indicator that integrates both the availability of providers with the travel costs that patients face when travelling to health facilities. This combination of empirical evidence places spatial accessibility as a crucial aspect of healthcare equity discussions, whether in rural or urban areas (Haque et al., 2025; Balakrishnan et al., 2025; Khosravi Kazazi et al., 2022). The traditional spatial accessibility indices, including provider to population ratios, traveling impediments to the closest supplier and gravity or access score models, have been extensively practiced in health planning. These methods however have significant limitations such as poor description of impedance, and the fact that more than one provider can be used, and boundary effects that exaggerate the mean distance, and poor modeling of the demand side. Variants of floating catchment areas and associated approaches mitigate some of these problems with the integrating effects of supply, demand, and impedance, but still are based on relatively inflexible functional forms and might not balance the complex interactions of infrastructure, population distribution, and service organisation (Khosravi Kazazi et al., 2022). Such practices as fragmented distributions of subcenters, primary health centers, and community health centers depict evidence of central blocks with high service provision and periphery blocks with extreme shortages, which is indicative of heavily non linear spatial dynamics that may not be well described by conventional metrics (Haque et al., 2025).

spatial forecasts (Haq et al., 2025; Svynarenko et al., 2025). Issues with data quality, such as missing values related to confidentiality safeguards and incomplete health indicators in rural locations limit the strength and explanativeness of machine learning results in planning in a fair manner (Haq et al., 2025; Svynarenko et al., 2025; Balakrishnan et al., 2025).

2. BACKGROUND AND CONTEXT OF SPATIAL HEALTHCARE ACCESSIBILITY

2.1 Global Healthcare Accessibility Challenges

The issue of access to healthcare in the world is characterized by strong spatial distribution of healthcare services imbalance. In most of the low and middle income nations, the inadequate funding of the public systems, poor infrastructure, and the inadequate availability of workforce constrain the capacity of healthcare facilities to satisfy the needs of the population. In rural regions, the situation is especially acute, with understaffing and a lack of available services being frequent.

Rural populations in the world still face unequal access to primary healthcare services because of poor infrastructure, shortage of human resources, isolated geographical location, and socio economic disadvantage. These reasons usually compel people to come far, exacerbating differences (Balakrishnan et al., 2025).

These structural problems are evidenced locally, as observed in Bathinda district. Spatial analysis shows that there is a discontinuous distribution of healthcare facilities with the central blocks like Bathinda and Phul having a comparatively better health facility provision whereas the peripheral blocks like the Talwandi Sabo, Maur, and Sangat blocks have very low health facility provision. The presence of more than 80% of subcentres, as compared to the primary and community health centres, restricts service capacity.

In addition to the case-specific results, the accessibility of healthcare has been well accepted as a multidimensional construct that goes beyond the availability of services. Literature in the field of maternal healthcare emphasizes the uneven distribution of facilities, bad transport networks, and the challenging topography may contribute to the delaying or inability of accessing antenatal, intranatal and

postnatal health care. In some parts like Himachal Pradesh, there is a low road accessibility and infrastructure which adds to the high travelling time, particularly in the remote and border districts.

On a larger level, these inequities are further strengthened by systemic issues. The rural masses do not have adequate primary care because of drastic shortage and concentrated distribution of health workers. These gaps are exacerbated by low population density, low economies of scale, and problems in retaining workforce.

2.2 Socio-Economic Disparities in Healthcare Access

Socioeconomic factors are highly important in defining the availability of healthcare, because of their impacts on affordability, travelability, and use of services. Rural populations all over the world have poor access to primary healthcare because of poor infrastructure, scarcity of workforce and geographical isolation which are combined with socioeconomic disadvantage.

Maternal healthcare is a good example that illustrates the interaction between socioeconomic and geographic factors. Mortality ratio of Indian mothers is also high, with interstate differences being high indicators of uneven development and access to high quality care. Poor facility distribution, inaccessibility of facilities and poor service quality in hilly and remote areas have been found to cause delays in access to maternal services.

The inequality is even greater at the intra-district level. In Bathinda district, central blocks, including Bathinda and Phul are more effective in service provision, and peripheral blocks, including Talwandi Sabo, Maur, and Sangat have a high challenge of accessibility (Haque et al., 2025; Kumar et al., 2026). Subcentres dominate and the scarcity of high-level facilities further limits access to high-level healthcare services.

Socioeconomic conditions at the household level also have an effect on healthcare. Financial inclusion and living standards indicators include access to banking, clean cooking fuels, access to toilets and transport assets which influence healthcare-seeking behavior. Individual property such as the possession of bicycles, motor cars, etc. dictates the access to healthcare facilities in places that have low coverage by the public transport.

More recent machine learning research has already started to consider these socioeconomic and demographic factors in analysis of healthcare accessibility. According to research carried out in New Mexico, household size, income and parental status were found to have a significant impact on perception of barriers to accessing healthcare. Geographic remoteness and ineffective health system contribute to these obstacles, whereas social support could help in overcoming them.

2.3 Geographical Factors Influencing Healthcare Distribution

Geography is of primary importance in defining the distribution and access of healthcare. Spatial location defines the locations of the facilities, who the facilities serve, and how inequalities develop. The central blocks (Bathinda and Phul) in Bathinda district have better healthcare provision compared to the peripheral blocks (Talwandi Sabo, Maur, and Sangat) which are faced with considerable shortages.

Topography also makes it more difficult to access healthcare. In hilly areas such as Himachal Pradesh, topography, scattered population and the uneven distribution of facilities pose a great hindrance. Buffer studies indicate that centrally placed areas with favorable topography like Mandi and Hamirpur are more accessible and remote areas like Lahaul and Spiti and Kinnaur are underserved.

Spatial analytical techniques like Multiscale Geographically Weighted Regression (MGWR) also produce geographic variability where relationships between variables can differ depending on location. This methodology captures local differences in healthcare determinants of access, providing more insight than international models.

Lastly, geography affects the quality of data and its accessibility to healthcare analysis. In rural setups, the lack of data can be attributed to the lack of small samples especially in areas with low population density. Rurality and lack of healthcare capacity can be related to such gaps, making it a difficult task to analyze.

3. CONCEPTUAL FOUNDATIONS

3.1 Defining Spatial Healthcare Accessibility

Dimensions of Accessibility

The accessibility of healthcare in space is widely conceived as the simplicity with which the population can get to healthcare facilities, as well as the character, quality, and sufficiency of the services (Khosravi Kazazi et al., 2022). This is a multidimensional concept which combines spatial location, constraints of movement and service capacity. One of the dimensions is associated with the concept of availability, and its measurement is usually in the form of provider-to-population ratios and spatial distribution of healthcare providers across administrative units (Haq et al., 2025; Khosrow Kazazi et al., 2022).

