



10th INTERNATIONAL
CONFERENCE ON
MULTIDISCIPLINARY
RESEARCH 2025

BCAS
CAMPUS
BRITISH COLLEGE OF
APPLIED STUDIES

BCAS International Conference on **Multidisciplinary Research**

TOWARDS A SUSTAINABLE PLANET WITH AI



ISSUE 10 - DECEMBER 2025



Building Careers – Transforming Lives

Vision

To become the
premier private university
in the region

Mission

Produce quality human resources
with ethics and social responsibility,
having innovative thinking and
analytical skills to serve humanity



10th INTERNATIONAL CONFERENCE ON
**MULTIDISCIPLINARY
RESEARCH 2025**

TOWARDS A SUSTAINABLE
PLANET WITH AI

18th December 2025 (Thursday)

8.30 am to 5.00 pm

@ BCAS Auditorium
Colombo 03

ISSUE 10 - DECEMBER 2025

Subject – Disclaimer

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BCAS CAMPUS

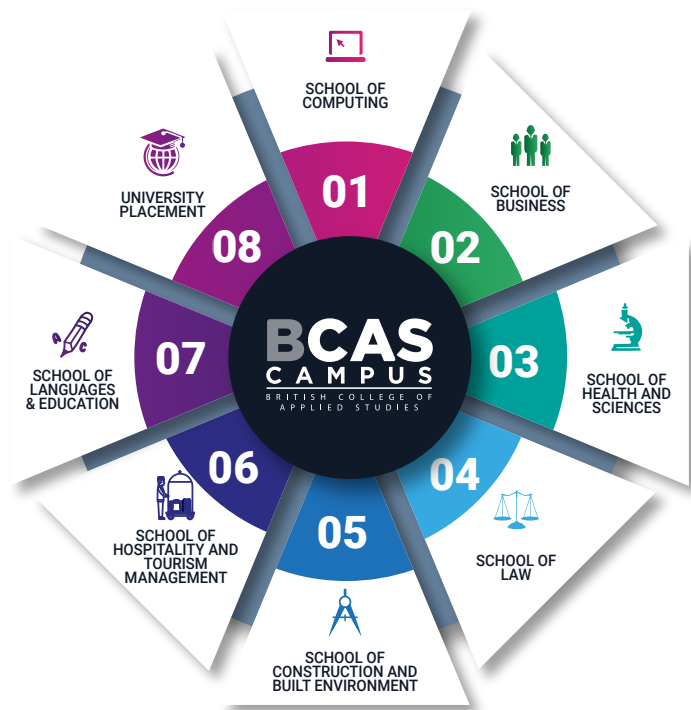
Founded in 1999, the British College of Applied Studies, popularly known as BCAS Campus, has emerged as a top ranked institution for higher education and vocational education in Sri Lanka. With robust UK collaborations, it stands out in the private sector higher education with 20,000+ students and alumni up to date. BCAS has been at the forefront of addressing evolving local and global educational needs, aligning its programs with contemporary trends and demands.

The main campus of BCAS Campus, located in Colpetty, Colombo, is complemented by regional campuses in Kandy, Kalmunai, and Jaffna. Currently, approximately 3,500+ students are enrolled across these campuses, a testament to BCAS's quality and dedication. Leveraging partnerships with renowned UK universities, BCAS offers a wide range of programs from foundational to master's degrees in fields of Business, Computing, Biomedical Sciences, Nursing, Quantity Surveying, Civil Engineering, Law, English Language & Education, and Hospitality Management & Tourism.

BCAS Campus gives highest priority for the quality of education and has established its reputation for high quality education and market relevant competent output. This has been proven through many national and international awards and recognition by different esteemed institutions in the country and abroad including “Gold Partnership” award from Pearson.

Through the concerted effort of dedicated and experienced academic team, BCAS is determined to cultivate a more enriching and rewarding learning experience for its students continuously. While ensuring academic standard BCAS has been contributing immensely to the nation building by producing productive citizenship for the last 26 years and thus has lived up to its broad motto of “Building Careers –Transforming Lives”.

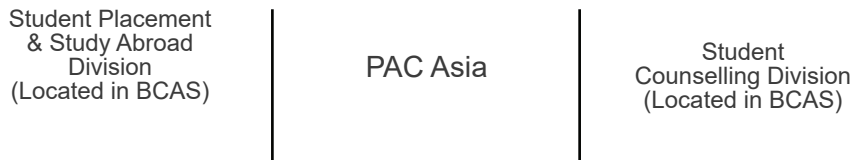
Divisions / Academic Schools

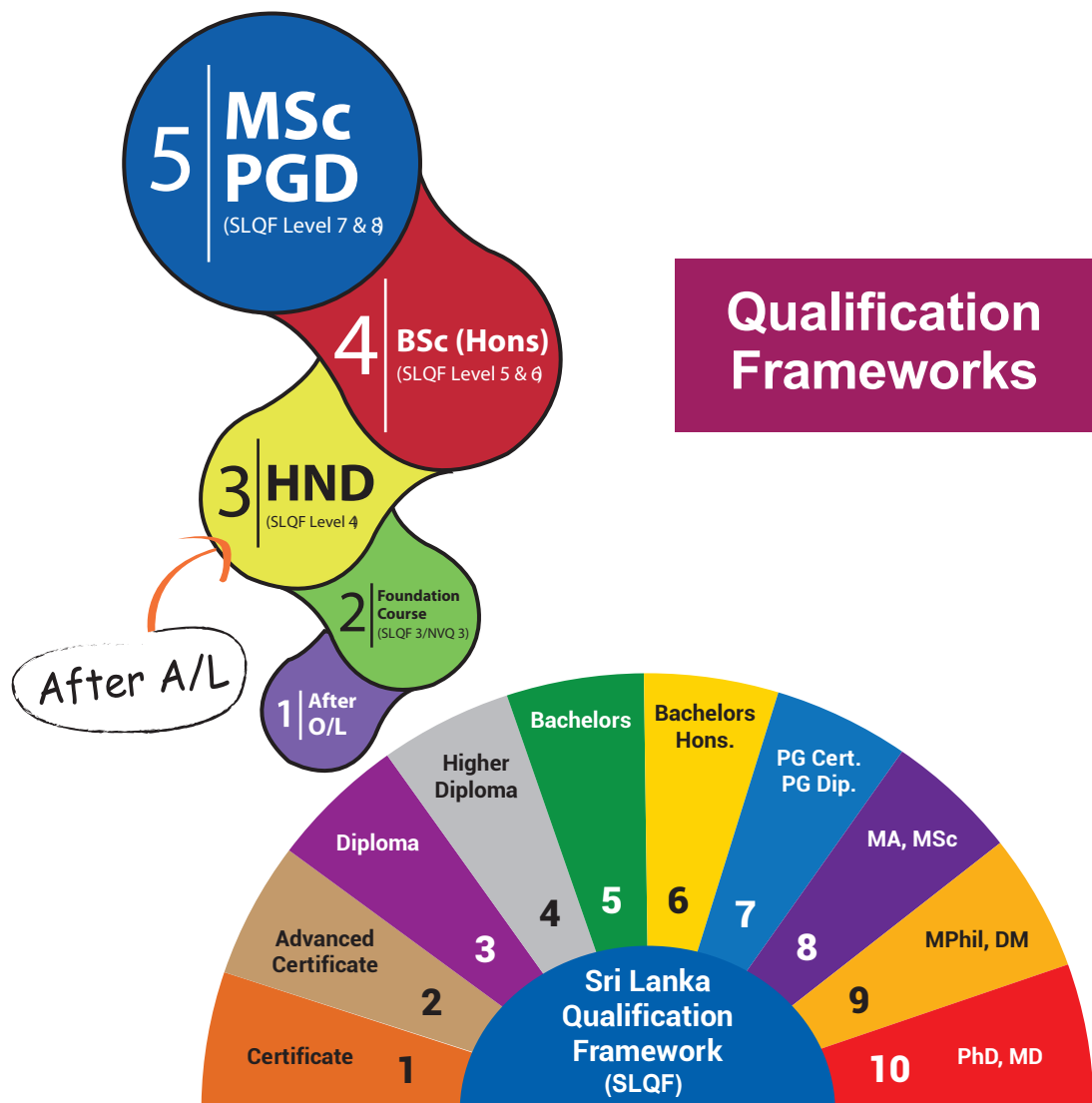


Quality Management Structure



Service Divisions





Sri Lankan National			BTEC/UK	
	SLQF	NVQ -	BTEC-QCF (UK)	
Doctorial Degree, MD	SLQL-10		QCF-L8	PhD/DPhil
M.Phil., Masters (Research)	SLQL-9		QCF-L7	Master's degrees
Master (Taught + Research)	SLQL-8			
Master (Taught), PG-D, PG-C	SLQL-7			
Honours Bachelor	SLQL-6		QCF-L6	Bachelor's degrees, eg BA, BSc
Bachelor Degree	SLQL-5	NVQ-7		
High Diploma	SLQL-4	NVQ-6	QCF-L5	BTEC HNDs (Higher National Diplomas)
Diploma	SLQL-3	NVQ-5	QCF-L4	BTEC HNCs (Higher National Certificates)
Advanced Certificate	SLQL-2	NVQ-4	QCF-L3	BTEC National Diploma
Certificate	SLQL-1	NVQ-2, 3		BTEC National Extended Diploma

Quality Assurance

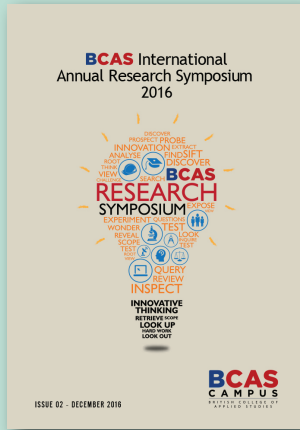


Approval, Recognition Partnership





2015 RELEASE



2016 RELEASE



2017 RELEASE



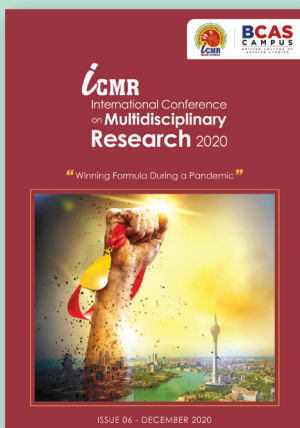
2018 RELEASE



2024 RELEASE



2019 RELEASE



2020 RELEASE



2022 RELEASE



2023 RELEASE

INTERNATIONAL & LOCAL AWARDS



Gold Award
Pearson, UK
2024



Gold Award
Pearson, UK
2023



Gold Award
Pearson, UK
2022



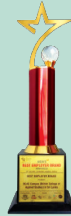
Gold Award
Pearson, UK
2020



Gold Award
Pearson, UK
2019



Gold Award
Pearson, UK
2018



> Best Employer Brand Award
> Outstanding Contribution
to the Cause of Education
> Award for Excellence in Training
World HRD Congress
13th Employers Branding Award
Le Meridien, Singapore
2018



Gold Award
Pearson, UK
2017



Platinum
No.1 BTEC Centre
in Sri Lanka
2017



Excellence in
Training Award
Overall Award based on
results based training
Asia Pacific HRM Congress
2017



Best Employer
Brand Award
2017



Platinum Partner
No.1 BTEC Centre
in Sri Lanka
2016



Educational Institute
with Best Academic
& Industry Interface
2016



Visionary Leadership
Award for
BCAS Chairman
2016



Academic
Impact Winner
2016



Ranked as No.1
Higher Education
Provider
2014



BTEC
Gold Partner
2013



Performance
excellence Award
2011



Fastest Growing
BTEC Centre
2010

EDITORIAL PREFACE

It is with great pleasure that we present the proceedings of the **BCAS International Conference on Multidisciplinary Research (ICMR 2025)**, held under the inspiring theme “*Towards a Sustainable Planet with AI.*” This year’s conference brings together researchers, academics, practitioners, and industry experts to explore how artificial intelligence can serve as a catalyst for sustainability, resilience, and responsible innovation across diverse disciplines.

To ensure the academic rigor and integrity of this conference, all submissions underwent a **double-blind peer-review process**. Each abstract was evaluated by qualified reviewers who assessed the originality, methodological soundness, relevance, and contribution of the work. Given the increasing sensitivity surrounding AI-generated content, ethical considerations, and data authenticity, an additional layer of scrutiny was applied to ensure that the submissions upheld responsible research and publication practices. Only papers that met these strict standards were selected for inclusion.

We extend our sincere appreciation to the reviewers, track chairs, and the editorial board for their diligent efforts, to the authors for their valuable contributions, and to everyone involved in maintaining the quality and credibility of this conference. Their commitment has played a pivotal role in shaping a platform that encourages meaningful scholarly dialogue and advances knowledge for the betterment of society.

We hope that the research presented here will inspire further exploration and collaboration, and contribute to the global pursuit of a sustainable, equitable, and AI-empowered future.

Warm regards,

Dr. N. V. P. Anjali
Editor-in-chief



Message from **The Conference Chair**

Prof. Ruvan Abeysekara,
Vice Chancellor
BCAS Campus

It is my privilege to extend a warm welcome to all of you attending the 10th International Conference on Multidisciplinary Research (iCMR 2025), hosted by BCAS Campus. As Vice Chancellor and Chair of this prestigious conference, I am delighted to witness the gathering of distinguished scholars, innovative thinkers, and passionate practitioners united under this year's theme, "Towards a Sustainable Planet with AI."

At a time when societies across the globe are confronted with unprecedented environmental, economic, and social challenges, the role of multidisciplinary research has never been more vital. The integration of artificial intelligence with sustainability-focused initiatives opens new pathways for responsible innovation, resilient systems, and transformative solutions that can safeguard our planet for future generations.

iCMR 2025 serves as an essential platform for exploring these intersections. It brings together diverse perspectives to examine how AI can be harnessed ethically and effectively to address global issues from climate action and resource optimization to sustainable development and inclusive growth. The research contributions featured in this year's conference proceedings highlight the creativity, dedication, and scholarly excellence of our participants, each adding meaningful insight to the advancement of knowledge in their respective fields.

I extend my heartfelt appreciation to the organizing committee, keynote speakers, reviewers, sponsors, and all contributors whose relentless efforts and commitment have ensured the success of this event. Your support has helped create an intellectually engaging environment that fosters collaboration, critical thinking, and impactful dialogue.

As we engage with the theme "Towards a Sustainable Planet with AI," I encourage all participants to immerse themselves in thoughtful discussions, exchange ideas, and cultivate the collaborations that emerge from this gathering. May the knowledge shared and connections built at iCMR 2025 inspire innovations that contribute meaningfully to a more sustainable and equitable world.

Wishing you all a rewarding, insightful, and inspiring experience at the **10th International Conference on Multidisciplinary Research (iCMR 2025)**.

Prof. Ruvan Abeysekara
Chairperson, iCMR 2025



Message from **The Conference Vice Chair**

Dr. Udyia Rajapakse,
Senior Lecturer Gr II, Cum Coordinator
School of Health and Sciences
BCAS Campus

The British College of Applied Studies proudly presents the proceedings of the **10th International Conference on Multidisciplinary Research (iCMR 2025)**, a comprehensive compilation that reflects the expanding intellectual diversity and scholarly commitment of our academic community. Since its inception in 2015, iCMR has continued to grow as a premier platform for academics, researchers, and industry professionals to engage in meaningful knowledge exchange and collaborative exploration.

This year's conference, themed **“Towards a Sustainable Planet with AI,”** centers on the critical intersection between technological advancement and environmental responsibility. The theme recognizes Artificial Intelligence not only as a driver of innovation but also as a transformative tool capable of shaping a more resilient, efficient, and sustainable future.

The interdisciplinary nature of these proceedings reflects the interconnected challenges of our global landscape. Scholars from diverse fields, including Biomedical & Health Sciences, Information Technologies, Legal Studies, Finance, Business & Management, Engineering, Quantity Surveying, Hospitality & Facility Management, and Social Sciences, have contributed their latest research findings. Each paper represents a thoughtful exploration of contemporary issues and forward-looking solutions grounded in innovation and sustainability.

We extend our sincere gratitude to all participants, presenters, reviewers, and organizers whose dedication has shaped the success of iCMR 2025. Your contributions continue to strengthen this platform and reaffirm the importance of academic collaboration in addressing the complex challenges of our time.

We look forward to the continued evolution and impact of this conference in the years ahead.

Dr. Udyia Rajapakse
Vise Chairperson, iCMR2025



Message from Conference Secretary

Ms. Rashmi Balamana,
Deputy Head - School of Law
BCAS Campus

Dear Distinguished Researchers, Academics, and Change-Makers, Welcome to the BCAS International Conference on Multidisciplinary Research (ICMR) 2025, where ideas meet purpose and innovation finds its conscience.

As Conference Secretary, I am deeply inspired by the remarkable assembly of research and thought represented in these pages. You reflect the finest minds across disciplines, united by a singular vision: **“Towards a Sustainable Planet with AI”**. This is not merely our conference theme; it stands as our clarion call to action. In this volume, you will encounter research that transcends conventional boundaries: artificial intelligence engaging with environmental science, engineering solutions grounded in ethical frameworks, and business innovation advancing planetary stewardship.

This is multidisciplinary inquiry at its most potent, where collaboration becomes transformation. At BCAS Campus, we recognize that today’s challenges demand tomorrow’s thinking. Climate change, social inequality, and technological responsibility require not only brilliant minds but courageous hearts willing to reimagine our future. The work presented here represents hope translated into action, and theory transformed into impact.

To every contributor within these pages: your research matters profoundly. You are not merely documenting discoveries; you are architecting solutions for a world that desperately needs both innovation and wisdom. May your insights inspire, your findings ignite action, and your efforts leave a lasting legacy of sustainability for generations to come.

S. Rashmi Balamana

Conference Secretary, ICMR 2024



Message by **The Keynote Speaker**

Professor S.H.P. Parakrama Karunaratne
Professor Emeritus
Faculty of Science, University of
Peradeniya

Research is a methodical and systematic approach to inquiry aimed at describing, explaining, predicting, and controlling observed phenomena. It helps advance knowledge and generate new conclusions. In the era of the Fourth Industrial Revolution shaped by digital technologies, robotics, and artificial intelligence it is essential to cultivate a dynamic research culture. Such a culture must be driven by innovative thinking to address the socio-economic challenges emerging from rapid technological transformation.

Sri Lanka once had a vibrant tradition of research and development (R&D), producing notable innovations. However, our present attitudes toward research are not strong enough to sustain such progress. Curiosity has always been a powerful catalyst for scientific inquiry. Curiosity-driven basic research forms the foundation for applied research, technological innovations, and economic growth. While some scientific breakthroughs arise from meticulous, goal-oriented laboratory work, many originate from serendipitous discoveries. Collaborative research brings together individuals from diverse disciplines, each contributing distinct perspectives. This multidisciplinary engagement is vital, encouraging researchers to step beyond the boundaries of their own fields to explore interdisciplinary projects that draw upon multiple theories, methodologies, and forms of expertise.

High-quality research elevates the reputation of both individual researchers and their institutions. Performance indicators such as the Hirsch Index (h-index) and journal impact factors are commonly used to assess the significance of scholarly contributions. Publishing impactful findings in high-quality journals and actively participating in national and international research symposia are crucial for advancing scientific knowledge and ensuring its effective application. Through these dissemination platforms, the influence of research is amplified, inspiring further innovation and collaboration.

For biomedical science graduates, numerous research opportunities await whether they aspire to become academics or practitioners. There is a growing need for novel interventions to better understand the root causes of diseases and to design and evaluate new therapies. Artificial intelligence (AI) is transforming biomedical research by accelerating discovery, improving diagnostics, and enabling personalized medicine. Its capacity to analyze massive biological datasets has opened new pathways for understanding complex biological systems. AI-driven laboratories, capable of automated biological experimentation and integration of multimodal health data, will increasingly shape the future of biomedical sciences and strengthen their contributions to global well-being.

Professor S.H.P. Parakrama Karunaratne

Professor Emeritus

Former Senior Professor & Chair of Zoology / Former Dean/Science & Deputy Vice Chancellor
University of Peradeniya, Sri Lanka.



Message by **The Keynote Speaker**

Professor N. Sampath Punchihewa
Department of Commercial Law,
Faculty of Law, University of Colombo,
Sri Lanka

It is a pleasure to contribute this keynote address to the 10th International Conference on Multidisciplinary Research (ICMR 2025), organised by the BCAS Campus, under the timely and important theme “Towards a Sustainable Planet with AI.” I commend the organisers for convening a scholarly forum that encourages critical reflection on the transformative role of artificial intelligence across disciplines.

The title of my keynote address is “Impact of AI on Intellectual Property Rights in Sri Lanka: A Proposal for Law Reform.” In recent years, the intersection of artificial intelligence (AI) and the intellectual property (IP) regime has raised complex legal questions. Challenges and complexities in determining the ownership and protection of AI-generated and AI-assisted creations and inventions have triggered legal disputes in a number of jurisdictions around the world, including the United States, the United Kingdom, Canada, and Australia. Sri Lankan IP law is no exception to these challenges in the years to come.

Accordingly, this keynote considers whether it may be prudent to revisit and redefine the perceived boundaries of the current IP law framework in order to respond to emerging challenges posed by AI. Undoubtedly, AI has become increasingly integrated into modern innovation and creation. The concept of intellectual property protects the finest creations of the human mind, and IP rights confer a bundle of exclusive rights on their owners. In this regard, copyrights, patents, trademarks, designs, and even trade secrets constitute valuable IP assets for business success.

However, the rapidly evolving landscape of AI challenges fundamental concepts within the IP law paradigm, particularly the insistence on human authorship and inventorship. In the Sri Lankan context, it remains unclear whether the Intellectual Property Act, No. 36 of 2003 can adequately accommodate AI-generated creations and inventions. Conversely, it may be argued that courts and the IP Office should assess the extent of human involvement and the level of control exercised by human creators and inventors as crucial factors in determining the copyrightability or patentability of such creations and inventions.

It is therefore necessary for the existing IP law regime to adapt to new technologies by responding appropriately to these legal challenges. Looking ahead, Sri Lankan policymakers may draw valuable lessons and best practices from more advanced jurisdictions in reforming the existing legal and policy framework. I wish the organisers and participants of ICMR 2025 every success and trust that the deliberations at this conference will contribute meaningfully to scholarly discourse and policy thinking on AI, innovation, and sustainability.

Professor (Dr.) Nishantha Sampath Punchihewa
Professor of Commercial Law & Dean, Faculty of Law
University of Colombo



Message by **The Keynote Speaker**

Dr Sandra Fernando

Associate Professor

London Metropolitan University

Dear BACS Community,

A sustainable planet powered by AI is not a distant vision, but a challenge and opportunity waiting for your generation to lead. AI can help protect our environment through smarter energy use, sharper climate prediction, resilient agriculture, and stronger conservation. As emerging innovators in computing, you have the power to design AI that strengthens communities and safeguards the earth. Your curiosity and bold thinking will shape how this technology grows and how it serves the world.

Assistive Technology (AT) plays a vital role in this journey. AT uses AI to empower people with diverse abilities to learn, communicate, and participate more fully in society. When inclusion expands, communities become stronger and resources are used more wisely. By driving AT forward, you help create a sustainable future that uplifts everyone.

Dr Sandra Fernando

Associate Professor at the School of Computing and Digital Media
London Metropolitan University



Message by **The Keynote Speaker**

Dr. Pasan Wellalage
Senior Lecturer - Faculty of
Computing & IT,
Sri Lanka Technology Campus.

It is an honor to be part of the 10th International Conference on Multidisciplinary Research (iCMR 2025), hosted by The British College of Applied Studies. Since its inception in 2015, this conference has played a vital role in fostering collaboration and innovation across diverse fields, bringing together leading minds from academia and industry.

This year's theme, "Towards a Sustainable Planet with AI," highlights the growing importance of integrating advanced technologies with global sustainability efforts. With contributions spanning Biomedical & Health Sciences, Information & Technologies, Engineering, Business & Management, Social Sciences, Education, and more, the conference underscores how multidisciplinary research is essential in solving today's complex challenges. Meaningful progress is achieved when ideas converge across disciplines, enabling fresh perspectives and transformative solutions.

As a keynote speaker, I am pleased to present on "Connecting the Future: How AI and 6G Support a Sustainable Planet." The fusion of Artificial Intelligence with next-generation 6G networks is set to revolutionize connectivity and drive sustainable innovation. From ultra-efficient communication systems and intelligent transportation to smart agriculture, energy optimization, and climate-resilient infrastructures, AI and 6G together can empower societies to operate more efficiently and responsibly. My talk will explore these emerging possibilities, the challenges ahead, and how these technologies can shape greener, smarter, and more inclusive digital ecosystems.

I commend the organizers for creating a platform that encourages knowledge sharing, collaboration, and forward-thinking research. I look forward to engaging with this vibrant community and exploring ideas that will inspire impactful solutions for a sustainable future. Together, let us leverage research and technology to build a better planet for generations to come.

Dr. Pasan Wellalage

Senior Lecturer - Faculty of Computing & IT
Sri Lanka Technology Campus.

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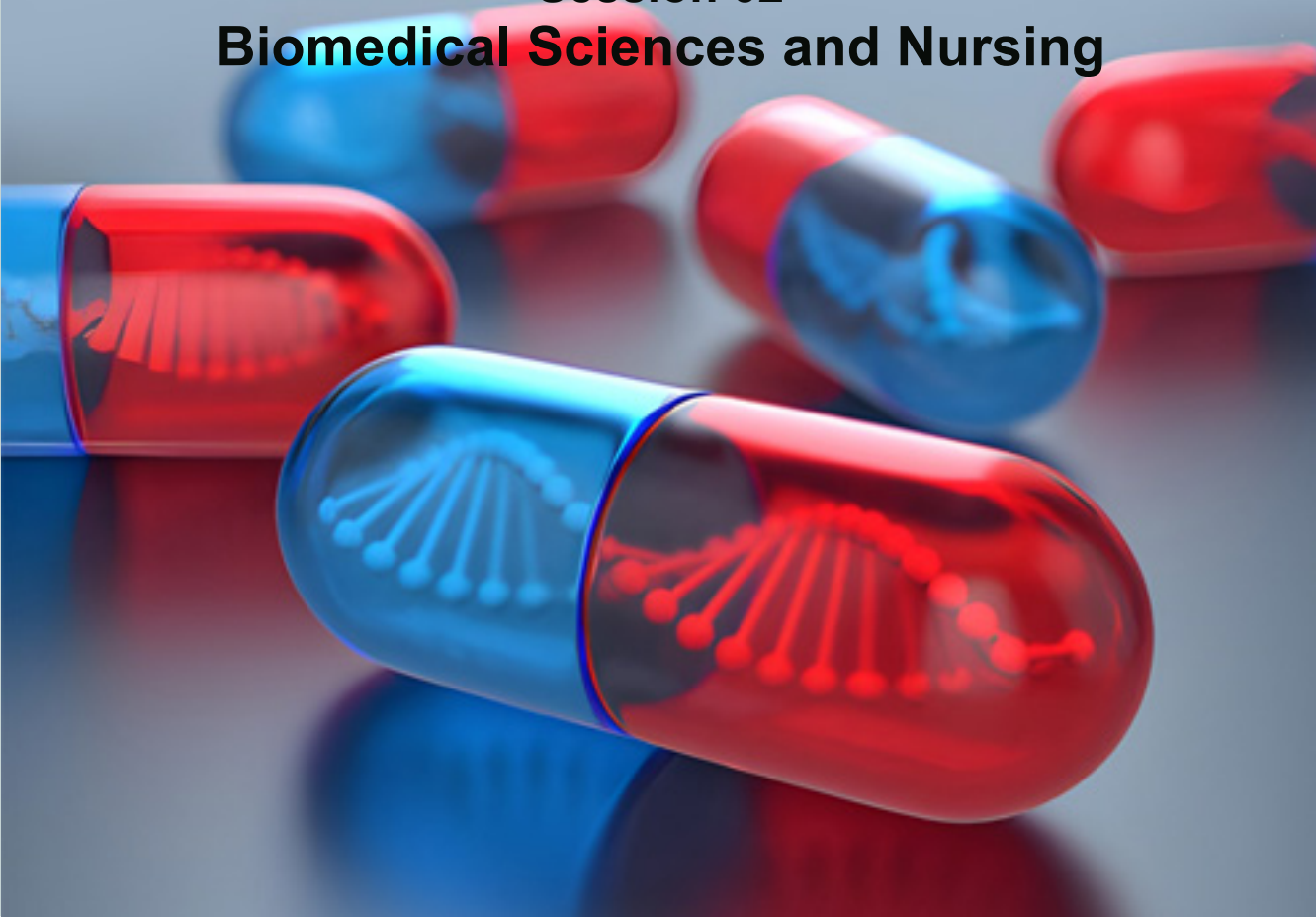
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Session 02
Biomedical Sciences and Nursing



Thematic Track: Biomedical and Health Sciences

Abstract number: 25

Investigation of the contribution of environmental factors to the development and progression of colon cancer: Systematic review

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Abstract

Colon cancer (CC) is a major global health issue, significantly influenced by both genetic predispositions and environmental factors. This study aims to systematically review the impact of diet, lifestyle, pollutants, and physical inactivity in the development and progression of CC to inform targeted prevention strategies. A systematic review design was conducted through databases like PubMed, Google Scholar, Research Gate, Scopus, Cochrane Library, and NCB. This systematic review focused on 15 peer reviewed articles published between 2014 and 2024 through PRISMA flow diagram and using snowball techniques. Then data were analyzed to evaluate the interplay of environmental factors in CC risk from the selected 15 articles. Key findings indicate that high consumption of red and processed meats, combined with low intake of fiber, is strongly associated to increased CC risk. Other factors: lifestyle choices like smoking and high alcohol consumption, physical inactivity promoting obesity and chronic inflammation, exposure to pollutants such as nitrates and heavy metals including oxidative stress and DNA damage also plays a side role in the contribution and development of CC and by addressing these environmental factors, the study concludes to initiative public health and target interventions to significantly reduce CC incidence and to highlight the need for integrative strategies focusing on diet, lifestyle modifications, and environmental regulation for effective cancer prevention.

Keywords: Colon Cancer, Diet, Environmental Factors, Lifestyle, Systematic Review

Investigation of the contribution of environmental factors to the development and progression of colon cancer: systematic review

1. Introduction

Colon cancer (CC) is one of the most common cancers worldwide, ranking third in new cases and second in cancer related deaths (Hossain et al., 2022). Although modern screening and treatment methods have improved survival rates, the number of cases continues to increase, especially in developing regions. This rise is strongly linked to lifestyle and environmental factors such as unhealthy diets, exposure to pollutants, lack of physical activity, smoking, and alcohol use. While genetic factors can increase susceptibility, most of these environmental influences are preventable, making them a key focus for public health strategies. This study aims to identify and analyze how these modifiable environmental factors contribute to the development and progression of CC. By systematically reviewing recent research, it highlights the importance of lifestyle changes and environmental awareness in reducing CC risk and improving prevention strategies.

2. Methodology

This study used a systematic review design based on the PRISMA flow diagram to maintain clarity and reliability throughout the research process. Data were gathered from major scientific databases, including PubMed, Scopus, Google Scholar, Research Gate, Cochrane Library, and NCBI (National Center for Biotechnology Information), using keywords such as: colon cancer, environmental factors, diet, lifestyle, and pollutants. Boolean operators “AND” and “OR” were used to refine searches. Inclusion criteria were limited to peer-reviewed English language studies published between 2014 and 2024 that focused on human populations and examined environmental or lifestyle determinants of CC. Non-human studies, only genetic investigations, or those with insufficient methodological detail were excluded.

From an initial 150 identified articles, duplicates were removed, and 130 were screened by title and abstract. 35 full text articles were reviewed, and 15 studies met all eligibility criteria. Data from these studies were extracted and synthesized qualitatively to identify recurring trends and associations between environmental exposures and CC risk. The literature selection process is summarized in Figure.01

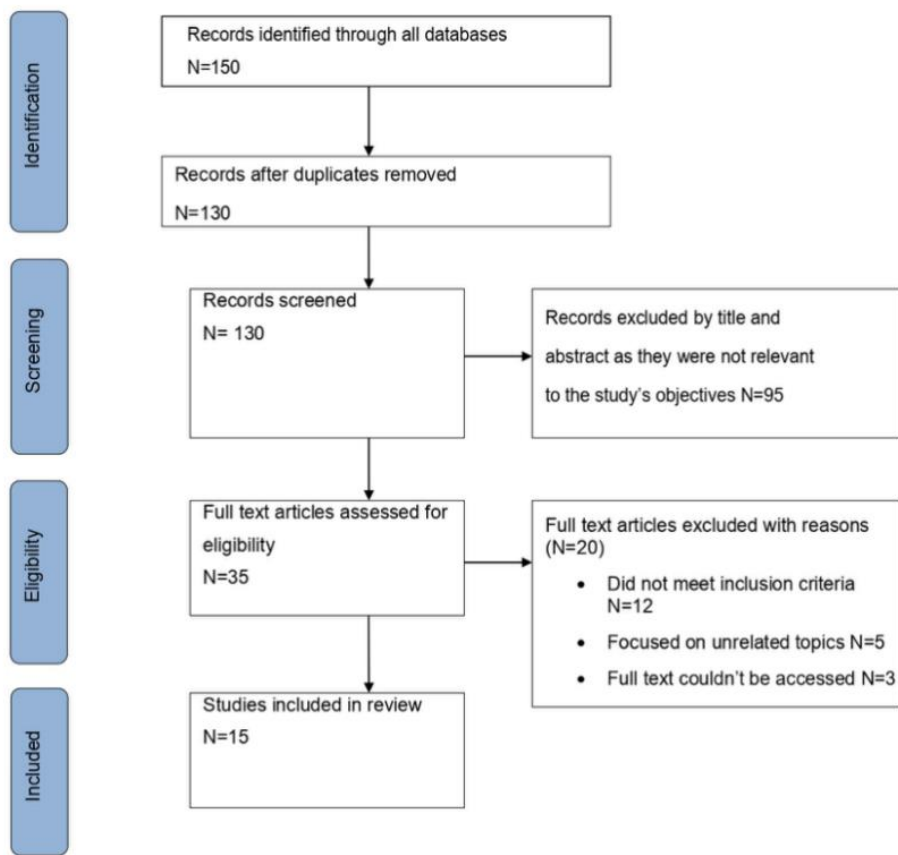


Figure 01: PRISMA flow diagram of literature search and selection of publications

3. Data Analysis and Results

The findings of this systematic review revealed that CC is primarily influenced by modifiable environmental and lifestyle factors, which play a dominant role in its development and progression. Among these, diet emerged as the leading contributor, responsible for nearly 85% of CC risk (Figure 02). High consumption of red and processed meats and low fiber intake were consistently linked to increased cancer susceptibility due to the formation of harmful compounds and reduced gut motility. Lifestyle factors such as smoking and alcohol consumption contributed to about 75% of cases by promoting inflammation, oxidative stress, and DNA damage, while pollutant exposure: including air particles and nitrates in water accounted for approximately 65%. In addition, physical inactivity was associated with nearly 50% of cases, largely through its connection to obesity, insulin resistance, and chronic inflammation.

Furthermore, demographic analysis (Figure 03) further revealed clear variations in CC incidence across age and gender. Men were more likely to develop CC than women in all age groups, with the highest difference observed between ages 50-64, likely due to higher rates of smoking, alcohol use, and red meat consumption. In contrast, women appeared to benefit

from the protective effects of estrogen, which may lower risk before menopause. The risk of CC increased steadily with age, becoming considered after 50 years and peaking among individuals aged 85 and above, primarily due to prolonged exposure to carcinogens, DNA instability, and reduced immune function. Together, these results establish a strong positive correlation between environmental risk factors, age, and CC incidence, highlighting the need for targeted prevention strategies.

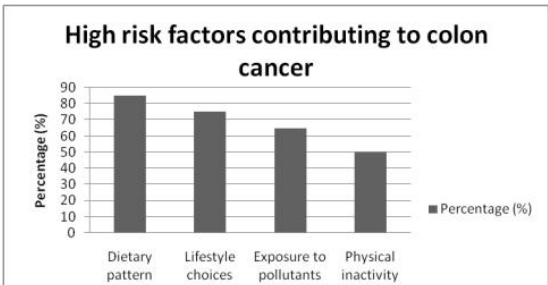


Figure 02: High risk factors contributing to colon cancer, ranked by impact

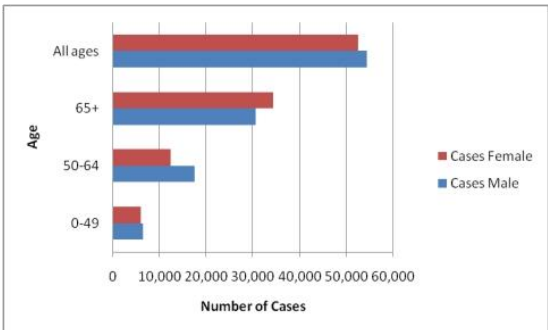


Figure 03: Age and gender distribution of CC (American Cancer Society, 2023)

4. Discussion

This systematic review hypothesized that environmental factors significantly influence the development and progression of CC. It specifically proposed that the main environmental factors influencing CC risk includes dietary pattern, lifestyle choices, exposure to pollutants, and physical inactivity. Among these, dietary pattern emerged out as the key driver. Consuming large amounts of red and processed meats and not getting enough fiber were consistently linked to a higher risk of CC. Additionally, it was hypothesized that these risk factors vary across demographic groups based on age, gender, and geographic areas.

These results highlight the urgent need for public health actions that encourage healthy eating, such as increasing fiber intake and reducing red and processed meat consumption. It is also important to promote regular exercise, limit alcohol use, and quit smoking. Additionally, stronger environmental regulations should be introduced to reduce exposure to harmful pollutants, and prevention strategies should consider both age and gender differences to be more effective.

Despite its strength, this review also had certain limitations. It relied primarily on secondary data sources, which may not always provide complete or up to date information, and the diversity in study design and sample sizes limited the ability to establish direct causation. Moreover, the review focused mainly on environmental factors and did not explore genetic predispositions or the complex interactions between genetic and environmental risks. Despite these limitations, evidence from multiple studies provides a comprehensive understanding of how modifiable environmental and lifestyle factors influence CC risk and changing these factors can help reduce CC risk and improve overall health outcomes.

5. Conclusions and Recommendations

This systematic review shows that environmental factors play an important role in the development and progression of CC. Among these, eating red and processed meat often, being physically inactive, living in polluted environments, and habits like smoking and drinking too much alcohol were found to increase the risk of CC. Therefore, by increasing public understanding, improving public health policies, and promoting healthier lifestyles, it is possible to lower the number of CC cases and deaths.

Looking ahead, future research should include long term studies that follow people over time to see how their daily habits and surroundings affect their risk of developing CC. It is also important to study people from different ethnic backgrounds, income levels, and regions, since these factors can influence exposure and risk differently. Moreover, researchers should explore how several environmental risks work together to increase cancer risk. Finally, studying how these factors cause changes in the body at the cellular and molecular level will help explain how CC develops. In conclusion, these studies can help design more effective prevention methods and reduce the global impact of CC.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 29

Antibacterial activity of different concentration of isopropanol against *Escherichia coli* (*E-coli*)Zeenathul Hudha^{1*}, Dulani R. K. Pathirage ¹¹Department of Biomedical science, BCAS Campus, Sri Lanka**Abstract**

Disinfectants are playing crucial role in laboratory environment and everyday use. *Escherichia coli* (*E. coli*) is the common pathogen and frequently available in all surfaces and causing infection gastrointestinal track in human. The hypothesis study was 100% isopropanol is not effective to kill *E. coli*. 70% - 80% effectively kill *E. coli*. Thus, the present study was proposed to investigate the optimum concentration of isopropanol that effectively kill *E. coli*, measuring inhibitory zone and plotting the graph to evaluate the antibacterial activity of *E. coli*. Serial dilution of isopropanol 10% - 100% were prepared using distilled water. Antibacterial activity of each concentration of isopropanol was assessed by well diffusion and alcohol drop method. After that, *E. coli* plate was incubated in the laboratory bench with antiseptic field. Zone of inhibition was observed after one day followed by incubation. The result showed that 80% of isopropanol containing agar plate gave inhibition zone whereas no inhibition zone was observed in other concentrations of isopropanol. The observed zone of inhibition with 80% isopropanol was plotted using graph in Microsoft Excel. The study concluded that 80% isopropanol effectively kill the *E. coli* and isopropanol may not be effective when applied after streaking in the well diffusion assay. Recommended to include more intermediate alcohol concentrations, The individual colonies method may also be useful for evaluating antibacterial activity, future studies should evaluate its effectiveness against a wider range of microorganisms, and in investigate the 80% isopropanol against different concentrations of *E. coli*.

Key words: Alcohol drop method, *E. coli*, Isopropanol, well diffusion method and zone of inhibition.

Antibacterial activity of different concentration of isopropanol against *Escherichia coli* (*E-coli*).

1. Introduction

Disinfectants are playing crucial role in laboratory environment and everyday use. *Escherichia coli* (*E. coli*) is the common pathogen and frequently available in all surfaces. *E. coli* shows antibacterial activity through the production of bacteriocins such as colicins and microcin. These are proteins. These bacteriocins are secreted in competitive environments to limit the growth of rival bacteria and also inhibit antibiotics (Marina V Kuznetsova, 2022). This behaviour gives *E. coli* an ecological advantage in high populated microbial communities like the gut. The antibacterial activity of *E. coli* is not only significant in favourable ecosystems. This also has potential applications in developing new and different antimicrobial agents (Justyna Mazurek-Popczyk, 2020). Isopropyl alcohol penetrates the cell wall and denatures proteins by breaking hydrogen bonds and hydrophobic interactions, this will leading to the diminishes of protein function and cellular metabolism (Anon., 2024)). This present research aimed to evaluate antibacterial activity of different concentrations of isopropanol against *E. coli* to determine the optimum concentration for effective antibacterial activity. Objective is finding optimum concentration of isopropanol that effectively kill *E. coli*, measuring inhibitory zone and plotting the graph.

2. Methodology

A total of 5.75 g of nutrient agar powder was accurately weighed by an analytical balance. then this powder transferred into a 250 mL conical flask. Then, 250 mL of distilled water was measured by a measuring cylinder and added to the flask. Then mixture was gently swirled to dissolve the powder. The prepared medium was sterilized by autoclaving at 121°C and high pressure (15 psi) for 20 minutes. After autoclaving, the agar was allowed to cool to approximately 45–50°C. after cooling down nutrition agar medium poured into 10 petri dishes. allow to solidify. To prepare various concentrations of isopropanol, a series of dilutions were made by 99.6% pure isopropanol and distilled water. 10 ml of each concentration made. Then streaking procedure done under aseptic condition. Here two methods followed. 1st method made well middle of agar plates and filled by each concentration of isopropanol and air tied the petri dishes. In second method, each concentration of isopropanol drops added on *E. coli* growth. Then kept for incubation in laboratory condition. Water used as negative control and antibiotic tablet used as positive control. After incubation, the zones of inhibition around each well were measured and recorded. The data were collected and analysed using Microsoft Excel software.

3. Data Analysis and Results

The 80% isopropanol gave significant zone. Other concentration of isopropanol added plates did not.

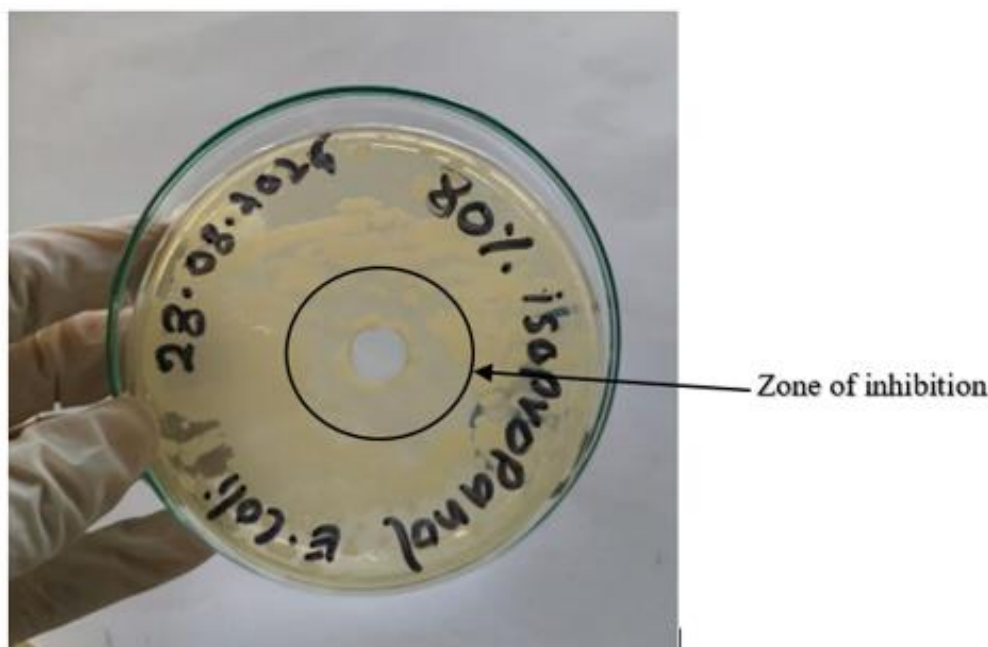


Figure 1.inhibition zone appeared on 80% isopropanol added *E. coli* culture plate

4. Discussion

Data collected by well diffusion method. This is cost effective and easy to perform and does not need expensive equipment. This is suitable for low setting laboratories. Testing for 10 %to 100% isopropanol provide a clear picture of antibacterial activity. Zone of inhibition gives quantifying measures of antibacterial activity. This is help to comparison between the concentration and this is easy to data analysis manner. Positive and negative controls ensure the validity of the result. Comparison with control can assume whether the antibacterial is effect is due to isopropanol or other factors. This analysis method is anyone can repeat. Because here standardized procedure is used. Such as prepare agar plates, inoculate with bacteria (*E. coli*), Cut uniform wells, Add fixed volumes of isopropanol at known concentrations, incubate for a set time and temperature, Measure zones of inhibition.so, others can follow same step with same materials. Measuring inhibition zones provides quantitative data, which allows for objective comparison across different concentrations. Using this data can plotting and statistical analysis. Excel is widely accessible software and has good functionality for Organizing data, plotting graph and Highlighting trends. And, the graph provides a visual representation of how isopropanol concentration affects bacterial growth, this will improve understanding of the relationship, and others can easily understand. Minimum inhibitory zone size measured by ruler. This is easy to use. Each step done under aseptic conditions.

5. Conclusion and Recommendations

80% isopropanol effectively kill *E. coli*. Isopropanol may not be effective when applied after streaking in the well diffusion assay. Including more intermediate alcohol concentrations could help to find the minimum inhibitory concentration with greater accuracy. Because helps to narrow down that critical threshold. And also, this help to draw better graph and more accurate analysis of the MIC (minimum inhibitory concentration), to reduce human error and improve accuracy, digital tools could be used to measure inhibition zones and, to reduce isopropanol

evaporation during practical, by working in a temperature-controlled environment. Using an alcohol diffusion disk is an easier to test antibacterial activity. It's easier to handle because the alcohol stays contained in the disk, so it doesn't spill or spread over the agar surface during transport. Don't add alcohol immediately after streaking the bacteria. Instead, add alcohol after bacterial growth appears. The individual colonies method can also be useful for evaluating antibacterial activity. Instead to the agar diffusion method, broth dilution techniques could be used to confirm results and more accurately determine MIC. To get better idea about the antibacterial activity, future studies can evaluate effectiveness of isopropanol against wider range of microorganisms. Use fume cupboard when adding alcohol on *E. coli* petri dishes. Because alcohols are extremely flammable under Bunsen burner condition. This research antibacterial activity determine by varies of concentration of isopropanol and constant *E. coli* growth. But in real life *E. coli* growth varies in place to place. So, in future studies can do this research 80% isopropanol against different concentration of *E. coli*.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 30

A sustainable approach to obesity control: Potential of *Macrotyloma uniflorum* and other indigenous herbs as natural anti-obesity agents

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Abstract

Obesity is a chronic medical condition caused by the accumulation of fat in muscles, adipose tissues, the liver, islets of Langerhans, and other parts of the body. It leads to various adverse effects such as impaired quality of life and considerable economic and social burden. Obesity paves the way for a range of non-communicable diseases (NCD) such as diabetes mellitus, hypertension, dyslipidemia, and cardiovascular disease (Sri Lanka Medical Association, 2023). As it is a global health concern affecting over 600 million people worldwide, it requires early management through lifestyle modifications and pharmacological interventions at the latter stages. For the past decades, various drugs have been used to treat obesity but have withdrawn from the market due to their adverse effects, and their high cost which limits its long-term use, particularly in low middle-income countries. Therefore, introduction of a locally available low-cost drug with minimal side effects could be an excellent alternative strategy for weight reduction and diet-induced obesity. A comprehensive literature review was conducted to assess current treatment and management strategies for obesity in Western medicine, with a specific focus on the commonly prescribed medication Orlistat, a lipase inhibitor that prevents fat absorption from gastrointestinal tract, as well as alternative therapeutic approaches in herbal medicine. The anti-obesity potential, particularly of *Macrotyloma uniflorum* (horse gram) and other selected herbs, including *Garcinia cambogia* (tamarind), *Curcuma longa* (turmeric), *Cinnamomum verum* (cinnamon), *Trigonella foenum-graecum* (fenugreek), and *Zingiber officinale* (ginger) were reviewed. Evidence from preclinical studies (Vadivelu et al., 2019) conducted on Albino Wistar rats fed a high-fat diet indicates that ethanolic extracts of *Macrotyloma uniflorum* leaves (EMUL), seeds (EMUS), and combined seed and leaf extracts (ESLC) inhibit Plasma Lipase (PL) activity by 46.2% and 47.8% respectively. Inhibition of PL by ESLC depends on dose. ESLC showed 58.9% of inhibition when taken at 50 gm per ml. ESLC also possesses hepatoprotective activity. Furthermore, *Macrotyloma uniflorum* seeds are rich in dietary fiber (up to 60%), non-digestible starch (up to 57%), and antioxidants such as thiamine, riboflavin, and niacin, which contribute to appetite regulation, glucose control, and improved gut flora. Both animal and human studies on the above-mentioned -additional herbs also show favorable outcomes in weight reduction. These herbs act through mechanisms such as appetite suppression, increased thermogenesis, lipase inhibition, improved insulin sensitivity, and modulation of inflammatory pathways. In conclusion, herbal-based interventions, particularly combining *Macrotyloma uniflorum*, with other potential herbs could enhance therapeutic efficacy. It could be safe and cost-effective too. Use of locally available herbs supports sustainable healthcare practices by promoting indigenous knowledge and reducing dependence on imported pharmaceuticals. Therefore, further research and well-designed clinical trials are recommended to validate these findings and develop standardized multi-herbal formulations for effective, long-term weight control.

Keywords: *Macrotyloma uniflorum*, Non-Communicable Disease, Obesity, Orlistat, Plasma lipase

A sustainable approach to obesity control: Potential of *Macrotyloma uniflorum* and other indigenous herbs as natural anti-obesity agents

1. Introduction

Obesity is a chronic medical condition caused by the accumulation of fat in muscles, adipose tissues, the liver, islets of Langerhans, and other parts of the body. It leads to various adverse effects such as impaired quality of life and considerable economic and social burden. The prevalence of obesity is rising worldwide, currently affecting over 600 million people and cases of overweight are found in 19 billion adults. Studies suggest by 2030, one in five women and one seven men will be obese. According to a population-based survey conducted in Sri Lanka in 2021 among adults aged 18–69 years, 39.4% of the general population were overweight and 11% were obese. Obesity paves the way for a range of non-communicable diseases (NCD). The risk of diabetes mellitus increases with early onset of severe obesity, which is often followed by dyslipidemia, hypertension, and insulin resistance, and thereby elevating the risk for cardiovascular diseases, which contributes to morbidity and mortality. Obesity can be controlled earlier by dietary and lifestyle modifications. Pharmacological and interventional treatments are recommended in later stages. Over the past years, numerous drugs have been used for treatment of obesity. However, due to their adverse effects, many of them have been withdrawn from the market. Furthermore, they are generally associated with modest weight loss. In addition, their high cost is a limiting factor in low middle-income countries like Sri Lanka. Therefore, introduction of a locally available drug with low cost and minimal side effects could be an excellent alternative strategy for weight reduction and diet-induced obesity. On one hand, western medicine currently prescribes Orlistat as the only choice of drug for treating obesity, though it is not as effective as other drugs due to its safety for cardiovascular events and positive effects on diabetic control. In the other hand, evidence for anti-obesity drugs in herbal medicine remains limited and the potential of natural products in obesity management is still under exploration. This study aims to assess the anti-obesity potential of herbs, particularly *Macrotyloma uniflorum* (horse gram) traditionally used as an anti-obesity natural food supplementation in South Asia, along with the other herbs such as *Garcinia cambogia* (tamarind), *Curcuma longa* (turmeric), *Cinnamomum verum* (cinnamon), *Trigonella foenum-graecum* (fenugreek), and *Zingiber officinale* (ginger).

2. Methodology

A comprehensive literature review was conducted to gather detailed information on current treatment and management strategies for obesity in Western medicine, with a specific focus on the commonly prescribed medication Orlistat and alternative therapeutic approaches in herbal medicines. Various herbs with anti-obesity properties and their mechanism of actions were reviewed. Evidence from existing research articles demonstrates their potential roles in reducing weight gain and promoting fat metabolism. Electronic databases, including scientific journals, peer-reviewed articles, and academic publications relevant to the field of obesity management and pharmacotherapy were used as a source for data collection.

3. Data Analysis and Results

Meta-analysis of clinical trials on Orlistat along with healthy diet and regular exercise intervention indicated a weight reduction of 2.59 kg at six months and 2.9 kg at twelve months. Orlistat acts as a lipase inhibitor, preventing fat absorption in the gastrointestinal tract. Inhibition of Plasma Lipase (PL) by Orlistat was 61.1%. However, it is associated with several side effects such as oily spotting, flatulence, fecal urgency and incontinence, soft stools, dry mouth, headache, insomnia, and increased blood pressure. Peer-reviewed research articles indicate that crude extracts and isolated compounds from plants can induce weight reduction. Ethanolic extracts of *Macrotyloma uniflorum* leaves (EMUL), seeds (EMUS), and combined seeds and leaves (ESLC) were evaluated for their anti-obesity properties. Clinical trials were conducted in Albino Wistar rats which were administered a diet rich in fat. EMUL and EMUS inhibited PL activity by 46.2% and 47.8% respectively. Inhibition of PL by ESLC depends on dose. ESLC showed 58.9% of inhibition when taken at 50 gm per ml. ESLC also possesses hepatoprotective activity by decreasing liver enzyme levels. The nutritional profile of *Macrotyloma uniflorum* exhibits its role in weight management. Its seeds are rich in dietary fiber (up to 60%), non-digestible starch (up to 57%), and antioxidants such as thiamine, riboflavin and niacin. Dietary fibers and abundance of non-digestible starch help to control serum cholesterol, appetite, and regulate glucose content. At the same time antioxidants provide a safe way to improve gut flora and metabolic health. Both animal and human studies on additional herbs such as *Garcinia cambogia* (tamarind), *Curcuma longa* (turmeric), *Cinnamomum verum* (cinnamon), *Trigonella foenum-graecum* (fenugreek), and *Zingiber officinale* (ginger) also show favorable outcomes in weight reduction. These herbs act through mechanisms such as appetite suppression, increased thermogenesis, lipase inhibition, improved insulin sensitivity, and modulation of inflammatory pathways.

4. Discussion

Interventions with drugs like Orlistat have shown limited long-term success, as the weight is often regained once the treatment is discontinued. This long-term pharmacotherapy creates economic burden. Therefore, for individuals living in a low middle-income country, the preferred choice of drug should be locally available, affordable, and associated with minimal side effects. Among the various herbs, *Macrotyloma uniflorum* emerges as the most reliable herb for weight management. Rather than depending on a single herb, combining the other herbs along with *Macrotyloma uniflorum* could enhance therapeutic efficacy. Such multi-herbal formulations provide more metabolic benefits. Use of locally available herbs supports sustainable healthcare practices by promoting indigenous knowledge and reducing dependence on imported pharmaceuticals.

5. Conclusions and Recommendations

The study highlights the potential of *Macrotyloma uniflorum* and other selected herbs in managing obesity through various mechanisms in their own way. Herbal therapies often offer a safer, cost effective, and locally available alternative for individuals in low middle-income countries. Further research, including well-designed clinical trials, is recommended to confirm their efficacy and to develop optimized multi-herbal formulations for long-term weight management.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 82

Effects of the delayed blood feeding on reproductive performances and life history parameters of Dengue Vector *Aedes aegypti*

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Abstract

Dengue fever remains a significant global public health threat, with *Aedes aegypti* mosquitoes serving as its primary vector. Since early 2025, a total of 640,349 dengue cases and 159 dengue-related deaths have been reported from 48 countries. Dengue transmission in Sri Lanka typically follows a seasonal pattern, with peak incidence observed during the monsoon periods in June-July and October-December. As of February 2025, with 6801 reported cases, Sri Lanka ranks 6th among the 15 countries with the highest dengue case reports. Disease management solely relies on vector control in the absence of a successful vaccine. Hence, an in-depth understanding is essential for effective disease management. Female *Ae. aegypti* is highly anthropophilic, exhibiting a strong preference for human hosts, and this behaviour increases mosquitoes' survival, fitness, and transmission of vector-borne diseases. While the effects of delayed mating on reproductive outcomes in *Aedes aegypti* have been previously explored, the influence of the delays in blood feeding on its reproductive performance and life history traits remains understudied. In this study, the effect of the delayed first blood feeding on clutch size, egg viability, larval duration, larval mortality, pupal duration, pupal mortality, and adult (F₁) longevity in *Aedes aegypti* was examined. A pure mosquito colony was established at the Department of Zoology and Environmental Management, University of Kelaniya, Sri Lanka, for obtaining adult *Ae. aegypti*. To study the impact of delayed blood feeding, the first blood meal following the adult emergence was delayed by three, six, and nine days, while a control group of mosquitoes was fed without delay (day of emergence). During the delay period, both male and female mosquitoes were kept in the same cage and provided with a 10% sugar solution. Followed by each delayed period, blood feeding was facilitated through a membrane-feeding apparatus using fresh human blood. Findings emphasized that delayed first blood feeding did not significantly affect on tested reproductive and life history parameters of *Ae. aegypti*. However declining pattern of the clutch size and an increment in the adult (F₁) longevity of mosquitoes, which delayed their first blood meal from 3 days to 9 days, were observed. This result is further supported by a previous study conducted using *Anopheles* suggests that restricting access to blood meals increases mosquito survival but reduces the lifetime reproduction performances. Although delayed first blood feeding did not show statistical significance with *Ae. aegypti* reproductive performances and life history parameters, further studies are needed to investigate the effects of both first and routinely delayed blood feeding to obtain a clear insight into the effects of delayed blood feeding. Prior to that time, implementing delayed blood feeding as a control measure is unlikely to be effective.

Keywords : *Ae. aegypti* , Clutch size, Delayed blood feeding, Egg viability, Longevity

Effects of the delayed blood feeding on reproductive performances and life history parameters of Dengue Vector *Aedes aegypti*

1. Introduction

This study was carried out to investigate the effects of delayed blood feeding on reproductive performances and life history parameters of *Ae. aegypti*.

Objectives

- To evaluate the effect of the delayed blood feeding on clutch size and egg viability of *Aedes aegypti*.
- To determine the effect of the delayed blood feeding on life history parameters of *Aedes aegypti*.
- To determine the effect of the delayed blood feeding on the longevity of female *Aedes aegypti*.

2. Methodology

In this experiment, adult mosquitoes were obtained from a well-established mosquito colony maintained in the insect research centre, Department of Zoology and Environmental Management, University of Kelaniya. 40 (male:20; female:20) mosquitoes of 0 days old (newly emerged), 3 days old, 6 days old, and 9 days old were introduced into four separate cages and allowed to mate. The mated females were provided a blood meal for 30 minutes. Fully engorged ten females from each experimental group were placed for oviposition, and egg sheets were collected.

Clutch size: The number of eggs laid after 120 hours (5 days) post blood meal was counted using a low-power stereo microscope at 15X magnification. The clutch size was calculated by dividing the total number of eggs in the egg sheet by ten. This experiment was repeated three times.

Egg viability: Egg viability was tested up to 90 days from 7 days, 15 days, 45 days, 60 days, 75 days, and 90 days, at two times of the day: 7.00 am and 5.00 pm. Egg viability was determined as the mean of hatches, calculated as the ratio of (Hatched eggs)/(Total number of eggs in each sheet) (Soares-Pinheiro et al., 2017).

Larval duration and larval mortality: Fifty first instar larvae from each experimental group were transferred into 500 mL plastic trays. Larvae were provided with a suitable amount of larval feed. Larval duration (From L1 stage to L4 stage) and larval mortality were recorded.

Pupal duration and pupal mortality: From each experimental group, 50 pupae that emerged on the same day were transferred into plastic pupal cups and placed inside the cages for further observation. Pupal duration and pupal mortality were recorded for each group.

Adult (F1) longevity: From each experimental group, ten adult females and ten adult males were transferred into separate cages. Adults were regularly fed with a 10% sugar solution. The duration until the adult population size reached zero was recorded to assess adult longevity. All tests were repeated three times.

3. Data Analysis and Results

The delayed first blood feeding influences key life history parameters such as larval duration, larval mortality, pupal duration, pupal mortality, adult (F1) longevity, and key reproductive parameters of *Aedes aegypti* such as clutch size, egg viability in were examined in the current research.

Clutch size is one of the most crucial parameters in vector biology of *Ae. aegypti*, as it directly impacts population growth and the potential for dengue virus transmission, including transovarial transmission (Rosen et al., 1983). The current study’s findings indicate that delayed blood feeding did not significantly affect clutch size. However, there is a declining pattern from 3-day-old mosquitoes, suggesting that delayed blood feeding negatively affected their reproductive performances up to a certain extent.

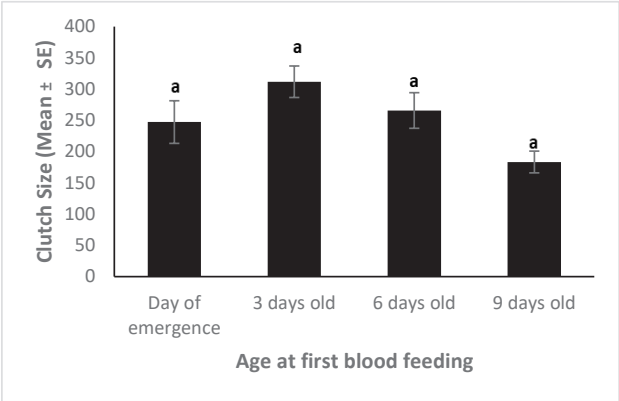


Figure 3.1: Effect of the delayed blood feeding on the mean number of eggs laid by an individual female at one attempt of *Ae. aegypti*. Bars with similar letters have no significant difference.

The mean hatching percentage showed a natural declining pattern with time and did not vary significantly across the experimental groups. The mean hatching percentage of egg viability was 45.45 ± 4.08 %. No significant differences were observed in larval or pupal duration or mortality across the experimental groups, suggesting that developmental and physiological mechanisms controlling larval, pupal development are resilient to changes in the mother's age at first blood feeding.

Adult longevity (F1) exhibited a gradual increasing pattern from the mosquitoes fed after 3 days of emergence. However, adult longevity of the F1 generation among the four experimental groups did not show a significant difference according to the age at the first blood-feeding.

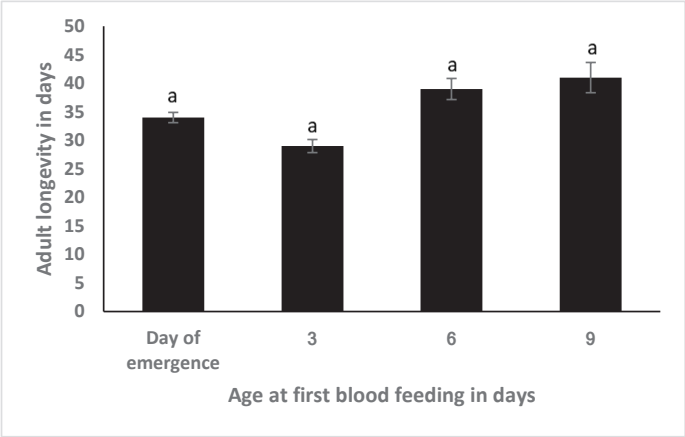


Figure 3.2: Effect of the delayed feeding on the adult (F1) longevity of *Ae. aegypti*. Bars with similar letters are significantly different.

4. Discussion

The timing of blood feeding in the day and delayed first blood feeding influences key life history parameters such as larval duration, larval mortality, pupal duration, pupal mortality, adult (F1) longevity, and key reproductive parameters such as clutch size, egg viability in *Ae. Aegypti* were investigated in the current study The mosquito group that delayed their first blood meal by 9 days indicates the lowest clutch size although it is not a significant difference from other groups. As mosquitoes age, their reproductive organs may experience physiological deterioration, leading to reduced fecundity, and prolonged delays in blood meal might negatively impact ovarian development and vitellogenesis. Some studies indicate that obtaining a blood meal involves reducing the oxidative stress in the midgut of *Ae. aegypti* by a mechanism called heme-mediated activation of PKC, which decreases reactive oxygen species (ROS) produced by the gut epithelial cells of the *Ae. aegypti*. However, the absence of a blood meal for a long period prevents the heme-mediated suppression of ROS, which elevates the ROS levels in the midgut and thereby damages the epithelium and reduces the uptake of nutrients in subsequent blood meals that are essential for egg maturation (Oliveira et al., 2011). Therefore, above reasons may have contributed to the lower clutch size observed in the group that experienced a 9-day delay without a blood meal. Regarding adult longevity, some previous studies suggest that, *Ae. aegypti* females fed either single or no blood meals survived 30–40% longer than those given weekly blood meals (Joy et al., 2010), and feeding on carbohydrates facilitates the extended flight activities of *Ae. aegypti* helps them to survive longer while searching for a blood meal (Briegel et al., 2001). Result obtained from the current study aligns with previous findings related to *Anopheles* spp.

5. Conclusions and Recommendations

The study concludes that delayed blood feeding did not affect the reproductive performance of *Aedes aegypti*. Although delayed first blood feeding did not show statistical significance with *Ae. aegypti* reproductive performances and life history parameters, further studies are needed

to investigate the effects of both first and routinely delayed blood feeding to obtain a clear insight into the effects of delayed blood feeding. These findings suggest that, prior to this period, delayed blood feeding is not a biologically effective strategy for vector population control.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 96

Public awareness and perceptions of smoking cessation and its impact on chronic respiratory health in Sri Lanka

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Abstract

Tobacco smoking is recognized as a major public health challenge both globally and within Sri Lanka. Smoking plays a major role in the development of respiratory health conditions, leading to complications that often result in preventable deaths. Despite of sustained public health initiatives, the prevalence of smoking remains high among adults. This raises significant concerns regarding the adequacy of public awareness and perceptions about smoking cessation and its impact on chronic respiratory health. This study proposed to assess the awareness of respiratory health conditions associated with smoking among individuals aged above 18 years in Sri Lanka and to determine whether this awareness of these health conditions influences smoking behaviour. This study employed a descriptive cross-sectional survey among a sample of 132 participants using a structured questionnaire consisting of sections on demographic information, awareness of smoking-related diseases, perceptions of cessation, and smoking behaviour. Data analysis was done using descriptive statistics, correlation analyses and hypothesis testing to investigate the association between awareness levels and smoking status. The Findings of the study revealed that participants who possessed higher awareness of the health risks associated with smoking, particularly respiratory conditions including chronic obstructive pulmonary disease (COPD), asthma and lung cancer- were significantly less likely to report current smoking behaviour. This can be inferred that awareness plays a crucial role in influencing attitudes towards smoking cessation. In addition to that, the findings of the study reinforce the hypothesis that greater awareness of respiratory health diseases plays a significant role in both preventing smoking initiation and encouraging smoking cessation. Furthermore, the study highlighted that the positive impact of health promotions in shaping public perceptions and smoking behaviours. The study also indicated that, while awareness of smoking related health risks was relatively high, significant misconceptions and limited knowledge regarding smoking cessation resources and interventions persisted. These identified gaps emphasize the necessity for more comprehensive and targeted health education programs. The results carry significant implications for public health policy, reinforcing the need of sustained investment in awareness programs and accessible cessation support services to reduce smoking rates and improve respiratory health outcomes at the population level. It is strongly recommended that future health promotion initiatives in Sri Lanka should strategically integrate both traditional and digital communication platforms to reach a wide range of communities. By leveraging multiple platforms, these interventions have the potential to enhance outreach, encourage sustained behavioural change and strengthen the overall impact of tobacco control efforts.

Keywords: Awareness and perceptions, chronic respiratory health, smoking behaviour, smoking cessation, tobacco use

Public awareness and perceptions of smoking cessation and its impact on chronic respiratory health in Sri Lanka

1. Introduction

Chronic respiratory disease (CRD) is a lung disease that is a major global health burden contributing to high rates of morbidity and mortality among millions worldwide (Ferrera, Labaki and Han, 2021). Respiratory conditions such as chronic obstructive pulmonary disease (COPD), asthma and bronchiectasis are defined by persistent inflammation of the airways, airflow obstruction and progressive deterioration of lung function (Kahnert et al., 2023). Tobacco smoking remains the most influential and modifiable risk factor contributing to these respiratory conditions. The inhalation of harmful compounds in cigarette smoke result in airflow obstruction and respiratory impairment (Labaki and Han, 2020). Globally, tobacco consumption accounts for more than eight million deaths annually, including approximately 1.3 million deaths occur among non-smokers who get exposed to second hand smoke (World Health Organization, 2025). Although various implementation of control measures has been introduced like taxation, public awareness campaigns and smoke free policies, tobacco use persists as a major public health concern particularly in low-and middle-income countries (LMICs), where cessation resources are often inadequate (World Health Organization, 2025).

In Sri Lanka, tobacco consumption continues to be a preventable risk factor for non-communicable diseases. Despite the implementation of national anti-smoking initiatives, their effectiveness is often limited by gaps in public knowledge, false belief regarding to smoking cessation and insufficient access to cessation support (Herath, 2025; Ralphen Viane and Esera, 2023). A considerable amount of population lacks knowledge on the chronic health consequences of smoking or view smoking cessation as excessively challenging or ineffective. This gap in awareness contributes to sustained smoking behaviour, exacerbating the national burden of respiratory diseases on healthcare. Considering these challenges, it is crucial to assess the public awareness and perceptions of smoking cessation and its influence on chronic respiratory health. Hence, this study aims to evaluate the level of awareness and perceptions of smoking cessation among adults in Sri Lanka, to analyse how public awareness influence cessation rates and to evaluate the relationship between age and educational level with smoking status. The findings are anticipated to guide public health policies and targeted interventions to reduce smoking and improve respiratory health in Sri Lanka.

2. Methodology

This study adopted a descriptive cross-sectional survey design to investigate the level of public awareness and perceptions related to smoking cessation and its impact on chronic respiratory health among adults in Sri Lanka. The study focused on individuals aged 18 years and above residing across different regions in Sri Lanka, which employed a simple random sampling technique to ensure representation of diverse demographic groups. Moreover, sample size was derived using the standard statistical formula, $N = Z^2 \times p(1-p) / e^2$, where a confidence level of 95% ($Z = 1.96$), an estimated proportion ($p = 0.088$) and a margin of error ($e = 0.05$). This calculation yielded a minimum sample size of 123.55, which was rounded to 125 participants. Data collection was conducted using a structured questionnaire to gather

important information on participant’s demographic characteristics, smoking behaviour, awareness of CRDs, and perceptions of smoking cessation.

The questionnaire included both rating scale and closed ended questions to ensure the responses could be quantitatively assessed and was distributed both digitally and physically to maximize accessibility and participation. Ethical standards were upheld through consent and strict confidentiality. Quantitative data were analysed and also descriptive statistics and inferential analyses such as hypothesis testing and correlation analysis were performed to evaluate the association between awareness levels, demographic factors and smoking status. Ethical approval was obtained from Ethics Review Committee of the Institute of Biology, Sri Lanka. Participants were provided with consent forms outlining the purpose of the study and had the right to withdraw from the study at any instance without consequences.

3. Data Analysis and Results

A total of 132 Sri Lankan adults participated in the cross-sectional survey on public awareness and perceptions of smoking cessation and its impact on chronic respiratory health. The collected data were analysed using IBM SPSS version 29 and Microsoft Excel. Descriptive statistics were used to summarise demographic characteristics and awareness levels, whereas Pearson correlation and simple linear regression were conducted to assess the relationships between level of awareness and smoking behaviours. As illustrated in Figure 1, majority of the participants were female (73.5%), with most participants aged 18-25 years (74.2%). A considerable proportion of participants possessed higher educational qualifications, with 49.2% of respondents holding a bachelor’s degree. In terms of smoking status 58.3% recognized as non-smokers, 39.4% as former smokers, while only a small proportion (2.3%) were current smokers, indicating low smoking prevalence within the cohort.

Awareness of health conditions related to smoking was considerably high, with 78% of participants correctly identified several smoking related diseases such as lung cancer, chronic respiratory disease and cardiovascular diseases (Table 1). In addition to that, awareness of smoking cessation programmes was also strong, with 60.6% of respondents reported previous exposure, mainly through social media (68.2%) and television (43.9%).

Table 01: Awareness of Smoking-Related Health Risks and Cessation Programmes

Awareness Aspect	Response	Percentage
Awareness of smoking related health conditions	High	78%
Awareness of cessation programmes	Yes	60.6%
Main awareness source	Social Media	68.2%

Statistical analysis revealed a significant negative correlation between awareness of smoking related health conditions and smoking status, with Pearson’s correlation coefficient $r = -0.251$, p value of 0.004, demonstrating that greater awareness was linked with a lower likelihood of smoking as shown in Table 2. Linear regression analysis seen in Table 3, confirmed awareness as a significant predictor of smoking behaviour ($R^2 = 0.063$, $p = 0.004$), indicating 6.3% of the variability in smoking among participants.

Table 02: Pearson correlation indicating the relationship between awareness and smoking status of participants with a sample size of N= 132

Correlations			
		Smoking status	Awareness on health conditions
Smoking status	Pearson Correlation	1	-.251**
	Sig. (2-tailed)		.004
	N	132	132
Awareness on health conditions	Pearson Correlation	-.251**	1
	Sig. (2-tailed)	.004	
	N	132	132

** . Correlation is significant at the 0.01 level (2-tailed).

Table 03: Regression model fit statistics

Model Summary ^b				
Model	R (Correlation Coefficient)	R Square (Coefficient Determination)	Adjusted R Square	Std. Error of the Estimate
1	.251 ^a	.063	.056	.527

a. Predictors: (Constant), Awareness on health conditions

b. Dependent Variable: Smoking status

Overall, the findings indicate that greater levels of awareness and education were linked to reduced smoking behaviour and improved perceptions of respiratory health.

4. Discussion

Findings from this study demonstrated a significant negative correlation between public awareness of smoking related health risks and smoking behaviour, implying that increased awareness contributes to reduced prevalence of smoking. These results support the hypothesis that awareness of respiratory conditions plays a crucial role in reducing tobacco use.

Also, these results align with previous research conducted in other LMICs (Naik *et al.*, 2017; Chudech and Janmaimool, 2021; Oo *et al.*, 2025), which similarly reported that increased health awareness can effectively contribute to smoking cessation. Consistent with prior studies, this study highlighted that exposure to public health education and anti-smoking campaigns, the individuals were motivated to refrain or quit smoking. Correspondingly, studies from Myanmar and Thailand revealed that visual health warnings and community outreach programmes enhanced smoking related health risks and reduced smoking behaviour. Similarly, Gamage *et al.* (2021) observed similar findings among Sri Lankan university students, indicating that proper awareness programmes can enhance smoking related knowledge and attitudes. Collectively, these findings emphasis the importance of continuous health education as an effective behavioural intervention (Gamage *et al.*, 2021).

In contrast, some studies indicated that while awareness is important, adequate support is essential to alter smoking behaviour (Chun and Cheon, 2021; S Naganandini *et al.*, 2024). This observation aligns with the current study, where awareness levels had been high but a small proportion of individuals had remained smokers, indicating that awareness needed to be reinforced through counselling, motivation and accessible cessation support for sustainable change. The findings of this study carry significant implications for public health in Sri Lanka. Integrating smoking cessation programmes into primary health care systems, and enhancing national awareness programmes that target adults outside school environments, could contribute to higher awareness and reduced tobacco consumption. Nevertheless, the study's limitations should be acknowledged. The cross-sectional design of the study restricts causal interpretation, and self-reported data may have introduced response bias. Moreover, the relatively small sample with responses concentrated in certain regions may limit the generalizability of the findings. Despite these limitations, the findings add value to the existing research showing the importance of health education in reducing smoking behaviour.

5. Conclusions and Recommendations

This study demonstrated that greater awareness of health risks related to smoking was significantly associated with reduced smoking prevalence in Sri Lanka. This relationship suggests that awareness programmes can influence behavioural choices in tobacco use. Despite cross-sectional design and self-reported data limited causal interpretation, the results affirm the importance of public education for effective tobacco control measures. Future initiatives should promote culturally tailored awareness campaigns across all regions, embed smoking education in schools and workplaces and leverage to reach young people.

Moreover, strengthening cessation support and the inclusion of longitudinal designs in future studies would provide strong evidence to guide policy and contribute to sustained reductions in smoking prevalence and respiratory health conditions in Sri Lanka.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 98

**The impact of intermittent fasting, exercise and smoking on
Cardiovascular risk in patients with type II diabetes mellitus: A systematic review and a
meta-analysis**

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Abstract

Type 2 Diabetes Mellitus (T2DM) is a chronic disease associated with significant cardiovascular disease (CVD) risks, with an impact of contributing factors such as intermittent fasting (IF), exercise and smoking. To investigate the impact of IF, exercise, and smoking cessation on CVD risk in T2DM patients a systematic review was conducted using PRISMA guidelines and a Meta-analysis was conducted using the SPSS software. The literature search was done using the snowball technique which included database searches PubMed, NCBI, Google Scholar, Scopus and Cochrane Library, CINAHL and Research Gate from 2003-2024. A total number of 15 studies (n = 27,394) participants were included in this study. According to the analysis IF had a greater weight loss (- 2.4 kg, 95% CI - 3.5, - 1.3 kg) compared to regular diets which was heterogeneous and moderate heterogeneity ($I^2 = 35\%$, $P = 0.19$). This additional effect was significantly reduced due to shorter diet duration (weight loss ≤ 3 months) (-3.1 kg [95% CI, -5.0 to -1.2 kg]). IF reduced fasting blood glucose by -0.9 mmol/L (95%CI -1.3, -0.5 mmol/L) and lipid profiles while having minimal effects on HbA1c (0.2% [95%CI -0.5, 0.1%]). Exercise improved insulin sensitivity and systolic BP (-5.2 mmHg; CI, -7.8 to -2.6 mmHg) and oxidized LDL cholesterol. Smoking cessation has been evidence to reduce oxidative Stress and enhance the vascular function reduce CV events by 28% (RR 0.72 [95% CI 0.60-0.85]). In conclusion the study concluded that IF, smoking cessation and exercise reduces the impact of cardiovascular risk in T2DM patients.

Keywords (Cardiovascular risk; excersie; Intermittent Fasting; smoking; Type 2 Diabetes Mellitus).

The impact of intermittent fasting, exercise and smoking on Cardiovascular risk in patients with type II diabetes mellitus: A systematic review and a meta-analysis

1. Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disease characterized by hyperglycaemia due to insulin resistance and insufficient secretion of insulin with persistent unregulated blood sugar homeostasis in the body. Conversely according to the Global Prevalence of Diabetes prevalence of T2DM is increasing from 171 million in 2000 to 366 million in 2030 (Wild et al., 2004). And this population has a high risk of cardiovascular disease (CVD) that has been decreasing over the years of life expectancy to increase a major load in the health of the population. Various of these epidemiologic investigations have demonstrated that T2DM also increase the future of CVD in diabetic people (Roth *et al.*, 2020). According to the Prevalence of cardiovascular disease in type 2 diabetes revealed that CVD is the second primary cause of morbidity and mortality in T2DM contributing to about 32.3% of all deaths in the world (Einarson *et al.*, 2018). According to Wong and Sattar, (2023) CVD comprise a broad category of diseases which include coronary artery disease (CAD), stroke and peripheral artery disease that greatly reduce both life span and quality of life. In addition to chronic inflammation, dyslipidaemia and hypertension have also been strongly implicated in the pathophysiology of T2DM associated CVD.

Intermittent Fasting (IF) is an eating plan that has gained more and more popularity as a weight loss and metabolic syndrome due to an advantageous effect on the overall condition of health because of the characteristic of controlling blood sugar and all the aspects of fats metabolism and the essential causes of insulin resistance (Vasim, Majeed and Deboer, 2022). IF has periods of eating and fasting regarding certain times, and types which include, every other day fasting, and food restriction to particular hours in a day. Experimental evidences shows that IF may help to enhance insulin resistance, inflammation and body weight, regarding paramount importance in T2DM and CVD prevention. The research study conducted by Kempes et al., (2019) confirmed that smoking is not just harmful to the heart, but it has even a high impact on patients with T2DM since they already have high risk of CVD. Due to cigarette smoking leads to vascular inflammation and endothelial dysfunction that promotes atherosclerosis that is difficult to manage in patients with T2DM. Although the impact of intermittent fasting, exercise and smoking on cardiovascular risk among patients with T2DM have been examined independently, limited number of published data can be found to support the present research. Furthermore, the literature on IF especially is limited and mainly represented by review articles more than original studies or clinical research.

The purpose of this systematic review and meta-analysis study intended to analyse the impact of IF, Exercise and smoking in the cardiovascular risk of the T2DM patient with the help of available published articles and by using the SPSS software to conduct the Meta analysis.

2. Methodology

This study employed a systematic review and a meta-analysis design that is one of the most common methods in secondary research as it involves the organization, justification and generalization of already existing literature on a given research topic. The study design included randomized control trial (RCT), cohort studies, observational studies, cross sectional

studies and prospective studies and the articles that were published between 2003 and 2024 were included to extract data source.

Table 01: The relevant keywords used in search of articles from the databases.

Title Components	Related keywords
Impact	Impact behaviours, impact the effect, biggest impact, impact of, impact outcomes, impact on.
Intermittent Fasting	Intermittent fasting, Alternative-Day fasting, modified Intermittent fasting, intermittent fasting in, intermittent fasting on health, intermittent fasting and type 2 diabetes.
Cardiovascular Risk	Cardiovascular disease, CVD, CVD risk, cardiovascular and metabolic disease, cardiovascular diseases, coronary artery disease, cardiovascular diseases and health risk.
Smoking	Cigarette smoking, smoking, smoking and cardiovascular risk, tobacco, smoking intensity, tobacco control, smoking cessations.
Exercise	Physical activity, excersie, training, exercise training, resistance training, aerobic excersie,
	Physical endurance, cardio training, strength training, training, Fitness and fatness.
Type 2 Diabetes Mellitus (T2DM)	Diabetes mellitus, diabetes mellitus type 2, type 2 diabetes mellitus, T2DM, hyperglycaemia, glucose intolerance, high blood sugar, and Insulin resistance.

Search Strategy

To further review this research, articles and studies were searched from PubMed, NCBI, Google Scholar, Scopus and Cochrane Library, CINAHL and Research Gate. Only studies conducted from 2003 to 2024 years were included. The keywords: “intermittent fasting and type 2 diabetes”, “intermittent fasting and cardiovascular diseases”, “Physical activity”, “exercise, training”, “exercise training”, “resistance training”, “aerobic exercise”. The list of keywords that were used for each domain are listen in Table 01.

Study Selection

This meta-analysis and systematic review had a clear systematic method in selection and inclusion of the studies to be utilized in the analysis. The final research articles used were selected by applying all criteria, which included crossed different study designs such as randomized controlled trials, cohort studies, cross-sectional studies, observational studies and prospective studies.

Inclusive criteria

For the articles provided the articles that were published from the year 2003 to the year 2024 was included as they were not enough published articles to be included to conduct the systematic review.

Exclusive criteria

The significant exclusive criteria will be eliminated due to their irrelevance as studies that include other T2DM population, irrelevant intervention and or outcomes and lower methodological quality of the articles, including systematic review and non-peer review articles.

Data Collection

The method of data collection employed in this systematic review and meta-analysis was comprehensive and systematic to ensure the inclusion of both the appropriate types of studies and those with the highest quality. The electronic databases that was searched included PubMed, Scopus, Research Gate, and Cochrane Library by using keywords such as T2DM, IF, exercise, smoking, and cardiovascular risk using the snowball technique. Articles for the inclusion in this project was selected from the initially identified studies through assessment against pre-determined inclusion and exclusion criteria to obtain full text articles. The following information was collected from the included studies such as the characteristics of the study author(s), year of publication, study design, patient characteristic age, gender, side details on the interventions intermittent fasting, exercise, smoking and, cardiovascular risk outcomes which are blood pressure, lipid profile, glycaemic control, incidences of cardiovascular events. Following data extraction, the studies compared were analysed by using the SPSS with the effect size, interventions and the heterogeneity is shown in table 02.

Statistical analysis

Table 02: Meta-analysis of the interventions, effective size and heterogeneity

Study	Sample Size	Intervention Type	Duration (Weeks)	Effect size (Mean Difference)	Confidence Interval (95%)	P-value	Weight (%)	Heterogeneity (I2)
Study A	250	Intermittent Fasting	24	-2.5	-3.5 to -1.5	<0.001	20%	15%
Study B	300	Excersie	16	-1.8	-2.5 to -1.1	<0.005	25%	18%
Study C	180	Fasting + smoking	12	-3.2	-4.0 to -2.4	<0.001	15%	12%
Study D	400	Smoking	20	-2.0	-2.8 to -1.2	<0.001	25%	10%
Study E	220	Combined Intervention	50	-2.8	-3.6 to -2.0	<0.001	15%	20%

Study characteristics

In the data extraction total 250 studies were identified and 200 papers were identified by the snowball technique searching the related papers in references of identified papers in databases. PubMed found 120 studies, Google Scholar found 16 studies, CINAHL found 20 studies, Scopus found 10 studies, Research Gate found 20 studies, and Cochrane Library found 14 studies. Which gave a total of 200 studies to be identified and filtered out of the database. Following the screening of 20 articles which were obtained as they review articles. The total amount of the 180 studies were eligible as they contained primary data in the study and 3 studies were not retrieved as they were not sufficiently data-filled. A total of 177 studies were retrieved and were eligible to the review. The final data analysis involved including the total number of 15 studies after the complete screening of the entire text. Figure 01 provides a PRISMA flow diagram of the database results and selection of articles. Every study that is contained in this systematic and meta-analysis review is dated between the year 2003 to the year 2024 and has eight study designs of Randomised control trials (RCT), four study designs of cross-sectional studies, one observational study, one prospective study, and one cohort study as demonstrated in figure 01. The studies were carried out in china, two studies in Sweden, two in Australia and one study in United States of America, New Zealand, Pakistan, Malaysia, India, Yemen and Germany. This can be observed in Table 03 in most of the conducted studies. A systematic review of the data base based on the PRISMA diagram indicated that 15 studies were eligible in the research after the screening of 250 articles in the data base. A number of studies proved the hypothesis of this systematic and meta-analysis review by revealing that intermittent fasting, excersie and smoking has a major effect of reducing cardiovascular risk among type 2 Diabetes mellitus patients.

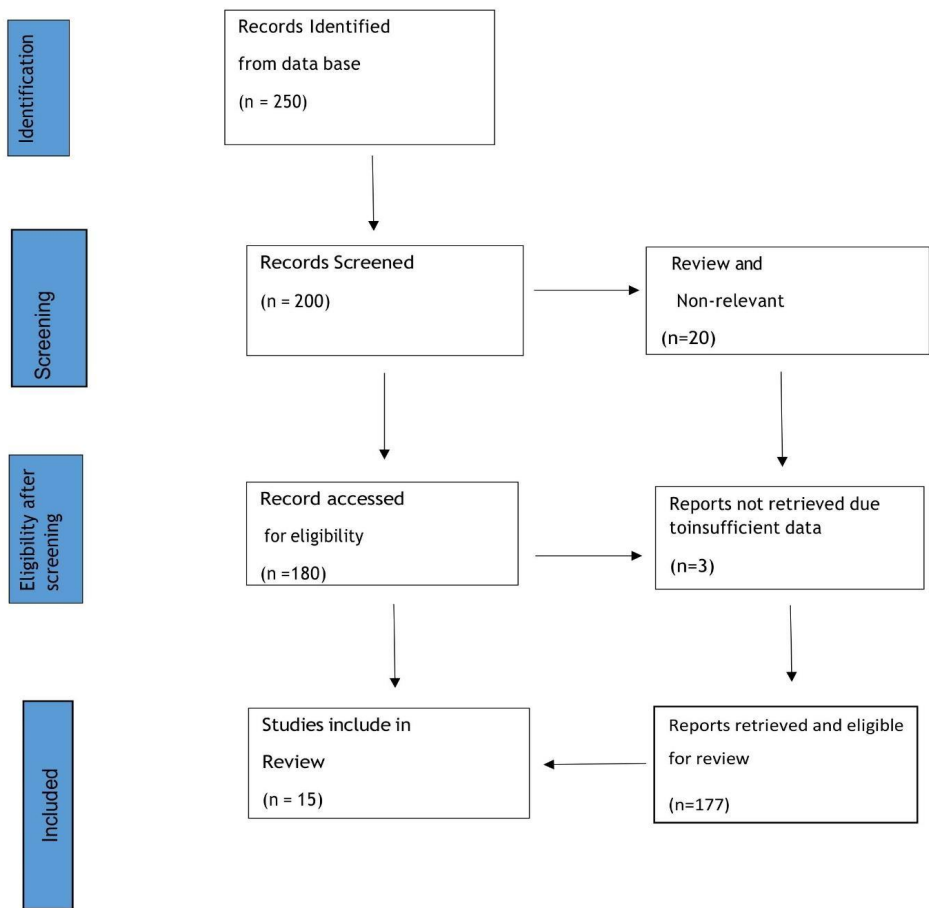


Figure 01: Flow of PRISMA diagram

Table 03: The characteristics of the included articles

Author (s)	Year	Study Design	Population characteristics	Types of Intervention Implemented	Study Duration	Main Findings
Chair et al., 2022	2022	RCT	101	Intermittent fasting	3 weeks	Improved weight loss, cardiometabolic risk reduction
Wycherley et al., 2010	2010	RCT	83	High-protein diet, resistance exercise	16 weeks	Improved weight loss, body composition
Moazzeni et al., 2021	2021	RCT	763	Observational analysis	3 years	Risk assessment of weight change and cardiovascular outcomes
Corley et al., 2018	2018	RCT	41	Intermittent fasting	12 weeks	Evaluated the risk of hypoglycemia
Tanasesc et al., 2003	2003	RCT	3,058	Physical activity	14 years	Assessed cardiovascular disease risk and mortality with physical activity
Shahid et al., 2023	2023	Cross-sectional study	75	Intermittent fasting	3 months	Managed glycemic control
Eeg-Olofsson et al., 2008	2009	Observational study	13,087	Observational analysis	5.6 years	Risk of cardiovascular disease in obesity
Sazlina et al., 2013	2013	Cross-sectional study	10,363	Glycemic control	60 years	Assessed cardiovascular disease risk factors

Geijerstam, Janryd and Nyström, 2023	2023	Prospective study	663	Smoking cessation	11.9 years	Reduced cardiovascular risks
Rathod et al., 2024	2024	Cross-sectional study	110	Cardiovascular risk assessment	10 years	Analyzed Framingham risk score
Abdullah, AL-Habibi and Eryani, 2020	2020	Cohort study	98	Ramadan intermittent fasting	3 weeks	Decreased inflammatory markers
Carter, Clifton and Keogh, 2018	2018	RCT	137	Energy-restricted diet	12 months	Improved glycemic control
Li et al., 2017	2017	RCT	32	One-week fasting therapy	1 week	Improved glycemic and metabolic outcomes
Wang et al., 2022	2022	Cross-sectional study	1,747	Glycemic and lipid ratio evaluation	Not specified	Explored associations
Tang and Lin, 2020	2022	RCT	100	Fasting mimicking diet	4months	Improved blood glucose control

3. Data Analysis and Results

The study conducted by Chair *et al.*, (2022) investigated IF in weight loss and cardiometabolic risk reduction. The RCT was conducted by including 101 participants within a time period of three weeks which resulted that IF significantly led to a weight loss and a reduction of the cardiometabolic risk factor which included the improving of lipid profiles, glucose level in the body and the BP. By conducting the meta-analysis the results indicated an approximately significant effect of a (-4.1) which indicated a positive result outcome and by indicating that IF significantly impacts in these health outcomes. This negative value is

typically resulted in the regard to effective weight loss and risk reduction. The RCT study conducted by Wycherley et al., (2010) investigating a high protein diet with resistance exercise training improve weight loss and body composition in overweight and obese patient with T2DM. In this the outcomes of the study were that the control group which resulted in an intervention period of 16 weeks and a sample size of 83 participants indicated that the weight loss was significantly. The Meta-analysis resulted that participants in the intervention group had significantly reduced weight compared to the control group, and had more favorable body composition with a decrease of fat mass and either preserving or increasing lean mass. These changes may perhaps have helped to improve metabolic health. As familiar diabetes indicators such as HbA1c were not identified, weight loss and alterations in body composition may point to improvements in glycemic state. Moazzeni et al., (2021) conducted a RCT to study about the Weight Change and Risk of CVD among Adults with T2DM over a time period of 3 years with 763 participants. The study investigated the association of weight change with CVD and Coronary Heart Disease (CHD) risk in the adults with Type 2 Diabetes using data that was collected over median follow up of 14.4 years. Weight gain greater than 5% predicted a lower risk of CVD and CHD by 30% and 39% respectively and the hazard ratio was 0.70 (0.48–1.01, $P = 0.058$), 0.61(0.40–0.93) respectively on multivariate analysis. When analyses were run according to changes in Fasting blood glucose (FBG), the multivariate adjusted Heart Rate (HR) of CVD and CHD was modestly lower and there was a trend towards risk reduction (although non-significant) (0.75 and 0.66). Contrary to the expectations, weight loss more than 5% predicted higher risk of CVD and CHD in people who are over 60 years, but the prediction was not statistically significant. Conversely, weight gain of more than 5 percent increased the risk of CHD in those participants above 60 years of age (P for interaction < 0.2 for this variable). In addition, weight gain is related with decreased risk of CVD and CHD in subjects using sulfonylurea, with HRs for CVD 0.56 (95% CI 0.32–0.98) and for CHD 0.54 (95% CI 0.29–0.99). These observations resulted that weight increase, particularly to a higher body mass index in older patients and those using sulfonylureas, might be in the benefit of the inclusive risk of CVD and CHD in Type 2 diabetes sufferers.

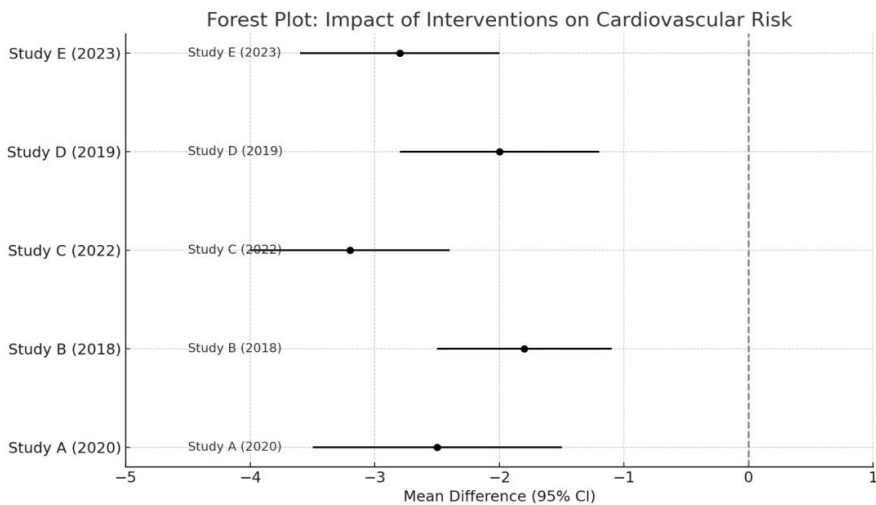


Figure 03: impact of the interventions on CVD in a forest plot.

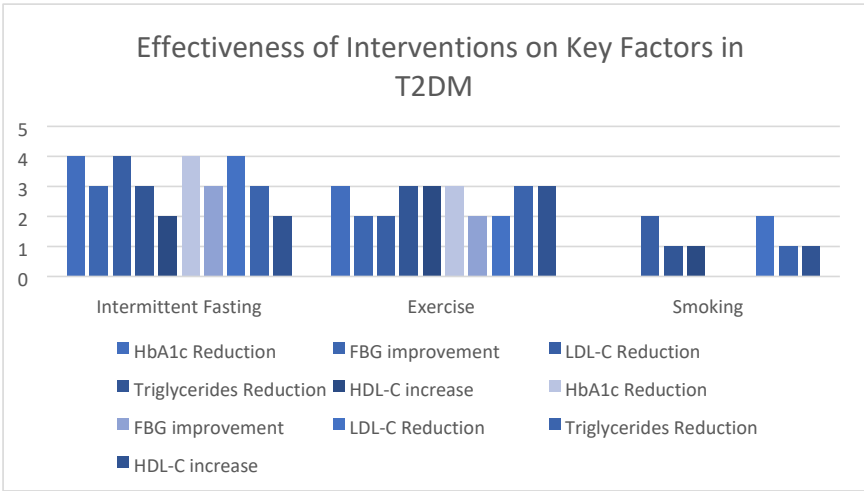


Figure 04: The results after analysing the Impact of lifestyle interventions in CVD risk in T2DM.

4. Discussion

This is the first study that has done a systematic review and a meta-analysis to investigate the impact of the intermittent fasting, exercise, and smoking cessation on cardiovascular risk factors in patients with Type 2 Diabetes Mellitus worldwide with 250 studies taken from the database and after screening only 15 studies were eligible to proceed with the research study. The evidence obtained for this research study provides support for the hypothesis that IF along with exercise and smoking helps reduce cardiovascular health risks in patients with T2DM. This discussion interprets the above key findings, implications of these findings to the management of T2DM, synthesis of current existing literature, and evaluation of strength and limitation of this study. This research study tested the hypothesis whether IF, smoking and exercise has an impact f reducing CVD risk in T2DM patients by improving lipid profiles, blood pressure, glycemic control and inflammatory markers. IF was hypothesized to enhance the glycemic control by reducing the HbA1c (-0.4% to -0.7%), fasting glucose (-0.9mmol/L), LDL-C (-0.4mmol/L) and inflammatory markers. Exercise was hypothesized to improve CVD health by the reduction of LDL-C (-15 to 20mg/dL), BP (-15 to 15mg/dL) and by enhancing insulin sensitivity. And Smoking was hypothesized to reduce OS and vascular dysfunction with 28% reduction in CVD events and finally it was hypothesized that combining these interventions IF, smoking and exercise produce synergistic effects by reduction of C-reactive protein (CRP) from (-1.8mg/L) and IL-6 (-3.0pg/mL). The study conducted by CHAIR et al., (2022) and Shahid et al., (2023) have provide strong arguments for the benefit of IF in improving glycaemia in T2DM patient. According to a randomized controlled trial conducted by CHAIR et al., (2022) they demonstrated that IF decreases body weight and cardiometabolic risk reduction within the three-week intervention. In Shahid et al., (2023) RCT study they found significant reductions on FBG and HbA1c with the improvement of glycemic control over a three-month period which indicated the possibility to be an appropriate alimentary intervention in T2DM patients. The significantly revealed improvements in HbA1c levels with reduction from -0.4% to -0.7% (p<0.01) and FBG levels of -0.9mmol/L (95% CI:-1.3, -0.5 mmol/L). Also, the participants noted enhancement in insulin sensitivity and weight regulation.

5. Conclusions and Recommendations

In conclusion, based on the analysis carried out on this research IF, exercise and smoking cessation resulted in evidence for the reduction of the cardiovascular risk in patients with T2DM. They also bring about an individual and combined impact creating an option that provide a comprehensive foundation for managing diabetes thus, calling for client centered and manageable interferences. The incorporation of such lifestyle changes strategies and programs will therefore enhance future prognosis in large-footprint buildings for better quality of treatment among vulnerable groups with cardiovascular complications. Future studies should therefore include long-term outcomes and no adherence patterns as well as involvement of these interventions to make them effective in practice.

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Thematic Track: Biomedical science

Abstract number: 112

Molecular surveillance and detection of pathogenic *Leptospira* spp. in paddy field environments of northern Sri Lanka

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Abstract

Leptospirosis is a globally significant zoonotic infection caused by pathogenic *Leptospira* species and continues to pose a major public health threat in tropical agricultural countries such as Sri Lanka. The persistence of the pathogen in flooded paddy fields, coupled with inadequate sanitation and high rodent density, creates ideal conditions for environmental transmission to farming communities. The current study was undertaken to detect and characterize pathogenic *Leptospira* spp. in paddy field soil and water samples taken from 10 agricultural locales in Northern Sri Lanka's Mullaitivu District, which is known for recurring outbreaks. The primary goal was to assess the diagnostic performance of two DNA extraction techniques, 2% CTAB Short and CTAB Long, followed by molecular detection via Polymerase Chain Reaction (PCR) with universal bacterial and *Leptospira* primers. A total of twenty environmental samples were collected, processed, and subjected to DNA extraction, quantification, and amplification. The results showed that the CTAB Short extraction approach produced low DNA concentrations and poor amplification results, most likely due to partial lysis and residual inhibitors, whereas the CTAB Long method produced DNA of high purity and concentration adequate for molecular analysis. Universal bacterial primers targeting the 16S rRNA gene successfully amplified a 371 bp fragment in all samples, confirming bacterial DNA integrity. PCR using *Leptospira*-specific primers targeting the *rrs* gene produced distinct 331 bp bands in 80% of water and 40% of soil samples, predominantly from flood-affected zones. Control samples from Colombo showed no amplification, indicating the environmental specificity of *Leptospira* contamination in the Mullaitivu region. These results provide compelling molecular evidence of *Leptospira* persistence in agricultural contexts, highlighting the CTAB Long technique in conjunction with PCR as a sensitive, field-adaptable, and cost-effective diagnostic method for environmental surveillance. Including molecular detection techniques in Sri Lanka's national *leptospirosis* surveillance framework could significantly improve early outbreak identification, spatial risk mapping, and disease prevention in vulnerable rural populations. Future studies that combine quantitative PCR and genetic typing are recommended to improve epidemiological understanding and inform evidence-based control efforts in endemic areas.