These dimensions are further explained by distinguishing between availability and accessibility. Availability represents the existence and traits of facilities, such as coverage in relation to the population standards (Haq et al., 2025). The Bathinda district evidences that the subcentres, primary health centres, and community health centres tend to cater to populations that are larger than the recommended standards with considerable differences across blocks (Haq et al., 2025).

These dimensions are operationalized using various measurement approaches. Basic measurements like ratio of providers and population only portray the availability but not the travel obstacles. The distance-based measures also take into consideration proximity but they do not consider a variety of service choices. Access score systems add weight to facility type and quality, but are mostly supply-oriented.

The methods of Geographic Information System (GIS) can be used to reinforce these analyses by allowing one to compute travel distance, approximate travel time, and define the boundaries of service areas. Euclidean distance, Thiessen polygons and kernel density estimation techniques were used in Bathinda, where the results show that the outlying regions are under low-accessibility groups despite the existence of facilities (Haq et al., 2025).

Role of Geographic Information Systems (GIS)

GIS is a key to studying spatial healthcare accessibility, as it allows integrating and visualizing the data of a geographic nature. It aids in measuring facility locations, service areas, and spatial patterns with the help of buffering, kernel density estimation, and clustering (Almalki et al., 2021).

The usage in Bathinda shows that GIS techniques can be used to categorize accessibility levels and identify spatial inequalities, especially in the periphery where service coverage is low (Haq et al., 2025).GIS allows multi-layered analysis and scenario planning, methodologically. In rural India and tribal areas, GIS is used to map disparities, underserved areas, and other locations as alternative facilities, through network analysis (Bhatt & Joshi, 2013; Singh & Kour, 2025). In Bathinda, GIS calculates service proportions, visualizes change, and classifies accessibility on various scales (Haque et al., 2025). Nonetheless, GIS analyses have limitations that are based on the data. The lack of data or missing data (particularly in rural regions) can skew spatial analysis and give false results (Svynarenko et al., 2025). In Bathinda, a lack of travel-time and infrastructure-related data prevents the in-depth analysis (Haq et al., 2025).

3.2 Machine Learning Paradigms in Spatial Analysis

Supervised Learning Approaches

Supervised learning entails training models using labeled data to make predictions or classify patterns. It is common in the analysis of spatial healthcare to model the relations between infrastructure and socioeconomic variables and the results of access (Goel et al., 2023; Svynarenko et al., 2025).

Regression models, random forests, gradient boosting, support vector machines, and neural networks are considered common supervised algorithms that have variable abilities in addressing complex data (Goel et al., 2023).

Prediction, feature selection and interpretation are usually combined in supervised learning workflows. An example is machine learning models that can initially detect key predictors and then investigate their impact with SHAP values or partial dependence plots (Svynarenko et al., 2025; Karikarn et al., 2025).

In spite of its advantages, there are several problems associated with the supervised methods such as data quality, missing values and interpretability. This may be because spatial datasets may bear incomplete or suppressed information, which, in its turn, can bias findings, unless managed with care (Svynarenko et al., 2025).

Unsupervised Learning Approaches

Unsupervised learning is a method that uses unlabeled data to establish patterns, clusters or latent structures. Clustering, principal component analysis, and autoencoders are the common tools and techniques used to conduct the exploratory analysis (Goel et al., 2023). They can be effective in revealing the concealed groupings in data that is not pre-specified, especially where outcomes are not known.

Nevertheless, they are not extensively applied in the context of spatial healthcare accessibility. The lack of labels complicates the process of their validation and interpretation, which makes them less relevant to policy in the short term. However, the unsupervised techniques may be used to supplement the supervised techniques, such as finding the spatial clusters of underserved groups or dimensionality reduction of the data (Karikarn et al., 2025; Svynarenko et al., 2025).

Hybrid and Ensemble Learning Frameworks

Hybrid and ensemble methods merge two or more machine learning models and methods of analysis to enhance performance and interpretability. Researchers combine machine learning and spatial regression algorithms like MGWR to learn both the global and local patterns in healthcare access (Svynarenko et al., 2025).

Such frameworks overcome shortcomings of single-model frameworks by modeling nonlinear relationships, spatial variation, and complex interactions (Bera et al., 2025). Nonetheless, they also have the problem of data quality, complexity of computation, and model consistency.

Altogether, hybrid frameworks show great promise to the future of research on spatial healthcare accessibility, especially in combination with interpretable and geographically sensitive methods.

4. THEORETICAL FRAMEWORKS FOR ACCESSIBILITY DISPARITY MAPPING

4.1 Spatial Equity and Justice Theories

Spatial equity in healthcare is most evident where infrastructure is not distributed according to the population demands. This imbalance is reflected in evidence in Bathinda district, with central blocks like Bathinda and Phul having a comparatively greater level of service provision, and with the peripheral blocks like Talwandi Sabo, Maur, and Sangat having a comparatively large accessibility deficit, with almost 46 percent of villages not being served adequately.

One of the theoretical problems is the measurement of the accessibility. Travel barriers are not reflected by conventional measures like provider-to-population ratios, whereas nearest-provider methods do not consider that there are many service options, and that boundaries have effects. More advanced but with a

complicated design, gravity models and access scores nonetheless cannot portray demand accurately and can yield counterintuitive results.

A change has been brought about by machine learning (ML) techniques where spatial accessibility is viewed as a pattern recognition problem. Unsupervised distance-based clustering of areas around healthcare services in Isfahan divides the areas into five accessibility levels without any equity standards set. Findings indicate that 31 percent of regions have low or very low accessibility with 47 percent highly accessible, with most prevalent along major corridors.Additional limitations to the implementation of spatial justice frameworks include data and methodological limitations. In Bathinda, the unavailability of the road network, health outcomes, and economy data limit the in-depth analysis. Likewise, the ML-based methods tend to use simplistic assumptions, including preset travel thresholds, that decrease contextual sensitivity (Haq et al., 2025; Khosrow Kazazi et al., 2022).

New insights take spatial equity beyond the traditional healthcare models. Ethnomedicinal resource Digital Public Health research emphasizes the reliance of underserved communities on local plant-based healthcare, and suggests that integrated GIS and ML systems be designed to help map discordances between the availability of resources and health requirements (Saran & Singh, 2025).

There are still major gaps in research. The ML-based classifications usually do not incorporate socioeconomic variables, health outcomes, and demand-side factors which restricts their applicability in studying equity. The work of Bathinda is spatially detailed though lacks predictive ML approaches since such is limited by data.