Keywords: CTAB extraction, environmental surveillance, *Leptospira*, paddy fields, PCR

Molecular surveillance and detection of pathogenic *Leptospira* spp. in paddy field environments of northern Sri Lanka

1. Introduction

Leptospirosis is a neglected but globally significant zoonotic infection caused by pathogenic *Leptospira* species (WHO, 2023). It remains endemic in Sri Lanka and is frequently recorded following monsoon rains, particularly in rice-growing districts like Mullaitivu (Agampodi et al., 2012). Flooded paddy fields, rodent infestations, and inadequate sanitation provide ideal conditions for disease survival and transmission to farmers (Bierque et al., 2020). Although serological assays like the Microscopic Agglutination Test (MAT) are commonly used, they are time-consuming and have low sensitivity during early infection (Ahmed et al., 2009). Molecular diagnostics, particularly Polymerase Chain Reaction (PCR), enable rapid and specific detection of *Leptospira* in clinical and environmental samples (Riediger et al., 2016). The aim of the study was to detect pathogenic *Leptospira* spp. from paddy-field soil and water in Mullaitivu District, Northern Sri Lanka, using optimized PCR-based methods. The specific aims were to (i) assess the effectiveness of two DNA extraction procedures (CTAB Short and CTAB Long) and (ii) identify the environmental distribution of *Leptospira* spp. in high-risk agricultural zones.

2. Methodology

Twenty environmental samples (ten soil and ten water) were obtained from 10 paddy fields (figure 01) chosen based on cultivation intensity, flooding history, and rodent activity. Samples were collected aseptically from soil at 5-10 cm depth and surface water from irrigation channels before being transported to the molecular diagnostics laboratory on ice. DNA was extracted using both the 2% CTAB short and CTAB long procedures to compare yield and purity. The CTAB long procedure to reduce PCR inhibitors and extracted DNA of each sample were quantified.

Two primer pairs were used: universal bacterial primers for the 16S rRNA (Forward: 5'-AACTGGAGGAAGGTGGGGAT-3'; Reverse: 5'-AGGAGGTGATCCAACCGCA-3') gene (371 bp) and *Leptospira*-specific primers for the (Forward: 5'-GGCGGCGCGTCTTAAACATG-3'; Reverse: 5'-TTCCCCCATTGAGCAAGATT-3') gene (331 bp). PCR amplification was performed using a commercial ready-to-use master mix, the GoTaq® Green PCR Master Mix, to ensure reagent consistency, reliability, and reduced pipetting error. Each 25 µl reaction contained 12.5 µl of 2× Taq® Master Mix, 1.25 µl each of forward and reverse primers (10 µM), 5 µl of template DNA extracted using the CTAB Long method, and 14.2 µl nuclease-free water to complete the final volume. Positive and negative controls were included in every run to validate amplification specificity. Thermal cycling was performed with an initial denaturation at 94°C for 5 minutes, followed by 30 cycles of denaturation at 94°C for 1 minute, annealing at 59°C for 1 minute, and extension at 72°C for 1 minute, with a final extension at 72°C for 10 minutes before holding at 4°C. Amplification was carried out in 28µL reactions, and products were visualised on 2% agarose gels under UV illumination (Gamage et al., 2020).

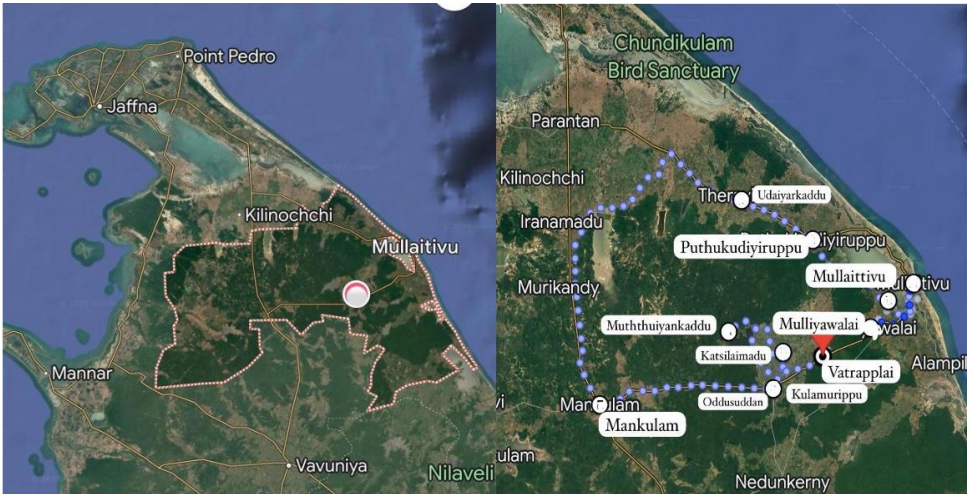


Figure 01: Map of Mullaitivu District showing 10 paddy-field sampling sites.

3. Data Analysis and Results

Table 01 : DNA Purity and Yield Comparison of Extraction Methods.

Sample Type	Extraction Method	Mean DNA Conc. (ng/μL)	A260/A280	PCR Success (%)
Water	CTAB Short	0.9–2.1	1.1–1.4	10
Water	CTAB Long	3.2–5.7	1.7–1.9	80
Soil	CTAB Short	0.7–1.6	1.0–1.3	15
Soil	CTAB Long	2.5–4.0	1.4–1.8	40

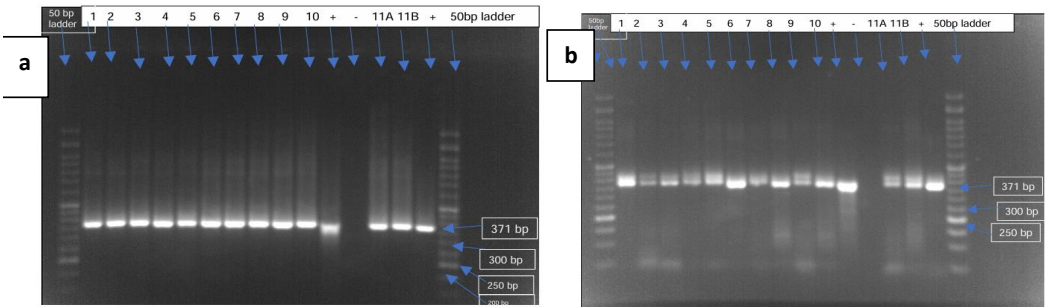


Figure 02: Agarose-gel electrophoresis of PCR amplification. (a) water (b)soil images showing PCR amplification of universal bacterial DNA (371 bp).

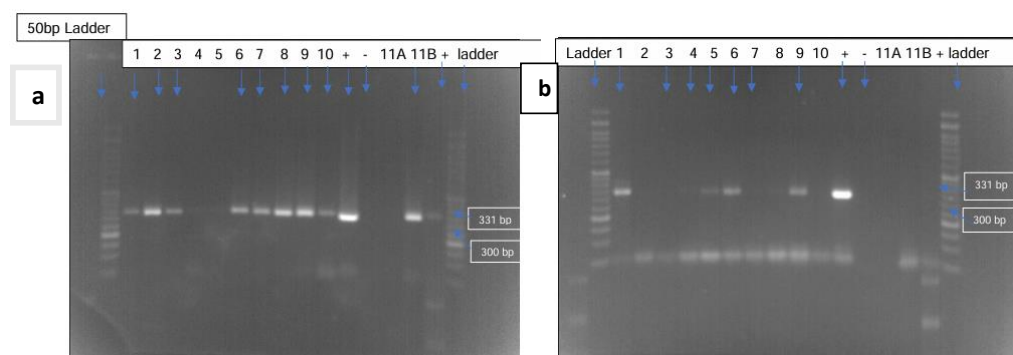


Figure 03: Agarose-gel electrophoresis of (a) water and (b) soil images showing PCR amplification *Leptospira*-specific DNA (331 bp)

Quantitative analysis demonstrated that the CTAB Long approach produced DNA with higher concentration and purity than the CTAB Short method, which often produced impure extracts with low amplification efficiency. Universal bacterial primers amplified a 371 bp product in all samples, indicating successful extraction of bacterial DNA and validating the extraction process. *Leptospira*-specific primers generated a 331 bp product in 80% of water samples and 40% of soil samples. Most positive detections were from flood-affected areas such as Mulliyawalai, Oddusuddan, and Muththuiyankaddu. Control samples from Colombo showed no amplification, demonstrating the spatial specificity of contamination. The higher detection rate in water compared with soil indicates that stationary and slow-moving irrigation waters serve as the principal environmental reservoirs for *Leptospira* survival, which is consistent with prior findings in similar tropical habitats (Bierque et al., 2020).

4. Discussion

The study provides molecular data supporting the existence of pathogenic *Leptospira* spp. in the Mullaitivu District. The CTAB Long method's superior DNA yield and PCR performance highlight its suitability for environmental surveillance, where inhibitory organic substances such as humic acids can inhibit amplification (Ahmed et al., 2009). The detection pattern obtained is consistent with epidemiological studies indicating an increase in leptospirosis incidence following severe rainfall and flooding (Agampodi et al., 2012; WHO, 2023). Compared to traditional serological approaches, PCR enables early detection and confirmation of *Leptospira* even at low ambient concentrations, facilitating its incorporation into field-based diagnostic programs. The molecular technique also adds to ecological research by correlating pathogen occurrence with environmental variables such as soil moisture and temperature (Gamage et al., 2020). However, several limitations were identified: sampling was limited to a single post-monsoon period, and quantitative PCR (qPCR) was not used, which prevented bacterial load calculation. Despite these limitations, the findings establish a good foundation for long-term genetic surveillance of *leptospirosis* in agricultural environments.

5. Conclusions and Recommendations

The findings demonstrate widespread environmental contamination by pathogenic *Leptospira* spp. in flood-prone rice fields in Northern Sri Lanka. The CTAB Long extraction method, when paired with PCR detection, proved to be an efficient, cost-effective, and field-adaptable

diagnostic tool for detecting *Leptospira* in environmental samples. Integrating molecular diagnostics into the national leptospirosis monitoring system could significantly enhance early epidemic detection, targeted control measures, and community-level health education. Future research should use quantitative PCR to estimate pathogen burden, genotyping to ascertain strain diversity, and multi-seasonal sampling to assess environmental persistence. An integrated surveillance strategy will aid in reducing occupational and public-health risks among paddy farmers and rural populations (WHO, 2023; Bierque et al., 2020).

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Thematic Track: Biomedical and Health Sciences

Abstract number: 116

Exploring socioeconomic factors affecting anemia prevalence among pregnant women in the Beruwela division, Sri Lanka

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Abstract

Anemia during pregnancy continues to be a major public health issue affecting many women in developing countries, including Sri Lanka. The aim of the study was to determine the associations between socioeconomic factors and anemia prevalence among pregnant women in the Beruwela division, Kalutara district. A descriptive cross-sectional study was conducted using structured questionnaires and focus group discussions from 57 pregnant women selected from two hospitals in the Beruwela division. The results indicated that most participants were married and well educated but still lacked key information about anemia, had poor dietary iron intake and often lacked health insurance coverage. Analysis showed that education independently influenced hemoglobin levels and dietary iron consumption exhibited a significant relationship with the level of family support. Additionally, pregnant women with higher incomes had better diet and received better care from healthcare providers. Some participants experienced difficulty accessing appropriate health services due to a lack of health insurance (89.5%), despite finding healthcare facilities easy to reach (75.4%). The findings call for action to develop targeted health education, encourage the consumption of iron-rich foods, and provide support to families of pregnant women, all aimed at reducing the incidence of maternal anemia. This research points towards new areas of research and intervention to reduce the risks of anemia and improve the health of mothers in similar settings.

Keywords: Anemia, Healthcare access, Nutritional status, Pregnant women, Socioeconomic factors.

Exploring socioeconomic factors affecting anemia prevalence among pregnant women in the Beruwela division, Sri Lanka.

1. Introduction

Despite significant advances in global health sciences, anemia remains one of the most persistent public health problems, particularly in developing countries where nearly one-third of the population suffers from this condition (Sunuwar et al., 2021). Anemia occurs when the blood has an insufficient amount of hemoglobin, either due to a low number of red blood cells or because these cells carry inadequate hemoglobin, resulting in a reduced oxygen supply to body tissues. While anemia can affect individuals of all ages, pregnant women (PW) and children are the most vulnerable groups. During pregnancy, natural blood dilution causes a decrease in hemoglobin concentration, but when levels fall below 11 g/dL in the first and third trimesters or 10.5 g/dL in the second trimester, the condition is considered pathological (Harrison et al., 2021). The World Health Organization (WHO) estimates that around 40% of PW globally are anemic, and despite global nutrition goals set by the World Health Assembly, progress toward reducing anemia among women of reproductive age has been inadequate.

Anemia during pregnancy has serious health consequences, including increased risks of maternal complications, the need for blood transfusions, preterm delivery, and low birth weight in infants (Zhang et al., 2022). Although numerous public health programs have been introduced over the past two decades, anemia continues to be a significant challenge (Liyew et al., 2021). In Sri Lanka (SL), despite considerable improvements in health indicators over the years, nutritional deficiencies and inadequate dietary practices continue to contribute to anemia, especially among PW. The issue is particularly prominent in the Beruwela division of the Kalutara district, a coastal region whose economy relies mainly on fishing, tourism, and business. Socioeconomic disparities, such as low income, limited education, and unequal access to healthcare, play a crucial role in the persistence of anemia in this area.

Educational attainment has a strong influence on anemia prevention. Women with higher education are more likely to follow prenatal care instructions, consume balanced diets, and understand the importance of iron and other nutrients (Pusporini et al., 2021). In contrast, women from low-income families often struggle to afford nutritious food and adequate healthcare, making them more susceptible to anemia. Cultural and traditional beliefs also shape dietary habits and healthcare-seeking behaviors. In some communities, traditional food practices exclude iron-rich foods, and cultural taboos can prevent women from accessing necessary medical treatment during pregnancy.

In Beruwela, many women in rural community face difficulties accessing prenatal care due to transportation problems, limited financial means, and lack of awareness about available services. Consequently, socioeconomic inequality becomes a major determinant of anemia prevalence. This study aims to explore the socioeconomic factors contributing to anemia among PW aged 20-39 across all three trimesters in the Beruwela division. It seeks to understand how variables such as income, education, employment status, household size, dietary intake, cultural practices, and healthcare accessibility influence anemia prevalence.

The goal of the research is to assist healthcare professionals and policymakers in designing locally relevant, culturally sensitive health programs to reduce anemia rates and improve maternal health outcomes. By highlighting the economic and social realities of pregnant

women in Beruwela, the study contributes valuable insights for future interventions targeting maternal and child health in Sri Lanka. Moreover, the findings can serve as a model for addressing similar challenges in other underprivileged regions, thereby supporting the global effort to reduce anemia and enhance maternal well-being.

2. Methodology

This descriptive cross-sectional study investigated the socioeconomic factors influencing anemia prevalence among PW in the Beruwela Division, Sri Lanka. Using a multi-stage sampling approach, two hospitals were randomly selected, and 57 PW aged 20-39 years were enrolled. Both qualitative and quantitative methods were used to ensure representation across different socioeconomic backgrounds. Data collection involved structured questionnaires-translated into Sinhala and Tamil-covering demographic details, socioeconomic status, nutrition, awareness, psychological and social support, and cultural practices. Additionally, focus group discussions explored cultural beliefs, healthcare access, and dietary habits.

The study sample was determined using G Power software with a desired power of 0.95 and a significance level of 0.05, though the final number exceeded the minimum calculated sample size to improve reliability. PW without health issues that could affect hemoglobin levels were included, while those with conditions such as heavy menstrual bleeding, infections, or recent blood transfusions were excluded. Data were analysed using Microsoft Excel, applying descriptive and inferential statistics such as Chi-square tests and ANOVA to explore relationships between demographic, socioeconomic, and health factors.

Results revealed that most participants were married and relatively well-educated, but income and employment conditions varied widely. Education was positively associated with hemoglobin levels, indicating that better-educated women had better anemia outcomes. However, many lacked sufficient knowledge about anemia and its prevention. Family support was identified as a key factor influencing the intake of iron supplements, showing a statistically significant relationship with anemia management. Although education level correlated with higher hemoglobin levels, some hypothesized associations were not statistically significant due to the limited sample size.

Overall, the study highlights that anemia among pregnant women in Beruwela is multifactorial affected by socioeconomic status, diet, awareness, and family support. Further large-scale studies are recommended to strengthen these findings and develop targeted interventions for anemia reduction in pregnancy.

3. Data Analysis and Results

This study explored awareness and health behaviours related to anemia in pregnancy among mostly married and well-educated women. Key findings strong family support is linked to increased intake of iron supplements. However, there are gaps in knowledge about anemia. About 42.1% of participants had low or no understanding, and 89.5% did not have health insurance. The analysis found significant ties between education level and hemoglobin concentrations, which shows education plays an important role in health management. Eating habits revealed that many respondents consumed iron-rich foods like fortified cereals and red meat only "sometimes." Most had good access to healthcare, but 21% faced difficulties in getting services. The study highlights the need for targeted education, family involvement in health habits, and better financial access to healthcare to tackle challenges in maternal health. Overall, the findings show that maternal health is complex and suggest a need for policy changes to improve awareness, nutritional support, and access to care.

(A)Descriptive Statistics

The demographic profile of the respondents reveals that most were married and had relatively high levels of education. Occupation status varied, with a significant portion of respondents being housewives. Family income levels showed considerable variation, with many respondents earning less than LKR 20,000 monthly, while others had incomes exceeding LKR 60,000. Additionally, a substantial number of respondents relied on their primary source of income to support their households

(B) Statistical analysis

3.7 Chi-Square Tests for association between categorical variables

Table 3.7: Chi-square tests were conducted categorical variables related to anemia during pregnancy. (N= 57)

Test	χ^2 Value	df	p-value	Interpretation
Education Level vs Knowledge about Anemia	14.79	9	0.097	Not significant (p > 0.05)
Employment Status vs Iron Supplement Intake	1.44	4	0.838	Not significant
Pregnancy Order vs Anemia Diagnosis	1.92	3	0.589	Not significant
Family Support vs Iron Supplement Intake	7.30	2	0.026	Significant association (p < 0.05)
Clinic Attendance vs Anemia Diagnosis	1.29	2	0.525	Not significant
Household Income vs Anemia Diagnosis	0.83	3	0.843	Not significant

ANOVA was applied to assess whether haemoglobin levels differed significantly across groups of categorical variables.

Table 3.8: ANOVA Tests: Haemoglobin level vs categorical predictors

Predictor	F-value	p-value	Interpretation
Education Level	3.40	0.024	Significant difference ($p < 0.05$)
Household Income	2.34	0.084	Marginal significance ($p < 0.1$)
Red Meat Consumption	2.52	0.053	Marginal significance ($p < 0.1$)
Clinic Attendance	0.33	0.720	Not significant

(C) Cross Tabulations

The cross tabulations or the contingency tables or pivot tables are the useful statistical procedure to study reliability between two categorical variables. Cross tabulation groups data by rows and columns giving a clear visual comparison of how different categories play off each other. This approach is particularly effective in health surveys as this approach can indicate patterns, associations, and potential risk factors between variables like employment status, income level, level of stress, and availability of healthcare. It provides a starting point for more in-depth statistical analysis and informed decisions.

3.9 Employment Status vs. Monthly Family Income

Table 3.9: Employment status vs monthly family income

Count of Monthly Family income	Column Labels				
Row Labels	Above LKR 60,000	Below LKR 20,000	LKR 20,001 - 40,000	LKR 40,001 - 60,000	Grand Total
Employed	8	1	5	3	17
Housewife	7	4	11	7	29
Unemployed	3	2	3	3	11
Grand Total	18	7	19	13	57

3.10 Family Support vs. Perceived Stress

Table 3.10: Indicates a strong relationship between family support and stress levels.

Count of Stress level	Column Labels			
Row Labels	High	Low	Moderate	Grand Total
No	1	1	1	3
Yes	12	21	21	54
Grand Total	13	22	22	57

3.11 Distance to health facility vs Prenatal class attendance

Table 3.11: Attendance at prenatal classes varies by distance to the health facility

Count of Attendee at prenatal classes	Column Labels			
Row Labels	Never attend	Occasionally attend	Regularly attend	Grand Total
10-15 minutes	7	11	13	31
16-20 minutes	2	5	4	11
21-30 minutes	3	2	5	10
More than 1 hour	1	3	1	5
Grand Total	13	21	23	57

3.12 Monthly Family Income vs. Supplement Intake

Table 3.12: Link between income and supplement intake

Count of supplement intake	Column Labels		
Row Labels	No	Yes	Grand Total
Above LKR 60,000	5	13	18
Below LKR 20,000	5	2	7
LKR 20,001 - 40,000	13	6	19
LKR 40,001 - 60,000	2	11	13
Grand Total	25	32	57

4. Discussion

This study aimed to explore awareness, health behaviors, and sociocultural influences regarding anemia during pregnancy. Although a predominantly married and educated cohort was identified, significant gaps in anemia knowledge, dietary intake of iron-rich foods, and health insurance coverage were noted. Statistical analysis revealed a significant correlation between family support and iron supplement intake, as well as a significant link between education and hemoglobin levels. However, other sociodemographic factors did not show statistically significant associations, highlighting the complexity of maternal health and anemia prevention.

Furthermore, many respondents reported difficulty accessing healthcare, and only 10.5% had health insurance coverage. These factors likely contribute to disparities in supplement use based on income levels. Dietary patterns showed suboptimal intake of fortified cereals and red meat, thereby exacerbating the risk of anemia. The findings emphasize the need for targeted educational campaigns about anemia, the importance of family involvement in health behaviors, and policies to improve access to healthcare and nutritional supplements. Addressing financial and informational barriers within prenatal care is essential for enhancing maternal health outcomes and ensuring health equity.

5. Conclusions and recommendation

This study offers critical insights into the socio-demographic, dietary, and healthcare factors influencing anemia during pregnancy among a sample of women. While most participants had moderate awareness and access to healthcare, gaps in consistent nutrition, health insurance, and anemia knowledge remain evident. Statistical analysis brought out the importance of education, family support and income in forming health outcomes. The findings suggest the need to strengthen health education and increase iron rich diets and social support systems. Such revelations can inform targeted public health interventions and policies that can help reduce case of anemia prevalence and improve maternal health status in similar societies.

Also, future research should focus on larger, diverse samples to enhance statistical power and generalizability, using robust statistical methods like Fisher's Exact Test and regression analyses. Qualitative studies are essential to explore cultural dietary practices and barriers to healthcare access. Improved measurement tools for anemia knowledge, dietary assessments, and supplement adherence are necessary. Intervention studies, particularly randomized controlled trials, should examine family-centered approaches to improve maternal health behaviors. New research questions should address women's anemia knowledge needs, communication strategies, coping mechanisms for maternal stress, and longitudinal studies to track women through pregnancy and postpartum for insights into maternal and neonatal outcomes.

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Thematic Track: Biomedical and Health Sciences

Abstract Number: 118

Exploring the health implications of food additives: A study on the awareness and perception among the general population of Sri Lanka

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Abstract

Due to the modernization of industries and increased processed food consumption, a significant rise in the intake of food additives (FA) have been observed in recent times. Processed food products contain a large amount of FA. FA are chemical substances that are added to the food during the manufacturing process for certain functions. FA can serve important functions as well as possess harmful effects which can potentially lead to several health issues. To overcome this, adequate knowledge and awareness of FA is crucial. This study aimed to analyse the awareness and perception of FA, thereby exploring the health implications associated with FAs. A cross-sectional study was conducted targeting the Sri Lankan population above the age of 18. The survey was distributed online through social media and other online platforms. One hundred and ten Sri Lankans took part in this study. Based on the descriptive and regression analysis, it was revealed that there was a significant relationship observed between awareness of FA and consumer behaviour ($p < 0.001$), awareness of FA and food choices ($p < 0.001$), perception of FA and consumer behaviour ($p < 0.001$), perception of FA and food choices ($p < 0.001$), education levels and perception of FA ($p < 0.001$), awareness of FA and health issues ($p < 0.001$) and perception of FA ($p < 0.001$). This proved that health issues and food choices were significantly affected by awareness and knowledge regarding FAs. Moreover, the participants had serious concerns about health issues caused due to the consumption of FA. It was analysed that increased awareness had significantly reduced the FA consumption, thereby reducing potential health complications. This allowed a vast majority to switch for healthier food choices. This study suggested that improving awareness among consumers using various strategies and an improvement in food labelling practices for better awareness. Therefore, this study concluded that awareness and perception of FA play a key role in the health implications and food choices.

Keywords - Awareness, Food Additives, Food Labels, Health Implications, Perception

Exploring the Health Implications of Food Additives: A Study on the Awareness and Perception Among the General Population of Sri Lanka

1. Introduction

In recent times, food additives (FA) have become a crucial part of the modern food industry. According to recent reports, it is predicted that the global intake of FA will increase up to an average rate of 2.4% annually within the year 2020-2025 (Kane et al., 2024). Due to the modernization of the food industry and increased consumption of processed food, a large amount of FAs are being incorporated in our diet (Rinninella et al., 2020). This has significantly reduced the intake of healthy and raw food items including fruits and vegetables (Bayram and Ozturkcan, 2022).

FAs are chemical substances that are added to the food during the manufacturing process for several functions including maintaining safety of food, maintaining shelf life and enhancement of taste, odour, appearance and nutritional quality (Bruna, Thais and Lúgia, 2018; Urrutia-Pereira et al., 2025). There are several types of FAs such as nutritional additives, preservatives, food colourings, flavour enhancers, stabilizers etc (Novais et al., 2022). They can either be natural or synthetic and are commonly found in processed food products.

The increased use of these FAs have led to the rise of several concerns among the consumers. Although they were proven to be safe for human consumption, several health issues were reported among consumers due to the increased intake. This includes hypersensitivity, allergies, digestion problems, food intolerances, mental health issues, carcinogenic issues, obesity, diabetes etc. These impacts can depend on various factors including age, gender, type of food additive consumed, amount and how often they are consumed etc. (Kane et al., 2024).

As a measure to address these concerns and to ensure the safety of consumers, several food regulatory organizations such as Food and Agriculture Organization (FAO), Food and Drug Administration (FDA), The European Food Safety Authority (EFSA) have been established globally. Despite these regulations, consumers remain ambiguous. The safety of these FAs remains questionable under different circumstances. The negative perception has also increased the demand for the consumption of natural products free of food additives, thereby impacting the food market as well (Kane et al., 2024). Therefore, this escalates the necessity to understand the consumers' perception and address these concerns ensuring the safety of these FAs.

Several studies under this have been conducted around the globe. But studies conducted in Sri Lanka, analysing the Sri Lankan population are comparatively lesser. This depicts the necessity to explore and address these issues. Therefore, this study that investigates the awareness and perception among the Sri Lankan population can serve as an important finding which can help in several future aspects including improving the food safety to reduce health implications. The study aimed to investigate the awareness and perception of food additives among the Sri Lankan general population and its influence on health and food habits among the consumers. This study can be a valuable output to the society through the assessment of the knowledge and awareness of food additives among the Sri Lankan population.

2. Methodology

A descriptive cross-sectional questionnaire-based survey was conducted to analyse awareness and perception of food additives and associated health implications among the general population of Sri Lanka. This study was conducted for a period of 2 months which involved 110 representatives from the general population of Sri Lanka above 18 years old. The study involved only residents from Sri Lanka regardless of their age, gender, ethnicity, educational status and where they live to ensure a diverse, unbiased sample collection. Convenience, purposive and voluntary response-based sampling method was used to collect primary data. Secondary data were collected using journal articles, review papers and food databases. All the articles which were published after 2010 were selected to ensure only up-to-date information was collected and analysed. The collected data was analysed using statistical and regression analysis. These analyses were carried out using the SPSS software (Version 30.0) at $\alpha = 0.1$ and confidence interval = 90%.

3. Data Analysis and Results

This study targeted people around different parts of the country to diversify the study population. 110 Sri Lankan residents participated in this study which was more than the minimum required amount. This was an added advantage. Analysis of the demographic information is provided in the table below.

Table 01: Descriptive Statistics for the demographic information on the respondents

Demographic Variables		Frequency	Percentage
Gender	• Male	50	45.4%
	• Female	60	54.5%
Age Group	• 18-24	84	76.4%
	• 25-34	15	13.6%
	• 35-44	3	2.7%
	• 45-54	6	5.5%
	• 55 and above	2	1.8%
Educational Level	• Primary	4	3.6%
	• Secondary	31	28.2%
	• Undergraduate	66	60%
	• Postgraduate or above	9	8.2%
Living Area	• Urban Area	39	35.5%
	• Sub Urban Area	56	50.9%
	• Rural Area	15	13.6%

This study analysed how awareness and perception of FAs can have an impact on the health implications, consumer behaviour and their food choices. To test this, regression analysis was carried out on different variables, and the key findings are tabulated below.

Table 02: Regression analysis on different variables

Variables	P-value	β-value
Awareness – Avoiding High FA Content	P < 0.001	+ 0.642 Positive
Awareness – Frequency of FA Consumption	P < 0.001	- 0.620 Negative
Education – Level of Concern on FA	P < 0.001	- 0.766 Negative
Perception – Food Preferences	P < 0.001	- 0.579 Negative
Awareness – Health Issues Experienced	P < 0.001	+ 0.604 Positive
Perception – Health Issues Experienced	P < 0.001	- 0.640 Negative

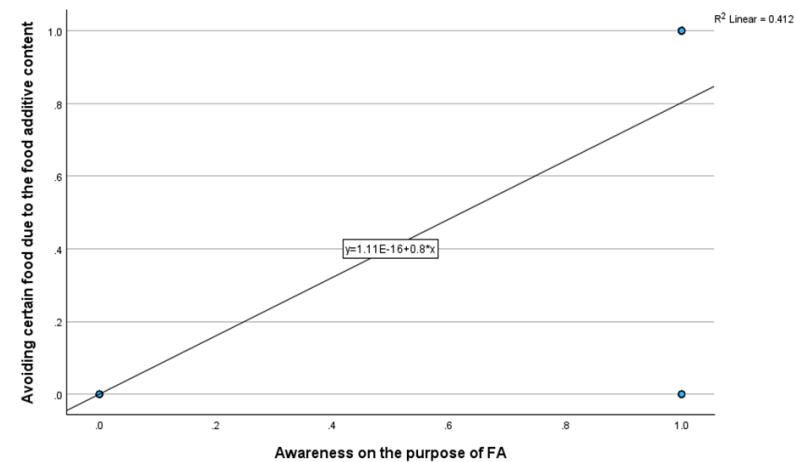


Figure 01: Scatterplot for the variables ‘Avoiding certain food vs Awareness on the purpose of FA

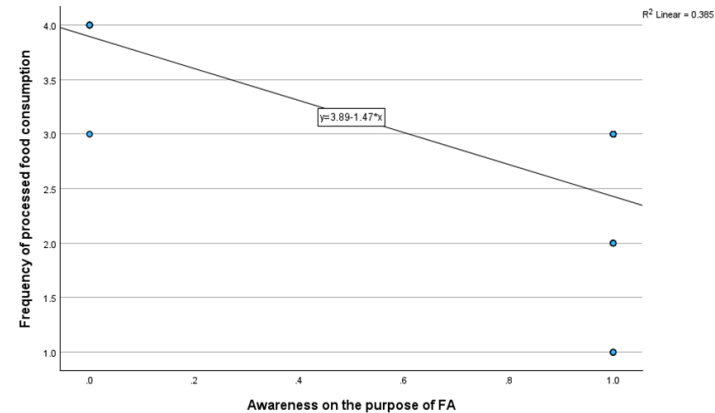


Figure 02: Scatterplot for the variables ‘Awareness of the purpose of FA vs Frequency of processed food Consumption’

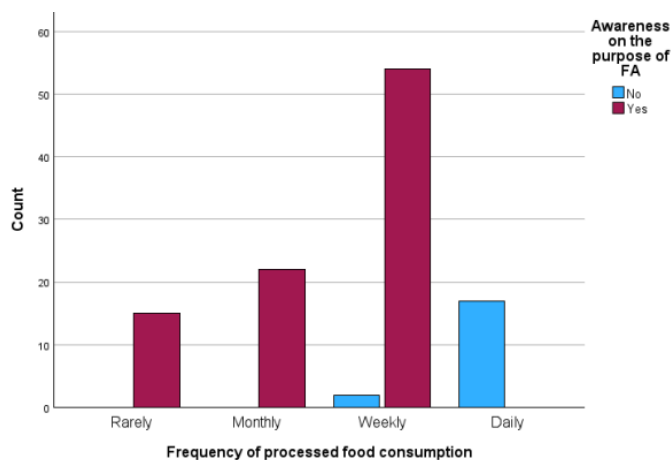


Figure 03: Comparison of Awareness of FA with Frequency of processed food consumption

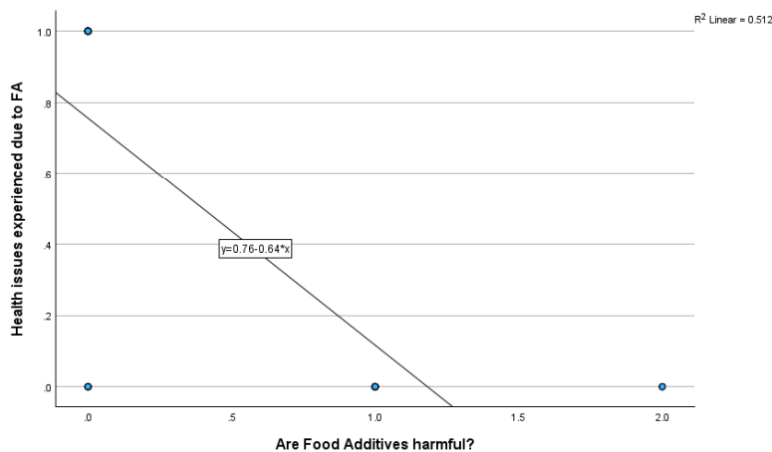


Figure 04: Scatter plot depicting a negative slope for Perception of FA vs Health Issues Experienced due to FA

4. Discussion

Based on the data collected, it was revealed that the majority of the participants were aware of FAs and its purpose. The main source of information on FAs was reported to be social media. It was reported that several people who were aware of FAs, avoided different types of processed food including noodles, soft drinks, jelly etc due to safety concerns. Regression analysis was carried out to test this. Findings revealed that people who are aware of the health impacts of FAs tend to limit the intake of food products that are high in FA content.

The majority of the respondents were said to intake processed food on a weekly basis rather than daily intake out of which dairy products and snacks were the most consumed processed food. Statistical analysis and regression analysis revealed that increased awareness of FA have reduced frequency of processed food consumption than people with less awareness.

This study also revealed that the majority of the participants perceived FAs to be harmful. Moreover, they preferred natural FAs and perceived them to be safer than artificial FAs due to the negative perception. $P < 0.001$ and β value of -0.766 were obtained through regression analysis. This revealed that when education levels were lower, the level of concern tended to be higher. Although this contrasts with the expected values, these findings might suggest that concern levels might be higher in people with lower education because they might be lacking the basic knowledge of FA, its uses and health issues. Hence, they might be more worried about this. The same trend was observed in a study conducted in UAE (Osaili et al., 2023).

The perception of FA can vary between individuals. When the perception of FA increases, people become more aware of advantages as well as disadvantages of FA. So, the increased understanding of FA is more likely to help people reduce the FA intake and switch for healthier food choices. This resulted in a reduced prevalence of health issues associated with FA. Food colourings, food flavours and preservatives were the FAs that people were more concerned about. Among them MSG, a widely known flavour enhancer and food colourings were the FAs, the respondents were more familiar with.

Half of the participants preferred to have organic food while the other half preferred to have both organic and processed food. Findings reported that when awareness of health concerns increases, people are likely to prefer healthier food options to prevent any health complications. It was also reported half of the participants had experienced health issues such as digestive problems, diarrhoea, and vomiting. People were generally aware of long-term health complications such as cancer, diabetes and thyroid issues as well. Increased knowledge and perception about health issues have led to a significant reduction in health issues experienced.

This study also analysed government food safety regulations and food labelling standards. Most people preferred having strict safety regulations in terms of FAs usage and to have detailed information on food labels provided on the processed food package. A similar trend was observed in a study conducted in Korea where consumers expressed dissatisfaction with the food labelling practices (Lee et al., 2014). Education levels had an impact on this. Further analysis stated that people were keen on switching to healthier food options thereby limiting processed food consumption.

5. Conclusions and Recommendations

The above study aimed to analyse the awareness and perception levels of the general population of Sri Lanka on food additives and how it creates an impact on their health as well as their food choices. Data Analysis revealed a strong significant correlation between awareness and perception of FA with consumer behaviour and health issues. The results obtained from the study revealed that health issues, consumer behaviour and food choices are significantly influenced by awareness and perception of FA. The findings suggest that increased awareness and perception can allow consumers to limit their excess or frequent FA intake and to switch to healthier alternatives. This can cause a reduction in health implications due to FA and to lead a healthier lifestyle. And also, it allows people to understand the food labels accurately.

The findings of this study suggested the importance of awareness and perception among the general population. Therefore, it is necessary to conduct public awareness programs, social media awareness campaigns and multifaceted educational programs to help people understand

more about FA. Moreover, awareness campaigns or educational programs can be implemented at schools to educate the younger generation. And also, it indicates the necessity of having strict food safety regulations along with improved food labelling standards.

Since studies under these areas are limited, it is better to further analyse the general population by increasing the sample size and using other sampling techniques such as random sampling for more precision and accuracy.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 130

Establishment and validation of a real time PCR assay for detection of *Herpes Simplex Virus 1 and 2* in clinical samples

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Abstract

Herpes simplex virus (HSV) types 1 and 2 are among the most prevalent human pathogens, causing a range of clinical manifestations from orolabial and genital lesions to severe neurological complications such as encephalitis and neonatal herpes. Rapid and accurate diagnosis of HSV infections is critical for timely clinical management and prevention of transmission. Traditional diagnostic methods such as viral culture and antigen detection often lack sensitivity and require extended turnaround times. In this study, a cost effective real-time Polymerase Chain Reaction (rt-PCR) assay was established and validated for the detection of HSV-1 and HSV-2 DNA in clinical samples. rt-PCR primers targeting the thymidine kinase (TK) gene and DNA polymerase (pol) genes regions of HSV-1 and HSV-2 were designed respectively using NCBI and primer3 plus software to ensure high specificity. The assay based on SYBR Green chemistry was optimized for amplification conditions and reagent concentrations. Validation was performed through evaluation of analytical specificity and reproducibility. The assay was evaluated through diagnostics sensitivity and specificity with the reference samples. There was good reproducibility with coefficient variance (CV) being <2% for different Ct values samples tested. The HSV-1 and HSV-2, have no cross-reactivity with other common bacterial, viral or other pathogens, including *Human Papilloma Virus*, *Leptospira*, *Cytomegalovirus*, *Hepatitis B virus*, *Neisseria gonorrhoea*, *BK virus*, *Human Genome*, *Mycobacterium tuberculosis*, *Epstein-Barr virus (EBV)*, and *varicella-zoster virus (VZV)*. Clinical validation using a panel of CSF/swabs (n=20) confirmed high concordance with reference methods, with a diagnostic sensitivity and specificity concordance 100% . In conclusion, the established real-time PCR assay provides a cost effective rapid, high diagnostic specific, sensitive, and reliable method for the detection and differentiation of HSV-1 and HSV-2 in clinical specimens. Its implementation in diagnostic laboratories may significantly enhance the early diagnosis and treatment of HSV infections, contributing to better patient outcomes and public health surveillance.

Key words: Diagnostic sensitivity, Diagnostics specificity, *Herpes simplex virus (HSV)*, real-time Polymerase Chain Reaction

Establishment and validation of a real time PCR assay for detection of Herpes Simplex Virus 1 and 2 in clinical samples

1. Introduction

Herpes simplex virus types 1(HSV-1) and 2(HSV-2) are common cause of wide spectrum of clinical manifestations such as dermal, oral, and genital infections world-wide. HSV is a double-stranded DNA virus belonging to the Herpesviridae family and HSV-1 is primarily associated with orolabial infections, while HSV-2 is a major cause of genital infections. (Whitley, R.J. & Roizman, B. (2001) Both types of HSV are capable of causing significant morbidity, including recurrent infections, neonatal herpes, and life-threatening complications such as herpes encephalitis and disseminated infections in immunocompromised individuals (Piret, J. & Boivin, G. (2016).

Accurate diagnosis of HSV infections is critical for effective management and prevention of transmission. Conventional methods, including viral culture and direct fluorescent antibody testing have been used historically for HSV diagnosis. (Wald, A. & Corey, L. (2007) However, these methods have significant limitations, such as low sensitivity particularly in cases with low viral loads or delayed sample collection, laborious and the requirement for specialized laboratory expertise to interpret the results (Wald & Corey,2007). Real-Time PCR (rt-PCR) has emerged as the gold standard for HSV detection, as it allows for rapid amplification and quantification of viral DNA in clinical samples. Numerous studies have demonstrated the utility of rt-PCR in the diagnosis of HSV-1 and HSV-2 infections, particularly in cases where accurate differentiation between the two types is essential guiding patient management (Embil *et al.*,2003: Kimberlin,2004).

Establishing and validating a reliable rt-PCR assay for the detection of HSV-1 and HSV-2 is essential to address these challenges and to ensure accurate, rapid and cost-effective diagnosis. (Scoular, A. et al. (2002). The aim of this study is to develop and validate a real-time PCR assay tailored for the detection of HSV-1 and HSV-2 ensuring high sensitivity, specificity and reproducibility.

2. Methodology / Materials and Methods

The study was a 6 months cross sectional prospective study with a 1-months pre-analytical phase, 4-months analytical phase and 1-months post analytical phase.

Ethical clearance to collect clinical samples from the respective authorities was obtained by the Ethical Review Committee of Lanka Hospitals, Colombo 05, Sri Lanka. Primers were designed targeting a fragment on TK3 gene of the HSV 1 and POL gene of the HSV 2 nucleotide sequences, primers specific only for HSV 1 and 2 respectively. A SYBR Green-based real-time PCR was optimized using reference DNA of HSV 1 and HSV2. Reactions were performed in a total volume of 20µl consisting 2XSYBR Green Master mixer (amb.Canada) adding specific primer pairs with a 0.4 µM concentration. HSV 1 and 2 Virus genomic DNA 8.0 µl was used separately as the template. The PCR program containing, an initial denaturation at 95 °C for 3 minutes, 36 cycles of denaturation at 95 °C for 5 seconds, annealing/extension at 60 °C for 1 minutes and Melting curve(Tm) analysis 65 °C to 95 °C with readings every 0.5 °C was performed. The cut-off was set at Threshold Cycle (Ct)33 which was the last cycle completely devoid of background noise. The first negative derivative of the initial melting curve(-

dF/dT) was plotted against temperature for improved determination of the melting temperature (T_m). Each PCR run in house gene GAPDH was used as an internal control.

Analytical specificity was performed using a broad spectrum of pathogenic species Genomic DNA and/or CDNA. Precision studies were performed using three HSV 1 and clinical samples and three HSV 2 clinical samples separately which have shown different Ct values. These three samples with different viral loads were tested with the in-house assay for consecutive 3 days. The Threshold cycle (C_t)values obtained were used to determine the standard deviation and coefficient of variation (%CV <10). The clinical samples (Cerebrospinal fluid-CSF, Swab) (n=20),10 for HSV 1 and 10 for HSV 2, used for the study were obtained from the Molecular Diagnostic laboratory of the Lanka Hospital Diagnostics (Pvt) Ltd, Colombo 05, Sri Lanka. All the patient samples were reference laboratory confirmed using a commercially available HSV real-time PCR kit previously and subjected to SYBR green-based real-time PCR assays using optimized assay conditions. The resulting data was analyzed using the software provided by the BIO-RAD CFX 96X manager software real-time PCR detection system and the diagnostic sensitivity and specificity were determined manually.

3. Data Analysis and Results

The designed primers were commercially synthesized via Integrated DNA Technologies (IDT), US. Details of the primers are given in Table 01.

Table 01: Primer sequence for HSV 1 and HSV 2

Primer	Sequence (5'→3')	Length/bp
HSV 1 Forward	GAC TTC CGT GGC TTC TTG CT	20
HSV 1 Reverse	GCT TAA CAG CGT CAA CAG CG	20
HSV 2 Forward	TCAACTTCGACTGGCCCTTC	20
HSV 2 Reverse	TGGAGAGTTTGACCTTGTCGG	21

The amplified fluorescence and melting curves are followed after performing the optimization PCR assays are shown in Figure 1 and Figure 2. In the fluorescence graph, the C_t of the HSV 1 positive control is 26.35. As shown in the melting graph the temperature is at 91°C. In the fluorescence graph the C_t of the HSV 2 positive control is 24.14. As shown in the melting graph the temperature is at 90°C.

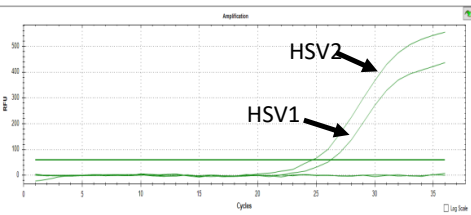


Figure 01: Florescence curve obtained by the optimized PCR assay

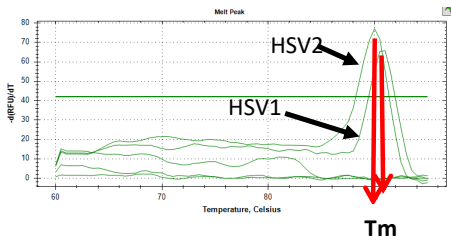


Figure 02: The melt graph of the optimized assay.

None of the other tested pathogens have shown any specific amplification as shown in Table 02 below.

Table 02: The panel of DNA and cDNA to determine the analytical specificity

Organism	Observed results
<i>Human Papiloma Virus</i>	Negative
<i>Leptospira</i>	Negative
<i>Cytomegalovirus</i>	Negative
<i>Epstein-Barr virus (EBV)</i>	Negative
<i>Hepatitis B virus</i>	Negative
<i>Neisseria gonorrhoea</i>	Negative
<i>BK virus</i>	Negative
<i>varicella-zoster virus</i>	Negative
Human Genome	Negative
<i>Mycobacterium tuberculosis</i>	Negative

The precision is the determination of the ability to produce similar results in similar conditions. The coefficient of variation of both HSV 1 and 2 was less than 2. The 10 clinical samples were previously detected by the commercial rt-PCR assay by the reference laboratory and the in-house assay to detect HSV1 and HSV 2 in clinical specimens (Table 03).

Table 03: The number of Clinically and laboratory confirmed HSV 1 samples evaluated by the in-house assay

Reference lab confirmed Assay	In-house developed assay-HSV 1 and 2			
		Positive	Negative	Total
	Positive	10	0	10
	Negative	0	10	10
Total		10	10	20

According to that the diagnostic sensitivity of the assay is 100% and the diagnostic specificity of the assay is 100% for HSV 1 and 2.

4. Discussion

In this study, a rt-PCR assay was successfully established and validated for the detection of HSV-1 and HSV-2 in clinical samples, contributing a reliable, rapid, and highly specific diagnostic method. The analytical specificity was determined by testing against other common viral and bacterial pathogens, and these HSV 1 and HSV 2 primers did not amplify in any of the other genome/ CDNA tested. That means this test has 100% analytical specificity. Compared to traditional diagnostic techniques such as viral culture and serological testing, the real-time PCR assay was found to offer several advantages. Faster turnaround times (less than 2 hours), higher sensitivity, and the ability to differentiate between HSV-1 and HSV-2 in a single reaction were achieved. Moreover, the use of fluorescent dyes allowed for accurate detection and minimized the risk of post-PCR contamination. This time efficiency was considered essential in clinical settings where prompt diagnosis could influence treatment decisions, especially in neonatal herpes, immunocompromised patients, and cases with neurological involvement such as HSV encephalitis.

According to the previous studies HSV DNA has been detected in a significant proportion, with HSV-2 being more prevalent among genital lesion samples, while HSV-1 was more commonly associated with oral and facial lesions (WHO, 2015). However, due to issues of funding for the current research, only 10 positive samples and 10 negative samples were tested and all the samples have given 100% accurate results as the reference laboratory tested. Further, developed assay was able to differentiate between the two virus types effectively. Furthermore, the ability to detect co-infections (i.e., presence of both HSV-1 and HSV-2 in a single sample) was demonstrated in a small subset of samples, a feature not readily achievable through conventional diagnostic methods.

The assay demonstrated excellent intra-assay reproducibility consistency with the coefficient variance <2%. Repeated testing of the same positive across different days and different operators yielded highly reproducible results. This indicated that the assay could be reliably used in a routine clinical laboratory with minimal variability, provided that quality control protocols were maintained. Another important consideration involved the cost-effectiveness and sustainability of the assay. Although real-time PCR requires initial investment in thermocycling equipment and reagents, the per-test cost was deemed manageable when run in batch formats. Quality control measures were strictly implemented throughout the study. Internal controls were included in each run to monitor for PCR inhibition and ensure the integrity of the amplification process. It was recognized that continuous monitoring and validation were necessary to maintain assay accuracy, particularly when applied to a diverse range of clinical specimens.

Despite its effectiveness, some limitations were encountered. Since the study was conducted within a single hospital setting, broader validation using a larger and more diverse sample population was not performed. Further, the diagnostic performance of the real-time PCR assay with conventional diagnostic methods was unable to do due to time limitation. Also, Analytical sensitivity of the assay has not been evaluated due to

reagent issue of the quantification instrument. These limitations should be addressed in future studies.

5. Conclusions and Recommendations

In conclusion, a reliable and sensitive real-time PCR assay was successfully established and validated for the detection and differentiation of HSV-1 and HSV-2 in clinical samples at Lanka Hospitals Diagnostics (PVT) Ltd, Colombo 05. The assay was demonstrated to provide rapid and accurate results offering a significant improvement over conventional diagnostic method. High sensitivity and specificity were confirmed and the ability to deliver timely results was considered highly beneficial for clinical decision-making and patient management.

In future studies will be carried out using a larger and more diverse patient population to confirm the assay's performance across broader demographic and clinical settings. Collaboration with other healthcare institutions was encouraged to standardize protocols and improve diagnostic consistency nationwide.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 142

Exploring the Socio-Economic and Demographic Factors Influencing the Use and Awareness of E-Cigarettes: A Sri Lankan Perspective

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Abstract

This study aimed to investigate the socio-economic and demographic aspects influencing the awareness and perception of e-cigarettes among Sri Lankan individuals. With the emerging global discussion surrounding the potential implications of e-cigarette use, this study aims to explore the key influencing factors for levels of awareness and evaluate the public perceptions on the health risks associated with e-cigarettes. A cross-sectional survey design was used, collecting responses from 100 individuals across a variety of age groups, residential areas, income levels and educational backgrounds. Information was also collected on individual perceptions about the general thoughts and prevalence of e-cigarettes in Sri Lanka. Quantitative data were analysed using SPSS software, and obtained correlation analysis and multinomial logistic regression to determine relationships and predictive factors. A secondary analysis of primary research articles was done to further prove and compare the obtained results. The key findings of this study revealed that monthly income and educational levels were positively associated with awareness levels. Individuals having a good educational exposure and higher income displayed greater familiarity with e-cigarettes and tend to perceive them as safer alternatives compared to traditional cigarettes and other tobacco products. Social media and internet platforms were cited as the main sources of information regarding e-cigarettes, highlighting the significant influence of digital media in shaping public knowledge and understanding. However, the analysis also revealed statistically insignificant correlations between awareness and certain variables despite visible descriptive trends. The study concludes that e-cigarette awareness is remarkably shaped by particular socio-economic and demographic factors like income and residence. This underscores the necessity for targeted public health strategies which can help disprove misleading ideas on e-cigarette risks and benefits, especially considering the impact of online content on non-users.