4.2 Health Geography and Spatial Epidemiology

Spatial epidemiology and health geography give us a framework of understanding accessibility differences in the form of spatial manifestations. In Bathinda, spatial analysis shows that the central blocks (Bathinda and Phul) concentrate healthcare services whereas peripheral blocks (Talwandi Sabo, Maur, and Sangat) have a lot of shortage. One of the major problems of spatial epidemiology is the measurement of geographic variability. The traditional regression models presuppose spatial homogeneity, and they do not provide an opportunity to consider the variance in the way determinants act in different regions. Multiscale Geographically Weighted Regression (MGWR) is used to deal with this by enabling the relationships between variables to change with location.

In terms of methods, recent solutions combine GIS, spatial statistics, and ML. ML is used in studies to filter large datasets on SDOH, and MGWR is used to analyze spatial relationships. Service ratio, variability visualization, and accessibility surface mapping in Bathinda are calculated using GIS-based approaches to reveal the intra-district discrepancies. The results of various studies highlight that accessibility of healthcare is a multidimensional interaction between various factors, such as infrastructure, workforce distribution, socioeconomic conditions, and geography.

Nonetheless, there are still significant challenges. The inaccurate modeling of missing data remains a problem with the spatial structure, especially in underserved rural regions. Also, ML approaches are frequently not made to be spatially sensitive, which results in statistical and machine learning interpretations that are not consistent.

5. BARRIERS AND LIMITATIONS

5.1 Data-related Challenges

Data Scarcity and Quality Issues

The use of spatially oriented machine learning (ML) in healthcare accessibility is greatly limited due to the data constraints. In Bathinda district, lack of detailed data (including information on facilities, travel time and road network, disease indicators broken by age and gender and rural level data on health expenditure and policies) hampered the intensity of spatial analysis. The main problem is that the missing data in the spatial health datasets are not random in nature but patterned. In rural settings, missing values is a common occurrence as a result of small counts were intentionally suppressed to protect privacy, and data holes depend on rural locations. The common imputation methods, which are based on randomness, could thus pervert local realities, as they borrow values on nearby areas.

These limitations empirically result in compromises to the methods. As an example, using zero as an indicator of missing data, such as in recent Canadian MGWR studies, makes the analysis easier, but may influence the picture of real situations. In Bathinda, lack of complete geospatial and health indicator data restricted the predictive modeling evidence base.In spite of these difficulties, scientists are practical. In Bathinda, the GIS analyses show the areas with underserved locations based on the available data, while considering limitations and proposing better datasets in the studies (Haqu et al., 2025). On the same note, ML-driven spatial research adopts cautious modelling techniques and makes inferences within constraints of data (Svynarenko et al., 2025).

Bias in Spatial Datasets

In spatial datasets, there is bias due to the process of data collection, suppression, and digitization. In most instances, rural regions do not capture healthcare-related variables due to the suppression that is driven by privacy in rural regions, and thus, underserved areas are not fully represented in datasets. Colonial imputation procedures do not frequently apply in these situations, where errors of random missingness are assumed. Local deficits and increasing the spatial variability can be obscured by filling gaps with regional averages.Real-world issues are found throughout ML workflows. In other studies, zero-value substitution is permissible and can lead to bias due to weakening relationships. The citizen science datasets have other biases since not all people participate in it equally, and the study may be biased against the underprivileged who do not have access to computers and smartphones.

5.2 Technical Barriers

Computational Complexity

When using ML on geospatial datasets of large size, it poses considerable challenges in computation. Classical algorithms like random forests, support vector machines, and boosted regression trees are resource consuming when there is a growth in data; whereas k-nearest neighbours is characterized by high-computational cost in estimating distances.One of the main shortcomings is that many models cannot learn spatial hierarchies automatically, and usually have to engineer features manually. Convolutional neural networks (CNNs) overcome this by learning patterns spatially directly, but are computationally expensive and overfit easily, particularly where data is limited.

These issues are especially applicable to healthcare settings in rural areas, where the computing infrastructure is scarce. Even sophisticated models can be not practical because of their high cost and the absence of automation (Balakrishnan et al., 2025). Although optimized deep learning models could be highly accurate, the models are required to trade-off between performance, scalability and resource constraints.

Model Interpretability Limitations

One of the biggest issues of ML application in healthcare is interpretability. Black-box models lessen trust in practitioners and policymakers, especially in rural areas where transparency is paramount. The use of non-representative training data further exposes the chance of biased outputs, which is ethically

challenging due to its unfairness and inequity (Balakrishnan et al., 2025). The SHAP values and partial dependence plots, which elucidate model predictions, are used as an attempt to better interpret the model predictions. There are, however, discrepancies when ML-derived feature importance cannot be associated with the outcomes of a spatial regression model, including MGWR, to underscore conceptual differences between modeling methods (Svynarenko et al., 2025).

The deep learning models, such as CNNs, are especially opaque even with new features such as attention models. The biases in the training data can still result in the inequitable outcomes even in cases of the generation of interpretable outputs (Karikarn et al., 2025; Bera et al., 2025).

5.3 Socio-political Constraints

Policy and Governance Limitations

The facilitative policy and governance structures are vital to the success of ML and geospatial tools in healthcare. In rural settings, the absence of regulatory frameworks, access to policy information, and the inability to coordinate institutions hamper the conversion of analytical knowledge into practice. More comprehensive research highlights the importance of ethical, transparent AI systems that are adapted to rural contexts, with data sovereignty and community engagement (Balakrishnan et al., 2025; Khan et al., 2025). In the absence of these frameworks, the ML applications are likely to bolster inequities instead of redressing them.

Ethical Considerations in ML Applications

In underserved areas, there are especially strong ethical problems with ML. Unbalanced datasets, black-box models, and privacy issues may lead to loss of trust and increase inequalities.Theories that stress on community co-design, transparency and fairness have been put forward but few have been put into practice. Poor digital infrastructure, low levels of trust in AI, limited technical capacity are all constraints to adoption.

On the whole, ethical, governance, and infrastructural issues overlap especially in areas where the problem of healthcare access is the most critical. The solutions to those involve incorporating fairness, transparency, as well as community involvement in the design of the ML systems, such that technological progress will make the healthcare accessible to more people irrespective of their background (Balakrishnan et al., 2025; Khan et al., 2025).

6. METHODOLOGICAL APPROACHES IN LITERATURE

6.1 GIS-integrated ML Models

Spatial Clustering Techniques

The clustering of space within GIS-based machine learning models is significantly used in works of Isfahan and Bathinda. Machine learning-based classification is applied to measure accessibility to various healthcare services at block level in Isfahan, mitigating the shortcomings of previous coarse-scale analyses.One of the major problems in all studies is the shortcomings of conventional methods of accessibility. Provider-to-population ratios disregard travel impedance, nearest-provider measures assume multiple options exist, and gravity or floating catchment models are based on assumptions that might not apply to actual behavior (Khosravi Kazazi et al., 2022).