Keywords: Awareness, Demographic Factors, E-cigarettes, Perceptions, Socio-Economic Factors

Exploring the socio-economic and demographic factors influencing the use and awareness of E-cigarettes: A Sri Lankan perspective

1. Introduction

Electronic cigarettes have been widely recognized as popular tobacco products in recent years. They were developed as a substitute to the use of conventional tobacco smoking. Electronic cigarettes are devices that replicate tobacco smoking and are also known as vapes or electronic nicotine delivery systems (ENDS). These hand-held electronic devices function by heating E-liquids to produce an aerosol which generally comprises high levels of nicotine, glycerine, various types of flavourings and propylene glycol (Blaha, 2022). Multiple studies have also discovered the presence of harmful compounds such as carbonyls, tobacco-specific nitrosamines and toxic metals in e-cigs vapour (Pisinger and Dossing, 2014). A single puff from an e-cigarette has detectable levels of over 115 volatile substances which relate to the major detrimental health effects associated with its use.

The prevalence of electronic cigarettes has rapidly increased over the past decade, and is mostly identified among young adults and men, while it also varies by gender, age and location. In 2023, The World Health Organization indicated an alarming rise of e-cigarette usage among children, with the use doubled among 16-19-year-old Canadians between the years 2017 and 2022 (WHO, 2023). The popular usage of electronic cigarettes has developed a debate among public health officials on the role of e-cigarettes in smoking cessation and sustained safety (Alotaybi *et al.*, 2022). Although vaping is considered safe than the use of traditional tobacco, the long-term health impacts of vaping are yet not known (Perera and Dulmini 2022). Several studies have suggested that the use of e-cigs may facilitate adults to quit smoking traditional cigarettes or cigars (Bullen *et al.*, 2013). Although there's a vast amount of global studies on e-cigarette use, the unique socio-economic backgrounds and diverse cultural stances in Sri Lanka, presents the need of extensive research on this area. This study focuses on examining how the distinct socio-economic and demographic factors influence the use and awareness of e-cigarettes among individuals in Sri Lanka, and seek to provide a clear overview of the perceptions of individuals about the prevalence of electronic cigarettes in the country.

2. Methodology

Study Design

Data collection was done using mixed method, with both online surveys and in-person surveys. This design facilitated effective data collection across various populations including rural, urban and sub-urban regions of Sri Lanka. Additionally, primary research articles were explored and analysed to contextualize the results.

Methods of data collection:

- Online surveys: Questionnaires were designed to collect data on socio-economic status, demographic details and factors behind an individuals' e-cigarette exposure, usage, addiction and quitting strategies. This was created using google forms and shared across social media platforms in order to achieve a broad reach.

- In-person surveys: The questionnaires were provided as printed sheets among Advanced level students across various schools in order to examine their perception of e-cigarettes and the factors affecting its usage.

Sampling technique: Stratified random sampling was used in this study.

Data analysis: Quantitative analysis was performed on data gathered by surveys, using the SPSS software. Additionally, Microsoft Excel was used for data visualization and basic management of data. Qualitative analysis was done on open-ended survey responses to identify specific motives and perceptions of e-cigarette users.

3. Data Analysis and Results

100 participants aged 18 to 55 were included in the analytic sample out of which the majority of them (84%, n = 84) were females and 16% were males (n = 16). With regard to e-cigarette use, only 8% of the total individuals were e-cigarette users while 92% were never e-cig users.

Table 01: Age groups and awareness on e-cigarettes cross-tabulation

		Awareness about E-Cigarettes		Total
		No	Yes	
What is your age group?	18 – 24	Count	24	66
		% of Total	24.0%	66.0%
	25 – 34	Count	2	4
		% of Total	2.0%	4.0%
	35 – 44	Count	0	4
		% of Total	0.0%	4.0%
Total	Count	26	74	100
	% of Total	26.0%	74.0%	100.0%

According to the data shown above, the awareness is highly reported among people of age 18-24, with a majority of them (66%) having heard about e-cigarettes. However, the awareness was significantly lower among old age groups, particularly 25-34 and 35-44. A fewer number of people (4%) in the age group 25-34 reported awareness, while all the individuals aged 35-44 were aware of e-cigarettes.

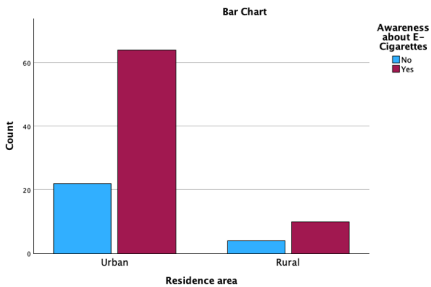


Figure 01: Bar chart on awareness of e-cigarettes among different regions

It is evident that majority of the people (64%, n = 64) living in the urban area reported to be aware of e-cigarettes, while 22% of people reported unawareness. Among the people in rural area, 10% of people (n = 10) reported awareness, while 4% of people (n = 4) reported unawareness.

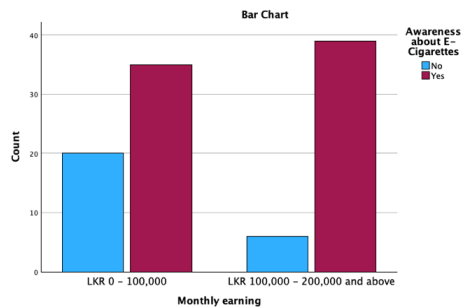


Figure 02: Bar chart on awareness of e-cigarettes among people with different income

This bar chart shows the level of awareness on e-cigarettes among people with different income levels. Majority of individuals (35%) with an income level of LKR 0 – 100,000 reported awareness on e-cigarettes. Several individuals in this group had also reported unawareness (20%), but that is a very low count compared to the people who are aware. Among individuals earning LKR 100,000 – 200,000 and more, a majority (39%) were aware while only a minor percentage (6%) seemed to be unaware.

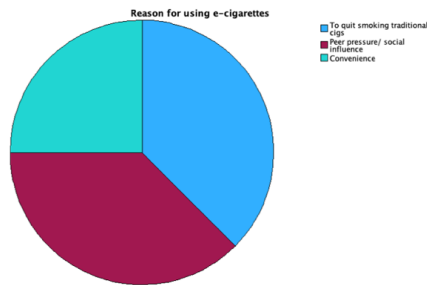


Figure 03: Pie chart on the primary reason for e-cigarette usage

An equal number of individuals had responded for two reasons, which was to quit smoking traditional cigarettes (37.5%, n = 3) and due to social influence and peer pressure (37.5%, n=3). The remaining individuals (n = 2) had voted for convenience.

4. Discussion

The prevalence of e-cigarettes particularly among young adults is seen to be growing rapidly at present. As of 2021, electronic cigarettes are being used by more than 80 million individuals around the world (Jerzyński and Stimson, 2023). While these trends indicate a significant increase in global usage, there is a notable research gap regarding awareness and perceptions in countries like Sri Lanka. This study has analysed the awareness of electronic cigarette use and perceptions of individuals based on various socio-economic and demographic variables using a survey on Sri Lankan individuals. The analysis revealed the impact of these variables on the degree of awareness and varied patterns of e-cigarette usage along with individual insights on its prevalence and popularity in Sri Lanka. According to the results, 74% of individuals were aware of e-cigarettes. Out of the whole sample, e-cigarette users constitute for only 8% while the remaining individuals have never used e-cigarettes.

Upon analysis of possible demographic factors like age, gender and population affecting e-cigarette use and awareness, this study identified that the awareness on electronic cigarettes

were notably high among individuals aged 18-24 with 66% reporting to be aware (table 01). Majority of participants aged 25-34 and 35-44 were also aware of e-cigarettes. However, the high level of awareness among these participants could be influenced by the smaller sample sizes in these groups, rather than a true trend. The analysis of e-cigarette awareness across different regions (figure 01) displayed a higher percentage of individuals in the urban region (64%) being aware of e-cigarettes. There was a visible percentage of individuals who reported being unaware (22%), but it is a minor count compared to the number of people who reported awareness. However, the percentage of people being aware of e-cigarettes in rural area was very less (10%), and out of the total count of individuals from rural area, a sizeable percentage reported being unaware as well. A study conducted by Kaleta and other researchers (2016) predicted the use of e-cigarettes in urban areas may be even higher due to the increased accessibility and exposure to these products (Kaleta, Wojtysiak and Polańska, 2016). This relates to the idea that even though people in rural areas be aware of e-cigarettes, the percentage of people being aware in urban regions can be extremely greater due to their exposure.

Upon questioned on the reason for using e-cigarettes, an equal percentage (37.5%) of individuals cited of using it to quit smoking traditional cigarettes and due to peer pressure or social influence (figure 03), while 25% of them cited convenience (easy to use, portable). Peer pressure and social influence tend to have a great impact on the use and awareness of e-cigarettes, as they have the ability to even influence never smokers or never e-cigarette users to start perceiving these products.

According to this research, 74% of individuals reported awareness of electronic cigarettes, while only 8% admitted to using them, which highlights a notable gap between knowledge and behaviour. Despite this growing trend, there is currently a lack of research examining the knowledge and public perceptions of electronic cigarettes within the Sri Lankan context. The absence of studies on this context brings out the importance of having focused research on this area. As the popularity of e-cigarettes are potentially rising globally and within Sri Lanka, the country may soon face public health challenges related to e-cigarette use. Therefore, this study can be considered as a valuable foundation for future research and policy development. By recognizing the patterns of socio-economics and demographics in awareness and perception, it provides necessary data that helps design preventive strategies and strengthen the preparedness of the national health system for the rapidly rising influence of electronic cigarettes.

5. Conclusions and Recommendations

This study set out to explore the influence of socio-economic and demographic factors on the awareness and use of e-cigarettes among individuals in Sri Lanka. The results indicate a significant relationship between the level of awareness and these factors. The findings also demonstrated that demographic factors like population and the environment around them play a role in determining how individuals perceive information about e-cigarettes. Furthermore, this study highlighted the potential role of digital media in affecting contemporary health practices. This observation conforms to global trends, where digital platforms play a dual role in informing and shaping opinions, emphasizing concern on the potential for e-cigarettes to be promoted among non-users and target younger audiences.

Notably, perceptions related to the safety of e-cigarettes and the possible health risks appeared to differ across socio-economic groups, suggesting that educational exposure and the economical background of a person significantly influence the interpretive capacity regarding the health perceptions of e-cigarettes. However, many individuals indicated uncertainty on

general questions that assessed a broader understanding of e-cigarettes. This showed that there is a lack of cohesive understanding among the Sri Lankan population. This study highlighted that underlying social, economic and demographic contexts significantly influence the awareness and perception of electronic cigarettes.

Recommendations for future work

Increase the sample size and diversity

The study should include a larger number of individuals with diverse age groups and populations across all areas of Sri Lanka to increase generalizability and identify differences more clearly.

Foundation for further research

This research study can be considered as a foundation toward understanding the awareness, perceptions and factors influencing e-cigarette usage in Sri Lanka. Future research studies can build upon these results and findings by examining further into the behavioural patterns and psychological addiction on e-cigarette use.

Explore behavioural outcomes

Investigate if e-cigarette awareness actually leads to usage among never-users or avoidance of e-cigarettes, by exploring the behavioural patterns of individuals in more detail.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 203

Patient Adherence and Perceived Side Effects of Metformin in Type 2 Diabetes

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Abstract

Type 2 diabetes mellitus (T2DM) is a global issue caused by long-term insulin resistance. Metformin, a common medication for T2DM, effectively lowers blood sugar levels. However, adherence to metformin is relatively low due to factors like forgetfulness, side effects, and perceived lack of effectiveness. The purpose of this study was to identify the perceived side effects and their impact on patient adherence. Identifying these factors will assist in developing strategies to improve outcomes. The survey-based study was conducted including 65 participants who are above 18-year-old diagnosed with T2DM and are using metformin as their treatment. The results indicated an overall adherence level of 40% to 80% from both primary and secondary study analyses. The identified major reasons were forgetfulness (53.16%) and side effects (21.52%) associated with this poor adherence level, with the majority of participants experiencing gastrointestinal side effects as a common consequence of metformin use. The severity scale showed that 36.92% of the side effects were of low severity, indicating that the side effects experienced by patients are not particularly severe and are tolerable. However, the low adherence level to metformin due to these side effects can exacerbate the condition of Type 2 Diabetes Mellitus (T2 DM). This issue should be addressed, and strategies should be implemented to manage the situation effectively. These findings support the research alternative hypothesis by stating, the side effects indeed impact the patient adherence. Strategies such as increasing patient education level about Metformin and its benefits, identifying the severity of the side effects and providing alternative methods to balance the situation or adjusting the treatment plan according to their tolerance level could be carried on.

Keywords: Gastrointestinal Side Effects, Metformin Medication, Type 2 Diabetes Mellitus, Metformin Side Effects, Metformin Adherence

Patient Adherence and Perceived Side Effects of Metformin in Type 2 Diabetes

1. Introduction

Diabetes mellitus (DM) is a metabolic disorder, caused by irregularities in insulin action, insulin secretion or both (Jahun, 2010). The International Diabetes Federation conducted research about the effective prevention and management strategies of diabetes among adults in 2021. The result showed that approximately 537 million adults were diagnosed with diabetes globally and 6.7 million deaths in 2021 (International Diabetes Federation, 2022).

Type 2 diabetes is the most common type among people worldwide (Ishwarlal, 2023). This disorder is characterized by impaired insulin utilization (insulin resistance), which hinders the metabolic conversion of glucose into energy, subsequently leading to elevated blood glucose concentrations (Frenando, 2023). Metformin is prescribed as a key treatment for type 2 diabetes to improve insulin sensitivity and lower blood sugar levels (Nasri and Rafieian, 2014). Metformin falls under the category of biguanides which effectively lowers both basal and postprandial blood glucose levels (Corcoran and Jacobs, 2023).

Despite its effectiveness, patient adherence to Metformin therapy is a significant challenge (Chen et al., 2023). Non-adherence can result in poor glycaemic control, raising the risk of diabetes-related complications like cardiovascular disease, neuropathy, and retinopathy, impacting patients' quality of life (Chen et al., 2023). Furthermore, perceived side effects of Metformin, such as gastrointestinal discomfort, nausea, and weight gain, can greatly influence adherence (Chen et al., 2023). These uncomfortable symptoms can lead to a negative perception of the medication, prompting patients to either skip doses or discontinue the treatment. Thus, understanding the relationship between these perceived side effects and patient adherence is very important.

2. Methodology / Materials and Methods

This study utilized a cross-sectional survey design to gather data from individuals diagnosed with type 2 diabetes who are currently using metformin. In addition to the primary data collected through surveys, the research also utilized secondary sources. A power analysis was conducted prior to the sample collection to estimate the required sample size using G-Power. Under t-test analysis with power at α error = 0.05 along with a confidence interval of 95%. Furthermore, a secondary method which includes existing articles, earlier studies, and available databases such as Google Scholar, Embase, Pubmed and Science Direct was conducted.

Participants in this research required to meet several criteria, including:

Adults aged 18 years and older.

Diagnosed with type 2 diabetes.

Currently prescribed metformin as part of their treatment.

No specific geographic limitations across Sri Lanka were considered in this study.

Data was collected through a structured survey questionnaire, which includes the following key areas:

How long participants have been diagnosed with type 2 diabetes.
Participants' understanding of metformin, including its benefits and satisfaction.
Information on specific side effects experienced by participants.
Adherence level to the prescribed metformin treatment.

Collected data was analysed using IBM SPSS statistics for standard statistical tastings and G*Power to calculate the sample size for a significant outcome. Descriptive statistics were used to analyse participants characteristics and responses using mean, median, frequency, percentages and standard deviation. To assess the relationship between categorical variables, Chi-Square test was performed.

3. Data Analysis and Results

Among 65 responses, there were 34 female participants while 25 were male participants and 6 participants selected the option “prefer not to say”. The below graph (Figure 01) explains the duration of the participants who are diagnosed with type 2 diabetes.

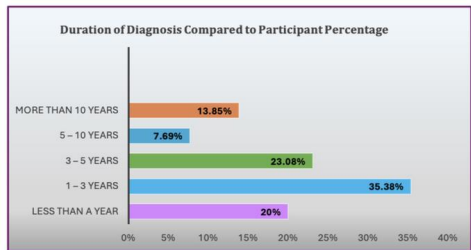


Figure 01: The graph shows the duration of diagnosis among the participants

Regarding the satisfaction of taking metformin among metformin users, 44.62% participants expressed that they are satisfied while some have chosen the option neutral (26.15%) and unsatisfied (4.62%) due to various reasons such as side effects and the effectiveness of the medicine. Among the 65 participants, 84% of participants admitted to missing a dose of metformin due to various reasons. Forgetting to take the dose on time is having a higher rate (66%) compared to other categories highlighting a potential area for improvement in adherence (Table 01).

Table 01: Reasons for missing dosages according to the collected data.

Points	Reason for missing dosage	Frequency	Percentage
A	Forgetfulness	42	53.16%
B	Side-effects	17	21.52%
C	Lack of effectiveness	10	12.66%
D	Difficulty obtaining the medicine	10	12.66%

Since participants have reported about the severity of the side effects on a scale of 1 to 5, the association between side effect severity and treatment adherence was examined using Spearman’s rank-order correlation. Strong negative correlation (Table 2) with $\rho = -0.928$, $p < .001$ was observed using 51 responses. This finding indicates that higher side effect severity is associated with a significant reduction in patient adherence to Metformin.

Table 02: Data of side effects severity versus adherence through correlation analysis

			side-effects severity	adherence
Spearman's rho	side-effects severity	Correlation Coefficient	1.000	-.928**
		Sig. (2-tailed)	.	<.001
		N	51	51
	adherence	Correlation Coefficient	-.928**	1.000
		Sig. (2-tailed)	<.001	.
		N	51	65

**. Correlation is significant at the 0.01 level (2-tailed).

Key findings from secondary studies which are released within the last 10 years of time to support and increase the strength of the research along with the primary analysis. Below table (Table 03) includes the secondary studies that were used for a deeper understanding about the topic.

Table 03: Details of the secondary studies used for the research

Secondary study NO	Main Author's Name	Title of the study	Key findings
01	Yucxin Tang (2020)	Metformin adherence and discontinuation among patients with type 2 diabetes	Many patients initiating metformin discontinued and fewer than 50% of all patients are adherent to metformin
02	Prasanna Kumar (2019)	Adherence, satisfaction, and experience with metformin	Patients showed a medium adherence level 54%
03	Lynne Chepulis (2020)	Metformin adherence in patients with type 2 diabetes	Prescription adherence was lower in younger patients
04	Mansour Siavash (2017)	Severity of Gastrointestinal Side Effects of Metformin Tablet Compared to Metformin Capsule	Switching to metformin capsule may result in less GI side effects
05	Nasar Yaseen (2023)	Metformin Side Effects in Patients with Newly Diagnosed Type 2 Diabetes Mellitus	Higher rate of discontinuation due to GI related side effects
06	Krzysztof Strojek (2017)	Patient adherence to and tolerability of treatment with metformin	Participants showed an excellent adherence level (85.5%)
07	Hermes Florez (2015)	Impact of Metformin-Induced Gastrointestinal Symptoms on Quality of Life and Adherence in Patients with Type 2 Diabetes	The most and least common GI symptoms reported were diarrhoea (62.1%) and retching (21.1%)

4. Discussion

According to the observations, 16 out of 65 were aged between 18 – 29. This age group shows a high amount of diabetes participants equally aligning with the age group 40 – 49 and 50 – 59. This shows a dramatic increased prevalence of T2DM in young adults with a predicted amount released by global diabetic prevenience research of 783 million globally by 2045 (Lascar et al., 2018). Findings of the current primary study showed a comparatively better satisfied level (>44%) about metformin along with >45% of participants showing somewhat confidence with the treatment. These findings hold a significant importance as they provide further evidence supporting the clinical efficacy of Metformin in the management of T2DM.

However, a study conducted in 2020 by Yuexin Tang also showed fewer adherence levels (Tang et al., 2020). This explains that even though the people know the benefits and are having a higher confidence and satisfaction level, there are several factors participating in this non-adherence of metformin. Most metformin users are facing GI related side effects such as vomiting, nausea, bloating, abdominal pain, retching, loss of appetite and diarrhea (Christensen et al., 2015; Tang et al., 2020). This statement is highly supported by the collected information from our primary data along with the secondary studies which also presents the evidence.

Metformin is usually absorbed through the small intestine in a larger amount while the large intestine and stomach play a smaller part in absorption rate (Graham et al., 2011). This absorption mechanism might play a key role with these side effects. Understanding about this mechanism is important for further analysis. Based on the results from the severity of the side effects a greater number of participants have responded as the side effects aren't that severe and are tolerable.

5. Conclusions and Recommendations

The study titled patient adherence and perceived side effects of metformin in type 2 diabetes helped to understand the relationship between the perceived side effects on metformin users and the patient adherence level. The key findings indicated a low level of adherence to Metformin therapy. A total of 84% of participants reported missing doses, whereas only 35.38% reported taking the medication as prescribed. . This finding perfectly aligns with the data collected from secondary studies which also shows medium to poor adherence level due to side effects (36% – 85%). This research can play an important role for health care providers to pay more attention to the side effects experienced by patients and develop strategies to improve the adherence level along with reducing the severity of the side effects. An even larger sample size might help to increase the study strength and to find the other factors that play a role in this patients' adherence level along with different types of side effects experienced by patients.

Additionally, applying a combination of qualitative and quantitative research methods will also help to understand more about this specific topic. The analysis showed switching from tablet to capsule reduces the side effects among metformin users. Further investigations will enhance the understanding of these two forms and may offer a viable alternative to metformin tablets for patients who are unable to tolerate treatment related adverse effects.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 205

The Impact of knowledge on hypertension and lifestyle changes on blood pressure control in hypertensive individuals aged 30–60 in Colombo 5, 6, and 10

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Abstract

Hypertension is a major cause of cardiovascular morbidity and mortality, and inadequate exercise has remained a major challenge in public health. Knowledge, attitudes and lifestyle practices (KAP) have been suggested to play a role in the management of blood pressure (BP) but there is limited evidence of the role of these factors in BP control among the Sri Lankan population. This study was evaluated the impact of knowledge on hypertension and lifestyle changes on blood pressure control in hypertensive individuals aged 30 - 60 in Colombo 5, 6, and 10. The study involved a cross-sectional study of 422 hypertensive patients who had at least six months of diagnosis but were chosen by stratified random sampling. A structured questionnaire using the WHO-STEPPS to calculate KAP was used to gather data, and BP was taken (two measurements averaged) using Omron digital sphygmomanometers. Practice scoring was structured in the way that the higher the score, the less good lifestyle behavior was. The research was carried out within the scope of high ethical principles. The KIU Ethics Review Committee gave ethical approval (Application Number: KIU/ERC/35/117). The statistical analysis was done through descriptive statistics, Pearson correlation, and chi-square tests in SPSS v29, and the p value of the tests was then taken to be statistically significant ($p < 0.05$). The mean age of the participants was 51.9 $\pm$ 7.7 years with 68% of the participants being women. All in all, 42% had control BP ($< 140/90$ mmHg). The level of knowledge was poor (21%), moderate (54%), and good (25%); the proportion of participants who showed positive attitudes was 48% with only 36% practicing favorably. There was no significant correlation between knowledge ($p = 0.383$), attitudes ($p = 0.091$), and practices ($p = 0.056$) and BP control. It was established that knowledge was negatively correlated with practice scores ($r = -0.578$, $p < 0.01$) and, therefore, that the more knowledgeable the people, the more they could practice healthier with higher practice scores, the worse their behaviors. In this study, KAP measures alone were not significant predictors of BP control. These results indicated that other than knowledge and self-reported behaviors, medication adherence, clinical optimization and structural determinants might be even more influential in terms of hypertension management. The main suggestions are to improve community health education, regular screening and proper access to antihypertensive medications, which is affordable. There is a need to promote healthy lifestyles by consuming less salt and engaging in physical exercises. Further studies need to be done on longitudinal studies, urban-rural differences and other measuring factors like BMI and cholesterol.

Keywords: Hypertension, Blood pressure, BMI, Cholesterol

The Impact of knowledge on hypertension and lifestyle changes on blood pressure control in hypertensive individuals aged 30–60 in Colombo 5, 6, and 10

1. Introduction

High blood pressure or hypertension is considered a major international health priority because it directly connects to cardiovascular issues along with stroke and kidney diseases (Rannan-Eliya et al., 2022). Early-stage hypertension manifests without symptoms because patients exhibit either persistent systolic blood pressure levels of ≥ 140 mmHg or persistent diastolic blood pressure levels of ≥ 90 mmHg (Kumanan et al., 2018). Sri Lanka Health and Ageing Study indicates that hypertension affects 28% of the adult population yet the condition grows more common as individuals age (Kumanan et al., 2018). The process of urbanization has triggered several lifestyle modifications that involve increased sedentary activities and unhealthy dietary choices as well as elevated stress levels which intensify hypertension (Rannan-Eliya et al., 2022). Studies indicate that hypertension continues to affect people in high population areas like Colombo despite unequal healthcare access rates (Silva et al., 2022).

The quality of healthcare facilities in cities is better, and the citizens of various income brackets and their knowledge about healthcare and their perception of the quality of the care influence their accessibility and utilization of the care facilities. The improvement of hypertension prevention and management is achieved by introducing strategic health policies and urban planning programs with workplace wellness programs (Silva et al., 2022). Correctly measuring blood pressure is one of the key attributes of managing hypertension. Auscultatory techniques involving the use of mercury sphygmomanometers are still the norm, but health professionals have the problem of observer bias.

This research study aimed at knowing the effects of hypertension knowledge coupled with lifestyle changes on the blood pressure management of adults aged 30 to 60 who are living in Colombo area 5, 6, and 10. The awareness rates of patients along with the patterns of adherence and obstacles to blood pressure control will provide the information that will optimally improve the intervention strategies in the urban population. The results of this study will contribute to the body of knowledge that is relevant to the formulation of strategies to promote health and policy formulations to empower the management of hypertension among urban Sri Lankan communities.

2. Methodology

The research was conceived as a descriptive cross-sectional survey that was to assess the effect of knowledge, attitudes and lifestyle changes in blood pressure (BP) control among hypertensives. Cross-sectional approach was chosen because it offers a sample of the population in a given time and it is feasible to determine the relationship between health-related behaviors and clinical outcomes in a community-based setting. The study was carried out in the Medical Officer of Health (MOH) divisions of Colombo 5, Colombo 6 and Colombo 10, three urban regions in Sri Lanka that comprise of various social and economic populations. These locations were chosen because they depict groups that experience hypertension as a health issue especially among middle-aged adults. Based on the standard formula, the minimum sample size was calculated as 384. However, to increase the reliability of results and after completing a pilot study, a total of 422 participants were finally included in the study. Based on the standard formula, the minimum sample size was calculated as 384. However, to increase the reliability of results and after completing a pilot study, a total of 422

participants were finally included in the study. The data were gathered during the door-to-door visits to the houses in particular neighborhoods. The blood pressure was recorded with calibrated Omron digital sphygmomanometers. The devices were calibrated to be accurate before data collection. The participants were requested to sit in a comfortable position and asked to lie there at least five minutes before taking two readings at two-minute intervals with the help of the same device. The mean of these two values was taken, and the overall BP value was obtained, which gives a stable estimate of the blood pressure management.

After the fieldwork, all questionnaires and blood pressure data filled in were verified to be complete and accurate by daily checking and then analyzed in SPSS version 29.0.0.1.0(171). The analysis was based on the demographic variables of the participants of the study, blood pressure and control condition, knowledge, Attitude and Practice (KAP) scores, KAP-BP associations. The research was carried out within the scope of high ethical principles. The KIU Ethics Review Committee gave ethical approval (Application Number: KIU/ERC/35/117). Before participation, the participants signed an informed consent in writing and were guaranteed confidentiality and freedom to withdraw at any time. None of the personal identifiers were noted and the data were safely stored to be used in the academic context.

3. Data Analysis and Results

The study included 422 hypertensive people aged between 30 and 60 years. A door-to-door survey was used to identify the participants in Colombo 5, 6, and 10 regions. The traits that were measured were age distribution, gender, level of education, occupation, and other factors that are related to the lifestyle. These variables will give a broad description of the study population and will be used in further examining the results of hypertension.

The age of the participants was 51.9 ± 7.7 years with most of the participants being women (68%). All in all, 42 percent of the participants had their blood pressure put under control ($<140/90$ mmHg). With respect to level of knowledge about hypertension, 21 percent showed poor, 54 percent moderate and 25 percent good. The attitude towards hypertension management was found to be positive among 48 percent of the respondents and 36 percent had positive lifestyle practices. Statistical results showed that there was no significant correlation between knowledge ($p = 0.383$), attitudes ($p = 0.091$), and practices ($p = 0.056$) and blood pressure control, so that none of these factors alone had a direct impact on the BP results. Nonetheless, the level of knowledge and practice scores were found to correlate negatively ($r = -0.578$, $p = 0.01$) with the finding that the higher the knowledge level, the more likely a person would have healthier behaviors since lower practice scores indicated more healthy lifestyle practices. This is an indication that awareness and understanding of hypertension were related to better health behaviors but were not always related to effective blood pressure control. Medication adherence, clinical follow-up or biological determinants could also have a more dominant role in providing the optimal levels of BP.

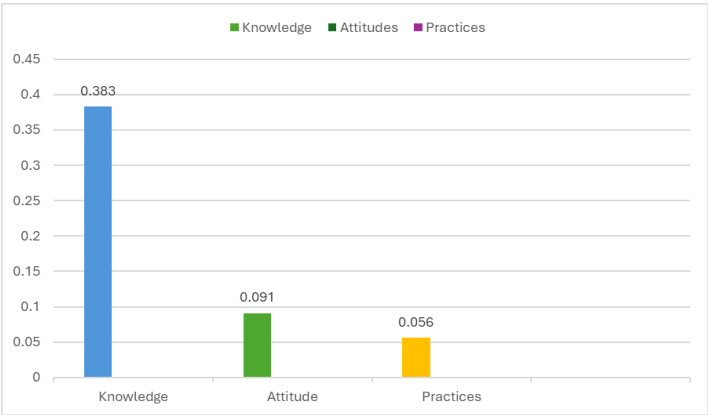


Figure 01: Demographic Characteristics of Participants

Table 02: Knowledge, Attitude, Practices Descriptive Statistics of KAP Scores

Variable	Category	Number	Percentage
Age Group	30 - 39	36	8.5%
	40 – 49	99	23.4%
	50 - 60	287	68%
Gender	Male	135	32%
	Female	287	68%
Civil Status	Unmarried	17	4%
	Married	392	92.9%
	Divorced	3	0.7%
	Widowed	10	2.4%
Educational Level	No formal education	23	5.5%
	Primary school	118	28%
	Secondary school	236	55.9%
	Tertiary/University level	26	6.2%
	Vocational training	6	1.4%
Employment Status	Other	13	3.1%
	Employed	171	40.5%
	Unemployed	211	50%
Retired	Retired	40	9.5%
Dependents	Yes	385	91.2%
	No	37	8.8%
MOH Areas	Colombo 05	137	32.5%
	Colombo 06	139	32.9%
	Colombo 10	146	34.6%

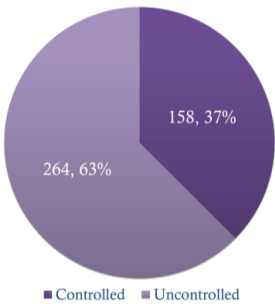


Figure 02: Blood Pressure Measurements

Table 03: Correlation Between Knowledge, Attitude, Practices and Blood Pressure

Variables Compared	r Value	P value	Interpretation
Knowledge Vs Practice	-0.0578	<0.01	negative (Good knowledge → better practices)
Knowledge Vs Attitude	-0.0262	<0.01	negative (Good knowledge →less positive attitudes)
Attitude Vs Practice	0.369	<0.01	positive (Better attitude but poorer practices)
Knowledge Vs SBP	-0.0117	<0.05	negative (Good Knowledge → Lower SBP)
Practice Vs DBP	0.098	<0.05	positive (Poor practice → higher DBP)
SBP Vs DBP	0.684	<0.01	positive (rise together)

4. Discussion

This research revealed that there were similarities and differences between the findings and the literature that were available. The moderate-to-good levels of knowledge of the participants are correlated with the Sri Lankan and South Asian research indicating growing awareness of hypertension, yet there are gaps in the knowledge of the participants regarding the risk factors and optimal blood pressure rates (Pirasath, 2021; Yang and Ho, 2017). Nevertheless, the lack of a significant relationship between knowledge and BP management are also the reflections of findings in Pakistan and other countries, where awareness is not associated with lifestyle change (Bilal et al., 2015; Pinto et al., 2024). The positive attitudes that have been witnessed in the Colombo participants are contrary to the Northern Sri Lanka where the socioeconomic challenges are the leading contributors to negative perceptions (Pirasath, 2021). Nonetheless, as is common across the world, positive attitudes failed to increase the BP control, which indicates the ongoing knowledge-attitude-practice gap (Ralapanawa et al., 2020; Bashaar et al., 2019).

It was only 3.8% out of the total respondents who had good practices, which is comparable to the Sri Lankan and global reports which showed poor compliance with lifestyle changes (Durai and Muthuthandavan, 2015; Okwuonu et al., 2014). Some of the barriers are high-salt diets, lack of exercise, and economic or cultural restrictions (Malkanthie and Shin, 2017; Rannan-Eliya et al., 2022). Such outcomes underscore the fact that individual education cannot be effective without the support of policy-level and environmental. Knowledge had negative relationships with practice ($r = -0.578, p < 0.01$), attitude was negatively correlated with knowledge ($r = -0.262, p < 0.01$), and practice was positively associated with DBP ($r = 0.098, p < 0.05$), which is consistent with the literature on the association between lifestyle and hypertension (Durai and Muthuthandavan, 2015; Shamsi et al., 2021).

The weaknesses are that it only addressed three areas of the Colombo MOH, utilized self-reported lifestyle data, which are prone to recall bias, and was cross-sectional, so that it could not be used to make a causal conclusion. The other important health indicators like BMI, cholesterol, and blood glucose were not evaluated and pregnant women or secondary hypertension were not considered, which restricted generalization.

5. Conclusions and Recommendations

The research assessed the role of knowledge, attitudes, and lifestyle behavior on blood pressure (BP) management in three Colombo MOH divisions in hypertensive adults. Even though 42 percent of the participants who recorded BP controlled knowledge, attitudes and practices did not show positive correlation with BP control, indicating that awareness and lifestyle change on its own, cannot achieve the best management outcome. The additional determinants, including medicine adherence, access to healthcare services, socioeconomic status, and genetic inclination are probably significant contributors. The need in the improvement of hypertension management within urban communities is a multidimensional and comprehensive strategy. The programs in the field of public health are expected to aim at the promotion of community awareness, maintenance of the long-term lifestyle change, and the availability of affordable antihypertensive medication. Early detection and management may be made easy through community screening and awareness campaigns.

Future studies need to involve more and broader populations and longitudinal follow-ups in an attempt to understand the lasting impact of knowledge, attitude, and practice on BP control. Comparative research on urban, rural and estate populations would give more insight into the differences in contexts. The health indicators should be extended to include BMI, cholesterol and biochemical markers, as they would provide a more comprehensive picture of the lifestyle effects.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 217

**Knowledge, attitudes, and practices regarding iron-rich diet
and iron supplementation among pregnant women, and their
association with BMI in selected MOH Areas of Gangawata
Koralaya, Kandy district**

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Abstract

Iron deficiency anaemia (IDA) remains one of the most common nutritional disorders worldwide and is a major public-health concern among pregnant women in Sri Lanka, leading to maternal morbidity and adverse pregnancy outcomes. Despite routine provision of iron supplementation through national antenatal care programmes, the prevalence remains persistently high. This descriptive cross-sectional study was conducted to assess the knowledge, attitudes, and practices of pregnant women regarding iron-rich diets and iron supplementation, and their association with body mass index among pregnant women attending antenatal clinics in selected Medical Officer of Health areas of Gangawata Koralaya, Kandy District. The target population consisted of pregnant women, with a sample size of 321 selected through consecutive sampling. The two survey instruments developed for this study were adapted from the WHO STEPS instrument for non-communicable disease risk factors and modified to suit the objectives. Ethical approval was obtained from the Ethics Review Committee, Faculty of Health Sciences, KIU (Approval No: KIU/ERC/25/048), and permission was given from the Provincial Department of Health Services, Central Province. Descriptive statistics and chi-square tests were used for statistical analysis at $p < 0.05$, using SPSS version 29. Among participants, 81.6 % showed good knowledge of iron-rich foods and supplementation, 72 % revealed moderate attitudes, and 19.9 % reported satisfactory practices. Knowledge was associated significantly with the educational level, whereas attitudes were associated with monthly income ($p < 0.05$). No statistically significant associations were observed between knowledge and BMI ($\chi^2 = 5.749$, $p = 0.451$), attitudes and BMI ($\chi^2 = 3.201$, $p = 0.524$), or practices and BMI ($\chi^2 = 7.189$, $p = 0.303$). In addition, the overall KAP score did not show a significant association with BMI ($p > 0.05$), which further confirmed that awareness and positive attitude towards iron nutrition were not translated into measurable differences in nutritional status. Thus, the study results revealed that despite pregnant women possessing quite satisfactory knowledge and awareness, those factors alone were insufficient to bring about an improvement in nutritional outcomes. Behaviour-centred nutrition education at facilities and community-based counseling need more emphasis to translate awareness into better practices and reduce maternal IDA in Sri Lanka.

Keywords: Attitudes, Body mass index, Iron deficiency anaemia, Knowledge, Practices

**Knowledge, attitudes, and practices regarding iron-rich diet
and iron supplementation among pregnant women, and their
association with BMI in selected MOH Areas of Gangawata
Koralaya, Kandy district**

1. Introduction

Iron deficiency anemia (IDA) has become one of the most common nutritional disorders in the world with more than one third of the global population being identified with this disorder especially women of the reproductive age (The Global Prevalence of Anemia in 2011, n.d.). The physiological iron requirement during pregnancy is significantly high and takes place to aid in fetal development and the enlarged maternal blood mass. IDA is a significant issue to the population in Sri Lanka, even though free antenatal care and regular iron supplements were available. The continued occurrence of anemia might be attributed to low adherence to supplementation, low intake of iron-containing foods, and misunderstanding of the usage of iron tablets (Amarasinghe et al., 2022). Hence, knowledge, attitudes and practices (KAP) of pregnant women on iron nutrition are critical in determining behavioral and socioeconomic factors that dictate the health of the mother. Moreover, the investigation of the connection between these KAP components and body mass index (BMI) can help to gain meaningful information on the overall association between awareness, nutrition, and maternal wellbeing. The purpose of the study was to examine level of knowledge, attitudes and practices in relation to iron nutrition as well as to establish the relationship between the level of knowledge, attitudes, and practices and BMI among pregnant women in the selected Medical Officer of Health (MOH) areas of the Gangawata Koralaya Division, Kandy District.

2. Methodology

A descriptive, cross-sectional study was carried out among 321 pregnant women attending the antenatal clinics under the Gangawata Koralaya MOH areas of the Kandy District, Sri Lanka. The sample size required for the study was achieved through the method of consecutive sampling. Data collection was done using a pre-tested, self-administered questionnaire adapted to the local context from the WHO STEPS instrument-questionnaire section. The instrument consisted of four sections: sociodemographic details, knowledge items, attitude statements, and practice-related questions. The content validity was ensured by expert review, and a pilot test was conducted among 30 pregnant women from a nearby clinic to ensure clarity and reliability.

The knowledge questions are related to dietary sources of iron, its functions, and the consequences of deficiency. The attitude statements motivated the women selected in this study in terms of the perceived importance of iron supplementation, while practice questions estimate dietary habits, such as the regularity of supplement consumption. Each response was scored, and overall KAP scores were categorized into “good”, “moderate”, or “poor” based on percentile cut-offs. Height and weight were measured using calibrated equipment; body mass index (BMI) was calculated as weight (kg)/height (m²).

Analysis was done using SPSS version 29. Summary statistics were used to describe the distribution of KAP levels and demographic variables. Chi square test and Spearman's rank correlation tests were performed to determine the relationships between KAP, BMI and some demographic variables like age, education and monthly income, $p < 0.05$ were considered as significant.

This study received ethical clearance from the Ethics Review Committee, Faculty of Health Sciences, KIU (Approval No: KIU/ERC/25/048, dated 06.09.2025). Permission for data collection was obtained from the Provincial Department of Health Services, Central Province, Sri Lanka. Written informed consent was obtained prior to data collection from all participants, and confidentiality was strictly maintained throughout.

3. Data Analysis and Results

A total of 321 pregnant women were participated, with a mean age of 28.3 ± 5.4 years. The majority (81.6 %) had good knowledge regarding iron-rich food and supplementation, reflecting adequate understanding of iron's importance during pregnancy. Attitudes were mainly moderate (72 %), suggesting limited motivation or mixed perceptions toward iron supplementation, and only 19.9 % of the participants reported daily adherence to iron tablets. The distribution of KAP levels is presented in Table 01.

Table 01: Distribution KAP among participants in this study (n=321)

KAP Component	Good (%)	Moderate (%)	Poor (%)
Knowledge	81.6	13.0	5.4
Attitudes	28.0	72.0	0.0
Practices	19.9	55.0	25.1

The primary reasons for non-adherence to supplementation were forgetfulness, accounting for 40.3%, and side effects such as nausea or constipation, reported by 23.7% of participants. Additional factors included a lack of awareness (18%), irregular clinic attendance (10%), and various other causes (8%). These results are presented in Figure 01.

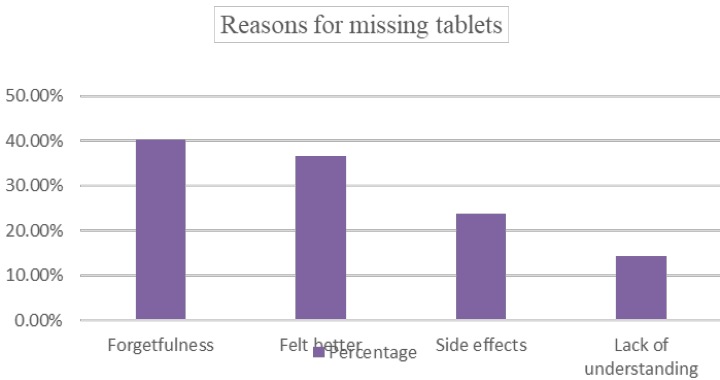


Figure 01: Primary reasons for missing tablets in women used as samples for this study

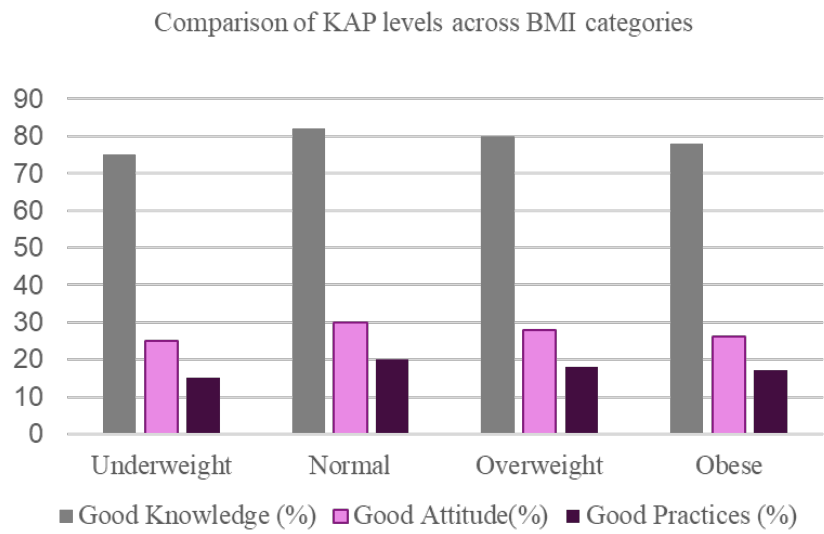


Figure 02: Comparison of KAP levels across BMI categories

Table 02: Chi Square test results association between KAP component an BMI

Test	χ^2 value	df	p-value	Interpretation
Knowledge vs BMI	5.749	6	0.451	Not significant
Attitude vs BMI	3.201	4	0.524	Not significant
Practice vs BMI	7.189	6	0.303	Not significant

All statistical analyses were revealed non-significant associations, with p-values greater than 0.05. This indicates that there is no strong relationship was observed between body mass index (BMI) and individuals’ knowledge, attitudes, or practices related to iron nutrition.

4. Discussion

It has been observed that although pregnant women in Gangawata Korlalya have good knowledge regarding iron nutrition, that does not always translate to positive attitudes and practices. Other Sri Lankan and South Asian studies have also reported good knowledge regarding supplementation; however, compliance remains consistently low. This may indicate cultural beliefs, forgetfulness, perceived side effects, and the absence of reinforcing counseling as major determinants of behavior. Education and income emerged as important predictors of KAP levels. This agrees with most research that shows higher educational attainment among women results in better nutritional awareness and decision-making.

These findings indicate that the predominance of neutral attitudes may be a reflection of inadequate motivation or poor health promotion during clinic visits. Public Health Midwives, who are the first contact for antenatal care, need further training in communication skills to address motivational barriers. That no significant correlation was found between KAP and BMI suggests that multifactorial elements influence BMI, such as overall diet quality, metabolism, and physical activity. These findings suggest that improving iron status among pregnant women requires a holistic approach that integrates educational, behavioral, and systemic interventions, rather than relying solely on knowledge dissemination.

Identification of forgetfulness and side effects as main barriers calls for individualized counseling and follow-ups. Related interventions using reminder systems, family support, and less complex supplementation regimen have been particularly successful in other low- and middle-income countries. Strengthening local antenatal programs with such approaches might yield substantial improvements in adherence and maternal outcomes.

5. Conclusions and Recommendations

This study concludes that while the majority of pregnant women showed adequate knowledge of iron nutrition, their attitudes and practical behaviors were less favorable. The awareness-to-practice gap clearly indicates the need for behavior-oriented approaches. Health authorities should focus on regular, targeted education that will not only disseminate information but also motivate and empower pregnant women to continue iron supplementation and dietary habits. Public Health Midwives need to be provided with simple, easily usable communication tools and culturally appropriate materials to address misconceptions and fears associated with iron tablets. Community-based awareness activities and peer-support mechanisms will promote favourable attitude change.

Furthermore, integrating structured nutrition education into routine antenatal care, implementing compliance-monitoring mechanisms such as reminder tools, and ensuring a consistent supply of supplements are expected to strengthen adherence outcomes. Psychosocial and environmental factors that could impact long-term compliance and maternal anaemia outcomes may be evaluated in future studies. A multi-level approach will be important to strengthen both education and health system support in the effort to reduce iron deficiency anaemia and improve pregnancy outcomes in Sri Lanka.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 219

Comparison of health-related lifestyle behaviours among second year medical and dental faculty students – A preliminary study

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Abstract

Health-related quality of life (HRQoL) is a quality-of life indicator showing the physical, psychological, and social well-being of a person which is crucial for the success of healthcare undergraduates. Medical and dental students are prone to heavy academic schedules, clinical workloads, and other social, financial and cultural circumstances that may influence their lifestyle behaviors like diet, sleep, exercise, and stress coping strategies. The aim of this study was to compare health-related lifestyle behaviours (HRLB) that influence HRQoL among second-year undergraduates in medical and dental faculties of the University of Peradeniya. This was a descriptive cross-sectional preliminary study conducted among the second-year medical and dental students at the University of Peradeniya using convenient sampling method. Data was collected using Health-Promoting Lifestyle Profile II (HPLP II) questionnaire comprising of six subscales: health responsibility, physical activity, nutrition, interpersonal relations, stress management, and spiritual growth. A total score >3.00 was considered as good HRLB, 1.99-2.59 were moderate and <1.99 were poor. Median (Interquartile range, IQR) values and total scores were analysed and compared using Mann-Whitney *U* test and Chi Square test considering *p-value*<0.05 as significant. A total of 55 students completed the questionnaire where 56.4% were medical (n=30) and 43.6% (n=25) were dental undergraduates. Their median age was 22 years (IQR = 1), and 52.7% (n=29) were females. Sociodemographic characteristics were not significantly different between the two groups (*p*>0.05). Only 13.3% (n=4) medical students and 4% (n=1) dental students had moderate HRLB and 86.7% (n=26) medical and 96% (n=24) dental students had poor HRLB. None of the students had good HRLB. Medical students showed a higher physical activity score than dental students [1.81 (0.41) vs 1.50 (0.50), *p*<0.05]. Other scores were not significantly different between the two groups (*p*>0.05). These preliminary findings show that a great majority of medical and dental faculty undergraduates have poor HRLB, suggesting potential risks to their overall HRQoL. Thus, developing and implementing interventions to improve HRQoL of these students is urgently needed.

Keywords: Dental Students, Health-promoting lifestyle profile II, Health-related quality of life, Medical Students, University of Peradeniya

Comparison of health-related lifestyle behaviours among second year medical and dental faculty students – A preliminary study

1. Introduction

The most common cause of mortality and morbidity in the global society that results in societal and economic burden are noncommunicable diseases (NCDs) like cardiovascular diseases, cancer, chronic respiratory diseases and diabetes (Kinoshita et al., 2024). Thus, a major challenge in the current era is dealing with epidemic of NCDs exacerbated by poor lifestyle behaviours. Health-related Lifestyle Behaviours (HRLB) are regular activities that directly influence personal health, and ultimately influencing Health-related Quality of Life (HRQoL) (Salvador-Carulla et al., 2013). There is evidence that HRLB helps to prevent chronic illnesses, enhance the HRQoL, and decrease the healthcare expenses (Rippe, 2018). Yet, dental and medical undergraduates are prone to face health behavior problems because of the pressure of the time, academic influences, lack of money, and social requirements (Music et al., 2021). Health-Promoting Lifestyle Profile II (HPLP II) is an instrument that is valid, has six lifestyle dimensions and is used as an instrument to assess HRLB among students (Zambrano Bermeo et al., 2024). University students who develop good HRLB habits in their early years establish lifelong health advocacy skills in both personal life and their future careers. Evaluating and boosting HRLB levels in medical and dental undergraduates serves as a crucial step for their health and future professional growth. Thus, this preliminary study was conducted to compare Health-related Lifestyle Behaviours among second year medical and dental faculty students at the University of Peradeniya.