In Isfahan, the conceptualization of accessibility is a three dimensional concept that incorporates the distance, service quality and availability. Unsupervised ML is employed to classify spatial units with no predefined labels and supervised learning can discover patterns where training data are present. Bathinda uses a weighted overlay of spatial indicators of equal weights to create accessibility classes, which are in effect cluster-like groupings (Haq et al., 2025; Singh and Kour, 2025).Spatial patterns are found to be

consistent empirically. Bathinda becomes a low-access cluster with peripheral areas like Sangat and Maur, but almost 46% of the villages are underserved (Haq et al., 2025). On the same note, Isfahan finds less accessibility in urban periphery over central corridors (Khosravi Kazazi et al., 2022).

6.2 Regression-based Spatial Models

Spatial approaches that use regression include Multiscale Geographically Weighted Regression (MGWR), frequently with machine learning. MGWR accounts for spatial non-stationarity by enabling relationships between variables to differ by location, which makes it a good fit to analyze healthcare disparities (Svynarenko et al., 2025).Conventional regression models have difficulties with large dimensional data and spatially uneven data. To solve the problem, ML features like Gradient Boosting, Random Forest, and XGBoost are applied to perform feature selection, followed by MGWR to infer the spatial feature (Svynarenko et al., 2025). SHAP analysis establishes the significance of predictors, whereas MGWR shows the spatial variation of the predictors. Nonetheless, there are a number of issues. In rural datasets, missing data, especially, are frequently suppressed in a systematic way, which makes it hard to impute missing values and adds bias (Svynarenko et al., 2025). Also, the differences between ML and MGWR feature importance and statistical significance indicate the disparities between predictive and inferential paradigms.

6.3 Accessibility Measurement Metrics

Travel Impedance Models

One of the fundamental elements of accessibility measure is travel impedance which is the effort needed in order to access healthcare services. Isfahan has the concept of impedance which is defined as travel distance or time and is included in various measures, such as nearest-provider distance, average impedance, and gravity-based models (Khosravi Kazazi et al., 2022). As significant as they are, impedance models have significant limitations. Most of the metrics disregard multiple service options or use pre-established thresholds which might not capture real-world behavior of travel (Khosravi Kazazi et al., 2022). In Bathinda, absence of both road network and data on time of travel inhibits analyzing more than straight-line distance, which limits realism (Haq et al., 2025). Studies are done in a variety of methods methodologically, both simple distance measurements and combined with ML and regression models. Results are always consistent (high impedance territories are severely under-accessible, especially peripheral ones) (Haque et al., 2025; Khosrowi Kazazi et al., 2022).

Provider-to-Population Ratios

Provider-to-population ratios are popular because they are easy to understand and interpret. They also assess the availability of healthcare by comparing the number of providers to population (Khosravi Kazazi et al., 2022).Nonetheless, there are serious limitations of these ratios. They do not take into account space factors like distance and traveling time, which may conceal the differences in accessibility. Bathinda shows that good aggregate ratios may be accompanied by local shortages in the periphery (Haq et al., 2025).

6.4 Evaluation and Validation Strategies

Cross-validation and Model Tuning

The most important aspect of ensuring robustness in ML-based spatial studies is cross-validation. Random Forest models and Gradient Boosting models are trained on five-fold cross-validation in MGWR-integrated frameworks and performance metrics like mean residual deviance are used to evaluate such models (Svynarenko et al., 2025).State-of-the-art methods apply Bayesian optimization to optimize deep learning models, enhancing generalization and alleviating overfitting (Bera et al., 2025).

Nonetheless, it has issues such as data constraints, spatially organized missingness, as well as discrepancies in predictive accuracy and interpretability. These problems emphasize that validation strategies in accordance to spatial inference objectives are required.

Sensitivity and Uncertainty Analysis

Sensitivity and uncertainty analysis have yet to be developed in spatial ML researches. Current literature recognizes the uncertainties caused by data quality, the absence of values, and model assumptions but seldom quantifies them (Svynarenko et al., 2025; Khosrowazi et al., 2022).Uncertainty is indirectly discussed in some research based on using cross-validation or Bayesian optimization, however, systematic sensitivity analysis is mostly neglected (Bera et al., 2025). The major gaps involve the management of non-random missing data, the reconciliation of the results of the ML and spatial regression, and the establishment of models that are conscious of uncertainty.

7. PATTERNS AND KEY FINDINGS IN LITERATURE

7.1 ML performance in spatial accessibility mapping

The effectiveness of the machine learning (ML) in spatial accessibility mapping can be best assessed within the framework where the models are directly tested to provide access to health-related outcomes or spatial determinants of access.New Mexico community-based research offers solid grounds in understanding how performance in high-disparity settings is in relation to ML. The work uses a broad set of predictors, including sociodemographic, geographic and household factors by using several algorithms to forecast perceived needs to healthcare and barriers to access in mental, medical and dental care. Findings show that nonlinear models, particularly neural networks provide greater predictive accuracy and give much finer granularity in their output.

Complementary data come by way of a county-level study involving ML with multiscale geographically weighted regression (MGWR). Here, tree-based ensemble models like Gradient Boosting Machine, Extreme Gradient Boosting, and Distributed Random Forest are trained on the basis of cross-validation and then paired with SHAP-based feature importance. These models exhibit high predictive accuracy in the explanation of the geospatial variation of rural healthcare setting.With the urban scale, accessibility mapping in Isfahan provides information on the performance of classification-based ML. Synthesized accessibility indicators are used to train supervised models like Logistic Regression, Linear Discriminant Analysis, KNN, CART, Gaussian Naive Bayes and Support Vector Machines.

Additional understanding is achieved through geospatial risk modeling, where it is most effective in mapping environmental susceptibility. Although both traditional ML algorithms like the Random Forests and the Support Vector Machines work, they are limited in the area of scalability, overfitting, and interpretability. Deep learning methods, especially Convolutional Neural Networks (CNNs) address these limitations by removing the need to manually extract spatial features and hierarchies.In these studies, a number of common trends are evident. To begin with, nonlinear supervised models, such as neural networks and ensemble methods, have been shown to be regularly superior to linear methods in the representation of complicated spatial associations. Second, even simpler models like KNN may perform well when trained on strong datasets.

7.2 Impact of integrating socio-economic variables

The incorporation of the socio-economic variables into the ML and spatial analysis models can contribute greatly to comprehend the existing disparities in healthcare access. In several studies, poverty and economic status turn out to be the key factors affecting healthcare demands and barriers to access.