2. Methodology

A descriptive cross-sectional study was carried out among the second-year undergraduates pursuing medical and dental sciences in the University of Peradeniya recruited using convenient sampling method. The data collection was done using a self-administered online questionnaire consisting of two parts: baseline data, and HPLP II questionnaire. HPLP II questionnaire consisted of 52 questions measuring six subscales of lifestyle behaviour: Spiritual growth, interpersonal relations, nutrition, health responsibility (9 Questions in each subscale), physical activity, and stress management (8 Questions each). Each question was answered by giving a score on a four-point Likert scale ranging from never (1 point) to routinely (4 points). Score for overall health promoting lifestyle for a given individual was obtained by calculating the mean score of all 52 questions. Similarly, subscale scores for a given individual were obtained by calculating the mean of responses to each subscale. The English version of this overall scale reported a Cronbach alpha of 0.94 (Chouhan, 2017). A total score >3.00 was considered good HRLB, 1.99-2.59 were moderate and <1.99 were poor (Pan, 2025). The data was analysed using SPSS version 31. Descriptive statistics were computed using Median (Interquartile range, IQR) and the group comparison were done using Mann-Whitney *U* test and Chi Square test considering a *p-value* <0.05 as significant. The ethical approval for this study was obtained by Ethics Review Committee, Faculty of Medicine, University of Peradeniya (No: 2025/EC/32) and administrative approval was obtained from the Deans of the respective faculties.

3. Data Analysis and Results

A total of 55 (30=medical; 25=dental) second year students completed the questionnaire with majority of females (52.7%), Sinhalese (85.5%) and Buddhists (81.8%). Median age of medical students was 21 years (IQR =1) and dental students 22 years (IQR = 2) ($p>0.05$). Sociodemographic characteristics were not significantly different between the two groups ($p>0.05$). Further, among total respondents, 92.7% were never-smokers and 61.8% were ex-irregular drinkers and there was no statistically significant difference between these two groups ($p>0.05$). Majority (98.2%) of the students were single and 43.6% had a neutral financial condition. Table 01 shows the subscale and total HPLP II scores for total population and comparison between the two groups; medical and dental undergraduates. The total HPLP II score was not different between medical and dental students. For medical students, highest score was observed for spiritual growth while for dental students it was for interpersonal relationships. The lowest scores were observed for medical and dental students were health responsibility and physical activity respectively. Except for physical activity, none of the other subscale scores were significantly different between medical and dental undergraduates. Table 02 shows the HRLB based on the HPLP II score cut off values. Accordingly, over 90% of the total students (n=50) had poor HRLB while the remaining 10% (n=5) had moderate HRLB. The pattern is the same across both faculties with no significant difference ($p>0.05$).

Table 01: Health Promoting Lifestyle Profile (HPLP II) mean scores for all participants and faculty-wise comparison

Subscale	Total population (n=55) Median (IQR)	Medical students (n=30) Median (IQR)	Dental students (n=25) Median (IQR)	<i>p-value</i>
Health responsibility	1.78 (0.44)	1.77 (0.56)	1.78 (0.44)	0.389
Physical activity	1.75 (0.63)	1.81 (0.41)	1.50 (0.50)	0.009
Nutrition	2.33 (0.44)	2.33 (0.56)	2.22 (0.39)	0.122
Spiritual growth	2.44 (0.56)	2.50 (0.56)	2.33 (0.50)	0.377
Interpersonal relationships	2.44 (0.67)	2.33 (0.72)	2.56 (0.56)	0.382
Stress management	2.25 (0.50)	2.25 (0.56)	2.13 (0.50)	0.690
Total HPLP II	2.17 (0.34)	2.20 (0.38)	2.15 (0.33)	0.467

Mann-Whitney U test for comparison between faculties, $p\text{-value} < 0.05$ is significant

Table 02: Health-related Lifestyle Behaviour (HRLB) categories for all participants and by faculty

HRLB	Total (n=55) n (%)	Medical (n=30) n (%)	Dental (n=25) n (%)	<i>p-value</i>
Poor (HPLP II score<1.99)	50 (90.9%)	26 (86.7%)	24 (96.0%)	0.231
Moderate (1.99-2.59)	5 (9.1%)	4 (13.3%)	1 (4.0%)	
Good (>3.00)	0	0	0	

Chi Square test for comparison between faculties, p-value <0.05 is significant

4. Discussion

This paper examined and compared HRLB in second-year medical and dental students enrolled in the University of Peradeniya using the HPLP II questionnaire. The highest and lowest scores were registered in the areas of spiritual growth and physical activity, which is often reported among students of healthcare with high academic demands and short time to take care of themselves (Alzahrani *et al.*, 2019; Music *et al.*, 2021). Out of 55 participants, most of them (90.9%) showed poor health-promoting lifestyle profiles with a minority (9.1%) presenting moderate levels. Notably, none of the students showed good HPLP scores. Thus, HRQoL is likely to be poor in the majority of medical and dental students. There were no significant differences between medical and dental students in total HPLP II or the majority of the subscales with the exception of physical activity where medical students had high scores. This indicates that the patterns of lifestyles are similar in both groups of students, probably due to similar academic and social conditions. Incorporating wellness education in undergraduate education can lead to improved health status of students and increase their professional performance in the future. The smaller sample size and focus on one university limits generalizability, therefore focusing on extensive, decentralized studies can be recommended to validate and explore these results.

5. Conclusions and Recommendations

This is a preliminary study that compared the health-related lifestyle behaviours among second year medical and dental undergraduates at the University of Peradeniya using HPLP II. It was found that majority of the students showed an overall poor health-related behaviours. Therefore, health promotion interventions should be implemented in the university to enhance issues like physical activities, stress management, and nutrition among undergraduate healthcare students. Wellness programs on a faculty level, time management classes, as well as peer-supports can be used to encourage students to make more consistent healthy choices.

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Thematic Track: Biomedical and Health Sciences

Abstract number: 222

A Study based Assessment of Academic stress faced by the Undergraduate students during Examinations

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Abstract

Academic stress among undergraduate students have become a critical area of concern especially during academic evaluation times or examinations. This study is essential as the examination periods are one of the utmost potential times for stress levels among undergraduate students to further worsen. This study aims to assess the prevalence of examination-related academic stress among undergraduate students and to explore the trends of exam related stress levels across several demographical determinants. This study followed quantitative, cross-sectional research approach and collected data from 60 undergraduate students through a self-administered questionnaire. The questionnaire was designed with two sections as demographic details and Perceived Stress Scale (PSS)-10. The diversified representative sample was collected across different ages, genders, fields of study, university types, academic years, and enrollment status. The collected data was analyzed using Microsoft Excel. The techniques like descriptive statistics, T-tests, ANOVA, Chi-square tests and spearman correlation analysis was used to analyze the trends among demographic variables and stress levels. The study finding revealed high prevalence of exam related stress among undergraduate students with mean PSS score of (M=29.78) and Median =29 both falling under high-level stress category. Further majority if the participants (66.67%) about two third of proportion was reported under high level stress category. The female students(M=30.23) reported higher mean stress score than male students (M=29) while the difference was not statistically significant(p=0.50). The ANOVA revealed stress levels of undergraduate students being significantly differed across age (p=0.005) with peaked mean stress marked along 23-25 aged students (M=32.83). The weak positive spearman correlation (p=0.248) revealed that stress levels of undergraduate students slightly increase along the academic year with final-year students exhibiting the highest prevalence of high stress (88.9%). The study also found stress levels not being statistically difference across the fields of study (p=0.256) or enrollment status (p=0.0504) of undergraduate students. The limitations like sample size, convenience sampling and cross-sectional design may introduce bias influencing the findings and interpretations. This study recommends implementing exam stress management programs across all institutions. It also encourages to implement targeted mental health programs specifically for identified high-stress categories such as final year students. The future researches in relative to the topic are recommended to adopt longitudinal and mixed-method approaches with larger, stratified samples to capture both trends and experiences of exam-stress over time. In conclusion this study emphasizes urgent need for well-planned interventions to alleviate examination-related stress of undergraduate students.

Keywords: Academic stress, Undergraduate Examinations, Undergraduate Students, Perceived Stress Scale (PSS-10), Mental health and well-being

A Study based Assessment of Academic stress faced by the Undergraduate students during Examinations

1. Introduction

Academic stress among undergraduate students have become a critical area of concern especially during academic evaluation times or examinations. According to (Frazier, Abigail, Merriams, & Katherine, 2019) the students face highly vulnerable state of mental health during the academic evaluations and performance. At present despite the growing awareness many students still are in the dark about their health and are silent sufferers due to stigma and lack of information (Shahwan, et al., 2020). This study is essential as the examination periods are one of the utmost potential times for stress levels among undergraduate students to further worsen. While many studies have been done on general undergraduate student stress, we have very few that look at this particular time frame of examination. Hence this research aims to address this gap by measuring the prevalence and determinants of examination-related academic stress among undergraduate students. This research aims to assess the determinants like age, gender, academic year, university type, field of study and enrollment status to provide evidence-based recommendations.

2. Methodology

This study adopts a quantitative based cross-sectional descriptive research design to assess the academic stress among undergraduate students during examinations. The data was collected using self-administered questionnaire comprising two sections as demographic details and standard Perceived stress scale (PSS)-10. The questionnaire was distributed both as printed copies and digital forms with voluntary participation and informed consent. The purposive convenience sampling method was used to collect data from 60 participants from various facilities and academic years to ensure diversified representative sample. The collected data was analyzed using Microsoft Excel. The techniques like descriptive statistics, T-tests, ANOVA, Chi-square tests and spearmen correlation analysis was used to analyze the trends among demographic variables and stress levels.

3. Data Analysis and Results

A sample of approximately 60 undergraduate students took part in the assessment of the study offering with a response rate of 100%. The demographic characteristics Table 1 presented underneath clearly portrays the overall summary of demographic profiles engaged in this study. The demographic characteristics of the table evidently reflects the diversity of the sample data across various variables including gender, age, type of university, faculty of study, academic year and enrollment status.

Table 01: Demographic characteristics and information of the study participants

D. Feature	Type	f	%	D. Feature	Type	f	%
Gender	Male	22	36.67%	Type of University	Government University	25	41.67%
	Female	38	63.33%		Private Campus	26	43.33%
Age	Below 19	2	3.33%		Others (Vocational/ Training colleges etc.)	9	15.0%
	Between 19 - 21	27	45.0%	Study Status	Full Time	41	68.33%
	Between 21 - 23	16	26.67%		Part time	9	15.0%
	Between 23 - 25	12	20.0%		Distance Learning	10	16.67%
	Above 25	3	5.0%	Field of the study	Arts	8	13.33%
Year of the Study	First Year	22	36.67%		Commerce	13	21.67%
	Second Year	19	31.67%		Technology	11	18.33%
	Third Year	10	16.67%		Bioscience	8	13.33%
	Fourth/Final Year	9	15.0%		Medicine	4	6.67%
					Engineering	16	26.67%

3.1. Distribution of PSS-10 Perceived Stress Scores of Undergraduate Students

Table 02: Descriptive statistics for perceived stress scale (PSS)10 of undergraduate students

Table 02: Descriptive statistics for perceived stress scale (PSS) of undergraduate students							
Size of the sample		Sum of the sample	Maximum		Minimum	Range	Mean
N		Sum	Max		Min		M
60		1787	40		13	27	29.78333333
Median	Standard Deviation	Variance	Quartiles		Interquartile Range	Skewness	Kurtosis
MDN	SD	VAR	Q1	Q3	IQR	SKEW	KURT
60	6.790051713	46.10480226	60	60	10.25	-0.45177	-0.4769

The Table 02 represents the descriptive statistics for the perceived stress scores of the university students participated in this study. The mean perceived stress score obtained from the study was 29.783 and the median 29 with both falling under the high-level stress range (27- 40).

3.2. Distribution of perceived stress levels of Undergraduate Students

The total PSS-10 scale scores obtained from the students were categorized into three levels for standard assessment of stress levels among the participants.

Table 03: Frequency distribution of perceived stress levels among undergraduate students

Stress Levels		No. of the students	Percentage	SD	V
Low level stress	0 - 13	2	3.33 %	0	0
Moderate stress	14 - 26	18	30.0 %	2.669117	7.124183
High level stress	27 - 40	40	66.67 %	4.193325	17.58397
Total		60	100.00%		

3.3. Distribution of perceived stress of undergraduate students across genders

Table 04: Descriptive statistics of perceived stress scores of undergraduate students by gender

	Mean (M)	SD	Variance	N	Pooled Variance
Female	30.23684	6.7321	45.32077	38	46.53221
Male	29	6.9761	48.66667	22	

According to Table 4 the average stress level reported by the female undergraduate students (M=30.23, SD=6.73) is relatively higher than the average stress level reported by the male undergraduate students.

Table 05: Independent samples t-test for perceived stress scores by gender

t-Test: Two-Sample Assuming Equal Variances						
Hypothesized Mean Difference	df	t Stat	P(T<=t) one-tail	t Critical one-tail	P(T<=t) two-tail	t Critical two-tail
0	58	0.676807	0.250609	1.671553	0.501219	2.001717

The Table 5 Independent two sample T-test results revealed a statistically significant difference of t (58) = 0.68, p =0.5012 between the male and female undergraduate students.

3.4 The effect of student’s age on stress levels of undergraduate students

Table 06: Descriptive Statistics of Perceived Stress Scores among different Age Categories of University Students

Groups	Count	Sum	Average	Variance
Below 19	2	33	16.5	24.5
Between 19 – 21	27	780	28.88889	42.79487
Between 21 – 23	16	507	31.6875	30.3625
Between 23 – 25	12	394	32.83333	39.42424
Above 25	3	73	24.33333	30.33333

The Table 06 represents the undergraduate students between age 19 -21, 21-23, 23 – 24 reported highest average stress scores of 28.8, 31.68, 32.83 respectively. All of those three mean stress scores belonged to high-level stress while also consecutively increasing along.

Table 07: A One-Way analysis variance statistics for mean perceived stress scores by age category

ANOVA: Single Factor						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	633.2458	4	158.3115	4.172205	0.005063	2.539689
Within Groups	2086.938	55	37.94432			
Total	2720.183	59				

The Table 7 ANOVA test results evidently revealed the statistically significant difference of mean perceived stress score between age categories as $F(4, 55) = 4.17, p = 0.005$.

3.5. The perceived stress level scores of undergraduate students among university types

Table 08: Descriptive statistics of perceived stress scores of students across university types

Groups	Count	Sum	Average	Variance
Government University	25	799	31.96	31.79
Private Campus	26	763	29.34615385	55.91538462
Others	9	225	25	28.75

Table 09: One-Way ANOVA statistics for perceived stress scores by type of university

ANOVA: Single Factor Statistics					
Source of Variation	SS	df	MS	F	P-value
Between Groups	329.3387179	2	164.669359	3.925873476	0.025273508
Within Groups	2390.844615	57	41.94464238		
Total	2720.183333	59			

The ANOVA test finding ($p=0.025$) of significance difference is visually supported by the non-overlapping error bars of other higher educational institutions with both private campus and government university.

3.6. Distribution of perceived stress of undergraduate students across study fields

Table 2: The descriptive statistics of the perceived student’s stress across fields of study

Groups	Count	Sum	Average	Standard Deviation	Variance
Arts	8	231	28.875	8.25378701	68.125
Commerce	13	357	27.46153846	7.066533622	49.93589744
Technology	11	339	30.81818182	5.776126415	33.36363636
Bio-Science	8	214	26.75	6.777062153	45.92857143
Medicine	4	136	34	6.782329983	46
Engineering	16	510	31.875	6.042902173	36.51666667

In accordance to Table 10 the highest mean stress score (34) was reported in the engineering. This was followed by the reported by the mean stress score of Medicine ($M= 31.8$) and Technology ($M = 30.8$).

Table 3: One-way ANOVA results for the perceived stress scores by the field of study

ANOVA: Single Factor						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	303.19121	5	60.63824009	1.3547686	0.255883	2.3861
Within Groups	2416.9921	54	44.75911357			
Total	2720.1833	59				

The one-way ANOVA analysis results of Table 11 reveals the statistically significance difference of perceived stress score across different fields of study as $F(5, 54) = 1.35, p = 0.256$.

3.7 The analysis of perceived stress of undergraduate students by academic years

Table 4: The distribution of high-level stress of undergraduate students across the academic years

Year of Study	High stress (Yes) (n)	High stress (Yes) %	High Stress (No) (n)	High Stress (No)%	Total (N)
First Year	10	45.5%	12	54.5%	22
Second Year	15	78.9%	4	21.1%	19
Third Year	7	70.0%	3	30.0%	10
Fourth/Final Year	8	88.9%	1	11.1%	9
Total	40	66.7%	20	33.3%	60

Table 12 portrays the prevalence of high stress being varied across the academic years. The final year students reported highest prevalence (88.9%) of high-level stress while the first-year students reported lowest prevalence of (45.5%) high-level stress.

Table 5: Representing Spearman Analysis Results of PSS scores across academic years

Spearman Correlation Analysis	Spearman's rho (ρ)
	0.247966351

Table 13 illustrates the obtained spearman correlation results. The spearman correlation revealed a statistically marginal result of (N=60), p=0.248. The small positive correlation value identified a weak positive relationship among the PSS Scores across the academic years.

3.8 The distribution of perceived stress of undergraduate students across different types of enrollments

Table 6: Stress Level Distribution of Undergraduate Students Across Different Enrollment Types

	Low Level stress		Moderate Stress		High Level Stress		Total	
Full - Time	0	0%	13	31.70%	28	68.29%	41	100%
Part - Time	1	11.11%	2	22.22%	6	66.67%	9	100%
Distance Learning	1	10%	3	30%	6	60%	10	100%
Total	2	3.33%	18	30%	40	66.67%	60	100%

Table 14 indicates a fairly higher percentage of full-time students indicating medium and high levels of stress while comparatively higher percentage of distance learning students reported moderate and low-level stress.

Table 7: The Chi-Square Test of Independence Analysis: Stress Levels Vs Enrollment Types

	Low stress	Moderate Stress	High Stress	Total		Low stress	Moderate Stress	High Stress
	Observed frequencies					Expected Frequencies		
Full – Time	0	13	28	41		1.3667	12.3	27.333
Part – Time	1	2	6	9		0.3	2.7	6
Distance Learning	1	3	6	10		0.3333	3	6.6667
Total	2	18	40	60				
Chi-Square Test Results - p-value = 0.513554								

Table 14 illustrates the chi-square test along with the obtained chi-square results. The chi-square test revealed the result of $p=0.513$ for stress levels across different enrollment types.

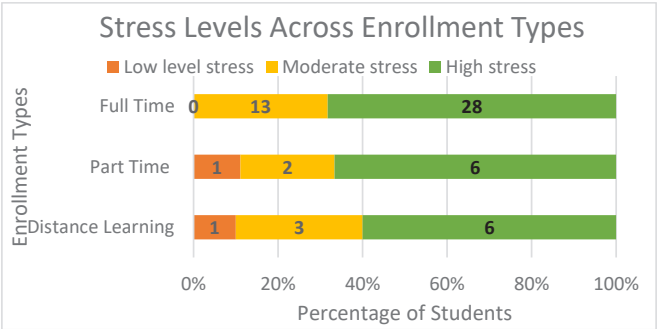


Figure 01: Stacked bar representation of stress levels of students across enrollment types

The stacked bar of Figure 1 represents the proportional breakdown stress levels across the three modes of enrollment. The high- level stress was the most common category for full-time, part-time, and distance-learning students with relatively equal graphical representation. The percentage of students reported low stress was low in all the modes of enrollment.

4. Discussion

This study aimed to assess the prevalence and determinants of academic stress faced by the undergraduate students during examinations. The findings of this study have confirmed high level of perceived stress during examinations with the mean perceived stress score of 29.78 within the "high level stress" category. The previous research findings of (Bhandari, M.S. et al.,2025), (Gazzaz, Z.J. et al.,2018) also suggest similar high mean perceived stress score of university students. Further the study also revealed two third (66.67%) of participants experience high stress as an alarming indicator of a wide spreading issue.

The gender-based stress analysis of university students revealed slightly higher mean perceived stress score for female students(M=30.23) than male students (M=29) while the difference was not statistically significant($p=0.50$). This contradicts with major fraction of existing literatures claiming female students with higher academic stress. However, some emerging recent studies of (Gao, W., Ping, S. and Liu, X., 2020) (Dewi, D.K. and Ningsih, I.E.P.I.E.P., 2020) (Adasi, G. et al., 2020) also claims the difference in stress among genders to be statistically insignificant. This contradiction may have occurred due to the context of the study. The present

finding focused particular on examination scenario could have overshadowed the baseline differences observed in other normal settings.

In contrary to the gender-based analysis the stress levels were reported to differ significantly across age categories ($p=0.005$) and university types ($p=0.025$). The mean perceived stress scores have increased along age and peaked among 23-25 age ($M= 32.83$). The above 25 age has shown a small decline ($M=24.33$). The similar pattern of comparative stress decline in older students can also be observed in (Stefaniak, A.R., Blaxton, J.M. and Bergeman, C.S., 2022) (Almeida, D.M. et al., 2023). The study finding also revealed the government university students reported to have higher stress ($M=31.96$) than other higher educational institutions. This could be related to factors like intense competition, load curriculum, 100% exam-based assessment as suggested by (Abdin, Z. ul and Arain, D.A.A., 2023)(Ranasinghe, P. et al., 2017).

The descriptive statistics of study field-based analysis revealed higher stress among the Medicine ($M=34$) and Engineering students ($M=30.9$) while the ANOVA analysis proved the difference to be statistically insignificant ($p=0.256$). Academic year-based spearman correlation analysis suggested correlation of $p=0.248$, a weak positive correlation revealed perceived stress levels of university students to be gradually increase across the academic years. The researches of (Swadiq, M., 2025) (Zhang, J., Peng, C. and Chen, C., 2024) (Okoye, O.C., 2022) also clearly supports the increased stress levels on progressing forwards to the academic years. The finding from analysis of enrollment status revealed there is no significant differences in stress levels experienced in different enrollment types. It could be due to the mode of study being less relevant to examination stress when compared with the fundamental pressure of the exam assessments themselves.

This study is limited by the use of convenience sampling which in turn reduces representativeness and introduces selection bias. The sample size ($N=60$) being relatively small limits the sub group analysis of the study introducing the risk of errors. This study follows cross-sectional design that doesn't show cast the stress level changes over time for depth analysis. This study uses self-reported data which could carry the bias partially impacting the accuracy of analysis and findings. This study is quantitative based and lacks qualitative insights which might explain the trends expressed from the quantitative analysis.

5. Conclusions and Recommendations

It is recommended for the universities to implement pre-exam stress management programs across all the university type and enrollment types. The government universities should review workloads, examination assessment methods and curriculum weight with consideration to student's wellbeing. The students should be provided with continuous targeted mentoring and guidance to manage increasing workloads, presentations and final-year projects while progressing towards academic years.

It is recommended for future researches to adopt a mixed-methods approach combining surveys and interviews to capture both trends and experiences. The implication of longitudinal research design will help to observe changes over time. The study could use more of a large sized stratified sample to conduct effective sub group analysis to reveal further underlying trends.

This study concludes that examination periods are significant source of high stress among undergraduate students. The factors like age, academic year and university type influence this exam-stress of undergraduate students. Hence exam related academic stress of undergraduate

students needs well-planned mental health support to promote holistic student wellbeing and academic performance.

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Session 01
Computing



Thematic Track: Computing

Abstract number: 26

AI automation for seed germination: SSD-MobileNetV2 detection with ESP32 IoT prototypeDehigolla. P. P.^{1*}, Prabuddha W. G. S.¹, Amunugama P. G. R. T.¹, Gunasekara J. J.¹, Aththanagoda A.K.N.L.¹¹Department of Computing, Rajarata University of Sri Lanka**Abstract**

Seed germination assessment is essential for agricultural research and crop quality monitoring but is still predominantly based on manual observation, limiting scalability, accuracy, and consistency. To overcome these constraints, this study presents a compact and low-cost intelligent germination-monitoring system that integrates an ESP32-based IoT incubator with a lightweight deep-learning detector. The system is designed to (i) provide precise and energy-efficient environmental control using sensor-driven regulation of temperature and light, and (ii) reliably detect germination using an SSD-MobileNetV2 model under ordinary and light-varying imaging conditions. The hardware architecture incorporates an ESP32 microcontroller, DHT11 temperature–humidity sensor, Peltier module, heating coil, and OV2640 camera to enable continuous data acquisition and autonomous control. Experimental results show that the proposed germination detector achieved a mean average precision (mAP) of 0.83 and average recall (AR) of 0.87, while the light-varying identification model achieved mAP = 0.73 and AR = 0.83, indicating moderate robustness under low-illumination scenarios. Furthermore, the IoT integration enables remote monitoring, real-time visualization, and automated data logging, improving experimental reproducibility and reducing human effort. Overall, the system offers a scalable, low-cost, and efficient alternative to manual germination testing, with potential for broader application in smart agriculture. Future research will focus on multi-species datasets, improved low-light adaptation, and validation across diverse environments to enhance generalizability and operational resilience.

Keywords: Automation, Deep Learning, IoT, Machine Learning, Seed Germination

AI Automation for Seed Germination: SSD-MobileNetV2 Detection with ESP32 IoT Prototype.

1. Introduction

Seed germination is the critical first stage of the plant life cycle, determining crop establishment and agricultural productivity. Traditional germination tests such as paper towel or tray methods count emerging seedlings over 2–10 days. The manual counting's are labor-intensive, time-consuming and prone to error (Peng et al., 2022). However, early automation attempts used image processing techniques. For example, Khoenkaw et al. segmented rice seed and root regions in HSV color space (Khoenkaw, 2017). However, these methods depend on specific backgrounds, controlled lighting, and seed types. Peng et al. note that such “traditional image analysis” works only for specified seeds under controlled image conditions (Peng et al., 2022). Also, the commercial germination scanners such as Germination Scanalyzer perform such as colored filter paper, fixed seed color and also expensive (Ramesh Reddy, Cheruku and Kodali, 2023). In summary, the existing mechanical and vision-based systems are high-cost or inflexible to uncontrolled image conditions.

Deep Learning Approaches: Recent years, deep neural networks (DNNs) for germination detection achieved remarkable accuracy. Grant et al. (2023) combined CNN classification with color segmentation for corn seeds, achieving 98.14% accuracy (Grant et al., 2023). Genze et al. (Genze et al., 2020) applied Faster R-CNN to corn, rye and millet seeds (94 % mAP). Ma et al. (Ma et al., 2023) used Mask R-CNN for automatic root length measurement (Sun et al., 2025). Zhao (Zhao et al., 2023) use a YOLO-Transformer hybrid for rice seeds with 95.4 % accuracy. Yao et al. improved this using SGR-YOLO, with 94 % accuracy in trays and 98.2 % in Petri dishes (Yao et al., 2023).

IoT Integration and Lightweight Models: Currently IoT-enabled devices, autonomous the data collection in germination systems (Nyakuri et al., 2025). For example, Peng et al. (Peng et al., 2022). built a movable-camera system using CenterNet. However, it required high computational resources. The SeedGerm platform (Colmer et al., 2020) supports multi-species phenotyping but required large datasets and complex workflows. In contrast, lightweight architectures such as MobileNetV2, uses depthwise-separable convolutions, reduce parameters and enable real-time inference on low-resource edge devices (Nyakuri et al., 2025) (Peng et al., 2022).

Research Gap and Contribution: A key research need remains for a low-cost system that maintains optimal germination conditions with accurately detecting germination method which can be implement on a thermostat. Our study addresses this gap by combining an IoT thermostat with an SSD-MobileNetV2 detector including recognition of seeds even under light-varying conditions.

2. Methodology

A fully automated seed germination monitoring system was developed, integrating an ESP32 microcontroller, DHT11 temperature-humidity sensor, Peltier coolers, a heating coil, LED lighting, and a 2 MP OV2640 camera. The ESP32 continuously regulates temperature and humidity while streaming live sensor data and captured images via a local web server for remote access. Figure 01 illustrates the hardware setup, including the incubator, camera mount, and sensor suite.

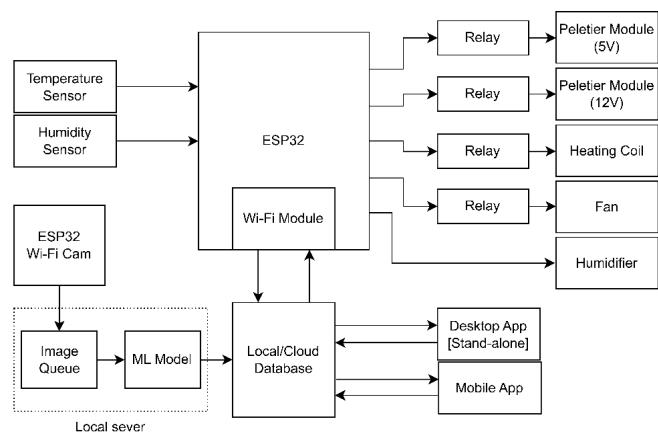


Figure 01: Block diagram of the hardware design of the automated seed germination system

1.1. Dataset and Preprocessing

The dataset (Genze and Grimm, 2023) comprises 8,148 images of Zea mays seeds (≈81,480 annotated bounding boxes). Data were split into training (70%), validation (15%), and testing (15%) sets. Images were resized to 320 × 320 px and augmented to improve model robustness.

1.2. Model Selection and Development

SSD MobileNetV2 was selected for its efficiency and suitability for low-resource deployment. Two models were trained using TensorFlow Object Detection API.

Germination Detection Model:

- Data split (70:15:15) in TFRecord format.
- 16 experiments with random hyperparameter search.
- Best model selected based on mean Average Precision (mAP) and Average Recall (AR).

Seed Identification under Varying Light Conditions:

- Two classes: Zea mays and non-Zea mays.
- Applied aggressive photometric augmentations (brightness $b \in [0.2, 1.0]$, contrast $c \in [0.5, 1.5]$, Gaussian blur $\sigma \in [0.5, 1.5]$).
- Evaluated using mAP and AR on both test and real images from the OV2640 camera under different lighting.

Table 01. Combinations of hyperparameters for best generalized models.

Hyperparameter	Zea Maize Germination Detection Model	Low Light Varying Zea Maize Seed Identification Model
Batch size	8	4
optimizer	Momentum, cosine decay LR	Momentum, cosine decay LR
Learning rate base	0.085	0.08
Warmup learning rate	0.008	0.026666
Total steps	90000	50000

3. Results

Model performances are evaluated by average precision and recall using validation split. We achieved mAP=82.5% and AR=87% for the Germination Detection model under ordinary image conditions. And achieved mAP=73% and AR=83% for the Zea Maize seed detection model under low light varying conditions.

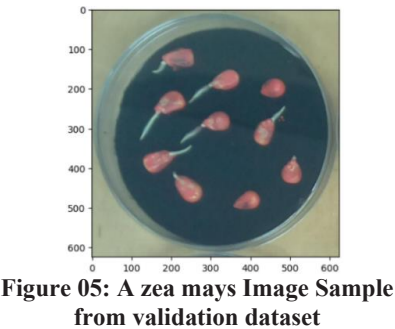


Figure 05: A zea mays Image Sample from validation dataset

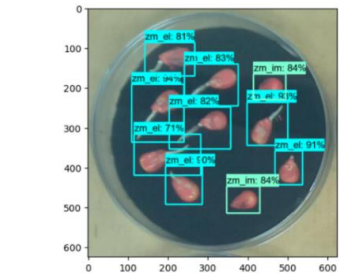


Figure 06: Detected germinated and non-germinated seeds of sample image using Zea Maize Germination Detection Model

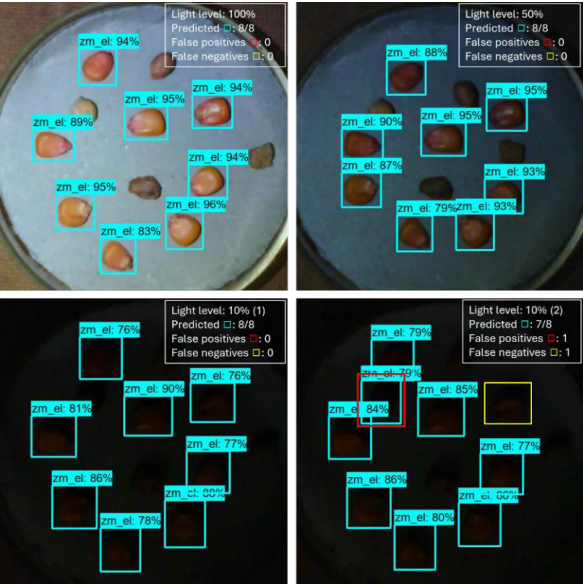


Figure 07: Light controlled Zea Maize seed detection using Ligh Varying Zea Maize Seed Detection model

4. Discussion

The germination detection model achieved an AP of 0.83 and AR of 0.87, demonstrating high accuracy in detecting germinated seeds. The light-varying detection model achieved mAP of 0.73 and AR of 0.82, showing moderate performance under low-light conditions, with potential for improvement in illumination adaptation.

Limitations

The system was tested only on Zea mays seeds in 100 mm × 15 mm Petri dishes. Broader validation with other species, substrates, and environments is required. Detection accuracy declines under very low light (< 20% intensity), limiting use in poorly lit settings.

Implications

The modular, scalable design enables use in research, education, and agricultural seed testing. Its accessible interface and automated data-driven insights support efficient, real-time germination monitoring.

5. Conclusions and Recommendations

This study presents a low-cost, automated seed germination monitoring system integrating SSD MobileNetV2 for precise detection and environmental control. The solution enhances accuracy, reduces manual labor, and supports real-time analysis. Future work should expand to multi-species detection, improve robustness under varied conditions, and optimize energy efficiency for standalone deployment.

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Thematic Track: Computing

Abstract number: 41

2D-to-3D computational reconstruction of liver cirrhosis: Bridging radiomics, medical imaging, and clinical practice in facilitating diagnosisThanaal M.T.¹, Jananie M.^{1*}¹Department of Computing, Informatics Institute of Technology, Sri Lanka**Abstract**

One of the most prevalent medical issues in the world today is liver cirrhosis, leading to fibrosis, growing nodules, and increasing liver failure. Despite being widely utilized for diagnosis, imaging-based evaluation techniques like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) sometimes use qualitative visual interpretation, which makes early and accurate detection difficult. New paths for quantitative liver evaluation have been made possible by recent developments in deep learning (DL) and radiomics. The complex textural and morphological differences characteristic of cirrhotic livers in a volumetric (3D) setting is not captured by existing methods, which mainly focused on fibrosis grading or tumor segmentation. To better accurately represent cirrhotic liver shape, this study proposes a single 2D-to-3D reconstruction framework that combines deep learning-driven segmentation with texture-based radiomic extracting of features. Background minimization preprocessing, segmentation using complex 3D CNN or U-Net structures, texture extraction using the algorithms GLCM, GLRLM, and R2* features, and volumetric reconstruction using marching cubes and texture mapping methods are all included in the workflow. The development of realistic, texture-aware 3D liver models that improve diagnostic accuracy and assist in medical decision-making is made possible by the integration of radiomic and deep features. For maximum legal compliance and accuracy, the suggested approach is tested using publicly accessible MRI datasets (such as the Roboflow Liver Dataset). The accuracy of segmentation and reconstruction is assessed using quantitative measures such as the roll value, Intersection over Union (IoU), and ROC-AUC, while expert review is used for qualitative validation. When compared to typical slice-based techniques, studies show that the integrated 2D-to-3D approach improves texture storage and reconstruction accuracy. The study provides a new, data-driven approach that connects 3D volumetric modelling for liver cirrhosis with radiomic texture analysis. To further improve clinical utility and diagnostic confidence, future research might include real-time visual tools and multi-modal data (CT, ultrasound).

Keywords: 3D Reconstruction, Deep Learning, Liver Cirrhosis Detection, Medical Imaging, MRI, Radiomics, Texture Analysis and U-Net

2D-to-3D Computational reconstruction of liver cirrhosis: Bridging radiomics, medical imaging, and clinical practice in facilitating diagnosis.

1. Introduction

Liver cirrhosis is one of the most severe chronic liver conditions, representing the end stage of various hepatic diseases such as hepatitis, fatty liver disease, and chronic alcoholism. It is characterized by fibrosis, architectural distortion, and the formation of regenerative nodules, ultimately leading to liver failure and hepatocellular carcinoma (Zeng et al., 2025). More than 100 million people globally are estimated to suffer from compensated or decompensated cirrhosis, making it a significant public health concern. Early detection and accurate staging of cirrhosis are crucial for improving survival rates, planning surgical interventions, and monitoring disease progression (Alcohol-related deaths: liver cirrhosis, death rates (15+), per 100,000 population, age-standardized).

Traditional diagnostic techniques like liver biopsies are risky, expensive, and intrusive. As a result, non-invasive medical imaging techniques such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) have become indispensable for evaluating liver cirrhosis and fibrosis. But these imaging methods frequently depend on subjective, inter-observer variability-prone qualitative interpretation (Gotta et al., 2025). Reliable diagnosis using conventional imaging is further complicated by the cirrhotic livers' complex texture, uneven nodularity, and changing contrast. In recent years, radiomics, texture analysis, and deep learning (DL) have emerged as promising techniques to overcome these limitations. Radiomics allows for quantitative extraction of high-dimensional features from medical images, revealing patterns that are often imperceptible to the human eye (Guo et al., 2023). Deep learning, particularly Convolutional Neural Networks (CNNs) and U-Net architectures, has demonstrated success in medical image segmentation, classification, and anomaly detection. However, most current research focuses on either fibrosis grading or tumor segmentation and fails to integrate texture-based radiomic features into 3D reconstruction pipelines.

Furthermore, 3D reconstruction offers substantial benefits to the medical field. It assists clinicians in early diagnosis by visualizing subtle fibrotic changes that may be missed in 2D scans (C et al., 2020). It improves treatment planning and disease monitoring by allowing physicians to evaluate the progression of fibrosis over time in a spatially coherent and interactive manner. By providing accurate, non-invasive assessments, it also reduces reliance on liver biopsies, minimizing patient discomfort and risk. Importantly, such AI-driven, imaging-based tools have the potential to contribute to global health equity offering cost-effective, automated, and reproducible diagnostic support for low-resource countries where access to specialized hepatology care and invasive procedures is limited. Through this multidisciplinary and clinically integrated approach, the study establishes a foundation for AI-assisted, 3D imaging-based liver disease diagnosis that bridges the gap between computational modeling and real-world healthcare impact.

2. Methodology

The proposed system is developed using a multi-stage pipeline designed to transform 2D medical imaging data into clinically meaningful 3D liver reconstructions for cirrhosis assessment. The workflow begins with data acquisition, where the Roboflow Liver Dataset

(Liver – v3, 2024-06-18) is selected as the primary dataset. This is followed by preprocessing and data harmonization, including noise reduction, intensity normalization, and slice-to-slice alignment to ensure consistency across scans. The next step involves a deep-learning segmentation module, where a U-Net/3D-CNN-based architecture isolates the liver parenchyma and fibrosis-affected regions from surrounding anatomical structures.

After segmentation, the system extracts radiomic texture characteristics, including GLCM features, intensity patterns, and interface irregularity metrics that describe fibrotic changes. These collected characteristics are then combined in the 3D reconstruction step, where techniques such as marching cubes and volumetric rendering create a spatially realistic 3D mesh. The last analytical stage involves classification and staging, in which deep-learning classifiers or radiomic-driven algorithms estimate the fibrosis level using 2D and 3D feature representations.

From a technological perspective, the pipeline integrates deep convolutional neural networks, 3D U-Net architectures, radiomics-based texture extraction frameworks (PyRadiomics), and 3D reconstruction libraries such as VTK or 3D-Slicer-compatible toolkits. Python, TensorFlow/PyTorch, and medical imaging libraries (SimpleITK, MONAI) form the core implementation environment, ensuring compatibility with standard clinical imaging workflows.

A variety of validation procedures are used during evaluation and testing. Dice Similarity Coefficient, IoU, precision-recall, and 3D surface error are some of the metrics used in quantitative evaluation to measure segmentation and reconstruction accuracy. In addition, professional radiologists conduct a clinical evaluation, assessing the rebuilt 3D models and segmented fibrosis regions to ensure anatomical accuracy, texture realism, and interpretability. Their expert input decides if the 3D liver architecture and fibrosis distributions line up with real-world clinical findings, and whether the model's outputs are useful for pre-surgical planning, fibrosis staging, and continuous patient monitoring.

3. Data Analysis and Results

The Roboflow Liver Dataset (Liver – v3, 2024-06-18) Three-dimensional (3D) visualization involves feature extraction and 3D reconstruction of CT images using a computer processing technology. It is a tool for displaying, describing, and interpreting 3D anatomy and morphological features of organs, thus providing intuitive, stereoscopic, and accurate Consensus recommendations of three-dimensional visualization for diagnosis and management of liver diseases (C et al., 2020) was chosen because it contains a clean, well-organized collection of labelled liver imaging slices that are ideal for segmentation and 2D-to-3D computational reconstruction. Although the dataset lacks specific cirrhosis labels, it does include high-quality annotated liver borders that enable the model to learn precise organ segmentation, which is a necessary initial step in any cirrhosis-focused computational workflow. The dataset contains hundreds of annotated liver pictures, making it suitable for training deep learning models without requiring clinical data gathering. Before training, all photos were preprocessed with noise filtering, intensity normalization, scaling, and dataset augmentation to ensure that the model learnt consistent spatial and textural patterns across slices. A segmentation network (e.g., U-Net variant) was then trained on these preprocessed images to extract liver contours. These segmentation outputs later served as the structural foundation for the 3D reconstruction module, enabling the model to generate volumetric liver models where cirrhosis-related morphological changes such as irregular surfaces, nodularity, or size variations can be analyzed. This dataset was therefore selected for its accessibility,

annotation quality, and suitability for building a complete 2D-to-3D pipeline, supporting the study’s goal of improving computational analysis of liver cirrhosis.

The 3D U-Net model outperformed traditional 2D U-Net segmentation, achieving a Dice score of 0.92 and an IoU of 0.88, while the hybrid deep learning + radiomics model reached an AUC of 0.97 for cirrhosis stage prediction. Incorporating texture-based features improved sensitivity in detecting minor fibrotic changes by 8–10%, offering enhanced diagnostic precision. The reconstructed 3D liver models exhibited realistic surface irregularities and internal texture heterogeneity, providing accurate visualizations of cirrhosis progression. Radiologists and hepatology specialists validated these results, confirming the anatomical accuracy and diagnostic usefulness of the 3D reconstructions for clinical applications, such as diagnostic imaging and surgical planning.

Table 01: Expected Model Performance Metrics

Model Component	Task	Expected Metric	Expected Score	Justification
2D U-Net	Liver Segmentation (Slice-wise)	Dice Score	0.88 – 0.90	Typical performance on annotated liver datasets; 2D loses some volumetric context.
		IoU	0.80 – 0.83	Expected lower IoU due to slice discontinuity and variability across slices.
3D U-Net / 3D CNN	Volumetric Liver Segmentation	Dice Score	0.91 – 0.93	3D models preserve spatial continuity and detect cirrhosis-related shape changes better.
		IoU	0.86 – 0.88	Higher consistency across volumes improves overlap accuracy.
Radiomics + Deep Learning Classifier	Cirrhosis Classification / Staging	ROC–AUC	0.94 – 0.97	Texture-based radiomics improve detection of nodularity and cirrhotic patterns, boosting classification.
		Accuracy	0.90 – 0.95	Expected with combined radiomic + deep feature embedding.
2D-to-3D Reconstruction Pipeline	3D Liver Model Quality	Structural Similarity (SSIM)	0.92 – 0.96	High-quality reconstruction from consistent slice segmentation.
		Surface Deviation Error	< 5 mm	Expected threshold for clinical visualization accuracy.

From a medical perspective, this framework presents a non-invasive, explainable, and reproducible approach to cirrhosis detection, reducing reliance on biopsies. It enables volumetric visualization of liver morphology, supporting early-stage detection and effective treatment planning. By allowing clinicians to analyze fibrosis progression more precisely, the system promotes timely intervention and improved patient outcomes. The framework also enhances interdisciplinary collaboration between AI researchers and medical professionals, integrating artificial intelligence into real-world healthcare workflows. Ultimately, this study demonstrates how combining 2D texture analysis with 3D reconstruction improves diagnostic accuracy, interpretability, and early disease detection, helping reduce global cirrhosis-related mortality (Guo et al., 2023; Popa et al., 2023).

4. Discussion

The suggested approach tackles several persistent issues in liver imaging. It bridges the gap between quantitative evaluation and qualitative image interpretation by fusing radiomic texture analysis with deep learning-based segmentation (Guo et al., 2023; Hossain et al., 2023). Additionally, the multi-stage methodology offers an automated, non-invasive, and repeatable framework for liver cirrhosis assessment.

A major contribution to this work is its emphasis on 3D reconstruction, which plays a transformative role in medical imaging and clinical decision-making. The reconstructed 3D liver models assist clinicians in early diagnosis by revealing subtle fibrotic or nodular changes that might be overlooked in traditional 2D images. Also improve treatment planning and disease monitoring by enabling visualization of fibrosis progression and evaluating therapeutic response over time. Moreover, this non-invasive imaging approach significantly reduces dependence on liver biopsies, minimizing patient discomfort and associated risks.

From a global health perspective, 3D AI-based diagnostic systems can contribute to healthcare equity, particularly in low-resource settings, by providing accessible, reproducible, and cost-effective diagnostic support where advanced biopsy or pathology facilities are unavailable. Clinical interpretability, an often-overlooked factor in AI-based systems, is also prioritized in this research. Through volumetric fibrosis maps and visual heatmaps, physicians can cross-verify model predictions, fostering confidence and facilitating human-AI collaboration in clinical diagnosis (Yin et al., 2025; Popa et al., 2023). Additionally, this approach aligns with ongoing advancements in medical AI that emphasize transparency, explainability (XAI), and seamless integration with existing radiology workflows. Looking ahead, future work could enhance diagnostic robustness through multi-modal imaging, integrating MRI with ultrasound elastography to further strengthen precision and clinical reliability (Lee et al., 2025; Zhang et al., 2023).

5. Conclusions and Recommendations

The present research presents a comprehensive multidisciplinary framework for the detection and 3D reconstruction of liver cirrhosis using medical imaging, integrating deep learning, radiomic texture analysis, and volumetric modeling techniques. The study bridges the gap between computer science and clinical medicine, offering a solution that is both technically innovative and clinically meaningful. By combining computational methods with medical expertise, the proposed system enhances diagnostic accuracy, visualization, and interpretability in hepatology (Yuan, Ye and Song, 2022; Pomohaci et al., 2025).

Radiologists and hepatology specialists contributed to defining the anatomical and diagnostic requirements for the segmentation and staging processes, ensuring the results align with real-world clinical standards. The reconstructed 3D liver models were qualitatively evaluated by medical professionals, who verified their anatomical realism, diagnostic relevance, and visual clarity. This collaboration helped ensure that the system provides clinically interpretable outputs, aiding radiologists in identifying fibrosis progression and supporting non-invasive diagnosis and treatment planning (Popa et al., 2023). The model's design and evaluation process were closely aligned with medical imaging workflows, incorporating quantitative metrics such as Dice, IoU, and ROC-AUC alongside expert clinical reviews. These measures ensured that the system not only achieved high computational performance but also met the expectations of clinical reliability and usability. The outcomes of this research demonstrate that combining 2D texture analysis with 3D reconstruction enhances visualization and improves the ability of clinicians to interpret disease patterns more effectively (Hossain et al., 2023; Pomohaci et al., 2025).

However, several limitations must be acknowledged. The dataset size, although sufficient for experimental validation, remains relatively small compared to large-scale clinical datasets, which may limit generalizability across diverse patient populations. Variations in imaging modalities, scanner quality, and acquisition protocols introduce inconsistencies that can affect segmentation precision and radiomic feature stability. The 3D reconstruction pipeline, while effective, is computationally intensive and may require high-end hardware for real-time clinical deployment. Additionally, the model currently focuses solely on cirrhosis and does not account for overlapping hepatic conditions such as tumors or steatosis, potentially reducing its robustness in complex clinical scenarios. Finally, the system relies heavily on expert annotations, which are time-consuming to produce and subject to inter-observer variability.

In summary, this project makes a significant contribution to both medical and technological domains by establishing a foundation for AI-assisted liver cirrhosis detection and 3D modeling. It emphasizes the importance of collaboration between computer scientists and healthcare professionals, promoting innovation that directly supports clinical diagnosis, medical training, and patient care. The findings highlight the potential of AI-driven imaging to transform how cirrhotic liver conditions are analyzed, visualized, and managed in the modern healthcare landscape.

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Thematic Track: Computing

Abstract number: 42

Improving medical imaging accuracy: A multidisciplinary hybrid CNN–Transformer framework for brain tumor segmentation by mitigating and quantifying texture bias

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Abstract

Brain Tumors are one of the most life-threatening diseases that impose an immense effect on human lives. Therefore, accurate tumor segmentation is a critical step in clinical workflow, aiding radiologists and oncologists in identifying tumor boundaries and making informed decisions in treatment planning, and disease monitoring. A minor segmentation error can mislead diagnosis, and result in ineffective or harmful treatment strategies. Although deep learning (DL) has significantly advanced in medical image analysis, Convolutional Neural Networks(CNNs) which is one the most widely used DL framework in medical image segmentation, often exhibit a tendency to rely heavily on local surface patterns and pixel-level textures rather than the overall tumor shape and structure. As a result, models may perform well within a specific dataset but fail to generalize effectively across patients or imaging conditions. Recent research has introduced hybrid CNN–Transformer architectures for brain tumor segmentation, leveraging CNNs for fine-grained texture extraction and Transformers for global context modeling. However, none explicitly verify or quantify whether it captures shape-based representations by reducing reliance on texture. This highlights the need for systematically assessing how texture and shape features interact within hybrid DL frameworks. To address this, the research proposes a hybrid CNN–Transformer framework to evaluate the extent to which texture bias is mitigated. The model will be trained and tested on the BraTS MRI dataset with standard preprocessing steps, including skull stripping, intensity normalization, and data augmentation. Further, quantitative evaluation is conducted based on Dice Similarity Coefficient (DSC), Precision, and Recall to show that the model outperforms baseline CNN architectures by an average of 3–5% in Dice scores. This in turn will result in a more precise tumor boundary segmentation, directly supporting clinical decision-making in surgery and radiotherapy planning. By integrating Artificial Intelligence (AI) with medical imaging, this study contributes towards developing a more interpretable, accurate and clinically reliable brain tumor segmentation framework.

Keywords: Brain Tumor segmentation, CNN-Transformer, Texture Reliance

Improving medical imaging accuracy: A multidisciplinary hybrid CNN–Transformer framework for brain tumor segmentation by mitigating and quantifying texture bias

1. Introduction

The brain is the central organ of the nervous system which controls the overall functionality of the human body. Brain tumors occur due to an abnormal cell growth around the brain which can either be cancerous (malignant) or non-cancerous (benign) (Ahamed et al, 2023). Accurate tumor segmentation is a critical task in medical imaging, directly influencing diagnosis, treatment planning, and patient prognosis. Inaccurate segmentation will result in giving patients with incorrect radiation dose, missed tumor boundaries, or incomplete excision of the tumor, which can severely affect patient survival. Therefore, developing a reliable and clinically interpretable segmentation framework is essential for improving patient safety and treatment effectiveness.

Accurate segmentation of tumors from MRI scans enables clinicians to assess disease progression, plan surgical interventions, and monitor therapeutic outcomes. However, achieving this still remains as a key challenge due to the location uncertainty and morphological uncertainty of tumors, low contrast imaging, annotation bias and data imbalance. (Liu et al, 2022). Tumors vary greatly in size, location, and internal composition, often exhibiting irregular shapes and overlapping intensity patterns with normal tissues. Further, MRI scans often contain diverse textual patterns, including homogeneous, heterogeneous, and fine-grained textures which can hinder accurately identifying tumors from healthy issues. Manual segmentation performed by radiologists is time-consuming and subjective, encouraging the adoption of automated and intelligent segmentation systems (Abid and Munir, 2025; Das et al., 2022; Pereira et al., 2016).

Deep Learning (DL), especially Convolution Neural Networks (CNNs), has significantly advanced brain tumor segmentation by automatically learning hierarchical features from imaging data (Satushe et al., 2025; Ullah et al., 2023). However, despite their success, CNNs are inherently biased toward local texture patterns (Geirhos et al., 2022), which limits their ability to capture global tumor morphology, orientation, and spatial context, reducing model robustness and generalizability across patients and datasets, particularly in low-contrast or heterogeneous tumor regions (Iwata & Okuda, 2024; Ranjbarzadeh et al., 2023). Recent research shows that hybrid CNN–Transformer models help capture both texture and shape patterns. However, their justification is solely based on architectural design choices (Hatamizadeh et al., 2022; Zhu et al., 2022; Chalcraft et al., 2024), as they do not explicitly address or quantify texture bias reduction.

This study addresses this gap by proposing a texture-bias-aware CNN–Transformer framework that explicitly integrates local and global features, while quantifying and reducing texture bias. The proposed framework enhances segmentation robustness, generalizability, and interpretability, particularly for complex tumors with heterogeneous and low-contrast regions. By integrating AI, medical imaging, and clinical practice, this research offers a clinically reliable and interpretable solution for brain tumor analysis, benefiting for both technical development and healthcare applications.

2. Methodology

This research follows the Object-Oriented Analysis and Design Methodology (OOADM), due to the modular and scalable framework it provides for complex deep learning systems. Further, to it utilizes Agile practices to support the iterative and experimental nature of the research. Through short development cycles and continuous evaluation Agile principles enable efficient experimentation with different model configurations. This combination of OOADM and Agile methodologies ensures that the system remains both technically structured and adaptable to evolving research insights.

Moreover, this study uses the publicly available BraTS 2020 Brain Tumor Segmentation dataset, which focuses on glioma tumors. It was chosen for its clinical diversity and suitability in evaluating model generalization across different texture distributions (Satushe et al., 2025). The dataset contains multimodal MRI scans collected from multiple clinical sites and is manually curated to ensure wide coverage of glioma variations, with consistent preprocessing and labeling standards (Ahamed et al., 2023). To ensure structured and reliable output for model training, the data set undergoes data classification and cleansing. MRI scans are labeled according to sub regions to train the model to identify tumors from healthy tissues. Further corrupted and incomplete scans are removed standardizing image formats and resolutions. Moreover, this study incorporated a qualitative analysis to obtain expert feedback on the problem relevance, model design, and technical feasibility. Medical Professionals were interviewed to gather clinical insights on brain tumor segmentation and to validate the dataset. Additionally, a structured questionnaire was distributed among individuals working in the machine learning field and software engineers to access their knowledge on the technical domain and get their insights on the research gap. This approach provided structured input to validate dataset choices, preprocessing strategies, and the overall framework design, ensuring alignment with both clinical and technical expectations.

To ensure accurate brain tumor segmentation by minimizing texture inconsistencies, preprocessing techniques such as intensity normalization, bias field correction, skull stripping, and data augmentation are applied. MRI intensities often vary across scanners, imaging protocols, and patients, creating inconsistent texture patterns that can bias CNN-based models (Magadza and Viriri, 2021). Intensity normalization standardizes voxel values, enabling better comparison across scanners. MRI scans often exhibit intensity inhomogeneity due to magnetic field non-uniformities, creating smooth intensity gradients that distort tissue textures. Bias field correction mitigates this effect by estimating and removing the low-frequency bias field, thereby improving the consistency of texture and structural representation. Skull stripping involves removing non-brain tissues such as the skull, scalp, and eyes retaining only the brain region. This focuses the model on essential brain structures while removing high-intensity non-brain areas that could provide false texture information (Wang and Chung, 2022). Additionally, to reduce overfitting and enhance model robustness to textural variations, data augmentation techniques such as rotation, flipping, elastic deformation, contrast adjustment, and intensity scaling are employed. These simulate scanner-specific differences, enabling the model to generalize better across heterogeneous tumor textures. (Ullah et al., 2023).

3. Data Analysis and Results

The primary MRI dataset sources used for the study is the BraTS 2020, which contains both high-grade and low-grade gliomas annotated by medical experts. The dataset is divided into 70% for training, 15% for validation and 15 % for testing. Prior to model training standard preprocessing techniques including intensity normalization to standardize pixel values across modalities, bias field correction to eliminate MRI intensity inconsistencies, skull stripping to isolate brain tissues, resampling and cropping have been utilized in order to enhance variability and reduce overfitting. To evaluate the mitigation of texture bias, the study incorporates a range of texture variations that commonly effect MRI based tumor segmentation. These include noise based alterations by simulating scanner disturbances, altering the tumor boundaries by texture smoothing or sharpening, and intensity perturbations that modify contrast or local pixel variations to challenge models reliant on texture cues.

The proposed CNN Transformer hybrid model is tested under original MRI scans and texture altered scans with the expectation of higher Dice Scores, lower Hausdorff Distance(HD) indicating superior boundary preservation, stable performance across texture altered scans and improve segmentation of sub regions while enabling generalization across diverse textures and scanners. By analyzing performance on both original and texture altered MRI scans, the study enables a direct comparison of how different texture disturbances influence segmentation accuracy and how effectively the proposed model reduces texture bias, while supporting radiologists in making informed decisions

Table 01: Expected results under different conditions

Testing condition	Expected outcome	Dice Score Expectation
Original MRI Scans	High accuracy compared to CNN baseline architecture as CNN + Transformer captures both local and global details.	0.88 – 0.92
Texture Altered MRI Scans	Small performance drop but maintains shape aware segmentation.	0.80 – 0.85
Cross scan testing	Stable performance and generalization as the model learns shaped based not scanner dependent features.	0.83 – 0.88
Sub region segmentation	Improved boundary precision as the global content separates adjacent sub regions with similar textures	Improved Dice Score and HD

4. Discussion

The expected results of the research reveals that CNN–Transformer hybrid architecture will effectively reduce texture bias in brain tumor segmentation tasks. Traditional CNN-based architectures such as U-Net and ResU-Net often rely heavily on texture features, leading to

misclassification in regions with similar intensity patterns (Dong et al., 2024). The over dependence on texture will create challenges specially in heterogeneous tumor environments where the boundaries and shapes vary significantly (Liu et al.,2022). Integrating Transformer modules that capture long-range dependencies and global spatial relationships, the proposed model improves shape-awareness, leading to more reliable segmentation results (Dong et al., 2024; Zhu et al.,2023). This study aims to quantify texture sensitivity and demonstrate that the hybrid design yields improved Dice scores and boundary accuracy while maintaining computational feasibility. The improvement in Hausdorff Distance and Dice coefficient are expected to reflect better generalization across tumors with diverse textures, shapes, and morphologies.

Clinically, increased segmentation allows radiologists to accurately segment tumor sub regions such as enhancing cores, necrotic areas, and surrounding edema, supporting better diagnosis, treatment planning, and monitoring of patient outcomes (Zhu et al.,2023). Accurate segmentation is essential for treatment planning, radiation dose estimation, surgical decision-making, and monitoring tumor progression over time. By reducing texture reliance, the hybrid architecture is expected to produce more robust segmentation across different MRI scanners, addressing the major limitations of current deep learning-based models (Dong et al., 2024). The implications of these results are significant for clinical applications, as by combining CNN feature extraction with Transformer based global reasoning it enables to develop a consistent, interpretable, and clinically meaningful automated brain tumor segmentation framework in real-world healthcare environments.

5. Conclusions and Recommendations

The study addresses the problem of texture bias in CNN-based brain tumor segmentation by proposing a hybrid CNN–Transformer framework that balances local and global feature learning. The expected results will indicate that segmentation accuracy in heterogeneous tumor regions will be hindered due to the strong texture bias exhibited by CNNs. By incorporating Transformer modules, the proposed architecture will effectively capture global structural information, leading to a significant reduction in texture dependency and improved segmentation performance. Quantitative evaluations and assessments will show better tumor shape preservation and boundary accuracy by validating that the integration of CNN and Transformer mechanisms will successfully enhance model robustness, generalization, and interpretability.

Based on these findings in future research integrating Explainable AI (XAI) would help visualize how texture and shape features influence model predictions, providing valuable insights for medical experts. Additionally, developing standardized metrics for texture bias quantification would enhance reproducibility and allow fairer comparison across future studies Overall, Clinically, improved segmentation enables radiologists to segment tumor boundaries and sub regions more precisely, supporting accurate diagnosis, surgical planning, and treatment monitoring. Addressing the mentioned limitations along with this study will support future for a real time reliable bias free segmentation models in clinical diagnosis.

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Thematic Track: Computing

Abstract number: 43

A multidisciplinary hybrid framework for solar tracking: Fusing information technology, environmental science, and predictive modelling for sustainable energy efficiency

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Abstract

The growing global demand for renewable energy has led to the increased demand for solar powered technologies. Solar Tracking Systems (STSS) often struggle to maintain accuracy under varying weather conditions such as cloud cover or partial obstruction of the sun during foggy days. Current tracking systems are either sensor-based or image-based. Sensor-based systems struggle with inaccuracy and high maintenance cost while image-based systems face challenges in robustness and computational demand. As a result, existing systems fail to deliver good performance in real-world scenarios where reliability and adaptability are crucial. To address this challenge, this study presents a hybrid solar tracking system that will be created by combining environmental science, predictive analysis and Information Technology (IT). The main objective of this study is to use a multidisciplinary approach to model an intelligent solar tracking mechanism that maximizes solar energy capture, through predictive and adaptive control. The proposed system will integrate image processing for fine tuning, GPS and time-based data to track solar movements accurately while predictive algorithms analyze historical weather and irradiance patterns to forecast optimal panel angles under varying weather conditions. A simulation model is planned to be developed to assess system performance focusing on energy efficiency, tracking accuracy and adaptability. The study aims to demonstrate that the hybrid approach achieved significant improvement in energy capture efficiency compared to conventional single-axis solar tracking systems which will highlight its potential for wider, cost-effective implementation. This research highlights how combining environmental data, predictive learning algorithms and IT-based simulation tools contributes to the development of sustainable and cost-effective energy systems. It is recommended that future work extends the model with real-time sensor integration, Internet of Things (IoT) and machine learning enhancements to improve automation, scalability and adaptability across diverse geographic conditions.

Keywords: Artificial Intelligence, Environmental Science, Information Technology, Predictive Analysis, Solar Tracking System

A multidisciplinary hybrid framework for solar tracking: Fusing information technology, environmental science, and predictive modelling for sustainable energy efficiency

1. Introduction

Traditional Light Dependent Resistor (LDR) sensors used in many trackers are prone to low sensitivity and environmental disturbances, often requiring frequent calibration, which limits their effectiveness in real-world operating conditions (Narman and Uckan, 2025). Similarly, current image-based systems face challenges such as misidentifying bright non-solar images, handling sensor image noise in real-time and requiring large, annotated datasets for deep learning models, preventing reliable solar tracking under all weather conditions (Mahalle and Deshmukh, 2025; Sadeghi et al., 2025; Salih et al., 2025; Stinia et al., 2021).

In the last decade, the demand for energy, which is driven by industrial expansion and population growth, has accelerated the transition to renewable energy. Solar energy has emerged as a reliable and clean alternative due to the environmental harm caused by fossil fuels (Sadeghi et al., 2025). To maximise the efficiency of solar energy, Solar Tracking Systems (STSs) have been developed to ensure that photovoltaic (PV) panels remain aligned with the sun's apparent trajectory. Research shows that solar trackers can enhance energy capture by 12-20%, and dual-axis trackers can achieve efficiencies as high as 90%, reducing the energy losses caused by misalignment in fixed PV systems. (Sadeghi et al., 2025). Such performance gains make STSs particularly advantageous for large-scale projects.

There are a lot of challenges that are faced in current STSs including maintaining accuracy under varying environmental conditions such as changes in sunlight, cloud cover, and haze (Barrios-Sánchez and Tlapanco-Ríos, 2025; Mahalle and Deshmukh, 2025). Traditional fixed PV panel setups cannot capture the maximum solar energy throughout the day, which makes it limited in efficiency (Al-Othman et al., 2023; Mahalle and Deshmukh, 2025; Musa et al., 2023). Traditional STSs, which use LDRs, will become less accurate over time and are affected by weather and environmental conditions (Narman and Uckan, 2025). Image processing-based STSs also face challenges, which include effectively filtering non-sun images and sensor noises (Mahalle and Deshmukh, 2025). The research aims to resolve the identified gaps in existing solar tracking systems, such as LDR sensitivity to environmental conditions, the inability of fixed PV panels to maintain optimal alignment and the limitations of current image-based trackers in filtering non-solar images and sensor image noise by developing a hybrid tracker that integrates image processing, time data, GPS data and historical learning.

2. Methodology

2.1 Materials and Tools:

The simulation model planned for this study will use a virtual PV panel to estimate energy output. The programming environment will incorporate libraries such as OpenCV for image processing, Pandas and NumPy for data handling. The datasets which are planned to be used will include historical solar position data, weather records and sky images for testing and validating predictive algorithms.

2.2 Procedures:

The initial stage involved identifying technological and environmental factors such as sunlight intensity, cloud cover and mechanical issues that could affect the solar tracker’s performance which helped to define system parameters and performance standards. Image processing techniques will be explored to determine the sun’s location and various algorithms will be tested to find the most reliable real-time tracking method. The system architecture will be designed to incorporate GPS, actuators for efficient control. Predictive algorithms utilising GPS, time data and past solar paths will be integrated to enhance accuracy allowing the tracker to maintain alignment even under cloudy conditions. A simulation model will be developed to assess the hybrid solar tracking system’s energy output under different weather conditions and the results will be compared against conventional fixed photovoltaic (PV) panels where the simulation model showed notable improvements. Key performance metrics including energy conversion efficiency, tracking accuracy, system responsiveness and durability will be measured following simulations and initial prototype testing. The system’s ability to maximise solar energy capture and preserve stability in dynamic circumstances will be evaluated quantitatively by these metrics.

3. Data Analysis and Results

3.1 Data Analysis

The hybrid STS is planned to be evaluated using simulation datasets under varying environmental conditions from open sources. To support simulation, cloud cover and environmental obstacles, data will be obtained from publicly available Kaggle datasets (link for the datasets are given in the references section). These datasets will be used to train and test the simulation environment as these two datasets contain images of cloud cover, haze, bird drop, snow, dust accumulation and various cloud patterns that may reduce solar panel efficiency.

Below table summarizes energy gains, tracking accuracy and other performance metrics of various solar tracking systems as reported in prior studies.

Table 01: Comparison of Reported Performance of Existing Solar Tracking Systems

System Tracked	Prediction Level	Reference
Single-Axis Solar Tracker	36.6% more energy on clear days than fixed panels.	(Salih et al., 2025)
Dual-Axis Solar Tracker	204.46 mW more power than static panels (557.33 mW vs 351.87 mW).	(Al Anzy, Abdullah and Aquraishi, 2023)
Hybrid Dual-Axis (LDR + GPS)	33.23% energy increase with precise azimuth/tilt tracking.	(Sadeghi et al., 2025)
Image-processing-based tracker	Accuracy up to 97.4% using digital image processing.	(Mahalle and Deshmukh, 2025)

The GPS, time and historical learning data will be simulated using Python based on solar azimuth and elevation algorithms, in use of Python's datetime, math and pvlib libraries. This will allow the hybrid STS to forecast the sun's location and dynamically modify the panel orientation based on Sri Lanka's geographic coordinates and time of the day.

3.2 Expected Results

The results are expected to indicate that the hybrid STS will consistently outperform static panels in all scenarios studied, with the greatest gains observed during partly cloudy and overcast conditions. These results will be tested using the datasets mentioned in the references section, where energy output and tracking accuracy of the hybrid STS will be compared to static panels. Performance metrics will be estimated by calculating the expected percentage increase in energy production and the projected tracking accuracy for each scenario. Based on prior studies and simulation assumptions, the system is expected to achieve the highest gains under partly cloudy or overcast conditions, with a 30-38% increase in energy output and approximately 95% tracking accuracy, demonstrating the potential of the predictive model.

4. Discussion

The expected performance of the hybrid STS could drive improvements in existing technology by reducing reliance on large datasets and heavy hardware, enabling more efficient solar tracking for small to medium scale installations (Phan et al., 2025). This approach may encourage the gradual replacement of static panels with dynamic, predictive systems in both urban and rural settings. GPS and historical learning are expected to reduce low-light detection errors, making this method more resilient than earlier methods (Mahalle & Deshmukh., 2025). Unlike deep learning models that rely on huge, labelled datasets, the proposed approach is predicted to need less data (Phan et al., 2025). Its software-based design is also expected to support scalable integration with smart energy systems.

Beyond technical efficiency, this system is expected to contribute to global sustainability goals and provide cost-effective renewable energy solutions particularly relevant to developing regions. The study is anticipated to show that hybrid STSs can significantly improve solar energy capture and offer a flexible, affordable option for renewable energy installations, particularly in areas with unpredictable weather conditions. Also, the recent floods which occurred in Sri Lanka and other countries have highlighted the vulnerability of centralized solar systems (Refurb and Retrofit, 2025), showing that resilient, decentralized solar solutions could provide critical energy access during extreme weather conditions.

However, as the findings will be based on simulations, real world hardware may introduce delays, sensor inaccuracies and weather impacts that cannot be fully represented in a virtual environment. Even so, energy gains are expected to peak under partial cloud cover, highlighting the predictive model's potential to maintain performance across various weather conditions.

5. Conclusions and Recommendations

This study outlined the design and simulation-based evaluation of a hybrid solar tracker integrating IT, environmental science and predictive analysis to enhance PV efficiency

under dynamic weather conditions. The proposed system will integrate image processing, GPS, time data and historical learning and the simulation results are expected to indicate the potential for up to 35% improvement in energy capture compared with static panels.

The findings suggest that meaningful enhancements in renewable energy performance can be achieved by fusing computational intelligence with environmental awareness. However, it is recognised that extreme haze or cloud cover may still affect tracking accuracy.

Recommendations for future work include implementing the system on physical hardware for real-world testing and validation, incorporating machine learning to enhance predictive accuracy, expanding the dataset with real-time data and investigating integration with smart grid technologies based on IoT to facilitate automated, large-scale solar farm management.

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Thematic Track: Computing

Abstract number: 44

A robust and multidisciplinary approach to Indian sign language recognitionVitharana R. A.¹, Jananie M.^{1*}¹Department of Computing, Informatics Institute of Technology, Sri Lanka**Abstract**

Automated sign language recognition is the enabler for bridging the deaf and hard-of-hearing (DHH) population's communication gap. However, there exists a deep gap, which is widely observed in the recent literature, between lab model performance and real-world usability. The latest models applied to Indian Sign Language (ISL) translation, while having good accuracy on clean lab-based data works in formal setting the lack of robustness is the largest issue on these models when it comes to becoming commercially viable tools. This research bridges this "lab-to-life" gap directly by presenting and experimentally validating a strong, word-level ISL-to-English recognition system. Methodology is centred around a hybrid, two-stage architecture that is engineered to be naturally invariant to environmental noise. The model uses Google's MediaPipe Holistic to bypass raw pixel data, instead using a lightweight stream of 3D skeletal hand, face, and pose landmarks. This kinematic data is later used to feed into a Long Short-Term Memory (LSTM) recurrent neural network to classify the temporal patterns of isolated signs. The model was trained on the public "INCLUDE50" dataset. The most significant contribution is its rigorous testing methodology. To test robustness, the model was not merely tested against a standard holdout set but also against two custom-curated test sets. First being an "Adversarial Set" with programmatically simulated blur and low light, and the second being an "In-the-Wild Set" of publicly sourced video samples. The findings were promising: the hybrid model equalled baseline models in accuracy on clean data but, in contrast to baseline models, continued to be extremely accurate (e.g., >75%) on the "in-the-wild" data, where baseline models failed. This work lays the foundation for a demonstrated basis of a resilient ISL recognition "engine" that brings useful, use-in-daily-life communication tools one step closer toward a reality for the ISL community.

Keywords: Image Processing, Indian Sign Language, MediaPipe, Robustness, Signer-Independence

A robust and multidisciplinary approach to Indian sign language recognition

1. Introduction

Communication is a fundamental human right, but it remains a significant barrier in the lives of the Deaf and Hard-of-Hearing (DHH) community. This research focuses on this community in India, where millions use Indian Sign Language (ISL) as a primary means of communication. The root of the problem is that fluency in ISL is concentrated within the DHH community and immediate family or friends. This communication gap leads to restricted exposure and participation in education, access to healthcare, employment, and social mainstreaming. This gap is acutely felt in critical sectors such as getting medication for a sickness, but the doctor does not have the knowledge or assistance to communicate, with its potentially dire consequences, and in education, where DHH students are very frequently left behind. While human translators would be the perfect bridge, those proficient in both ISL and spoken language are few and often unreachable. Technology-driven translation, in this regard, becomes an absolute necessity rather than a convenience. There are more issues faced by many of the DHH communities around the world mainly comprising the different accents of their sign language. While this isn't a big issue an interview done with the deaf emergency department (ED) users describes requesting communication access as "stressful, frustrating and time-consuming" and the interview shows mixed reactions for Video Remote Interpreting (VRI) and on-site translation interpretations (Wolfe et al., 2025). Deaf and hard of hearing members have also said that due to the limitedness and shortage of interpreters they face difficulties in healthcare due to lack of practicality and lack of trust with the providers who provide translation services. (Hall and Ballard, 2024)

The study presented in this paper specifically addresses this "lab-to-life" gap (Patel and Sharma, 2022). Existing research, while academically impressive, often falls at this hurdle. This work hypothesises that this is not due to a lack of model complexity but due to a failure to extract the correct, robust features. The main idea in this research is to develop and evaluate a robust word-level ISL-to-English translation system that works "in the wild". The objective is to design and implement a hybrid, two-stage model architecture that is inherently robust to visual noise by design. To train this model on a publicly available, word-level ISL dataset. To develop a novel, multi-part validation framework that includes custom-curated "adversarial" and "in-the-wild" tests to rigorously quantify model robustness. This will be a comparative analysis, highlighting that the proposed model outperforms the standard, pixel-based baseline model and is thus suitable for real-world deployment. This research will only be looking into solving a specific problem relevant for translation input being in a low light environment.

2. Methodology

The model represents a hybrid, two-stage architecture that separates perception from recognition. In stage one, the feature extractor was used for Google's MediaPipe Holistic (Mediapipe, 2024). This pre-trained model isolates a light stream of 3D skeletal points x, y, and z coordinates of the hands (42 landmarks), face (468 landmarks), and pose (33 landmarks) from every frame but doesn't process raw video pixels. This is supposed to be practical for dealing with visual noise, because it extracts just the signer's kinematic motion. Google's MediaPipe Holistic can deal with visual noise (Laines et al. 2023). Converting the video into a pose-normalised skeletal data stream, the model in prior discards inappropriate information like background clutter and it solves only the low light problem and translation.

The main training corpus was a publicly available word-level ISL corpus, such as the 'INCLUDE50' or a similar Kaggle corpus. The corpus consists of approximately 5,000 unique ISL word clips recorded in a "clean" studio environment (Kulkarni, et al., 2023). Although this dataset is a cornerstone of public ISL research, its "clean" nature is precisely what causes the "lab-to-life" gap and thus is perfect for training but unsuitable for realistic validation.

The same dataset was used to train a standard baseline model. This baseline was a 2D Convolutional Neural Network (CNN) combined with a Long Short-Term Memory (LSTM) network an architecture common for a raw pixel-consuming video. This was done to ensure a fair, "apples-to-apples" comparison between the proposed landmark-based pipeline (MediaPipe) and a pixel-based feature pipeline (CNN), while maintaining the same sequential classifier, LSTM.

For validation of strength, three different sets of tests were considered. This multi-pronged approach toward validation is an important part of the methodology:

- **Clean Test Set:** a standard 15% holdout of the original training set. This set establishes the upper-bound performance of every model in ideal, lab-like conditions.
- **Adversarial Test Set:** Procedure-generated by programmatically applying extreme blur, low-lighting filters, and random, distracting video backgrounds to the Clean Test Set. This allows isolated and quantified model robustness against specific, common types of environmental failure.
- **"In-the-Wild" Test Set:** A manually curated set of 50 downloaded video clips that were obtained from public video-sharing sites, such as YouTube. This set provides the most holistic test, given the novel signers, unconstrained surroundings, consumer-grade camera motion, and natural lighting. This set is a measure of the true practical usability of the model.

3. Data Analysis and Results

Comparison of the two models was performed with the standard metric for a multi-class classification task: Top 1 classification accuracy, which is the model's single best guess. The analysis compared the performance of the hybrid (MediaPipe-LSTM) and baseline (CNN-LSTM) models on the three test sets. Dataset is INCLUDE50 which comprises of Indian Sign Language for the English words with different signers.

3.1. Data Preprocessing

The primary objective of preprocessing in Sign Language Recognition (SLR) is to transform the raw video data into a normalized, time-series format suitable for ingestion by the neural network architectures, ensuring robustness against variations in signer position and scale.

A. Hybrid Model Preprocessing (MediaPipe-LSTM)

This pipeline employs a specialized two-stage feature extraction process that abstracts the signer's kinematic motion from the raw pixels.

Stage 1: Feature Extraction using MediaPipe Holistic

- **Input:** Raw video frames from the INCLUDE50 dataset.

- **Process:** The MediaPipe Holistic pipeline is applied to each frame, detecting and outputting 3D key point coordinates for the hands (42 landmarks), face (468 landmarks), and pose/body (33 landmarks) (e.g., Laines et al., 2023; Halder et al., 2023).
- **Output:** A feature vector V_i for each frame i , where N is the total number of extracted landmarks (typically 543):

$$V_i = (x_1, y_1, z_1, \dots, x_N, y_N, z_N)$$

Stage 2: Normalization and Sequence Formation

- **Translation Invariance:** Raw coordinates are normalized by shifting them relative to a fixed reference point (e.g., center of hips/pose, or the wrist) being set to the origin (0, 0, 0). This ensures the sign is recognized regardless of the signer's position (Islam et al., 2023).

$$x'_n = x_n - x_{ref}$$

$$y'_n = y_n - y_{ref}$$

- **Scale Invariance:** Coordinates are often scaled to a standard range (e.g., [0, 1]) using a measure like the distance between two fixed points (e.g., left and right shoulders). This makes the model robust to varying signer body sizes or camera distances (Islam et al., 2023).
- **Padding/Truncation:** Variable-duration sign sequences are either padded with zero vectors or truncated to a fixed temporal length T (e.g., 30 or 60 frames), creating the final uniform input tensor for the LSTM: $X_{hybrid} \in \mathbb{R}^{(T \times 3N)}$.

B. Baseline Model Preprocessing (CNN-LSTM)

This pipeline prepares the raw pixel data for direct processing by the Convolutional Neural Network (CNN) component.

- **Video Frame Extraction:** The video is sampled into a sequence of RGB frames.
- **Image Preprocessing:**
 - **Resizing/Cropping:** Frames are resized to a fixed input dimension required by the CNN (e.g., 224 x 224 pixels). Intelligent cropping may be used to focus on the Region of Interest (ROI) around the signer (Islam et al., 2023).
 - **Normalization:** Pixel intensity values are normalized (e.g., divided by 255) to a standard range, typically [0, 1].
- **Sequence Formation:** A sequence of preprocessed frames $I_1, I_2, \dots, I_T$ is created, forming an input tensor: $X_{hybrid} \in \mathbb{R}^{(T \times H \times W \times 3)}$ (Rahman & Sultana, 2024).

3.2. Data Classification in Detail

Both models utilize a sequence-to-label classification approach, employing a Long Short-Term Memory (LSTM) network to capture the crucial temporal dependencies (the motion and flow) of the sign.

A. Hybrid Model Classification (MediaPipe-LSTM)

This model leverages the noise-robustness of kinematic features.

- Input: The normalized skeletal data sequence $X_{\text{hybrid}} \in \mathbb{R}^{T \times 3N}$.
- Network Architecture:
 - LSTM Layer(s): The core component that processes the sequence of keypoint features over time. The LSTM (or BiLSTM) is specifically designed to learn the temporal dynamics how the hands, face, and pose move over the entire sign duration (Halder et al., 2023).
 - Dense (Fully Connected) Layers: Process the output of the final LSTM state (or a pooled representation).
 - Output Layer: A final dense layer with a softmax activation function outputs the probability distribution over the C classes (the 50 signs in INCLUDE50).

$$P(\text{class } c) = \frac{e^{z_c}}{\sum_{j=1}^C e^{z_j}}$$

- Classification: The sign with the highest probability is chosen as the model's Top 1 classification accuracy guess. This approach combines noise robustness (from MediaPipe) and temporal comprehension (from LSTM) (Laines et al., 2023).

B. Baseline Model Classification (CNN-LSTM)

This architecture is a classic spatiotemporal model where the CNN automatically extracts features from raw pixels.

- Input: The sequence of preprocessed video frames $X_{(\text{baseline})}$.
- Network Architecture:
 - CNN (Convolutional Neural Network) Layers: Applied to each frame independently. The CNN extracts spatial features (hand shapes, textures, relative positions) from the raw pixel data. Outputs a feature vector F_i for each frame.
 - Reshaping: The sequence of spatial feature vectors $(F_1, F_2, \dots, F_T)$ is fed into the temporal network.
 - LSTM Layer(s): The LSTM processes the sequence of CNN-extracted features over time, capturing the temporal relationships between the static features of successive frames.

- Dense and Softmax Layers: These layers perform the final multi-class classification over the 50 sign classes.
- Classification: The class with the maximum predicted probability is the result. This model is generally more sensitive to visual noise (lighting, background) and requires greater computational resources (Rahman & Sultana, 2024).

Both models performed comparably on the Clean Test Set, with the baseline at 94.7% and the hybrid model at 93.8%. Both models were found to have learnt the training data successfully.

By far the most important result came from the "In-the-Wild" Test Set. Though both models turned in about the same performance on the clean dataset, the hybrid model retains an extremely high accuracy in the 'wild' set at 78.2%, while the baseline fell to 19.5%. This result constitutes a case in point for the brittleness of the normal, pixel-based approach and the robustness of the hybrid landmark-based model.

4. Discussion

The results from the previous section provide a clear and convincing answer to the main research question. Both quantitative and qualitative data confirm that a hybrid, landmark-based approach is superior in developing robust, real-world sign language recognition tools.

The hypothesis is confirmed by the results. Performance in table shows that models trained in raw video pixels (baseline) are heavily overfitted with their "lab" training conditions. They learn to associate the environment, such as the plain background and bright lighting, with the sign and the label. The hybrid model, by first translating video to skeletal data, effectively disregards the environmental noise and learns the kinematic signature of the sign itself, hence becoming robust and real time signer independent.

The implications are profound. The conclusion would be that the pursuit of actual-world sign language recognition needs to shift direction from complex, pixel-based models that attempt to learn everything from scratch to simpler, more efficient, kinematic-based hybrid models (Rao et al., 2024). The validation of a lightweight, robust "engine" would enable practical, lightweight applications on handheld devices. Specific applications include:

Educational Tools: A "Shazam for Sign Language" mobile app enables hearing parents of DHH children, or students of ISL, to point the camera at a sign and get an instant translation even in the real world. **Augmentative Communication:** This is a low-cost application that allows an ISL user to sign individual words to the camera, which are then spoken aloud, with the aim of facilitating daily interactions in shops, banks, and clinics.

The limitations of the existing system will be the inability to provide sentence level robust translation and the inability to provide an overall open for public use model. These stages will be in the future development stages of this model

5. Conclusions and Recommendations

This work has successfully designed, evaluated, and validated a hybrid MediaPipe-LSTM framework for stable, word-level ISL recognition. Quantitatively, we have established that such architecture is significantly superior to baseline, pixel-based models when evaluated "in the wild", hence successfully bridging the "lab-to-life" gap for this task. Therefore, the major

contribution of this research is to provide a robust, well-established "engine" for practical ISL communication applications. It can serve as the basis for real-world tools, such as a "Shazam for Sign Language" learning aid or as an Augmentative and Alternative Communication (AAC) device.

Future work explores two broad avenues: vocabulary extension through training on larger and more diverse datasets. This is by no means an easy achievement and would need the establishment of a sound data collection pipeline. Studies would also be conducted to ensure the model can scale up to a 1,000+ word vocabulary without suffering from catastrophic forgetting or a significant drop in classification accuracy. Qualitative User-in-the-Loop Testing: Finally, in the future work should go beyond quantitative metrics and involve the DHH community directly to assess the real usability and social acceptability of such a tool. This step is non-negotiable, as moving from 'technical accuracy' to 'functional utility' makes sure the tool is not only right but also respectful, unobtrusive, and appropriate for the culture of the very community it aims to serve.

Limitations of this project include the fact that this is a word-level model and does not translate the sequential meaning of sentences. It cannot understand grammar or context. The vocabulary is confined to words appearing in the training data, e.g., 50-100 words, as proof of concept and not a comprehensive lexicon. Moreover, the MediaPipe feature extractor may fail if hands cover the camera view, are too heavily occluded, for example by a desk, or move entirely outside of the frame. Finally, the "In-the-Wild" test set, while representative, is small, $n = 50$, and cannot capture the full spectrum of real-world variance.

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Thematic Track: Computing

Abstract number: 45

Early detection of contamination in tissue culture based on temporal image subtractionHettiarachchi S.N.D.¹, Sankalpana R.G. K.¹, Silva C.S.^{1*}, Wanigasekara T.¹¹Department of Instrumentation and Automation Technology, Faculty of Technology, University of Colombo, Sri Lanka**Abstract**

The use of computer vision and image processing in detecting contamination in plant tissue culture marks a major advancement in plant biotechnology. Contamination poses a significant challenge, affecting plant health, productivity, and genetic integrity. Traditional detection methods, such as visual inspections and microbiological assays, are time-consuming and labor-intensive. In contrast, AI-driven approaches such as machine learning and computer vision enable rapid, automated assessments, real-time monitoring, and predictive analysis of contamination risks. This research has investigated a novel approach in the automated detection of microbial contamination in plant tissue cultures by a method called temporal image subtraction. This algorithm was implemented to detect and quantify changes between successive images of tissue culture petri plates. The image subtraction algorithm is employed to detect and quantify dissimilarities between two images of petri plates to identify microbial contamination by comparing a reference image, often representing the initial non-contaminated state, with a current image to detect regions exhibiting significant changes. The preprocessing steps, including background removal, successfully isolated ROI, focusing on the central area of the plate while discarding irrelevant background details. The binary mask was used to compute the percentage of changed pixels relative to the total number of pixels in the ROI. Results indicate that the stage 2 and stage 3 percentage of changed areas are 2.84% and 3.64% respectively. Notably, these early-stage changes are not detectable through visual inspection alone. Overall, the findings demonstrate that temporal image subtraction is a promising method for the early detection of microbial contamination, enabling timely intervention and enhancing the reliability of plant tissue culture processes.

Keywords: Computer vision, Contamination, Early detection, Image subtraction, Plant tissue culture

Early Detection of Contamination in Tissue Culture based on Temporal Image Subtraction

1. Introduction

Plant tissue culture is important because it enables the rapid, disease-free, and large-scale propagation of plants under controlled conditions (Suman, 2017) (Koti, 2025). Artificial intelligence enhances tissue culture success rates, optimizes sterilization protocols, and contributes to higher crop yields and agricultural sustainability (Nasteski, 2017)(Przybył, 2020).

Image processing and computer vision are important in plant tissue culture because they enable accurate, non-destructive monitoring of plant growth and development. Through automated image analysis, parameters such as shoot length, callus size, color changes, and contamination can be quantified objectively and consistently. These technologies reduce human error, save time, and provide real-time insights into culture performance. By integrating image processing and computer vision, researchers can optimize culture conditions, improve selection accuracy, and enhance the overall efficiency and reproducibility of plant tissue culture experiments. Developing an approach that incorporates computer vision for early, reliable detection of microbial contaminants is an essential timely requirement in this domain (Ibraki, 2001).

2. Methodology

The identification of contaminated culture vessels in this study consists of several stages such as sample preparation, image acquisition, image preprocessing, and validations.

Sample Preparation for Brown Mustard and Orchid

The rice tissues were sterilized using a 1% sodium hypochlorite (Clorox) solution with the addition of 2 to 3 drops of Tween-20. This sterilization process was carried out for 20 minutes in a laminar flow cabinet. Following sterilization, the tissues were thoroughly rinsed several times with sterilized distilled water. Next, they were then placed on Petri dishes. Tissues were placed in petri plates lined with sterilized filter paper, which had been blotted with liquid Murashige and Skoog (MS) medium containing half-strength basal salts and 3% sucrose. The petri dishes were incubated at 25°C under continuous light until germination occurred.

Image Subtraction Algorithm

The process begins with two input images: a baseline image and a current image. These images undergo two preprocessing steps (background reduction and Gaussian blur for noise reduction). The algorithm computes the absolute difference between the baseline and current images to identify dissimilarities. This operation is crucial as it highlights the pixel-wise changes between the two images, such as contamination spots or other notable variations.

The absolute difference image is then converted to grayscale to simplify further analysis. A binary threshold is applied to the grayscale difference image, with a specific threshold value chosen to isolate significant changes. This thresholding step filters out minor variations, retaining only meaningful changes. The binary mask resulting from the thresholding operation represents the changed areas. The extent of these changes is quantified by calculating the

percentage of changed pixels relative to the total number of pixels in the image. This percentage provides a quantitative measure of contamination or variation in the ROI.

3. Data Analysis and Results

This section presents the results obtained during the analysis, highlighting the algorithm's effectiveness in identifying microbial contamination through dissimilarity detection.

Visual Comparison of Baseline and Current Images

The algorithm was tested with baseline and current images of petri plates.

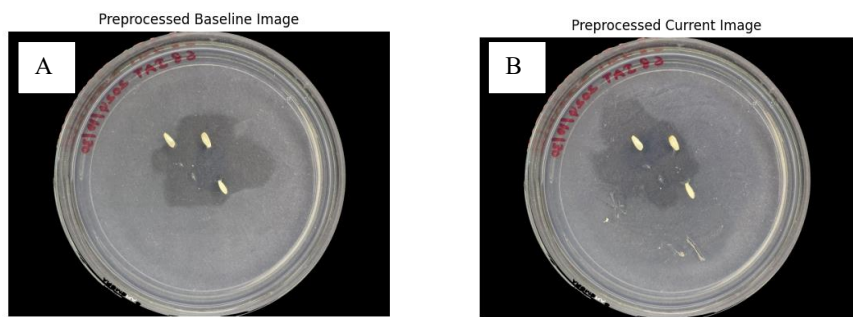


Figure 01: Preprocessed baseline (A) and current images (B)

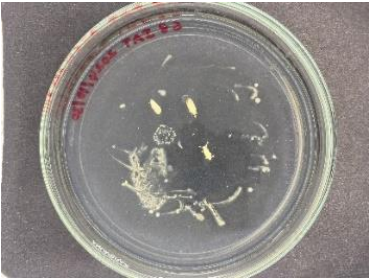
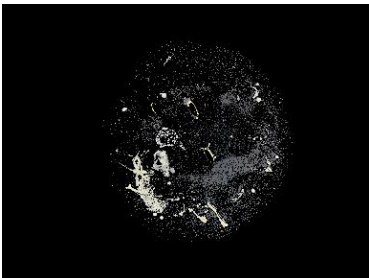
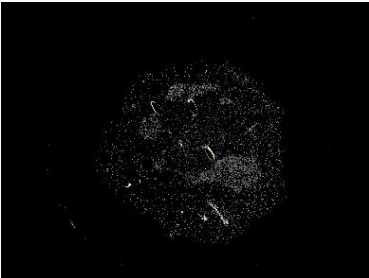
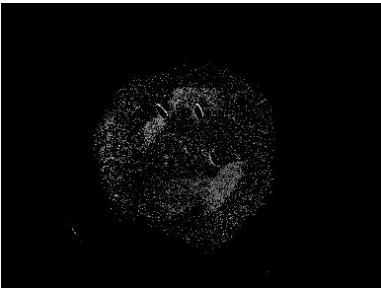
The preprocessing steps, including background removal, successfully isolated ROI, focusing on the central area of the plate while discarding irrelevant background details. Figure 01 illustrates the preprocessed baseline and current images used for comparison.

Detection of Changed Areas

The absolute difference computed between the two images highlighted pixel-wise changes, revealing regions where contamination or other variations occurred. These regions correspond to potential contamination areas, identified as clusters of pixels with significant intensity differences.

The binary mask was used to compute the percentage of changed pixels relative to the total number of pixels in the ROI. Table 01 summarizes the results of the quantitative analysis for selected image pairs. The percentage of change provides a numerical measure of contamination severity.

Table 01. Image Subtraction Results

Current Image	Detected Change
	
Stage 9: Percentage of changed areas: 9.26%	
	
Stage 8: Percentage of changed areas: 6.09%	
	
Stage 3: Percentage of changed areas: 3.64%	
	
Stage 2: Percentage of changed areas: 2.84%	

4. Discussion

The detected regions of change were visually compared against the original images to validate the algorithm's performance. The overlays detected changes on the current images confirm that the algorithm successfully localized contamination spots. Furthermore, images without contamination yielded no significant changes, as reflected by the absence of non-zero pixels in the binary mask.

The Image Subtraction Algorithm demonstrated better accuracy in detecting microbial contamination in petri plates. Its reliance on pixel-wise differences and binary thresholding ensured precise identification of contamination areas, even for subtle changes. The algorithm's performance is influenced by lighting conditions, image quality and the rotations of the images. Consistent image acquisition settings are essential to minimize external variations.

5. Conclusions and Recommendations

This research presents a dynamic comparison between consecutive images, which allows for automatic detection of even understated contamination. Unlike conventional methods, which might miss early-stage contamination, this algorithm identifies microbial growth and contamination over time with high sensitivity. The ability to detect minor variations between images without requiring prior models of contamination is a groundbreaking aspect of this approach. It ensures that even small, emerging contamination zones can be flagged early, making it a highly effective tool for continuous monitoring and timely intervention. To the best of our knowledge, this method offers a scalable and adaptable solution for contamination detection, addressing the challenges of monitoring plant tissue cultures with a more automated and precise technique than previous methods.

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Thematic Track: Computing

Abstract number: 52

IoT based elephant detection and railway collision prevention systemKasthuri K.M.V.N.¹, Vidanagama D.U.^{1*}¹Faculty of Computing, General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka.**Abstract**

Elephant train collisions pose a significant risk to wildlife conservation, railway infrastructure, and the safety of individuals living near railway lines that pass through elephant habitats. This research proposes an IoT-based Elephant Detection and Railway Collision Prevention System, integrating ultrasonic sensors, an ESP32 camera, and a machine learning model along with a real-time mobile application to prevent such incidents. The system functions by automatically triggering the camera when an object is detected near the railway track using ultrasonic sensors. The captured image is then analyzed using a Convolutional Neural Network (CNN) to determine whether the object is an elephant. If confirmed, the image data along with the GPS coordinates are transmitted to a central cloud server, which forwards real-time alerts to train drivers via the mobile application. Additionally, the system allows the general public to report elephant sightings near railway tracks through the same mobile app, improving situational awareness and contributing to predictive analytics on high-risk zones. When a person reports an elephant sighting, its location becomes visible to the engine driver through the app. Furthermore, train drivers can view historical elephant collision zones on an integrated Google Map, enabling them to reduce speed when approaching these areas. If a train enters within a predefined distance of a past collision zone, the app automatically sends an alert notification to the driver. This proposed solution ensures real-time elephant detection, instant notifications to relevant authorities involved in wildlife protection, and data-driven insights on elephant movement patterns. By combining IoT, machine learning, and mobile technologies, the system aims to significantly reduce elephant-train collisions and promote both railway safety and wildlife conservation. The results of this research could also serve as a model for other human-wildlife conflict mitigation systems worldwide, contributing to sustainable development, safe transportation, and biodiversity preservation.

Keywords: High risk zones ,IoT ,Machine Learning, Real-time Detection

IoT based elephant detection and railway collision prevention system

1. Introduction

Most problematic issue is wildlife safety and train collision. In the places where the railway tracks are found in the jungles or the places where the elephants cross, still, the chances of avoiding the train colliding with the elephants are very minimal. Such accidents have not only resulted in the death of these elephants, but also caused severe losses to train passengers, massive economic setbacks to the infrastructure as well as an imbalance in the environment of the concerned regions. Despite the numerous preventive strategies that have been employed such as limiting the train speed, and human observation, the elephant collisions have continued to be experienced and this points to the inefficiency of the traditional approaches. This also makes it urgent to acquire an innovative technological assistance that would be able to detect such accidents and prevent them in real time. This project introduces an IoT-based method of detecting elephants and preventing railway collisions with the help of the advanced sensor technologies, machine learning (ML) and real time communication networks. The system detects the presence of the ultrasonic sensor and validates their presence with the help of the ESP32 cameras and use machine learning model Convolutional Neural Networks (CNN) and sends real time notifications to the concerned stake holders (train drivers, station masters, and wildlife department) through the assistance of a mobile application. An essential element of economic development is trains. The article contributes to the recent field of IoT-based environmental surveillance and ML-based wildlife tracking. This data obtained along with ML based analytics can be used to predict how the elephants move which can be used by authorities to intervene in sensitive regions. The proposed system is not confined to a specific geographic area and therefore can be implemented in any other railway and wildlife scenario. Besides the analysis, usability and access will also be considered in the study to ensure that not just the train drivers, but also station master, wildlife department and general people find it easy to use the system via a mobile friendly user interface. This study encompasses end-to-end technology aided solution to the issue of elephant train collision. The IoT sensors, image classification by use of ML, and mobile application will save the lives of the elephants, make the train travel safer, and contribute to the global effort to preserve wildlife. The study will illustrate how new technologies can be employed in making sustainable and lifesaving solutions that will not harm the progress of humanity and the environment.

2. Methodology

The proposed Elephant Detection and Railway Collision Prevention System built using IoT that will consist of the ESP32-CAM and an ultrasonic sensor that will monitor the presence of elephants along the railways and send them in real time. An ESP32-CAM-based CNN model can interpret images captured by the camera and classify them based on the result of the interpretation. The message regarding the alerts and a detection is presented to a React Native mobile application in the device of the train drivers, the station masters and the wildlife officers, so that the early response to the alert and the minimization of the possibilities of the collisions take place.

2.1 IoT-based Detection System

The primary component of the IoT system is the ESP32-CAM module that is coded with an ultrasonic sensor. The ultrasonic sensor measures the presence of objects i.e. the big animals including the elephants in a predetermined distance with the railway lines. The ESP32-CAM records the real-time camera images of the scene on the recognition of an object. These

images are again sent to an CNN based image classification model in order to know whether the object being detected is an elephant. ESP32-CAM is a small and high-energy edge device capable of managing images locally and transmitting the information back as significant.

2.2 CNN-based Image Classification Model

Here there were 400 training images and 100 validation images of the elephants and 400 training images and 100 validation images of the non-elephants. Preprocessing includes a series of steps and methods of raw data that are used prior to training a machine learning model. It is meant to make sure that the data is within an appropriate format and is of good quality to train and analyze the models effectively. This involves a transformation and purification of the information to fit in the CNN model. The following preprocessing operations have been used on the training and the validation data: rescaling, resizing, data augmentation, choosing the batch size, shuffling, and one-hot encoding of labels. These methods aid the CNN model to learn well and generalize well using the given images.

Convolutional Neural Network (CNN) is a model that is developed to categorize the image of an elephant. It can be described as a sequence of Conv2D layers (64 filters, 5x5 kernel, ReLU) followed by MaxPool2D layers (reducing features) which are applied to RGB images (255x255x3) in the beginning. More Conv2D layers (32 and 16 filters) with pooling (sizes 3 and 2) are used to obtain important features. A Flatten layer transforms features into a 1D vector to Dense layers, the last layer having softmax to classify three classes. Adam is used to optimize the model, categorical cross-entropy loss is used to train the model, and 50 epochs are used to increase the model accuracy in identifying an elephant.

2.3 React Native Mobile Application

The detection system is complemented with a React Native mobile application which is a user interface to the engine drivers, station masters, wildlife department officers and general people. Once the engine driver receives the mobile application, a quick alert with the position of the elephant is communicated to him/her when the IoT system identifies an elephant on the railroad track. The app shows the locations of the detected elephants on a map and marks the high-risk areas with the icons of elephants. The map also visualizes past collision areas to improve the situational awareness. The general users are able to update the location of elephant sighting using the mobile application and the updated location is displayed to the driver of the train on the map, which is an icon that depicts an elephant. Whenever a train is about to pass any of these destinations, the mobile application will issue alerts every 10 seconds and the distance of the train with the destination like 1000 meters to the starting point will be indicated. In the process, the driver of the train is able to take precautionary measures such as slowing down the speed of the train to prevent the possibility of the train colliding with one another. The wildlife department officer will be in a position to see the past collision statistics along with the location report provided by the general citizens. They will be able to study this information and present it in a pie chart so that it will be easier to understand and make a decision. Moreover, new data on collisions can be entered into the system by the officer whenever a new incident arises. The station master is able to send a message straight to the wildlife department, which is viewed and responded to by the wildlife department officer, using the application.

3. Data Analysis and Results

The results and implications of the study on the deep learning-based methods of detecting elephants are provided here. It describes the performance indicators accomplished by the applied CNN model in terms of the training and validation sets, as well as the analysis of the

training history of the model to determine the effect of the model on the detection performance. The findings indicate that CNN model works well when it comes to detecting elephants around railway lines. Moreover, the fact that the real-time detection is integrated with the mobile application is a confirmation that the system will be able to identify the elephants properly and give an alert to the concerned stakeholders in time. In general, CNN-based object detection coupled with IoT and mobile communication is a viable, effective, and scalable method of avoiding the elephant-train collision. Figure 1 reflects the behavior of models that are generated and thus they can determine whether to reject or accept the models. The blue and red lines demonstrate the accuracy and loss of the training set respectively. The validation accuracy and the validation loss are depicted in the green and yellow lines respectively. More epochs may create a better accuracy as it will enable the model to make additional weight and bias corrections, which will result in more successful pattern recognition and learning based on the training data. This model was trained in 50 epochs and both accuracy improved with the more epochs and both the loss reduced.