In community-based ML research in New Mexico, socio-economic factors like income, household size, and parental status are explicitly defined as predictors.In the same way, a county-level analysis based on SDOH data highlights the idea that healthcare access cannot be merely attributed to the infrastructural factors. It, instead, is affected by a multitude of socio-economic factors, such as insurance status, working conditions, and population traits.

This conclusion is further supported by evidence in India. Mother healthcare research in Himachal Pradesh finds income and education as determinants of access with the poor having lower income and lower education levels having significantly lower access to pregnancy care.Although they are important, incorporation of socio-economic variables has some challenges. The limitations of data, especially missingness caused by suppression in SDOH data, make analysis complex. In the countryside, small values are usually smothered due to privacy concerns, thus missing data are spatially structured.

In studies, there are a variety of methods used methodologically to introduce socio-economic variables. These involve survey-based ML models, regression analysis, and census-based measures, like access to banking, type of fuel, and transport assets.On the whole, it is clear that socio-economic variables greatly contribute to the explanatory power of healthcare accessibility models. Nevertheless, there are still gaps in the incorporation of these variables within a fully spatialized ML framework, and an approach to data constraints

8. RESEARCH GAPS AND FUTURE DIRECTIONS

8.1 Need for multi-scale and multi-level modelling

The core of the spatial access to healthcare is a multi-scale and multi-level modeling as determinants are active at various geographic and institutional levels. According to MGWR-based research, it is essential to embrace spatial nonstationarity by letting relationships between variables to differ across space (Svynarenko et al., 2025).Multi-level modeling using a combination of ML and MGWR is one of the promising methods. The feature selection is performed with the help of ML methods, whereas MGWR accounts to the spatial variations in the relationships. Nevertheless, the lack of consistency between feature importance as calculated by ML and MGWR statistical significance indicates methodological complexities, which require additional investigation (Svynarenko et al., 2025).

The biggest obstacle is data limitations. The absence of data, time-series data, and detailed rural indicators make it difficult to perform thorough multi-level analyses.Further studies are needed to create ML models that are specifically aimed at multi-scale spatial modeling and enhance multi-level integration of data.

8.2 Integration of qualitative and participatory approaches

The qualitative and participatory methods are essential to increase the relevance and ethical foundation of the ML-based spatial analyses. Community-based data-gathering and citizen science platforms can also allow incorporating local knowledge and experience of access to health care into healthcare-accessibility mapping (Saran & Singh, 2025).

Participatory frameworks focus on joint generation of data and assimilation of indigenous knowledge system. Such strategies enhance the relevance of the model and make sure that the outputs are relevant to

community needs. Nevertheless, digital divides, data biases, and the lack of involvement of marginalized groups still exist (Khan et al., 2025).The new frameworks are in support of using ML, geospatial analysis, and participatory techniques as a single system. Such methods like federated learning present the chance of a trade-off between data privacy and model performance.

8.3 Enhancing policy relevance of ML outputs

The policy applicability of ML outputs is determined by how much they elicit actionable interventions. Research shows that spatial analysis can inform infrastructure planning, allocating resources, and improving service delivery (Haq et al., 2025).But there is a disconnect between technical deliverables and policy action. Difficulties are the constraints on data, the absence of regulatory frameworks and the inability to integrate the results of the ML into the decision-making process (Balakrishnan et al., 2025).Further work ought to be done to match ML models to policy requirements, enhance interpretability, and make the outputs accessible to decision-makers.

9. CONCLUSION

Implementing spatial healthcare disparities is also a critical issue, especially affecting areas with a low population density and healthcare access. Conventional approaches cannot be used to capture the spatial dynamics, and the ML approaches have considerable strengths of being able to deal with nonlinear relationships and multidimensional data. In spite of these developments, issues of data quality, interpretability and governance continue to be an issue. The inclusion of socio-economic variables, multi-scaled modelling methodologies and participation structures are critical in enhancing validity and applicability of accessibility studies. The future research must be focused on the creation of the robust, interpretable, and policy-corresponding ML frameworks. The ML-based spatial analysis can help to advance more equitable healthcare planning and better accessibility of underserved groups by helping to overcome technical, data, and socio-political barriers.

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MATHEMATICAL STUDY OF PATHOPHYSIOLOGICAL PARAMETERS OF TYPE-2 DIABETES MELLITUS - A COMPARISON USING HYPOTHETICAL CLINICAL PARAMETERS

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ABSTRACT

The study concerns the computation of some pathophysiological parameters of Type-2 Diabetes Mellitus. Present model consists of non-linear ordinary differential equations as a coupled form. The study is carried out to compare the computed pathophysiological parameter values with that of hypothetical clinical values which include the concentration of glucose, glycogen, glucagon and insulin in the blood plasma. Black and Red portions are introduced to define the protein, fat and carbohydrate inputs in a simple weighted diet for prescribing the calorie to type-2 diabetes mellitus cases. Comparisons of computed values are presented in the analysis.

Keywords: diabetes mellitus, metabolism, glucose, insulin, black and red portion.

1. INTRODUCTION

Diabetes mellitus refers to a disorder of carbohydrate metabolism due to non-oxidation of sugar which in turn fails to produce energy due to insufficient pancreatic hormone insulin. The presence of sugar will be reflected in blood and then in urine. Long term complications of accumulation of sugar may cause the defects such as bulging of arteries that may damage the retina which in turn results in problems relating to vision. Obesity, stress, lack of physical fitness, genetic may be the reasons of Type 2 Diabetes Mellitus(T2DM).

2. LITERATURE REVIEW

Allick Gideon et. al(2004) discussed about the betterment of glycaemic management in T2DM by the reduction of glycogenolysis. Athena Makroglou et. al(2005) analysed the various computing tools and mathematical models for the case of diabetes and regulatory system which includes glucose and insulin. Bagust A et. al(2003) explained a long term model which explains the functioning of beta cells in type II diabetes. Bartholovistsch A et. al(1999) studied the variations associated with the viscosity of blood in both type 1 and type 2 diabetic patients. Brownlee M et. al(1988) discussed about the severe effects biochemicals that creates the complications in diabetes. Boli V W(1961) studied the blood glucose regulations by analysing its parameters. Katiyar V K et. al(2003) studied the composition of palatable diet for the case of glucose levels in T2DM. Andrea Mari et. al(2020) described various thoughts, approach of the problems that arise in diabetes by considering variety of examples which includes biomedical cell reactions. Richard M et. al(2001) explained about the control mechanism of type 2 diabetes mellitus. Boli (1961) discussed about the parameter coefficients of normal blood glucose and its regulation for a sustainable life. Naoya Emoto el. al(2015) investigated a study to analyse the development of complications and their risk factors. Also their study was confined to the behavioral traits in decision making. Gatewood et. al(1970) studied a mathematical model to explain the effect of hormone glucose and insulin secreted by pituitary gland. Katiyar V K et. al(2003) investigated a palatable diet composition in order to control the blood glucose level in diabetes mellitus. Kamru Md. Khan (2025) studied various statistical models in order to predict T2DM. Nelida Elizabeth et. al(2020) explained a mathematical study of blood sugar in healthy individuals. The study includes emulating pathophysiology of type – 2 diabetes mellitus metabolism. Nani et. al(2015) studied the modelling and simulation methodology of pathophysiology of T2DM. Sviatlana (2021) investigated the long term pathophysiological parameters of T2DM.