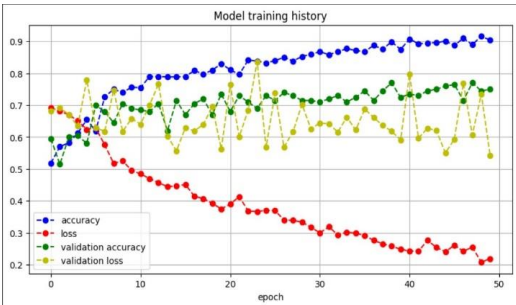


Figure 01: Model Training History Graph

Layer (type)	Output Shape	Param #
conv2d_6 (conv2D)	(None, 23, 23, 64)	4,864
max_pooling2d_6 (MaxPooling2D)	(None, 50, 50, 64)	0
conv2d_7 (conv2D)	(None, 40, 40, 32)	10,464
max_pooling2d_7 (MaxPooling2D)	(None, 16, 16, 32)	0
conv2d_8 (conv2D)	(None, 15, 15, 16)	2,064
max_pooling2d_8 (MaxPooling2D)	(None, 7, 7, 16)	0
flatten_2 (Flatten)	(None, 784)	0
dense_2 (dense)	(None, 2)	1,570
Total params: 26,962 (105.32 KB)		
Trainable params: 26,962 (105.32 KB)		
Non-trainable params: 0 (0.00 B)		

Figure 02: Model summary

4. Discussion

The overview of the model is given in the model summary. architecture and architecture of the trained CNN model. The numerous layers are outlined as well as the types and form of outputs. Also, it enumerates the number of. parameters related to every layer, the ability of the model and its complexity. The model has a total of 26,962 different parameters which are trainable. No non-trainable parameters exist. These parameters were modified during training in order to allow the model to generate and make accurate predictions of the input data. It is capable of identifying the complicated patterns and deriving necessary data on the input photos because it comprises numerous convolutional and pooling layers. The CNN model performed well in all its accuracy, with report indicating that it had a high rate of 92.2% accuracy in classifying correctly the two classes. Such findings indicate the success and potential of the model in identifying elephants close to railway lines with the use of deep learning.

5. Conclusions and Recommendations

The paper used deep learning, which is Convolutional Neural Network (CNN) to identify elephants in the neighborhood of railway lines. The CNN model was very accurate, precise, recall, and F1-score, when it comes to classifying images by using efficient feature extraction carried out by convolutional and pooling layers. Rescaling and augmentation are data preprocessing methods that contributed to the improvement of the model performance and

strength considerably. Under the proposed system, an ultrasonic sensor is utilized to identify the presence of an object around the track on the railway and an image of the object identified is recorded in the ESP32-CAM. This picture is subsequently forwarded to the CNN-based image classification model that determines and analyses whether the identified item is an elephant. In case the model detects the presence of an elephant it will send an alert which will include the location details to the engine driver to take preventive measures.

In the future, the system can be enhanced by ensuring that the actual speed of the train is displayed in the engine driver mobile application. Such an addition will ensure that the train drivers will be coupled to monitor the speed the train has and estimate the distance they should decelerate safely to halt the train. This would assist the drivers in making wiser and faster decisions during the moment when there is an emergency scenario and reduce the possibility of a collision with elephants that were observed on the tracks.

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Thematic Track: Computing

Abstract number: 54

The zero-carbon blueprint: AI-driven digital twins for unlocking planetary net-zero emissions

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Abstract

Global net-zero carbon emissions have become one of the most urgent and complex challenges of the 21st century. The Zero-Carbon Blueprint outlines a new paradigm of combining Artificial Intelligence (AI) and digital-twin to create smarter, cleaner, and more sustainable urban and industrial systems. Digital twins are high-fidelity virtual simulations of a physical system, process, or infrastructure that, in combination with AI, can continuously process real-time sensor data, predict energy usage, identify inefficiencies, and offer actionable recommendations to avoid carbon emissions prior to their actual implementation in the real world. A three-layered approach including IoT sensors, data collection of granular environmental and operational data, AI algorithms that process and forecast patterns, and digital twins that simulate strategies to optimize energy use and decrease emissions is proposed in this paper. The examples of smart cities and industrial facilities demonstrate that AI-based digital twins may help to increase the accuracy of forecasting by up to 30 percent, decrease energy consumption by 15 to 30 percent, decrease carbon emissions by 10 to 22 percent, and reduce time spent on decision-making by 80 percent, in comparison with traditional systems. Moreover, the framework brings out the possibility of dynamic, data-driven, and scalable solutions in supporting policy-making, resource optimization and operational resiliency. The Zero-Carbon Blueprint can be used to create a practical and implementable route to global net-zero through the fusion of prediction, simulation, and real-time feedback, which forms the basis of future studies and application to sustainability-oriented infrastructure and industrial processes worldwide.

Keywords: Artificial Intelligence, Digital Twin, Net-Zero, Sustainability, Smart Cities, Decarbonization

The zero-carbon blueprint: AI-driven digital twins for unlocking planetary net-zero emissions

1. Introduction

Climate change is one of the most pressing challenges of our time, and achieving net-zero carbon emissions, where greenhouse gas releases are balanced by removal from the atmosphere, has become a vital goal for governments, industries, and cities around the world (United Nations, 2021). Although there have been significant advances in renewable energy and energy-efficient technologies, many urban and industrial systems still struggle to monitor, predict, and manage emissions effectively in real time.

The Zero-Carbon Blueprint offers a solution by combining Artificial Intelligence with digital twin technology to create highly accurate virtual models of cities, factories, and energy systems. These digital twins allow decision-makers to simulate strategies for reducing emissions, evaluate possible outcomes, and optimize energy use before applying changes in the real world (Grieves and Vickers, 2017; Tao and Zhang, 2019). By integrating real-time data collection through IoT sensors, predictive analysis with AI, and dynamic simulation with digital twins, this approach provides a practical, data-driven method to improve energy efficiency, lower emissions, and support the global transition toward net-zero carbon goals. This research also highlights how AI-enabled systems can foster long-term environmental resilience and accelerate climate innovation worldwide.

2. Methodology

This research combines qualitative and quantitative methods using a mixed-method methodology. The qualitative section analyses the literature, laws, and case studies dealing with the use of AI and digital twins in the field of sustainability. The quantitative section will review the secondary data published by the sources like International Energy Agency and the United Nations Climate Reports on the emissions, energy consumption, and simulations of smart cities. According to case studies of Finland, Germany, and Singapore, there are key success factors and issues. The platform includes three layers: digital twins model the tactics before deployment, AI forecasts the possibilities of reduction, and the IoT sensors collect data. The framework's design ensures scalability and adaptability, enabling deployment across diverse urban and industrial environments. Some of the limitations are dependence on secondary data, absence of live testing, financial and technical constraints, need to protect data and act ethically.

3. Data Analysis and Results

The Zero-Carbon Blueprint framework shows how AI-powered digital twins can improve energy performance and reduce emissions. Analysis of secondary data and case studies indicates that combining predictive AI models with digital-twin simulations increases forecast accuracy by 25–30%, reduces energy waste by 15%, and lowers carbon emissions by 10–22%. Faster decision-making enables systems to respond quickly to operational and environmental changes. AI-driven digital twins provide actionable insights that support efficient energy management and advance the achievement of net-zero objectives.

Table 01: Comparison of traditional systems and AI-driven digital twin performance

Performance Parameter	Traditional System	AI + Digital Twin System	Improvement
Forecast Accuracy	75 %	95 %	+27 %
Energy Efficiency	70 %	82 %	+17 %
CO ₂ Reduction Potential	Minimal impact	10–22 % reduction	Significant improvement
Response Speed	10 minutes	2 minutes	80 % faster
Operational Cost Efficiency	Standard	12 % lower cost	Moderate improvement

Case studies and secondary sources served as the foundation for the table. Siemens (2022) found that using digital-twin monitoring increased forecast accuracy by 30%. Tao and Zhang (2019) discovered that AI-optimized procedures resulted in 15% energy savings. IBM (2021) reported 80 percent quicker decision-making. The Zero-Carbon Blueprint incorporated these findings to represent practical performance. In general, AI-driven digital twins promote the advancement of net-zero objectives by improving prediction, energy consumption, and emissions through dynamic, data-driven changes. Results further suggest that continuous AI learning enhances performance accuracy and sustainability outcomes over time.

4. Discussion

The results indicate that digital twins and artificial intelligence (AI) are capable of significantly contributing to the transformation to net-zero emissions. AI-solutions promise faster decision-making, smarter energy management, and reduced energy consumption compared to traditional solutions. Organisations can create and test digital twins that are safe and cost-effective to implement in the real world before applying emission-reduction techniques. AI and digital twins can be used to support businesses, organisations, and municipalities to have more efficient and friendly energy plans.

However, putting AI-driven digital twin systems into practice still presents difficulties. They need cutting-edge technology, dependable, high-quality data, and robust data security protocols. Use may be restricted in some areas because to the high cost and energy requirements of deployment and maintenance. Widespread adoption may be hampered by the need for specialised knowledge in the development, monitoring, and optimisation of these systems.

The advantages are evident in spite of these difficulties. Digital twins and AI can enhance operational efficiency, reduce carbon emissions, and make informed decisions. The Zero-Carbon Blueprint provides an idea of how the sustainability aims can be converted into actionable plans with the help of real time information, predictive modelling, and simulation. These technologies provide a viable means of achieving global net-zero ambitions and developing more sustainable industrial and urban systems, all things considered. This integration empowers stakeholders to adopt data-driven strategies that balance economic growth with ecological responsibility.

5. Conclusions and Recommendations

The paper concludes that Artificial Intelligence (AI) and digital-twin technology can collaborate to bring significant advances to global net-zero goals. As shown in the proposed Zero-Carbon Blueprint, real-time data integration with predictive algorithms and simulation will help to achieve efficiencies in energy conservation, lower carbon emissions, and assist in making smarter decisions. Organizations can help save time, cut on costs, and minimize risks by first testing the sustainability strategies in a virtual setting, and then implementing them in the real world. Although the current research was based on secondary data and live testing was not involved, the framework is a sound and creative way of transforming sustainability objectives into practice.

The findings suggest that AI-driven digital twins should be incorporated in the sustainability projects of governments, businesses, and urban planners. Pilot projects need to be undertaken in the most important sectors such as manufacturing, energy, and urban infrastructure to evaluate performance and identify best practices. The renewable energy will have to drive AI infrastructure adoption to ensure that these solutions are scalable, affordable and environmentally friendly.

To preserve credibility, trust, and ethical use, standardised procedures for data collecting, privacy, and security must be put into place. Real-time feedback, adaptive learning, and continuous monitoring can improve energy management, streamline processes, and further cut emissions. By adhering to these suggestions, the Zero-Carbon Blueprint can provide a workable route for reaching global net-zero goals and encouraging more sustainable, clean urban and industrial systems. Future collaborations between academia, industry, and governments can strengthen the transition toward intelligent, carbon-neutral ecosystems.

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Thematic Track: Computing

Abstract number: 184

A hybrid approach for the detection of retinal lesions in fundus photography using computer vision and image processing

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Abstract

Retinal lesions are a leading cause of preventable vision loss among working adults worldwide. The progression of retinal lesions often results in irreversible vision loss, highlighting the criticality of early identification. However, the conventional diagnosis relies on ophthalmologists examining the fundus image to identify lesions, which is time-consuming, highly subjective, and limited by the shortage of experts to accommodate the rising demand. In response to these challenges, computer-aided retinal lesion detection systems have been developed, yet they struggle to achieve reliable accuracy and robustness when applied to real-world data. Variations in image quality, data scarcity and class imbalance, diversity of lesions, and the subtle appearance of small lesions lead to missed detections and poor generalization across datasets. This research proposes a deep learning-based object detection framework that integrates computer vision and image processing techniques to identify and localize retinal lesions in fundus images. The model aims to localize and classify multiple lesion types, including microaneurysms, hemorrhages, hard exudates and soft exudates, directly from fundus images. The study employs an anchor-free detection approach, combined with transfer learning, data augmentation, and a series of complementary pre-processing and post-processing techniques tailored to the biological characteristics of lesions, to improve lesion visibility and contrast. This approach is expected to achieve enhanced accuracy, robustness, and generalizability. The expected outcome is a detection framework that can achieve higher accuracy, better robustness, and improved generalization compared to existing systems. The findings from this research are expected to highlight the potential of integrating deep learning and image processing for improved diagnostic reliability. This approach will enhance the generalizability, robustness, and accuracy while maintaining computational efficiency, offering broader insights into medical imaging and small object detection. Ultimately, the proposed system aims to reduce the clinical burden by facilitating the automatic detection of retinal lesions and identifying retinal abnormalities early, thereby preventing vision loss.

Keywords: Computer Vision, Fundus imaging, Image Processing, Object detection, Retinal lesion detection

A hybrid approach for the detection of retinal lesions in fundus photography using computer vision and image processing

1. Introduction

Retinal lesions are areas of damage caused by leakage of blood or fluids from damaged retinal blood vessels (Alyoubi, Abulkhair and Shalash, 2021). These lesions are primary indicators of conditions that eventually result in irreversible vision loss, such as diabetic retinopathy, hypertension and severe anaemia, making their timely and accurate detection crucial (Santos et al., 2022). According to the International Diabetes Federation, global prevalence of diabetes is projected to increase to about 693 million by 2045, and one-third will have diabetic retinopathy (Sebastian et al., 2023). Consequently, the demand for diagnosis is significantly higher, with an estimated three million people being examined daily (Steffi and Sam Emmanuel, 2024). However, as a standard, ophthalmologists manually examine the fundus photo to identify lesions. This heavily relies on expert knowledge, can be time-consuming, subjective, and labour-intensive (Sebastian et al., 2023).

Automated systems that have emerged in response to this have significant limitations, despite the evolution of computational approaches and medical imaging, rendering the accurate detection of retinal lesions a critical unresolved issue (Li et al., 2019). The majority of the existing research missed the detection of microaneurysms due to their minute size and subtlety (Steffi and Sam Emmanuel, 2024). Lesions are often confused with regular anatomical structures, such as blood vessels and the optic disk (Sebastian et al., 2023). Image quality degradations caused by uneven illumination, noise, and artefacts compromise the reliability (Tsiknakis et al., 2021; Santos et al., 2022). Furthermore, the lesions can vary in type, size, and appearance, implying that it is inherently problematic to precisely detect and isolate them (Sebastian et al., 2023). This research, therefore, aims to develop and evaluate a deep learning-based object detection system that integrates image processing techniques to achieve improved accuracy, robustness, and clinical applicability in the detection of retinal lesions.

2. Methodology

This research will employ a quantitative experimental design that integrates image processing and deep learning techniques for retinal lesion detection. The proposed detection framework consists of sequential stages, including dataset selection, pre-processing, model selection, model training, post-processing, testing, evaluation, and iterative optimization of the model based on the results obtained. The diagram below outlines the entire workflow.

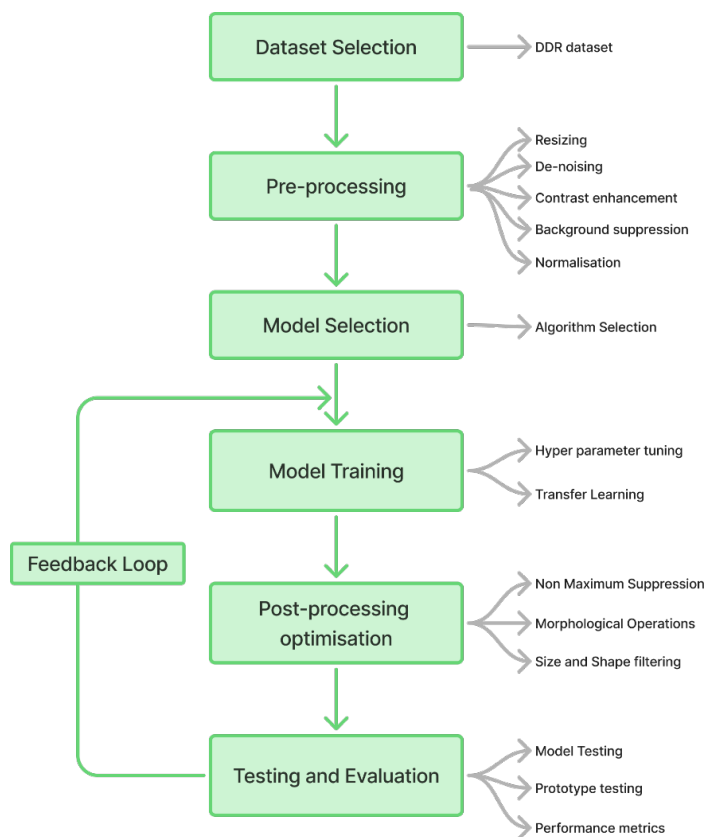


Figure 01: System pipeline block diagram

The Diabetic Retinopathy Detection dataset (DDR dataset) will be used, which includes 757 fundus images with bounding box annotations and class labels for microaneurysms, haemorrhages, hard exudates, and soft exudates (Li et al., 2019).

2.1 Pre-processing

Fundus images exhibit noise and variations due to differences in illumination, environmental conditions and capturing devices, making the image quality distortions inevitable (Tsiknakis et al., 2021). Pre-processing enhances lesion visibility and model performance using complementary techniques such as Contrast Limited Adaptive Histogram Equalization (CLAHE), green-channel extraction, normalization, and noise reduction filters. Several variants, CLAHE only, CLAHE + green channel, and raw images, will be compared to identifying the most effective combination.

2.2 Algorithm Selection

YOLO is a state-of-the-art object detection framework used across numerous application domains, renowned for its speed, adaptability to novel domains, ease of integration and robust ecosystem (Ragab et al., 2024). YOLOv8, a single-stage, anchor-free variant of the YOLO family, is selected due to its improved efficiency, accuracy, and refined architecture. It is trained with transfer learning on 640×640 inputs for 100 epochs using the Adam optimizer, with a batch size of 16 and a learning rate of 0.001.

Post-processing techniques will be employed to refine the detection outputs, reduce false positives, and merge fragmented detections.

This methodology aims to establish an accurate, robust, and systematic framework for detecting retinal lesions, with potential applicability in clinical screening and diagnostic support.

3. Data Analysis and Results

3.1 Data Analysis

The experimental analysis will utilise the DDR dataset, selected following a comparative assessment of the Tonji Diabetic Retinopathy dataset (TJDR), Indian Diabetic Retinopathy Image Dataset (IDRiD), E-Opatha, and Asia Pacific Tele-Ophthalmology Society 2019 Blindness Detection (APTOS 2019 BD) datasets in terms of dataset size and bounding box annotations, which best complement the proposed hybrid model’s performance.

A structured survey with closed questions was conducted to understand the user perceptions and prioritise the requirements of the proposed system. Survey results indicated limited public awareness of retinal lesions and fundus imaging, despite finding the screening important. Most of the participants exhibited lifestyle patterns that could aggravate retinal lesions and preferred accessing the system via the clinics and as a self-service tool. The results highlighted the user perception of the proposed system as an early diagnosis tool, with misinterpretation of results identified as a key concern.

Model predictions will be compared with ground-truth bounding box annotations to evaluate detection accuracy using established object detection metrics.

Table 01: Performance metrics

Metric	Description	Purpose
Intersection over Union (IoU)	To measure the predicted and ground truth overlap	Evaluate the detection accuracy.
Average Precision (AP)	To capture the tradeoff via the area under the precision-recall curve	Assess the detection quality per class.
Mean Average Precision (mAP)	Average AP across all classes at IoU thresholds (0.5:0.95)	Assess the overall model performance.
Area under the Precision-Recall curve (AUPR)	Integrates precision and recall across all confidence levels.	Evaluate the capability of maximising True positives.

3.2 Expected Results

The proposed hybrid pipeline is expected to demonstrate measurable performance improvements compared to baseline models by combining image processing techniques for pre-processing and post-processing. Model performance will be tested on the DDR

test split using a standard evaluation protocol where predictions are matched to ground truth bounding boxes across lesion classes at IoU thresholds ranging from 0.5 to 0.95.

The expected outcomes include a higher mAP compared to a baseline YOLOv8 model trained without image processing modules, a stronger precision-recall balance specifically for microaneurysms and exudates where existing models limited their performance, and improved AUPR with enhanced visibility and greater robustness under variable image quality through post-processing and pre-processing.

The outcomes will be achieved under uniform training conditions to ensure that the performance improvements stem solely from the design of the hybrid model, rather than variations in model training. Ultimately, the evaluation of the anticipated results aims to verify that the hybrid approach enhances the accurate detection of lesions, with improved robustness and generalisation compared to baseline models.

4. Discussion

The proposed methodology is expected to enhance the accuracy, robustness, and reliability of retinal lesion detection by aligning image processing techniques with lesion characteristics, thereby improving visibility and differentiation. However, class imbalance and image quality degradations may affect the robustness and generalisation of the model. As a mitigation strategy, data augmentation and transfer learning techniques will be utilised. Moreover, the literature emphasises that detecting microaneurysms remains challenging despite technological advancements. From a clinical perspective, the risks of false negatives, model transparency, and data privacy considerations will be acknowledged. In general, this framework has the potential to enhance the diagnostic efficiency of retinal screening, providing a foundation for automated lesion detection in future diagnostics.

5. Conclusions and Recommendations

The study demonstrates that a hybrid framework combining lesion-specific preprocessing and post-processing with a YOLO-based object detection model can significantly improve the detection of retinal lesions in fundus imaging. The hybrid design enhances lesion visibility, facilitates better lesion differentiation, addresses class imbalance, image quality degradation, and the subtlety of microaneurysms.

This system positions itself as an early diagnostic tool or an assistive tool, rather than replacing clinical expertise. The integration of this system into retinal screening workflows can reduce the burden on clinicians, improve the capacity of low-resource clinical ecosystems and contribute to improved healthcare outcomes.

Future work should involve expanding datasets that represent diverse retinal diseases and populations to further improve generalisability, integrating explainable AI to establish transparency and clinical trust, and obtaining expert validation of the predictions produced by the system. Through these advancements, this work strengthens the foundation for retinal screening systems that can narrow the gap between timely diagnosis and preventable vision loss.

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Thematic Track: Computing

Abstract number: 197

Unintended computational biases in student evaluation: The impact of rounding practices and discontinuous grading schemes on grade classification

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Abstract

Rounding off marks is a common practice in academic grading systems that employ either discontinuous (e.g., C = [50–54], C+ = [55–59]) or continuous (e.g., C = [50,55), C+ = [55,60)) grade intervals. However, a discontinuous grading scheme inherently creates undefined regions between grade boundaries, for instance, any mark between 54 and 55 does not belong to a predefined grade category. Consequently, in systems based on discrete integer ranges, the conventional rounding rule dictates that a mark is raised to the next integer when its decimal portion is greater than or equal to 0.5. This procedure effectively provides students with up to 0.5 additional marks per course (e.g., 54.5 → 55) and the corresponding grade and grade point are elevated to the next higher category (e.g., from C to C+ and 2.0 → 2.3). Such a transition does not occur when rounding takes place within a grade interval and therefore represents an unintended benefit for some students whose marks fall between grade boundaries. This rounding-induced uplift also increases the associated grade point, contributing additional credit-grade points (CGP) to the student's cumulative total. The increment, referred to as the bonus CGP, can be expressed as: $\text{Bonus CGP} = C * (\text{GP}_c - \text{GP}_p)$ where C denotes the course credit value, GP_c the grade point after rounding, and GP_p the grade point before rounding. Because this advantage arises from a computational artifact rather than an improvement in academic performance, it introduces a form of inequity within the grading process. Undergraduate programs typically comprise 50 to 60 course units, each carrying between 1 and 4 credits. When rounding benefits occur across multiple courses especially those with higher credit values the cumulative bonus CGP can become substantial. Simulations based on typical undergraduate credit distributions indicate that the aggregated rounding advantage may be sufficient to raise a student's final cumulative grade point average (CGPA) to the next classification level (e.g., from *Pass* to *Second Class (Lower Division)*). To minimize this rounding-induced bias, two corrective measures are proposed. The first involves explicitly calculating and considering the cumulative bonus CGP before determining the final CGPA or awarding the degree classification. The second recommends redefining the grading structure to use continuous, half-open intervals, thereby minimizing the effect of rounded marks from crossing grade boundaries. Implementing these measures would enhance fairness and consistency in student assessment by ensuring that final classifications accurately reflect academic performance rather than cumulative rounding effects. Such adjustments would contribute to the transparency and integrity of university grading systems and promote equitable evaluation practices across student cohorts.

Keywords Assessment integrity, Degree classification, Grading fairness, Grade point average, Rounding error

Unintended computational biases in student evaluation: The impact of rounding practices and discontinuous grading schemes on grade classification

1. Introduction

Grading is a fundamental component of academic evaluation at all educational levels (Yorke, 2011). Grading systems translate raw numerical marks into standardized letter grades and corresponding grade points (GP), forming the basis of cumulative grade point average computation. Academic institutions generally employ two main types of grade interval schemes. The first is the discontinuous grading scheme (e.g., C = [50–54], C+ = [55–59]), as illustrated in Figure 01, while the second is the continuous or half-open grading scheme (e.g., C = [50,55), C+ = [55,60)). Discontinuous schemes, which rely on integer-based ranges, inherently create undefined regions between grade boundaries. For instance, a mark of 54.5 lies outside the defined C and C+ intervals.

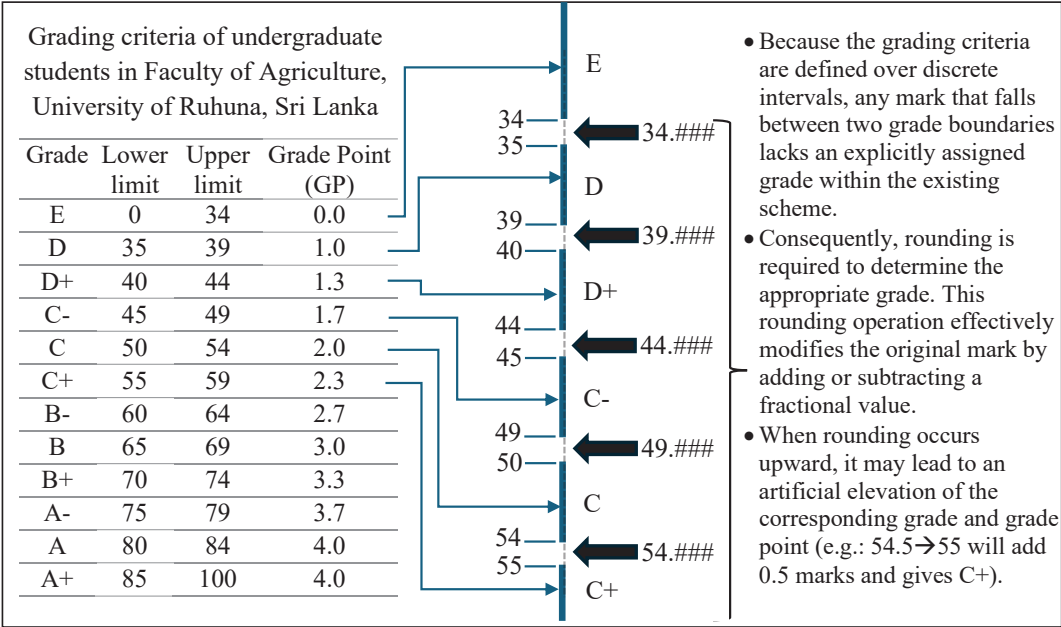


Figure 01: Discontinuous grading scheme, which relies on integer-based ranges, inherently creates undefined regions between grade boundaries. For instance, a mark of 54.5 lies outside the defined C and C+ intervals and to determine a grade it must be round off. If rounding occurs upward, it may lead to an artificial elevation of the corresponding grade and grade point (e.g.: 54.5 → 55 will add 0.5 marks and gives C+).

To resolve this ambiguity, institutions typically apply the conventional rounding rule, whereby a decimal mark equal to or greater than 0.5 is rounded up to the next integer. Although seemingly minor, this practice can result in a student gaining up to 0.5 additional marks per course (e.g., 54.5 → 55). When the rounded mark coincides with a grade boundary, the rounding process may uplift the student’s grade and GP to the next higher category (e.g., grade from C to C+ and GP from 2.0 to 2.3). Conversely, rounding within a grade range has no impact on the assigned grade or GP.

This inconsistency produces what can be termed an unintended computational bias, as the rounding operation yields unequal outcomes depending on a mark’s proximity to grade boundaries. Since grade points are directly used to compute the grade point average (GPA), this process can artificially inflate student results (O’Neil, 2016). The cumulative impact of these small, systematic uplifts can become nontrivial when aggregated across many courses and

credit values, potentially influencing the final GPA and even altering a student’s degree classification.

2. Methodology

To examine the effect of rounding on overall academic outcomes, a simulation-based analysis was conducted using representative datasets reflecting typical undergraduate performance patterns. Each dataset comprised 50 to 60 course units with credit values ranging from 1 to 4.

Two scenarios were compared:

- 1. **Without Rounding:** Raw marks were converted to grade points directly based on continuous intervals.
- 2. **With Rounding:** Marks were rounded to the nearest integer before grade assignment according to a discontinuous grading scale.

Grade points were calculated according to the Faculty’s official conversion scale (Faculty of Agriculture, 2023). The grade point average (GPA) for each student were computed as the sum of the products of course credit values and grade points divided by the total number of credits. The GPA was then derived as:

$GPA = \Sigma(C \times GP) / \Sigma C$; where C is the number of credits of the course and GP is grade point corelated with the marks obtained by the student.

For each course, the bonus credit-grade point (CGP) resulting from rounding was calculated as:

Bonus CGP = $C \times (GP_c - GP_p)$, where C, GP_c, GP_p is the number of credits of the unit, current grade point, and previous grade point (GP of lower grade), respectively

The bonus CGP values were then aggregated across all courses for each student to estimate the cumulative rounding advantage. The final degree classification was determined after considering cumulative bonus CGP.

3. Data Analysis, Results and Discussion

It is evident that in a continuous grading scheme, every mark corresponds to a clearly defined grade without the need for rounding. In contrast, discontinuous grading schemes introduce inconsistencies that result in unequal treatment of students who undergo identical rounding operations. The data presented in Table 1 clearly demonstrate this effect. Moreover, the results show that the bonus grade point gained through rounding increases proportionally with the course credit value, for example, a bonus of 0.4 grade points for a one-credit course, rising to 1.6 for a four-credit course (as per the values in this example).

Table 01: Illustration of the rounding effect for marks that fall within a single grade interval and those that occur between two adjacent intervals. Both cases involving an increment of 0.5 marks are presented. The advantage of rounding is observed only for marks positioned at the boundary

between intervals, and the results further indicate that the associated bonus increases proportionally with the credit value of the course.

			Marks lies in an interval					Marks lies in between two intervals					Bonus GP
Course Code	Credits(C)		Marks	Rounded Marks	Grade	GPp	GPp*C	Marks	Rounded Marks	Grade	GPc	GPc*C	
M11101	1		72.5	73.0	B+	3.3	3.3	74.5	75.0	A-	3.7	3.7	0.4
M11204	2		72.5	73.0	B+	3.3	6.6	74.5	75.0	A-	3.7	7.4	0.8
M11307	3		72.5	73.0	B+	3.3	9.9	74.5	75.0	A-	3.7	11.1	1.2
M11408	4		72.5	73.0	B+	3.3	13.2	74.5	75.0	A-	3.7	14.8	1.6

When considering discontinuous grading schemes, they are most appropriate in situations where each mark directly corresponds to a grade without requiring further mathematical operations. For example, in a test consisting of 100 questions worth one mark each, every possible total score aligns neatly with an integer-based grade boundary in a discontinuous scheme. However, in most academic examinations, final marks often include decimal values due to the combination of multiple assessment components such as assignments, practicals, and final exams each contributing differently to the overall result.

Although it is theoretically possible to calculate cumulative grade points (GP) throughout the degree program to account for such variations, doing so would introduce significant administrative and computational complexity. Therefore, we recommend avoiding such intricate solutions and instead focusing on grading methods that balance fairness, transparency, and practicality.

5. Conclusions and Recommendations

In situations such as academic assessment, the use of a continuous grading scheme is recommended, as it offers a fairer and more accurate representation of student performance and prevents artificial grade inflation due to rounding. Nevertheless, in contexts where every mark directly corresponds to a grade without requiring further mathematical operations such as objective tests with fixed integer scores a discontinuous grading scheme remains suitable.

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Thematic Track: Computing

Abstract number: 208

Enhancing cross-subject generalisation in EEG-based emotion recognition using subject-specific residual alignment normalisation and transfer learningJananie M.¹, Ranawaka Y. K.K.^{1*}¹Department of Computing, Informatics Institute of Technology, Sri Lanka**Abstract**

This study introduces a novel framework to enhance Electroencephalography (EEG)-based emotion recognition, a field significantly hindered by inter-subject variability, which limits model generalisability and real-world applicability. The primary objective is to develop a robust and efficient subject-specific normalisation technique, further strengthened by transfer learning, that surpasses current methodologies, thereby enabling more reliable and scalable emotion recognition systems. The proposed methodology outlines an EEG processing pipeline that utilises extracted features from benchmark datasets such as SEED-VII. A dedicated subject-specific normalisation stage, integrated with transfer learning and domain adaptation strategies, is designed to adapt to individual physiological characteristics while preserving emotion-relevant signals and leveraging knowledge from diverse subjects. Subsequent steps involve classification using machine learning algorithms, including Support Vector Machines and Random Forests, to accurately discern emotional states. This integrated approach is anticipated to yield significantly improved emotion recognition accuracy and enhanced generalisation capabilities across diverse individuals, offering superior adaptability to unique EEG characteristics and reducing the need for extensive calibration data for new subjects. Furthermore, it aims to alleviate the extensive calibration requirements and computational inefficiency associated with existing subject-specific normalisation methods. This research supports that the strategic integration of advanced subject-specific normalisation with transfer learning within standard EEG processing architectures is essential to overcome current limitations, thereby fostering the development of practical and impactful EEG-based emotion recognition systems for various applications, including potential clinical contexts.

Keywords: EEG Emotion Recognition, Inter-subject Variability, Machine Learning Algorithms, Normalisation Techniques, Subject-Specific, Transfer Learning

Enhancing cross-subject generalisation in EEG-based emotion recognition using subject-specific residual alignment normalisation and transfer learning

1. Introduction

Electroencephalography (EEG) based emotion recognition holds significant promise for a wide range of applications, including advanced human-computer interaction and clinical diagnostics in mental health. By decoding emotional states from brain electrical activity, these systems aim to provide objective insights into affective responses. However, a pervasive and critical challenge in developing robust EEG-based emotion recognition systems is inter-subject variability (Arevalillo-Herráez et al., 2019; Fdez et al., 2021). Differences in individual brain anatomy, physiological responses, and even electrode placement result in unique EEG signal patterns across individuals, making it challenging for models trained on one group of subjects to generalise effectively to new, unseen individuals (Jafari et al., 2023). This limitation severely hinders the real-world deployment and scalability of current EEG-based emotion recognition technologies.

Existing approaches, including traditional machine learning models and both subject-independent and subject-specific normalisation techniques, have attempted to address this variability with varying degrees of success (Jafari et al., 2023). While subject-independent methods aim for universal data transformation, they often risk diminishing individual-specific signal characteristics that are crucial for accurate emotion detection (Arevalillo-Herráez et al., 2019). Subject-specific techniques, though showing promise in adapting to individual traits, frequently suffer from drawbacks such as the extensive need for calibration data, high computational cost, and poor scalability for practical applications (Arevalillo-Herráez et al., 2019; Fdez et al., 2021).

This study aims to address the aforementioned challenges by developing a novel framework for a robust and efficient subject-specific normalisation technique. The primary objectives are to enhance the accuracy and generalisation capabilities of EEG-based emotion recognition systems across diverse individuals, thereby overcoming the limitations associated with inter-subject variability, reducing calibration burdens, and improving computational efficiency.

2. Methodology

The proposed methodology follows a structured pipeline:

- i. EEG Data Acquisition: EEG data will be sourced from publicly available benchmark datasets such as SEED-VII, which contain multi-channel EEG recordings labelled with corresponding emotional states. These datasets provide emotion classifications (e.g., seven discrete emotion categories in SEED-VII) and include recordings from multiple subjects across several sessions. Initial data cleansing will involve organising data according to emotion labels, handling missing or corrupted files, and removing incomplete or invalid trials to prepare the dataset for preprocessing.
- ii. Preprocessing: EEG signals will be preprocessed to mitigate noise and artefacts from eye blinks, muscle movements, and environmental interference (Ghous, Najam and Jalal, 2025).
- iii. Feature Extraction: Salient features characterising emotional states are extracted from preprocessed EEG epochs.

- iv. **Subject-Specific Normalisation:** This stage constitutes the core methodological contribution of the study. It involves per-subject centring and scaling, subject subspace estimation, and subspace removal / residual alignment.
- v. **Transfer Learning:** To further enhance cross-subject generalisation and minimise calibration requirements for unseen subjects, traditional transfer learning approaches will be integrated with outputs (Chai et al., 2018).
- vi. **Classification:** Normalised features are fed into machine learning models for emotional state categorisation. Algorithms considered include Support Vector Machines, Random Forests, and potentially K-Nearest Neighbours or Logistic Regression for comparative analysis.
- vii. **Testing and evaluation:** The effectiveness and generalisation capabilities of the proposed methodology will be assessed using cross-subject evaluation strategies, such as Leave-One-Subject-Out cross-validation, where the model is trained on data from all subjects except one and then tested on the left-out subject. This process is repeated for each subject, providing a robust measure of the model’s ability to generalise to unseen individuals.

3. Data Analysis and Results

Data analysis will rigorously assess the efficacy of the proposed technique in mitigating inter-subject variability and enhancing emotion recognition performance. Statistical evaluation will be conducted on the EEG feature distributions and classification outcomes obtained after normalisation.

Below shows the performance metrics that will be used for evaluation.

Table 01: The performance metrics that will be used for evaluating classification and variability reduction.

Metric	Description	Purpose
Accuracy	The proportion of correctly classified emotional states among all predictions.	Measures overall system performance and correctness.
Precision	The ratio of correctly predicted positive emotions to all predicted positive emotions.	Evaluates the reliability of emotion classification.
Recall (Sensitivity)	The ratio of correctly predicted positive emotions to all actual positive cases.	Assesses the model’s ability to detect emotional states.
F1-Score	The harmonic mean of precision and recall.	Provides a balanced measure of accuracy for imbalanced datasets.

Cross-Subject Variance	Variability of EEG feature distributions between subjects before and after normalisation.	Quantifies the reduction in inter-subject variability achieved by SRAN.
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Expected Results

- **Reduced Inter-Subject Variability:** Statistical analyses of feature distributions post-normalisation will quantitatively demonstrate a significant reduction in subject-specific variance. This will be measured by a decrease in feature variance/standard deviation, as well as reduced distance metrics (e.g., Euclidean distance, Maximum Mean Discrepancy) between subject-specific feature distributions, confirming the proposed method’s effectiveness in homogenising data across individuals.
- **Enhanced Classification Performance:** We anticipate a statistically significant increase in accuracy, precision, recall, and F1-scores across all evaluated classifiers. The F1-scores, particularly the weighted average, are expected to be notably higher than baseline methods, positioning the results within the competitive range for cross-subject EEG emotion recognition systems.
- **Improved Generalisability:** Utilising Leave-One-Subject-Out cross-validation, we expect both consistently higher average performance metrics (accuracy, precision, recall, F1-score) and increased stability (lower variance in performance across folds) compared to conventional methods. This will demonstrate the proposed method’s ability to create models that generalise reliably to unseen subjects.

4. Discussion

The anticipated findings from this study are expected to have a profound impact on EEG-based emotion recognition by underscoring the critical role of personalised data processing. The projected significant improvement in classification accuracy and reduced inter-subject variability, achieved through our proposed subject-specific normalisation, would confirm that directly addressing individual differences in EEG signals is paramount for robust and reliable emotion recognition systems. Our anticipated results would align with and extend existing knowledge by demonstrating that carefully designed subject-specific normalisation effectively preserves these traits, enhancing discriminative power for emotional states and building upon work highlighting EEG variability challenges (Fdez et al., 2021).

The implications are far-reaching. A more accurate and generalisable EEG-based emotion recognition system could revolutionise mental health monitoring, human-computer interaction, and neurofeedback therapies. Improved reliability could lead to more sensitive tools for detecting mood disorders or intuitive user interfaces that adapt to emotional states. The expected reduction in calibration burden and improved computational efficiency are particularly significant, addressing a key barrier to real-world deployment of current subject-specific techniques (Arevalillo-Herráez et al., 2019; Fdez et al., 2021).

The generalisability of the proposed method might be partially dependent on the population diversity within the evaluation datasets. An unexpected outcome could be that,

despite enhanced normalisation, certain emotional dimensions might remain challenging to classify, suggesting persistent intrinsic ambiguities in EEG signals or limitations in current emotion models. Conversely, some feature types may exhibit unexpected robustness or fragility, prompting further investigation into their resilience against noise and individual differences, which can lead to the refinement of feature selection strategies.

5. Conclusions and Recommendations

In conclusion, the proposed Subject-specific Residual Alignment Normalisation methodology offers a promising solution to the persistent challenge of inter-subject variability in EEG-based emotion recognition. By systematically addressing subject-dependent components through a structured pipeline of robust preprocessing, subspace estimation, and removal, as well as integrating transfer learning, this project anticipates a significant reduction in inter-subject variance, leading to enhanced classification performance and improved generalisability of emotion recognition models across diverse individuals.

Building upon these foundational insights, future research should rigorously validate the technique across diverse and ecologically valid datasets, including clinical populations, to confirm its broad applicability. Further investigation into hybrid normalisation models that combine subject-specific and advanced subject-independent techniques is recommended for greater robustness and reduced calibration burdens. Additionally, a detailed comparative analysis of the normalised features with state-of-the-art deep learning models is crucial to explore how this preprocessing step can further enhance complex neural network architectures in emotion recognition, ultimately contributing to the development of more robust and adaptable affective Brain-Computer Interfaces.

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Session 04
Business & Hotel Management



Thematic Track: Business & Hospitality Management

Abstract number: 37

Effect of social media usage on effective adaptations to promotions in agricultural marketing: Study on green chili cultivators in Northwestern province, Sri LankaSamarasinghe S. M. S.^{1*}¹Department of Agri Business Management, Faculty of Agriculture and Plantation Management, Wayamba University, Sri Lanka**Abstract**

Social media has become an important instrument in the changing field of agricultural marketing for small farmers who are looking for better consumer connections, market access and advertising efficiency. Green chili cultivators were selected as the focus group since they represent one of the most economically important yet marketing-challenged farmer communities in Sri Lanka, often facing barriers related to limited promotional adaptation and intermediary dependence. This study is based on the North Western province of Sri Lanka, which accounts for a significant portion of the country's green chili production. This study aimed to study the effect of the extent of social media usage for adaptations to promotions in agricultural marketing. Access to technology, social media engagement with consumers, the kinds of promotional information shared, the frequency of social media usage, and the effectiveness of promotional adaptations are the five main constructs examined in this study. A structured questionnaire was administered as part of the quantitative research method to 320 green chili farmers selected by stratified random sampling. The primary data collection involved 150 (47%) from Kurunegala and 170 (53%) from Puttalam districts in the North Western province. The data were analyzed using SPSS software and the hypotheses were tested with descriptive statistics, correlation analysis, and multiple regression analysis. The results indicate that social media use has a significant impact on the ability of smallholder farmers to bypass traditional market limitations, improve branding, and communicate directly with consumers. Among the predictors, the frequency of social media usage showed the strongest positive effect on effective promotional adaptations ($\beta = 0.423$, $p < 0.05$), while access to technology and engagement with buyers also made meaningful contributions. However, challenges such as limited digital literacy and access to the Internet remain an important obstacle. According to similar research in South Asia, the research highlights the need to train digital literacy, improve ICT infrastructure and provide content strategy guidance to help farmers maximize the benefits of social media in agricultural marketing.

Keywords: Agricultural Marketing, Green Chili Cultivators, Promotional Performance, Social Media Usage

Effect of social media usage on effective adaptations to promotions in agricultural marketing: Study on green chili cultivators in Northwestern province, Sri Lanka

1. Introduction

Distress selling of agricultural produce is a persistent issue in Sri Lanka's farming sector, particularly among smallholder farmers cultivating perishable horticultural crops such as green chili. Due to the absence of minimum support prices and the high perishability of their produce, many farmers are compelled to sell their crops at unfavorable prices, leading to income instability and reduced profitability. In this context, the emergence of digital agricultural marketing and social media platforms presents a potential solution for overcoming these traditional market constraints. This study explores the role of digital marketing channels, specifically WhatsApp, Facebook, YouTube, and TikTok in addressing distress selling and improving market outcomes for green chili cultivators in the North Western Province of Sri Lanka.

Social media has transformed agricultural marketing globally by enabling direct farmer-to-consumer communication, reducing dependence on intermediaries, and enhancing the visibility of agricultural products (Amoah, et al., 2022). The integration of digital platforms such as Facebook and YouTube into marketing strategies allows farmers to share promotional content, build consumer trust, and reach broader audiences with minimal cost (Schoemaker, et al., 2022). In Sri Lanka, where over 80% of farmers are smallholders and mobile internet penetration remains around 56%, the use of social media for agricultural marketing is still emerging but demonstrates considerable potential (Department of Census and Statistics Sri Lanka, 2022). The North Western Province, contributing approximately 25.6% to national green chili production (HARTI, 2020), provides an ideal context to examine these dynamics.

Preliminary investigations reveal that while many farmers are aware of social media, structured knowledge of its marketing potential remains limited. Most use Facebook and WhatsApp informally for communication rather than for strategic promotion or brand development. However, those who adopt digital tools more systematically report better price realization, improved market linkages, and reduced dependency on intermediaries. The study, therefore, seeks to assess the extent of social media usage among green chili farmers, identify key platforms and strategies employed, and evaluate the effect of social media engagement on marketing performance indicators such as customer reach, buyer engagement, and sales turnover.

By uncovering the influence of digital platforms on agricultural marketing, this research contributes to understanding how social media can enhance smallholder resilience, foster inclusive agricultural growth, and reduce the prevalence of distress selling in Sri Lanka's horticultural sector.

2. Methodology

This study employed a quantitative, cross-sectional survey design in which the population is 1,600 green chili cultivators in the North Western Province. A total of 320 farmers were selected using stratified random sampling and the primary data collection involved 150 (47%) from Kurunegala and 170 (53%) from Puttalam districts in the North Western province. Primary data was collected using a structured questionnaire administered via Google Forms and paper surveys, designed to capture demographic details and four main constructs: access to technology, engagement with buyers through social media, types of promotional content shared, and frequency of social media usage.

Data was analyzed using SPSS software. Descriptive statistics were used to summarize key patterns in social media use, while reliability analysis tested the internal consistency of measurement scales. Correlation and multiple regression analyses were applied to determine relationships and the strength of influence between independent variables and the dependent variable: effective adaptation to promotions. Ethical standards were maintained through informed consent, participant anonymity, and adherence to the ethical guidelines. This structured approach ensured methodological rigor and validity in exploring the role of social media in agricultural marketing performance.

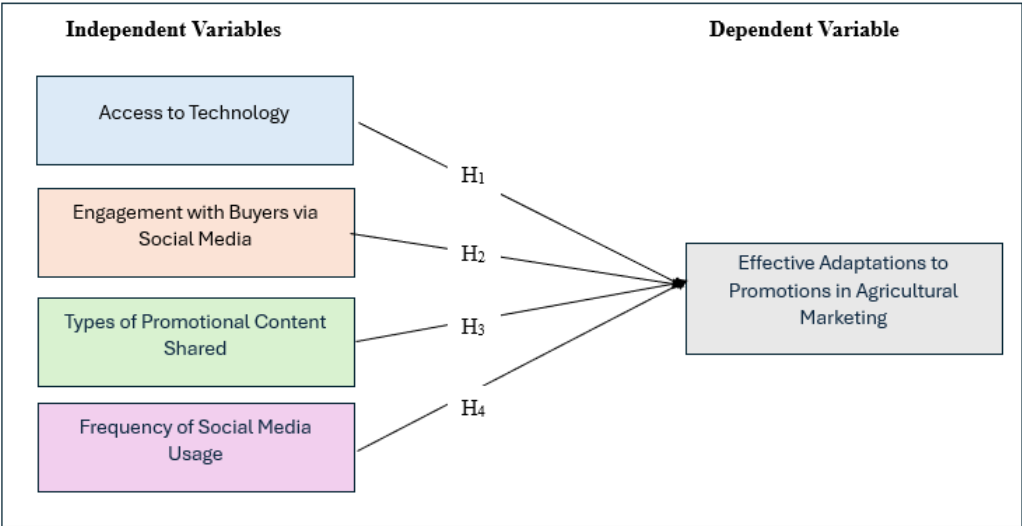


Figure 01: Conceptual Framework

3. Data Analysis and Results

The overall Cronbach’s Alpha value for the dataset was 0.810, indicating a high level of internal consistency among the items used in the questionnaire. This confirms that the measurement items for the constructs are reliable and can be used for further analysis.

Table 01: ANOVA Table

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101.871	4	25.468	53.798	.000 ^b
	Residual	142.966	302	.473		
	Total	244.838	306			

a. Dependent Variable: DV_Mean
b. Predictors: (Constant), FS_Mean, EB_Mean, AT_Mean, TPC_Mean

The p value of the analysis is less than 0.05, denoting that the analysis is statistically significant.

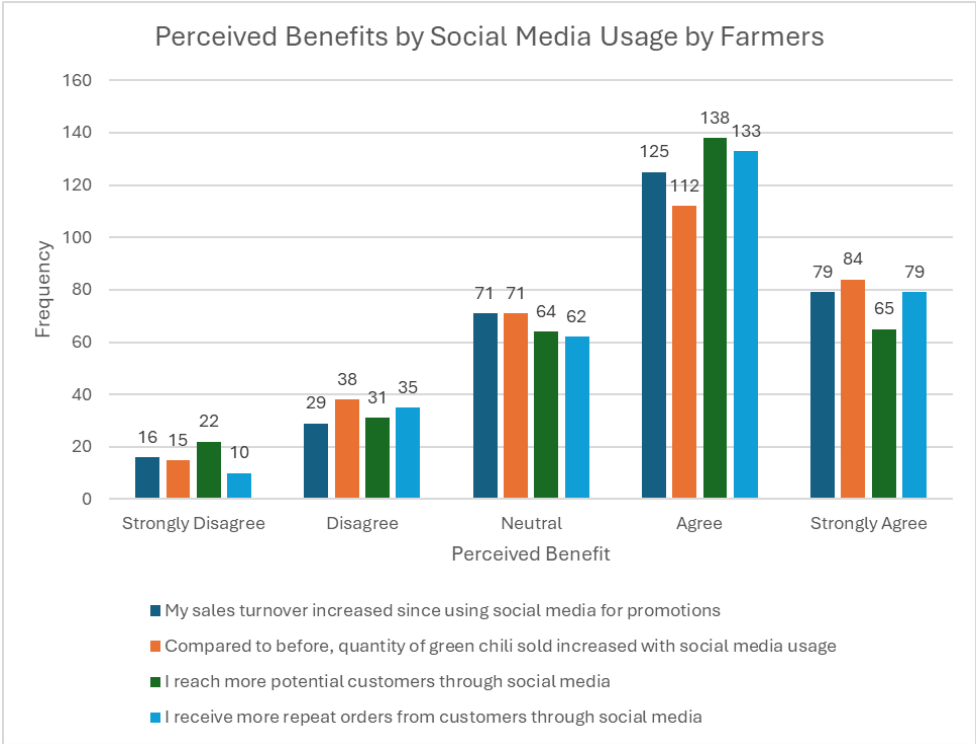


Figure 02: Perceived Benefits by Social Media Usage of Farmers

The results of the survey reveal a generally positive perception among green chili cultivators regarding the use of social media for marketing and promotional adaptations. A significant proportion of respondents reported improvements in key marketing outcomes attributed to their engagement on digital platforms. Specifically, 63.75% of the farmers either agreed or strongly agreed that their sales turnover increased as a result of using social media for promotions. Similarly, 61.25% indicated that the quantity of green chili sold had increased compared to prior to their use of social media. These findings suggest that social media engagement translates not only to greater visibility but also to tangible improvements in sales and business performance. In addition, 63.4375% of respondents agreed that social media has helped them reach more potential customers, emphasizing the power of digital platforms to extend the market reach of smallholder farmers beyond traditional local buyers. Furthermore, 66.25% of farmers acknowledged receiving more repeat orders from customers through social media marketing, highlighting that online engagement also fosters customer loyalty and sustains business relationships. These insights align with the existing literature which notes that interactive and trust-based digital communication can significantly improve market linkage and consumer retention (FAO, 2024).