In view of study made by various researchers, the present study concerns the computation of some pathophysiological parameters of T2DM by considering coupled system of non-linear ordinary differential equations. the effect of hormone glucose and insulin secreted by pituitary and thyroxin produced by thyroid as simplest mathematical form.

3. FORMULATION AND ANALYSIS

Several mathematical models proposed by various researchers explained the study of glucose relating to hormone insulin. The pathological values will vary each other with reference to the blood glucose level which depends on the change in the secretion of insulin from the pancreas. The mathematical study represents the changes in pathophysiologic values by considering the following system of ordinary differential equations. Taking G(t) as concentration of glucose at time t and I(t) as concentration of insulin at time t, then we can construct the changes in glucose and insulin as,

$$\frac{dG(t)}{dt} = \frac{dG}{dt} = -C_1G - C_2I + C_3(G_0 - G) + H(G_0 - G) + K_1 \quad (1)$$

$$\frac{dI(t)}{dt} = \frac{dI}{dt} = -C_4G - C_5 I + K_2H(G - G_0) \quad (2)$$

G(t) = concentration of glucose at time t

I(t) = concentration of insulin at time t

$C_1, C_2, C_3, C_4, C_5, K_1, K_2$ are the model parameters

$G(t) - G_0 = G - G_0 =$ rate of change of I(t) which varies with excess of blood sugar over its fasting range.

$H(G - G_0)$ = the step function which takes the value unity, when $G > G_0$ and takes the value zero otherwise.

t = time

Present model has relevance with minimal model of glucose, insulin dynamics [7]. Use of aggregated integro differential equations were used to construct the dynamics of insulin -glucose model,

which will explain the variations of the concentrations of glucose, glycogen, glucogon and insulin. Several other models were studied by [5,8,9,10]. But compositions with those of hypothetical clinical values becomes the main objective of present work. A clinically plausible model depicted in the study will explore glucose – insulin mechanism and comparison with clinical pathophysiological parameters of diabetes mellitus type-2.

Mathematical model with non-linear deterministic approach can be proposed as,

$$\frac{dx_1}{dt} = \alpha_1 G_1 + \beta_1 H(G - G_0) + \xi_1 x_2 x_3 - \alpha_{11} x_1 x_4 - K_1 x_1 - K_{01} \quad (3)$$

Where $\frac{dx_1}{dt}$ is taken for the variation of glucose in the body is equal to the post prandial input $\alpha_1 G_1$, $\xi_1 x_2 x_3$ shows the impact of glucagon on glycogen, $-\alpha_{11} x_1 x_4$ shows the loss of glucose during glycoenesis, $K_1 x_1$ shows the catablolism and K_{01} shows the rate of degradation of glucose.

The glycogen equation depends on the post prandial rate of glycogen then the equation is taken as,

$$\frac{dx_2}{dt} = \alpha_2 G_2 + \beta_2 H(G - G_0) + \xi_2 x_1 x_4 - \alpha_{23} x_2 x_3 - K_2 x_2 - K_{02} \quad (4)$$

Due to post prandial input assuming the supplement includes more black portion than red portion of the meal, the variation of glucagon in the body can be compared to the rate of extra black portion and due to the insulin input, the glucagon dynamical equation will be modelled as,

$$\frac{dx_3}{dt} = \alpha_3 G_3 + \beta_3 H(G - G_0) - \alpha_{32} x_2 x_3 - K_3 x_3 - K_{03} \quad (5)$$

After successive steps of implementing (1),(2),(3) and (4), the relative concentrations of glucose and glycogen during the mediation process shows the conversion of glucose to glycogen then we can model the equation for the variation of insulin in the blood plasma will be same as rate of insulin input,

$$\frac{dx_4}{dt} = \alpha_4 G_4 + \beta_4 H(G - G_0) - \alpha_{41} x_1 x_4 - K_4 x_4 - K_{04} \quad (6)$$

In the above deterministic system ordinary differential equations (3), (4), (5) and (6), we have the terms $x_2 x_3$, $x_1 x_4$ as non-linear terms, where these product terms are alternately chosen in such a way that x_1 is analysed for closed form solution with x_4 as constant supplement at time 't' and vice versa and x_2 analysed form solution with x_3 as constant supplement at time t and vice versa. As a result the deterministic nonlinear equations (3),(4),(5) and (6) can be discretised to linear equations. Numerical values obtained by implementing Runge- Kutta Felhberg method of 6^{th} order step size t as three hours between each pair of black and red portions in each meal. Joslin's principle has been adopted for balancing the protein, fat, carbohydrate (PFC) to achieve the necessary calorie output for the approximations of diet computations for diabetes mellitus type-2 in reference to clinical pathophysiological values.

Consider,

$$H(G - G_0) > 0 \text{ ie., } H(G - G_0) = 1 \quad (7)$$

Rate of change of glucose in the body is given as,

$$\frac{dx_1}{dt} = 90\alpha_1 + \beta_1 + 0.95 x_2 x_3 - \alpha_{11} x_1 x_4 - 1.5 x_1 - 7.5 \quad (8)$$

The glycogen dynamical equation is considered as,

$$\frac{dx_2}{dt} = 90\alpha_2 + \beta_2 + 0.7 x_1 x_4 - \alpha_{23} x_2 x_3 - 2.5 x_2 - 7.5 \quad (9)$$

The glucagon dynamical equation becomes,

$$\frac{dx_3}{dt} = 60\alpha_3 + \beta_3 - \alpha_{32} x_2 x_3 - 0.00001 x_3 - 0.0025 \quad (10)$$

and,

$$\frac{dx_4}{dt} = 50\alpha_4 + \beta_4 - \alpha_{41} x_1 x_4 - 0.05 x_4 - 0.15 \quad (11)$$

For $\frac{dx_1}{dt}$,

$$\alpha_1 = 0.14,\ \beta_1 = 0.1,\ x_2 = 150, x_3 = 70, \alpha_{11} = 0.01, x_4 = 20 \quad (12)$$

Here, $\alpha_1 = Z_1$, I(t) = 1265 -2495 calories , t = 0,6,9,12 hrs.

For $\frac{dx_2}{dt}$,

$$\alpha_2 = 0.21,\ \beta_2 = 0.05,\ x_1 = 200, x_4 = 20\ , \alpha_{23} = 0.02 \quad (13)$$

Here, $\alpha_2 = 2$, I(t) = 1265 -2495 calories , t = 0,6,9,12 hrs.

$$\alpha_3 = 0.45,\ \beta_3 = 0.03,\ x_2 = 150, \alpha_{32} = 0.03 \quad (14)$$

Here, $\alpha_3 = Z_3$, I(t) = 1265 -2495 calories , t = 0,6,9,12 hrs.

For $\frac{dx_4}{dt}$,

$$\alpha_4 = 0.46,\ \beta_4 = 0.02,\ x_1 = 200,\ \alpha_{41} = 0.2 \quad (15)$$

Here, $\alpha_4 = Z_4$, I(t) = 1265 -2495 calories , t = 0,6,9,12 hrs.

Solving equations (1) for G(t), (2) for I(t) and further introducing in equations (3),(4),(5) and (6), with time dependent flow (pulsatile flow) as,

$$\alpha_1 = Z_1(t) = (\text{sinnt})_{n=1} \qquad \alpha_2 = Z_2(t) = (\text{sinnt})_{n=2}$$
$$\alpha_3 = Z_3(t) = (\text{sinnt})_{n=3} \qquad \alpha_4 = Z_4(t) = (\text{sinnt})_{n=4}$$

4. RESULTS AND DISCUSSION

Mathematical model proposed in the present model predicts the comparison of the computed values with those of hypothetical physiological values with four different configurations of model parameters. Model parameters are chosen as:

In the figure (1), $x_1(t)$– Glucose : $G_1 = 90, K_{01} = 7.50,\ K_1 = 1.5,\ \xi_1 = 0.95$

In the figure (2), $x_2(t)$– Glycogen : $G_2 = 90, K_{02} = 7.50,\ K_2 = 2.5,\ \xi_2 = 0.7$

In the figure(3), $x_3(t)$– Glucogon : $G_3 = 60, K_{03} = 0.0025,\ K_3 = 0.00001, \xi_3 = 0.0085$

In the figure(4), $x_4(t)$– Insulin : $G_4 = 50, K_{04} = 0.15,\ K_4 = 0.05,\ \xi_4 = 0.8,$

to maintain the required calorie using Joslin's Principle for PFC: 1:4:1 ratio to diabetes Mellitus type - 2 patients with four different meals. Numerical values predict via graphs as shown in the fig.1,2,3 and 4 respectively, give insight the relevance with computed and hypothetical physiological values. Comparison is made with other findings [5], [6], [8] which has relative importance for the chosen parameters.

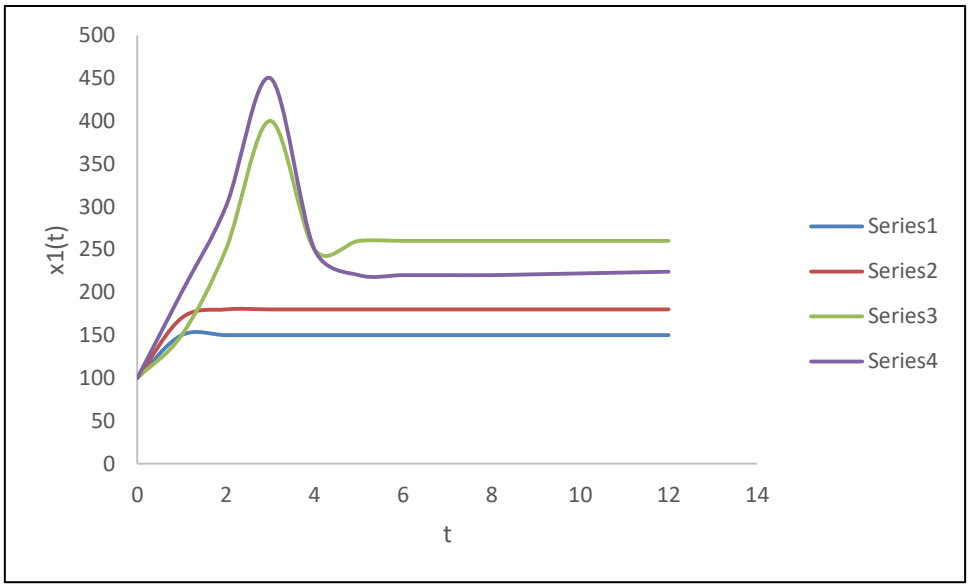

Figure 1: $x_1(t)$ -variation of Glucose with time

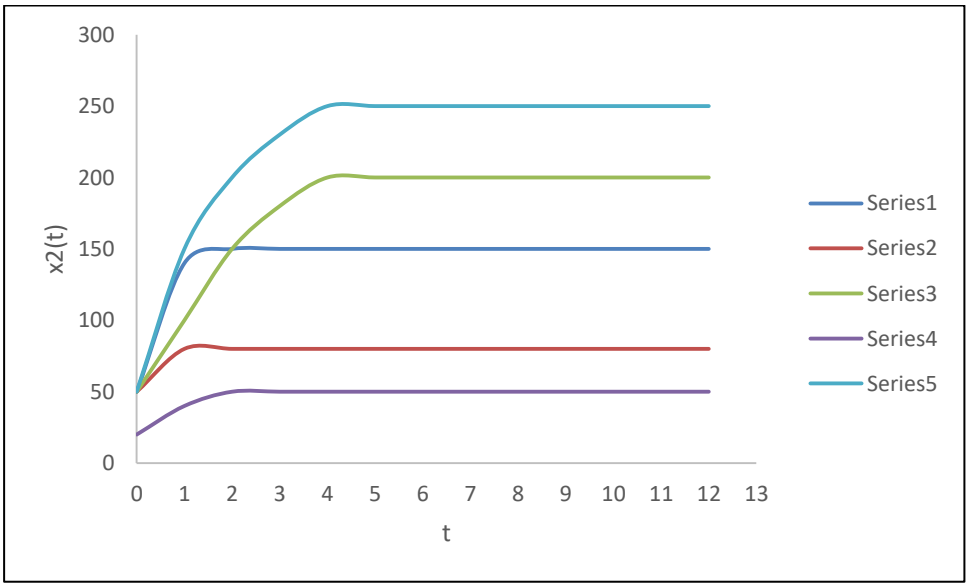

Figure 2: $x_2(t)$ -variation of Glycogen with time

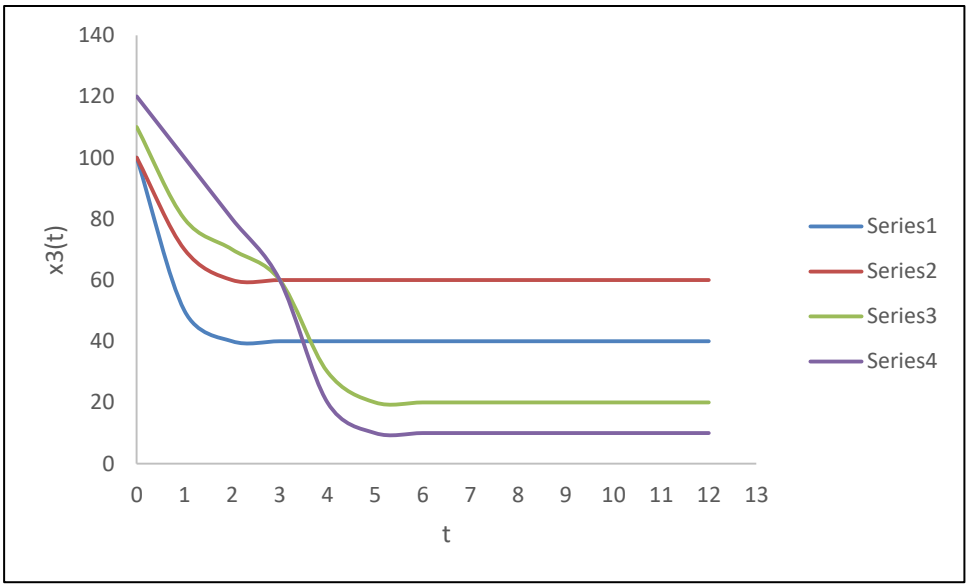

Figure 3: $x_3(t)$ – variation of Glucogon with time

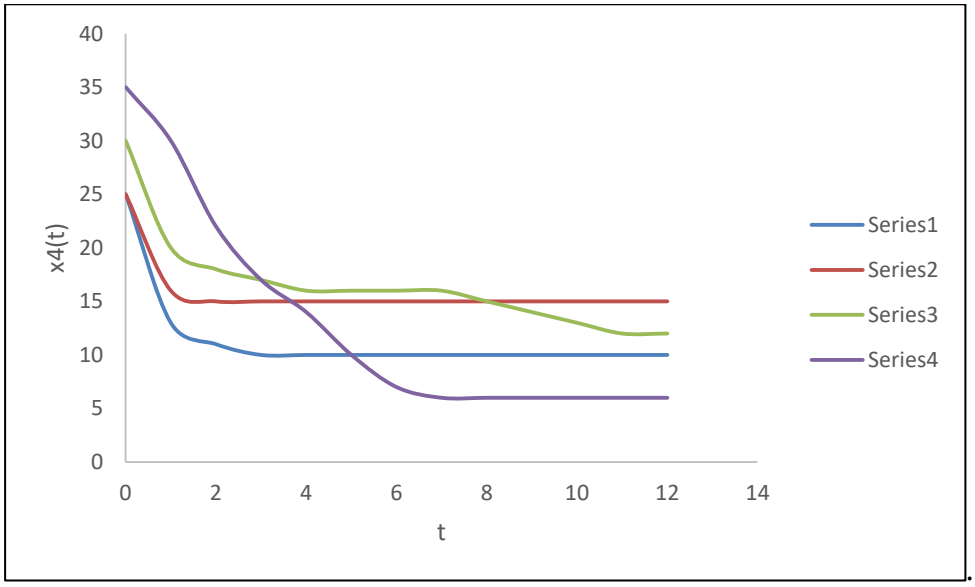

Figure 4: $x_4(t)$ – variation of Insulin with time

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AUTOMATED DETECTION AND GRADING OF DIABETIC RETINOPATHY USING DEEP CONVOLUTIONAL NEURAL NETWORKS: A MULTI-STAGE CLASSIFICATION APPROACH

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ABSTRACT

Diabetic Retinopathy (DR) is one of the main preventable causes of blindness around the world, and it affects millions of people with diabetes. Finding the disease early and treating it quickly can help stop vision loss. However, when ophthalmologists screen for DR by hand, the process takes a lot of time, costs a lot of money, and results can vary from one doctor to another.

In this study, we built an automated system using deep learning to detect and grade diabetic retinopathy from retinal fundus images. We designed a multi-stage pipeline that includes preprocessing of images, data augmentation, transfer learning, and ensemble modeling. For feature extraction and classification, we used a modified ResNet-50 together with DenseNet-121.

We trained and tested our model on 35,126 retinal fundus images taken from two public datasets: APTOS 2019 Blindness Detection and EyePACS. The model classifies images into five levels of DR severity: No DR, Mild, Moderate, Severe, and Proliferative DR.

Our ensemble model reached an overall accuracy of 94.2%, a sensitivity of 96.8%, a specificity of 93.5%, and a quadratic weighted kappa score of 0.912 on the test set. Compared to single-architecture models and other current state-of-the-art methods, our approach performed better — especially at detecting referable DR cases (Moderate and above).

Overall, this deep learning framework shows high diagnostic accuracy for automated DR detection and grading. It has the potential to be used in real clinical settings and large-scale screening programs. The system could help ophthalmologists catch the disease earlier, lower screening costs, and make eye care more accessible in places with limited resources.

Keywords: Diabetic Retinopathy, Deep Learning, Convolutional Neural Networks, Transfer Learning, Medical Image Classification, Fundus Image Analysis, Ensemble Learning

STRESS, CONTROL, RESILIENCE, AND THE ROLE OF YOGA: INSIGHTS FROM A PILOT SURVEY AMONG YOUTH

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ABSTRACT

This study investigates stress prevalence among young adults and compares the effectiveness of common coping strategies. The survey results consistently show high levels of stress caused by academic pressure, socially set expectations, and low control over everyday activities. Among the reported coping methods, yoga and yogic relaxation have been associated with much lower levels of stress, emotional stability, and better frustration and anxiety management. Yoga practitioners also demonstrate a higher level of confidence in problem solving and adaptability in relation to significant changes in life. Although music and outdoor activities were the most frequently used, yoga therapy gave the most prominent improvement across key stress indicators. Therefore, the findings indicate that yoga is an accessible, evidence-based intervention and support its incorporation into personal routine, education settings, and community wellness programs to increase mental resilience and overall well-being. From the outcome of the pilot survey, 42.7% of the respondents favoured yoga and meditation for stress relief, 41.4% favoured music therapy for stress relief, and 15.9% of the respondents relied on outdoor and social activities for stress relief. Yoga and meditation were preferred for stress relief from the net outcome of this pilot survey.

Keywords: Yoga therapy, stress reduction, young adults and mental well-being