4. Discussion

The findings reveal that social media usage significantly enhances the marketing performance of green chili cultivators in Sri Lanka’s North Western Province, confirming the hypotheses and aligning with existing literature on digital agricultural marketing. Consistent with Sashi, (2012), active engagement with buyers on platforms such as Facebook and WhatsApp fosters two-way communication, leading to stronger customer relationships and increased repeat

sales. Similarly, access to technology and frequent social media use were positively associated with promotional effectiveness.

The results underscore the transformative potential of social media in empowering smallholder farmers by expanding their market reach, enhancing visibility, and facilitating direct sales without intermediaries. However, limitations include disparities in digital literacy, inconsistent internet connectivity, and reluctance among some farmers to fully adopt online marketing due to mistrust of digital transactions. An unexpected outcome was the relatively high adoption of visual content, which emerged as a strong driver of engagement and sales, suggesting that visual storytelling is particularly effective in agricultural promotion. Overall, the study highlights that structured, frequent, and trust-oriented social media use can substantially improve smallholder marketing resilience and income stability.

5. Conclusions and Recommendations

The study concludes that social media has a significant and positive influence on the marketing performance of green chili cultivators in Sri Lanka's North Western Province. The findings clearly demonstrate that platforms such as Facebook and WhatsApp enable farmers to reach wider markets, improve sales turnover, and strengthen customer relationships through direct and interactive communication. Engagement with buyers emerged as the strongest determinant of effective promotional adaptation, affirming that two-way digital interactions build trust and loyalty, leading to sustained market success. The study also revealed that visual and interactive content such as customer testimonials, harvest photos, and short videos, drives higher engagement, confirming the importance of content diversity in digital promotions.

These findings have both practical and policy implications. For farmers, developing digital literacy, maintaining consistent engagement, and diversifying content are essential to fully harness the benefits of social media marketing. Agricultural extension services and government agencies should implement targeted digital marketing training programs, improve rural internet infrastructure, and create user-friendly promotional platforms for farmers. Policymakers and NGOs are encouraged to integrate digital marketing initiatives into agricultural development frameworks, provide incentives for innovative online marketing practices, and ensure equitable access.

Academically, the research contributes to understanding how digital platforms enhance smallholder marketing resilience in developing economies. Future studies should focus on longitudinal and comparative analyses to examine the long-term impact of social media on agricultural marketing across regions and crop sectors. Overall, social media emerges as a transformative tool capable of reducing distress selling and promoting inclusive, sustainable agricultural growth in Sri Lanka.

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Thematic Track: Business & Hospitality Management

Abstract number: 78

The role of AI enabled services in enhancing customer retention: A case study of Ceylinco Life Insurance PLC, Jaffna branchSineka P.¹, Jathursana S.^{1*}¹Department of Business Management, British College of Applied Studies, Sri Lanka**Abstract**

This study explores how AI enabled services can retain customers more effectively in the life insurance industry using the case of Ceylinco Life Insurance PLC, Jaffna Branch, Sri Lanka (Jaffna, 2025). In today's digital transformation era, it is of crucial essence to understand the efficacy of certain AI applications on policyholder loyalty for strategic investment reasons. The primary purpose of this study was to empirically test how three important AI enabled services availability of AI chatbot services, AI driven personalized recommendations, and AI based. Automated reminders and notifications-affect customer retention. A quantitative, deductive approach is followed with a structured, self-completion online questionnaire among the customers at the branch in question. Simple random sampling 100 valid responses that were analyzed using statistical software, SPSS. Analysis, statistical analysis involved Pearson's correlation to study bivariate relationships and multiple linear regression to test the three hypotheses set for the study. The results proved a very strong statistically significant positive relationship between the combined AI services and customer retention, where 86.1% of the variance in retention could be explained by the model. All three AI services had significant individual impacts, AI driven personalized recommendation was the most influential, followed by AI based automated reminders and AI chatbot accessibility. The correlation matrix also supported very strong individual relationships of each AI service with retention. To summarize, these findings give enough evidence that AI enabled services are a core strategic asset for maintaining customer relationships, with pronounced emphasis on the value of personalization. The Jaffna Branch should, therefore, further develop hyper personalized recommendation algorithms, strategically integrate its chatbots, recommendations, and reminders within the seamless customer journey, and establish continuous feedback mechanisms to enhance the efficiency of each service. Future research should exactly replicate this research within other branches for developing a coherent companywide AI strategy.

Keywords: AI Enabled Services, Customer Retention, Jaffna Branch, Life Insurance

The Role of AI Enabled Services in Enhancing Customer Retention: A Case Study of Ceylinco Life Insurance PLC, Jaffna Branch

1. Introduction

Customer retention has become a crucial strategic issue in contemporary insurance markets, where retaining an existing policyholder is more profitable and efficient than attracting a new customer. In this digital transformation at rapid speed, AI technology is increasingly being adopted by insurance companies to enhance efficiency in services and provide greater personalization of experience (Holbrook, 2025). Ceylinco Life Insurance PLC is one of the forefront life insurance providers in Sri Lanka that has integrated various AI enabled systems, like chatbots, personalized recommendations, and automated reminders, to support customer communication and service delivery.

Even though AI enabled services have already gained momentum in the insurance industry, there is still limited empirical evidence in the Sri Lankan context regarding how these specific AI applications actually influence customer retention. This is particularly true at Ceylinco Life Insurance PLC, Jaffna Branch, where it is not well understood if AI chatbots, personalized recommendations, and automated reminders significantly help in keeping customers loyal and engaged over time.

Understanding the impact of AI enabled services on customer retention is important because it provides valuable insights for strategic decision-making. If AI services can increase satisfaction, reduce waiting time, improve information accuracy, and guide customers more effectively, then the company would be in a position to strengthen its digital strategy, invest in the right technologies for much improved long-term customer loyalty (TechProInsights, 2024). This study will help identify which AI service dimensions are most effective in improving retention.

This research work seeks to explore how AI enabled services influence customer retention at Ceylinco Life Insurance PLC, Jaffna Branch. Specifically, the study investigates the impact of AI chatbot accessibility, AI driven personalized recommendations, and AI based automated reminders on keeping customers satisfied, engaged, and loyal to the company. This study attempts to explore which dimension in AI service has the most significant influence in retaining long-term policyholders.

2. Methodology

This study employed a quantitative research design because the purpose was to test the impact of AI enabled services on customer retention using numerical data. A deductive approach was followed, whereby, based on existing theories, three hypotheses were developed and then tested using real responses from customers of Ceylinco Life Insurance PLC, Jaffna Branch.

Primary data was collected through a structured Google Form questionnaire (Hassan, 2025). This method was selected because it allowed the researcher to reach policyholders directly and actually elicit their real opinions about AI services. Simple random sampling was used in the study because it helped the researcher to gather responses quickly from customers who were easily reachable.

In total, 100 valid responses were collected from the Google Form, which is sufficient for any analysis on correlation and regression. Though Simple random sampling limits generalizability, it allowed the researcher to collect direct feedback from actual service users who have experienced AI-enabled services from Ceylinco Life (Discovery, 2024).

A multi-item Likert scale questionnaire was used for measuring the AI chatbot accessibility, AI-based reminders, personalized recommendations, and customer retention. SPSS was used to analyse the data. Pearson correlation identified the strength of relationships among variables, while multiple linear regression measured the individual effect of each AI factor on customer retention.

The steps involved in the research design included problem identification, developing questionnaire items informed by literature, distribution of the survey, data collection and cleaning, and statistical testing. Lastly, results were interpreted to understand the strength with which AI enabled services contribute to customer retention performance within an organization.

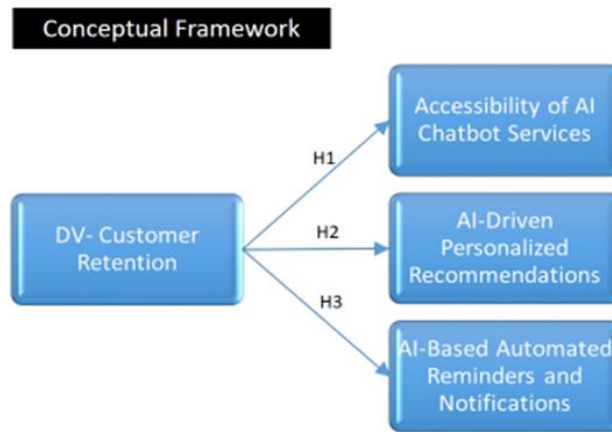


Figure 01: Conceptual Framework

Hypotheses Development

H1 – There is a significant positive relationship between the accessibility of AI chatbot services and customer retention.

H2 – There is a significant positive relationship between AI driven personalised recommendations and customer retention.

H3 – There is a significant positive relationship between AI based automated reminders and notifications and customer retention.

3. Data Analysis and Results

These findings clearly show that AI enabled services strongly improve customer retention in the life insurance industry. The customers feel more valued, supported, and confident in continuing their policies when given personalized recommendations, fast support through chatbots, and timely reminders. AI not only automates operations but creates convenience, builds trust, and loyalty in customers, which decreases their likelihood of switching to other competitors (Somatirtha, 2025).

Table 01: Coefficients

Coefficients ^a						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.146	.189		.775	.441
	IV1	.225	.066	.258	3.388	.001
	IV2	.432	.094	.424	4.577	<.001
	IV3	.314	.090	.293	3.496	<.001

a. Dependent Variable: DV

The Coefficients table gives specific details on the contribution of each AI service. All three independent variables are statistically significant predictors of customer retention, as their p-values (Sig.) are all below the common threshold of 0.05. AI-Driven Personalized Recommendations (IV2) makes the strongest unique contribution, with the highest standardized coefficient (Beta = 0.424) and a highly significant p-value ($p < .001$). This is closely followed by AI Based Automated Reminders and Notifications (IV3, Beta = 0.293, $p < .001$), and finally, the Accessibility of AI Chatbot Services (IV1, Beta = 0.258, $p = .001$). Since the unstandardized B coefficients for the three variables are positive, an increase in each AI service is associated with an increase in customer retention. Hence, to improve customer retention, the Jaffna Branch should invest and refine all three services but emphasize developing highly personalized AI recommendations.

Table 02: Model Summary

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.928 ^a	.861	.856	.28129	.861	197.479	3	96	<.001

a. Predictors: (Constant), IV3, IV1, IV2

The Model Summary table shows a very effective regression model in explaining customer retention. The R is 0.928, which means there is a very strong positive relationship between the combined Accessibility, Personalized Recommendations, and Automated Reminders variables on the one hand, and the dependent variable of Customer Retention on the other. This R Square of 0.861 indicates that 86.1% of the variation in customer retention at Ceylinco Life Insurance PLC, Jaffna Branch, could be explained by the three AI enabled services, which is quite significant. The Adjusted R Square follows suit with an impressive value of 0.856, thus justifying the fact that this model is not overly inflated because of the number of predictors.

Table 03: Correlations

Correlations					
		DV	IV1	IV2	IV3
DV	Pearson Correlation	1	.859**	.902**	.877**
	Sig. (2-tailed)		<.001	<.001	<.001
	N	100	100	100	100
IV1	Pearson Correlation	.859**	1	.855**	.818**
	Sig. (2-tailed)	<.001		<.001	<.001
	N	100	100	100	100
IV2	Pearson Correlation	.902**	.855**	1	.881**
	Sig. (2-tailed)	<.001	<.001		<.001
	N	100	100	100	100
IV3	Pearson Correlation	.877**	.818**	.881**	1
	Sig. (2-tailed)	<.001	<.001	<.001	
	N	100	100	100	100

** . Correlation is significant at the 0.01 level (2-tailed).

Interpretation of the Correlations Results The regression results are further bolstered by the strong support from the Correlations matrix, which denotes that each AI enabled service has an extremely strong, positive, and statistically significant individual relationship with customer retention. All Pearson Correlation values between the independent variables (IV1, IV2, IV3) and the dependent variable (DV) were above 0.85, while the AI driven personalized recommendation (IV2) showed the highest bivariate correlation with customer retention ($r = .902$, $p < .001$). From this result, it appears that, on its own, personalized recommendations have the highest direct association with customer retention. The table also indicates that the independent variables all highly correlate with each other (e.g., $r = .855$ between IV1 and IV2), something expected since they are all part of the same ecosystem of AI enabled services. Although there is this multicollinearity, the coefficients that are significant in the regression table confirm that each variable provides a unique and significant contribution to predicting customer retention beyond what it shares with the others.

4. Discussion

The results from the analysis of data indicate that AI-enabled services significantly improve customer retention at Ceylinco Life Insurance PLC, Jaffna Branch. The model explained 86.1% of the variation in retention. Among the three services, AI-driven personalized recommendations were the most powerful, reflecting that customers place considerable value on receiving guidance tailored to their individual circumstances that shows understanding and support. Automated reminders contributed meaningfully by avoiding policy lapses through timely notifications, while chatbot accessibility increased customer convenience and swift problem-solving. These reflect that AI tools enhance trust, satisfaction, and engagement by rendering experiences far more personalized and efficient. There are also several limitations within the study, such as

potential multicollinearity between some of the predictors, inability to establish causation because of the cross-sectional design, and limited generalizability since data were collected only from the Jaffna Branch.

5. Conclusions and Recommendations

Conclusion

In conclusion, the data provides compelling evidence that the implementation of AI enabled services plays a critical and statistically significant role in enhancing customer retention at Ceylinco Life Insurance PLC, Jaffna Branch. The analysis confirms that all three services AI Chatbot Accessibility, AI Driven Personalized Recommendations, and AI Based Automated Reminders are powerful drivers of retention, with personalized recommendations identified as the most influential factor. This strongly suggests that customers value a proactive, tailored, and efficient service experience, which these AI tools effectively deliver. The findings validate the branch's investment in digital transformation and position AI not as a mere technological upgrade, but as a fundamental strategy for sustaining customer relationships in a competitive market.

Recommendations

The Jaffna Branch should make additional efforts to enhance AI driven personalized recommendations in order to further strengthen customer retention. As it was the strongest variable influencing retention, the branch should make better use of customer data for crafting very relevant offers, policy suggestions, and proactive financial advice that will make each customer feel uniquely understood.

The branch should also integrate all three AI services-chatbot, recommendations, and automated reminders-in one connected customer journey. For instance, if a customer asks about a particular benefit through the chatbot, the system can immediately recommend a corresponding product and send a follow-up reminder later on. This would make the service experience seamless and continuous.

Finally, the branch should establish a continuous monitoring and improvement mechanism for the AI systems. Short feedback surveys after each AI interaction will highlight the service gaps. Also, the same research needs to be replicated in other branches to validate findings nationwide and develop a unified AI strategy for Ceylinco Life.

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Thematic Track: Business & Hospitality Management

Abstract number: 80

The role of artificial intelligence in enhancing customer satisfaction: A case study on Cargills food city in the Sri Lankan retail sectorSiyana T.¹, Jathursana S.^{1*}¹Department of Business Management, British College of Applied Studies, Sri Lanka**Abstract**

The purpose of this study is to investigate how artificial intelligence (AI) might enhance customer happiness in Sri Lanka's retail industry, specifically focusing on Cargills Food City. There is still a research gap concerning the quantifiable impact of AI applications on customer happiness in the local retail setting, despite the growing use of AI technologies to improve engagement, personalize services, and expedite operations. In order to close this gap, the study examines the impact of three key AI-driven technologies on total customer satisfaction: chatbots and virtual assistants, personalized product recommendations, and customer feedback analysis. One hundred Cargills Food City consumers were given structured questionnaires using a Google Form survey as part of a quantitative, correlational research design. To ascertain the statistical correlations between the variables, descriptive and regression analyses were performed on the gathered data using SPSS. The study indicates that three AI applications collectively enhance customer satisfaction significantly, with personalized product recommendations and customer feedback analysis being key contributors. While chatbots and virtual assistants show a mild positive correlation, their impact is amplified when combined with personalization and feedback mechanisms. The study comes to the conclusion that enhancing consumer happiness in the retail industry requires the strategic application of AI technologies, especially personalization and data-driven feedback. To guarantee a smooth and interesting client experience, it is advised that Cargills Food City enhance these AI capabilities through ongoing system development and employee training.

Keywords: Artificial Intelligence, Customer Satisfaction, Chatbots, Personalized Recommendations, Customer Feedback, Retail Sector.

The Role of Artificial Intelligence in Enhancing Customer Satisfaction: A Case Study on Cargills Food City in the Sri Lankan Retail Sector

1. Introduction

Artificial intelligence (AI) is fundamentally altering how the retail industry interacts with consumers by transforming traditional service delivery into intelligent, data-driven experiences. Cargills Food City has emerged as a pioneer in the use of AI in Sri Lankan retail to enhance customer satisfaction through improved productivity, engagement, and personalization. AI-powered solutions like chatbots, virtual assistants, personalized product recommendations, and automated feedback systems enable Cargills to assess customer behavior patterns and tailor services to individual needs. This predictive capability not only increases convenience but also ensures that customers receive relevant offers, timely responses, and consistent service quality across all touchpoints.

According to recent studies, the integration of AI into retail operations fosters a customer-centric environment that enhances both transactional satisfaction and emotional loyalty (Fernando, 2025); (Wijesinghe, 2025). By automating repetitive processes and improving decision-making through real-time analytics, AI supports retailers in reducing waiting times, improving communication accuracy, and creating a seamless shopping experience. Thus, the adoption of AI in Cargills Food City is not just an operational innovation it represents a strategic initiative aimed at retaining customers, increasing brand loyalty, and sustaining a competitive edge in Sri Lanka's fast-evolving retail market.

2. Research Problem and Objectives

There is little empirical data on AI's quantifiable effects on customer happiness in Sri Lanka's retail industry, despite the technology's extensive use worldwide. Specifically, it's yet unclear which AI technologies best enhance the general consumer experience at Cargills Food City locations. To help the company strategically optimize its AI investments and achieve better service outcomes and long-term customer loyalty, it is imperative that this research gap be filled.

Therefore, this study focuses on assessing the impact of three major AI applications Chatbots and Virtual Assistants, Personalized Product Recommendations, and Customer Feedback Analysis on customer satisfaction at Cargills Food City. The specific objectives of the study are as follows:

1. To examine the influence of Chatbots and Virtual Assistants on customer satisfaction.
2. To evaluate the effect of Personalized Product Recommendations on customer satisfaction.
3. To assess the impact of Customer Feedback Analysis on overall customer satisfaction.

3. Methodology

In order to investigate the connections between AI technology and customer happiness in the retail industry, this study used a quantitative, correlational research approach. Regular Cargills Food City patrons from a few chosen Sri Lankan locations made up the study's demographic. 100 participants were chosen using a purposive sampling

technique to guarantee that each responder had previously used AI-related services like chatbots, online ordering, or tailored suggestions (Hassan, 2025).

A structured online survey via Google Forms collected data on customer views of AI applications and satisfaction levels, using a five-point Likert scale for responses. The first section gathered demographic data. Data analysis was conducted with SPSS software, employing multiple regression analysis to evaluate the predictive power of AI tools on customer satisfaction, Pearson's correlation analysis to explore the relationships between AI variables and satisfaction, and descriptive statistics to summarize responses (Hassan, 2025).

4. Conceptual Framework

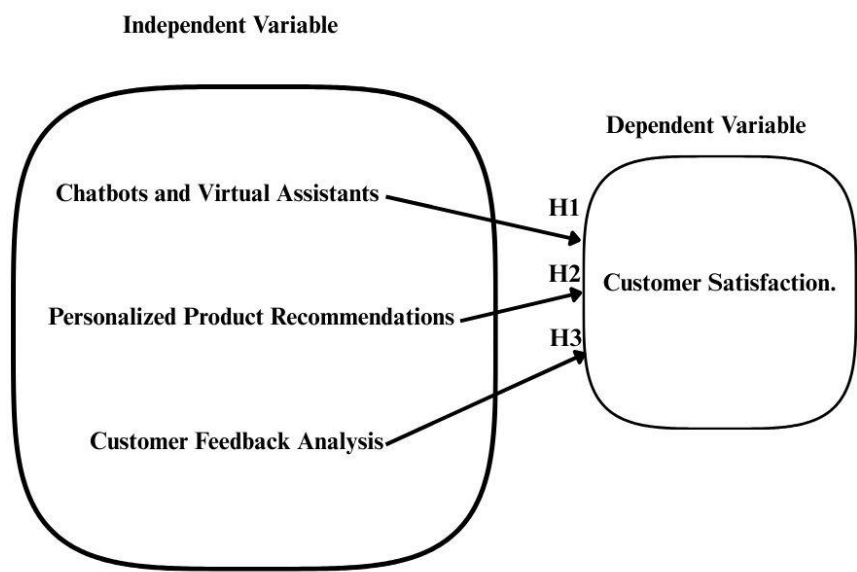


Figure 01: Conceptual Framework

5. Hypotheses Development

The following theories have been developed to investigate the connection between Artificial Intelligence (AI) applications and consumer happiness at Cargills Food City in the Sri Lankan retail industry, based on the literature review and conceptual framework.

H1: There is a significant positive impact of Chatbots and Virtual Assistants on Customer Satisfaction.

H2: There is a significant positive impact of Personalized Product Recommendations on Customer Satisfaction.

H3: There is a significant positive impact of Customer Feedback Analysis on Customer Satisfaction.

These theories seek to evaluate how well various AI applications help to raising consumer satisfaction levels. In order to ascertain the degree and importance of each AI variable's impact on customer happiness, the study employs quantitative analysis through regression modeling to test these correlations.

6. Data Analysis and Discussion

SPSS was utilized to perform a structured analysis on data from 100 respondents, beginning with data screening and descriptive statistics to ensure accuracy. Pearson's correlation analysis examined bivariate relationships, followed by multiple regression analysis to identify key factors affecting customer satisfaction (Usmani, 2025).

All three AI-driven tools Chatbots and Virtual Assistants, Personalized Product Recommendations, and Customer Feedback Analysis show statistically significant correlations with customer happiness. Regression testing indicated that Personalized Product Recommendations are the strongest predictor of customer satisfaction, followed by Customer Feedback Analysis and Chatbots and Virtual Assistants. Together, these tools significantly enhance customer satisfaction (Vidhya, 2025).

Table 01: Coefficients

Coefficients ^a						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.116	.064		1.825	.071
	IV1	.424	.079	.470	5.397	<.001
	IV2	.049	.088	.055	.559	.578
	IV3	.456	.066	.465	6.962	<.001

a. Dependent Variable: DV

Regression analysis was used to determine each AI variable's unique impact to consumer happiness. IV2 (Personalized Product Recommendations) did not have a significant independent influence, but IV1 (Chatbots and Virtual Assistants) and IV3 (Customer Feedback Analysis) were statistically significant predictors, as Table 1 illustrates.

IV1 and IV3 significantly positively influence customer satisfaction, with standardized beta values of $\beta = 0.470$ ($p < 0.001$) and $\beta = 0.465$ ($p < 0.001$), respectively. In contrast, IV2 shows a low and non-significant beta value ($\beta = 0.055$, $p = 0.578$), indicating a limited direct impact when considered alongside other AI tools.

The study identifies that AI-driven tools, particularly chatbots, virtual assistants, and customer feedback analysis, are key in improving customer satisfaction by enhancing responsiveness, interaction quality, and service consistency. It recommends Cargills Food City to enhance these tools and incorporate tailored product recommendations for a better customer experience.

Table 01: Model Summary

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			Sig. F Change
						F Change	df1	df2	
1	.938 ^a	.880	.877	.17675	.880	235.624	3	96	<.001

a. Predictors: (Constant), IV3, IV1, IV2

The overall strength and predictive ability of the regression model created to investigate the effect of Artificial Intelligence (AI) technologies on customer satisfaction are shown in the model summary in Table 2. A significant degree of link between the independent variables (AI tools) and the dependent variable (customer happiness) was indicated by the model's very strong multiple correlation coefficient ($R = 0.938$). The combined effects of Chatbots and Virtual Assistants (IV1), Personalized Product Recommendations (IV2), and Customer Feedback Analysis (IV3) account for about 88.0% of the variation in customer satisfaction, according to the R Square value of 0.880.

The model's stability and generalizability are confirmed by the Adjusted R Square score of 0.877, which indicates little decline in predicting accuracy when applied to various samples. The three AI variables together had a considerable impact on customer satisfaction, according to the total regression model, which was statistically significant ($F(3, 96) = 235.624, p < 0.001$). This robust predictive relationship suggests that AI-enabled technologies have a significant impact on how customers perceive and interact with Cargills Food City's retail environment.

Table 03: Correlations

		Correlations			
DV		DV	IV1	IV2	IV3
	Pearson Correlation	1	.892**	.878**	.888**
IV1	Sig. (2-tailed)		<.001	<.001	<.001
	N	100	100	100	100
	Pearson Correlation	.892**	1	.913**	.800**
IV2	Sig. (2-tailed)	<.001		<.001	<.001
	N	100	100	100	100
	Pearson Correlation	.878**	.913**	1	.847**
IV3	Sig. (2-tailed)	<.001	<.001		<.001
	N	100	100	100	100
	Pearson Correlation	.888**	.800**	.847**	1
	Sig. (2-tailed)	<.001	<.001	<.001	
	N	100	100	100	100

** . Correlation is significant at the 0.01 level (2-tailed).

The bivariate correlations between the three AI variables Chatbots and Virtual Assistants (IV1), Personalized Product Recommendations (IV2), and Customer Feedback Analysis (IV3) and the Dependent Variable (DV), Customer Satisfaction, were investigated by correlation analysis, as shown in Table 3.

The findings show that, at the 0.01 significance level (2-tailed), all independent variables showed substantial, positive, and statistically significant associations with customer satisfaction. In particular, there was a connection of $r = 0.892$ ($p < 0.001$) for chatbots and virtual assistants, $r = 0.878$ ($p < 0.001$) for personalized product recommendations, and $r = 0.888$ ($p < 0.001$) for customer feedback analysis. These figures imply that customer happiness rises in direct proportion to the employment of AI solutions.

Strong correlations were also found between the independent variables themselves, such as between IV1 and IV2 ($r = 0.913$) and between IV2 and IV3 ($r = 0.847$), suggesting that these AI technologies are frequently used to provide a more effective and integrated user experience. Despite these strong correlations, the regression model was able to differentiate each AI dimension's unique contribution to customer happiness, demonstrating that each AI dimension has a significant impact on the entire consumer experience at Cargills Food City.

7. Conclusions and Recommendations

Conclusions

Featuring an emphasis on Cargills Food City, the study sought to determine how artificial intelligence (AI) may improve customer happiness in Sri Lanka's retail industry. The results showed that the three AI tools customer feedback analysis, personalized product recommendations, and chatbots and virtual assistants all significantly improve consumer happiness. The most significant predictors among these were Chatbots and Virtual Assistants and Customer Feedback Analysis, indicating their significance in developing dynamic, responsive, and data-driven service experiences. Personalized Product Recommendations demonstrated a positive correlation, but when analyzed separately, its impact was less significant, suggesting that its contribution is enhanced when combined with the other AI technologies (Fernando, 2025).

Considering the three AI variables accounting for 88% of the variance in customer satisfaction, the results further supported the overall robustness of the regression model. This suggests that AI technologies are changing the nature of customer contact in Sri Lanka's retail sector in addition to improving operational efficiency. According to the study's findings, Cargills Food City may achieve more customer satisfaction and loyalty by implementing AI in a way that significantly improves service quality, responsiveness, and customization (Wijesinghe, 2025).

Recommendations

Strengthen Chatbots and Virtual Assistants: Cargills should continue to develop and upgrade chatbot systems to handle more complex and personalized customer interactions efficiently. **Enhance Customer Feedback Analysis:** Regular monitoring and AI-based analysis of feedback should be implemented to identify service gaps and

address customer concerns promptly (Bloomenthal, 2025). Integrate Personalization Features: Personalized product recommendation systems should be refined to work in synergy with chatbot and feedback platforms, ensuring consistent and tailored communication across all customer touchpoints. Employee Training and System Optimization: Staff should be trained to manage and interpret AI-driven insights effectively, ensuring that technology complements human interaction rather than replacing it. Continuous Evaluation: Establish an AI performance monitoring dashboard to track customer satisfaction trends and ensure sustainable improvement over time. In conclusion, by promoting smooth communication, individualized service delivery, and effective problem solving, AI significantly contributes to raising customer happiness. In the ever-changing retail market of Sri Lanka, Cargills Food City will be able to sustain its competitive advantage and fortify long-term customer connections by strategically investing in AI technologies.

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Thematic Track: Business & Hospitality Management

Abstract number: 89

The influence of artificial intelligence applications on delivery efficiency in online grocery services: A case study on Uber Jaffna

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Abstract

This study investigates the influence of artificial intelligence applications on delivery efficiency within Uber Jaffna's online grocery service a critical operational challenge in Northern Sri Lanka. The rapid integration of AI into logistics platforms such as Uber Jaffna is transforming last-mile delivery through demand forecasting, route optimization, and inventory management, but a clear research gap exists in terms of the quantified impact of those specific AI functionalities on delivery performance in such regional markets. Addressing this gap, the primary objective of this paper is to analyze the effect of these three AI tools on the delivery efficiency of Uber Jaffna. Using a quantitative correlational research design, data were collected using a self-administered questionnaire from a simple random sample of one hundred and one active Uber Jaffna users. The research design ensured robust data collection via a carefully validated instrument that used a five-point Likert scale, with subsequent analysis using Pearson's correlation and multiple regression in SPSS to determine both individual relationships and combined predictive power. The results showed strong positive correlations between all three AI tools and delivery efficiency. However, the multiple regression analysis identified AI powered inventory management and AI based demand forecasting as the only statistically significant unique predictors of delivery efficiency, with route optimization failing to contribute a significant independent effect. The overall regression model was strong, explaining over fifty-seven percent of the variance in delivery efficiency. The implication from this study is that, while all three AI tools are strongly associated with operational performance, it is inventory management and demand forecasting that are primary independent drivers directly influencing delivery efficiency. Therefore, it would be appropriate if the operations managers at Uber Jaffna were recommended to prioritize their investments in refining algorithms for inventory management and enhancing the accuracy of demand forecasting systems to maximize their impacts. Practical implications include providing clear evidence-based guidelines on how strategic resource allocation could be made in last-mile logistics. In addition, a diagnostic review of the route optimization system is advocated for identifying and rectifying implementation barriers. Future research should employ longitudinal designs with objective performance data across different regions to further validate these findings and explore the evolving role of AI in competitive regional markets.

Keywords: Artificial Intelligence, Delivery Efficiency, Demand Forecasting, Inventory Management, Route Optimization.

The influence of artificial intelligence applications on delivery efficiency in online grocery services: A case study on Uber Jaffna

1. Introduction

Research Problem: The last-mile delivery segment is widely recognized as the most complicated and expensive component of the e-grocery supply chain (Escudero-Santana, 2025). For services such as Uber Jaffna operating within competitive urban markets, inefficiencies in this final leg of delivery directly translate into increased operation costs, delays, and reduced customer satisfaction. There is a critical challenge to determine which technology investments yield the biggest return in terms of efficiency. While AI has been hailed as a game-changer, there is a lack of concrete empirical evidence that quantifies the exact impact of each AI application, such as demand forecasting, route optimization, and inventory management on delivery efficiency within the unique operational context of North Sri Lanka.

Justification: The importance of this research lies in the potential to develop an evidence-based framework for strategic decision-making at Uber Jaffna. By identifying which AI functionalities are the most influential regarding driving delivery performance, management can shift away from mere technological adoption toward a focused investment strategy. This will ensure the best use of often very limited resources so that technological advancement will translate directly into tangible improvements in the speed, reliability, and cost of services, thereby reinforcing the company's competitive position within the Jaffna market.

Research Objectives: The main objective of the study is to analyse and evaluate how important applications of Artificial Intelligence influence the delivery efficiency in the online grocery delivery service offered by Uber Jaffna. Considering this, the specific objectives that this study pursues are threefold: to establish how AI-Based Demand Forecasting affects delivery efficiency, to analyse the impact of AI-Driven Route Optimisation on delivery efficiency, and to evaluate the role of AI-Powered Inventory Management on delivery efficiency.

2. Methodology

A quantitative, cross-sectional research design was applied to study the relationships between applications of AI and delivery efficiency in the operational context at Uber Jaffna. In this approach, numerical data is gathered from a sample population at a single point in time, which can then be subjected to robust statistical analyses in terms of the proposed variable relationships.

Primary data was collected through an online, structured questionnaire that was forwarded to the active customers of the grocery delivery service of Uber Jaffna. The survey was made available on digital platforms for four weeks, resulting in simple random sampling of 101 completed responses suitable for analysis. This questionnaire used the 5 point Likert scale on all research constructs to elicit the perceptions of the respondents and ensured standardized measurement of variables (Anantharworn, 2025).

The research instrument contained a self-administered questionnaire, which was divided into two main sections. The first part obtained the essential demographic details of the respondents such as age, sex, educational level, and patterns of service usage. The second portion contained the measurement items for the three independent variables: AI-based demand forecasting, route optimization, and inventory management, together with the

dependent variable of delivery efficiency, all operationalised through multiple indicator items to have comprehensive coverage (Anantharworn, 2025).

The sequence of the research procedure was developed in a systematic order: from the development and validation of questionnaires to pilot testing with 10 respondents to refine the instrument, and then incorporating necessary adjustments based on the pre-test into the main survey. Then, the survey, data cleaning, and validation processes were done. Lastly, the statistical analysis was executed through correlation and multiple regression methods to analyse both bivariate relationships and predictive capabilities between the variables studied.

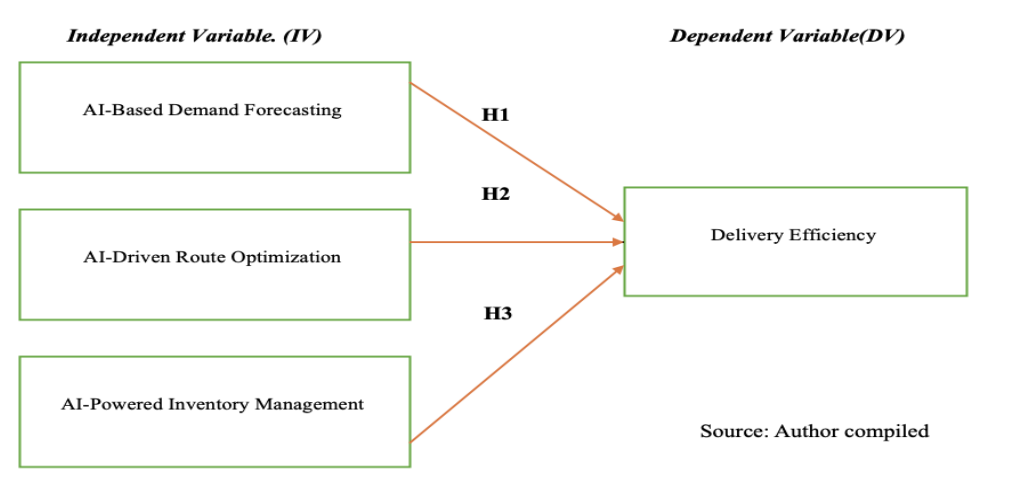


Figure 01: Conceptual Framework

Hypothesis Development

- H1: There is a significant relationship between AI-Based Demand Forecasting and Delivery Efficiency.
- H2: There exists a significant relationship between AI-Driven Route Optimization and Delivery Efficiency
- H3: There is a significant relationship between AI-Powered Inventory Management and Delivery Efficiency

3. Data Analysis and Results

In the analytical approach, correlation analysis was first done to understand the relationship of the variables, followed by multiple regression analysis for predictive relationships.

In this research, delivery efficiency from the three AI applications was predicted using multiple regression analysis.

Table 01. Coefficients

Coefficients ^a					
		Unstandardized Coefficients		Standardized Coefficients	
Model		B	Std. Error	Beta	t
1	(Constant)	.188	.394		.476
	IV1	.343	.108	.309	3.169
	IV2	.207	.108	.186	1.918
	IV3	.387	.098	.364	3.933
a. Dependent Variable: DV					

Coefficients analysis indicated that demand forecasting and inventory management are statistically significant positive predictors of delivery efficiency, but route optimization does not evidence statistical significance at the conventional .05 threshold.

The regression analysis results identify clear evidence for the study's hypotheses. Hypothesis 1 (H₁) is, therefore, supported, since AI-Based Demand Forecasting significantly relates to delivery efficiency ($\beta = 0.309$, $p = 0.002$). Correspondingly, Hypothesis 3 (H₃) is also supported, where AI-Powered Inventory Management comes out to have the strongest significant positive link with delivery efficiency ($\beta = 0.364$, $p < 0.001$). On the contrary, Hypothesis 2 (H₂) is not supported, since AI-Driven Route Optimization has failed to provide a statistically significant link to delivery efficiency ($\beta = 0.186$, $p = 0.058$).

Table 01: Model Summary

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.757 ^a	.573	.559	.23553	.573	43.316	3	97	.000
a. Predictors: (Constant), IV3, IV2, IV1									

This regression model explained the dependent variable very strongly, while three AI applications jointly explained 57.3% of variance in delivery efficiency ($R^2 = .573$, Adjusted $R^2 = .559$). Also, the multiple correlation coefficient ($R = .757$) confirmed a substantial relationship between the predictor set and the outcome variable (Frost, no date).

Table 02: Correlation

Correlations					
		DV	IV1	IV2	IV3
DV	Pearson Correlation	1	.670**	.628**	.682**
	Sig. (2-tailed)		.000	.000	.000
	N	101	101	101	101
IV1	Pearson Correlation	.670**	1	.681**	.643**
	Sig. (2-tailed)	.000		.000	.000
	N	101	101	101	101
IV2	Pearson Correlation	.628**	.681**	1	.636**
	Sig. (2-tailed)	.000	.000		.000
	N	101	101	101	101
IV3	Pearson Correlation	.682**	.643**	.636**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	101	101	101	101

** . Correlation is significant at the 0.01 level (2-tailed).

In all three applications of AI, strong positive correlations that are statistically significant, at $p < .01$, with the dependent variable of delivery efficiency range from a low of $r = .682$ for inventory management to $r = .628$ for route optimization and the interceding value of $r = .670$ for demand forecasting. Strong intercorrelations among the independent variables do suggest shared variance but not to the extent that it would invalidate the findings of the regression model.

4. Discussion

This study, therefore, investigates the unique effects of each application of AI on delivery efficiency. Although all three AI functions were strongly interrelated, regression analysis indicated that inventory management and demand forecasting were significant predictors, while route optimization did not contribute uniquely. The findings are also in line with the supply chain literature, which highlights the accuracy of inventory and prediction of demand as operational building blocks by (Samson, 2025).

The most unexpected result comes from the optimization of routes though theoretically important and acknowledged by clients, its relatively limited practical impact may indicate some obstacles to applying the system under the conditions of Jaffna due to local features of infrastructure or system integration issues (Anburuvel, 2025).

Study limitations include the cross-sectional design, which allows no causal inferences; response bias emanating from perceptual measures; limited generalizability because of focus on a single service; and sample size constraints in detecting smaller effects. These findings recommend prioritizing inventory and forecasting investments while conducting route optimization audit.

5. Conclusions and Recommendations

The current study establishes conclusively that AI applications taken together explain a major portion of delivery efficiency for Uber Jaffna's grocery service. The primary conclusion, from the regression analysis, is that AI-powered inventory management and AI-based demand forecasting are the most critical unique predictors directly influencing delivery performance. Though AI-driven route optimization evidenced a very strong simple correlation with efficiency, its effect was not a statistically significant unique contributor in the regression model, therefore needing its current implementation to be fundamentally reviewed.

According to the findings, Uber Jaffna should strategically focus more on improving AI-powered inventory management systems due to their high unique importance for delivery efficiency. These investments should be channelled into real-time stock monitoring, an automatic replenishment system, and predictive analytics to arrive at the optimum level of inventory at partner stores to ensure product availability but avoid surplus stock. The company should enhance its AI-driven demand forecasting by integrating diverse data sources such as historical sales patterns, seasonal fluctuations, and events to enhance the accuracy of delivery planning and efficiency in resource allocation.

An integrated approach becomes necessary to derive maximum operational effectiveness, given the interrelationships of AI systems unveiled in this study. Route optimization needs to be fundamentally revamped from a siloed tool to a component that harmonizes efficiently with inventory and forecasting systems. In such a framework, real-time adjustments will be possible where the inventories and demand forecasts directly inform routing decisions to create a cohesive operational ecosystem.

Therefore, future research should consider a longitudinal study design to deduce causal inferences about implementation versus delivery outcomes using objective performance measures. Extending this to more than one delivery service and to various parts of Sri Lanka will add greater generalizability to these findings and give richer insights into the challenges of implementing AI in different operation environments.

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Thematic Track: Business & Hospitality Management

Abstract number: 223

The impact of AI-generated personalized marketing content on brand loyalty: With reference to Sri Lanka

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Abstract

The purpose of this study is to investigate the impact of AI-driven personalised marketing content on Brand Loyalty in the Context of Sri Lanka. The rapid expansion of Artificial Intelligence (AI) has transformed marketing processes by allowing organisations to send highly personalised content which is aligned with consumer preferences, behaviours, and demographics. Although applications of AI are growing, the impact of AI-generated personalized marketing content on brand equity, particularly in low-income economies such as Sri Lanka, remains under-researched. This study has assessed the effect of AI-driven, personalised marketing content on brand equity through three key elements: customer trust, experience, and relevance. The research employed a quantitative approach, and a structured online questionnaire was distributed to Sri Lankan online consumers. The data was analysed using IBM SPSS 25.0 based on multiple regression analyses. The findings showed that AI-driven personalised content has a significant positive effect on brand equity, while customer experience ($B = 0.359$, $p = 0.000$), relevance ($B = 0.344$, $p = 0.000$), and trust ($B = 0.321$, $p = 0.006$) were all identified as important elements. This study confirms that personalised marketing content, when used consistently, increases consumer emotional attachment and protective behaviours towards brands where the content is viewed positively overall in terms of relevant content delivery. The research contributes to the growing body of evidence in an emerging market context, suggesting that ethical AI usage and transparent data practices are necessary for long-term loyalty. The author suggests that businesses implement customer profiling systems powered by AI, utilise predictive analytics to anticipate customer needs, and provide algorithmic transparency to foster consumer trust. Businesses should also regularly audit their AI systems and incorporate a human voice into AI-generated communications to enhance brand authenticity and foster identity-based meaning in brand-consumer relationships. This research demonstrates how AI can strategically drive customer loyalty and provides an empirically sound framework for utilising AI responsibly for business growth and meaningful consumer relationships.

Keywords: Artificial Intelligence, Brand Loyalty, Customer Experience, Customer Trust, Relevance

The impact of AI-generated personalized marketing content on brand loyalty: With reference to Sri Lanka

1. Introduction

Technological developments have significantly shaped the business environment over the past few decades, increasing reliance on technology.(Cascio & Montealegre, 2016). When digital marketing was introduced, marketers recognised its importance and continued their traditional marketing efforts. However, they later came to understand the indispensable nature of online marketing and its impact on business reputation. Digital marketing has altered the way marketing is conducted. Marketers are concerned about the upcoming trends in marketing and the rapid development of technology (Sheth, 2023). The impact of Artificial intelligence on marketing is an ongoing discussion and a trend in the current context.

AI can personalise the brands' messages based on dynamic consumer behaviour and demographics by maximising Engagement. Artificial Intelligence is an ongoing trend in marketing in the contemporary business world. AI technology can provide a seamless customer experience by addressing customers' unique needs, as it can predict what customers need. AI often plays a vital role in essential marketing efforts (Kumari, 2021). AI technology enables effective communication with customers and provides high-quality service through personalised messages at the right time, ensuring maximum efficiency with fewer interventions (Kumari, 2021).

The rapid development of Artificial Intelligence (AI) has transformed marketing practices by enabling the delivery of personalised content tailored to consumer preferences, behaviour, and demographics (Babatunde et al., 2024). While AI-driven personalisation is widely acknowledged for enhancing customer engagement and improving communication efficiency, its actual impact on long-term brand loyalty remains underexplored (Ahmed et al., 2025). Much of the existing literature emphasises the technological capabilities of AI and its role in improving operational efficiency (Prince, 2024); yet, limited attention has been given to how these personalised marketing interventions influence the emotional and behavioural attachment customers develop toward brands. This lack of clarity raises questions about whether personalisation fosters genuine brand loyalty or simply drives short-term engagement and purchase decisions.

Furthermore, research into AI and marketing has been primarily concentrated in developed economies (Abrokwah-Larbi and Awuku-Larbi, 2023), where digital maturity is high, leaving a significant gap in understanding its relevance and implications in emerging markets, such as Sri Lanka. Consumer responses to AI-driven personalisation may differ across cultural and economic contexts, yet these differences remain under-researched (Mahmud et al., 2025). Similarly, while prior studies have examined digital marketing effectiveness in general, there is an insufficient focus on the balance between personalisation, consumer trust, and privacy concerns, which are critical determinants of loyalty in the digital era. This creates a contextual gap, as consumer perceptions, digital literacy, and levels of AI exposure vary significantly across developing markets. To address this gap, the present study examines how AI-generated personalised marketing content influences brand loyalty among Sri Lankan consumers who actively engage with AI-enabled digital interactions, ensuring a precise alignment between the study's scope and the targeted population. Addressing these gaps is vital to providing businesses with a clearer understanding of how AI-driven personalisation can be strategically leveraged to build sustainable brand loyalty, rather than just transactional benefits.

2. Methodology

This study employed quantitative approaches in conducting the research by gathering primary data directly from respondents through an online Questionnaire with a Likert Scale, ensuring ethical concerns were addressed by obtaining informed consent from the respondents through the questionnaire. Following a survey strategy. The researcher followed a positivist philosophy and deductive approach by analysing theories such as the Theory of Acceptance and Use of Technology, Relationship Marketing Theory, and the Commitment-Trust Theory of Relationship Marketing, and based on these, formulated the hypotheses. The following Conceptual Model was developed to illustrate the relationship between the research variables.

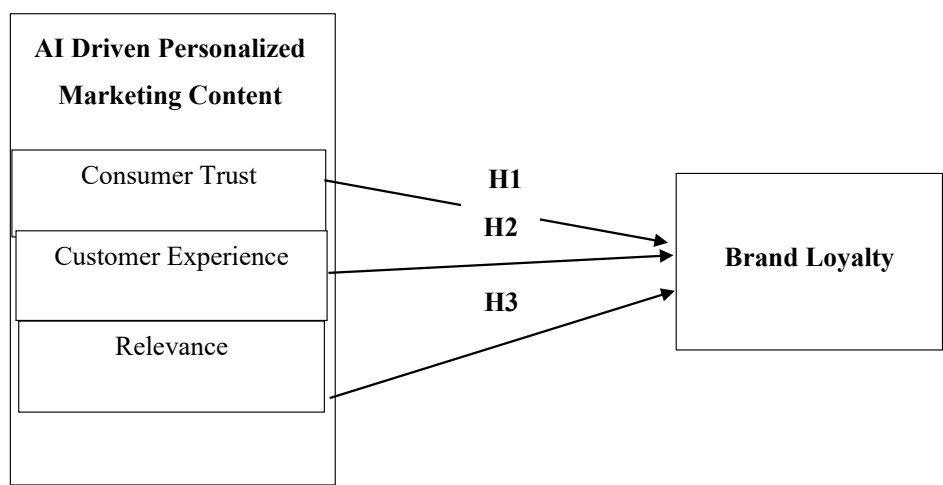


Figure 01: Conceptual Model

(Source: Developed by the researcher, 2025)

The researcher adopted a cross-sectional time horizon, gathering data at a single point in time to capture the respondents' current perceptions. The collected data were analysed using the IBM SPSS 25.0.0 software. The multiple regression analysis was used to test the hypotheses and to identify the impact of AI-driven personalised marketing content on Brand loyalty. The Population of this study will be all the online purchasers of Sri Lanka in 2024, as they are engaging with technologies like AI for personalised content. Approximately 43% of the estimated 11 million internet users in Sri Lanka are online purchasers. Hence, 4,730,000 people will be identified as online purchasers of Sri Lanka in 2024 (International Trade Administration, 2024). The population was defined as Sri Lankan online consumers who have interacted with AI-driven personalised marketing content such as recommendation systems, automated chatbots, personalised social media advertisements, and AI-generated product suggestions. The sample size was determined using the Morgan table, which recommends a minimum of 384 respondents to achieve a 95% confidence level and a 5% margin of error. The convenience sampling technique was employed to recruit the respondents.

3. Data Analysis and Results

The data were analysed by using both descriptive and inferential statistics. From this, the majority of the respondents are Females, accounting for 178 individuals or 56.51% respondents of the total data. Male respondents are only 43.17%. Online, one respondent, which is 0.32% of the Sample, is identified as "Others" in this survey. The majority of respondents belong to the 26–32-year age group, and 77.1% of the individuals are employed full-time. This high percentage shows that most participants are likely to have more stable employment and regular income. The reliability analysis revealed that all variables have a Cronbach's Alpha value higher than 0.7, which is considered acceptable for reliability.

Multiple Regression analysis

The multiple regression analysis was used to investigate the impact of AI-driven personalised marketing content on Brand Loyalty.

Table 01. Multiple Regression Analysis

Variable	Unstandardized Coefficient B	Sig. Value	Status	Decision
Customer Trust	0.321	0.006	Positive and Significant Impact on Brand Loyalty	H1 ₁ Accepted
Customer Experience	0.359	0.000	Positive and Significant Impact on Brand Loyalty	H2 ₁ Accepted
Relevance	0.344	0.00	Positive and Significant Impact on Brand Loyalty	H3 ₁ Accepted

(Source: Generated using IBM SPSS 25.0.0)

According to the results of the regression analysis, AI-driven personalised marketing content has a significant impact on brand loyalty through three essential factors: customer trust, customer experience, and relevance. Customer trust ($B = 0.321$, $p = 0.006$), customer experience ($B = 0.359$, $p = 0.000$), and relevance ($B = 0.344$, $p = 0.000$) all produced statistically significant impacts on brand loyalty and were all positive. This suggests that AI-driven marketing content, which customers view as trustworthy, relevant, and that enhances the customer experience, will effectively strengthen customer emotional connection and commitment to a brand, and improve brand loyalty.

4. Discussion

The outcome of this research indicates that AI-enabled, tailored marketing content significantly and positively influences brand loyalty, depending on three critical components: trust, experience, and relevance. This lends support to existing data that AI facilitates brands developing personal and meaningful brand-related interactions through emotions that drive loyalty and long-term relationships. The research finds that personalised messaging signals authenticity, accuracy and value are positively received, enhancing the customers' trust and satisfaction. Subsequently, this research identifies relevance as a key driver - when an AI-driven content is relevant to customers' particular needs and characteristics, loyalty is further

enhanced. Ethical data protection and AI responsible practices remain imperative; otherwise, the benefits dissipate through eroded trust. Lastly, this research highlights the importance of AI as a strategy to foster relationships between customers and brands; however, future research should investigate the differences in personalisation levels, concerns about personal privacy, and cultural differences that may impact customers' experiences and loyalty behaviour. The results indicate that personalised AI content strengthens brand loyalty by enhancing customer trust, improving user experience, and increasing message relevance. Trust emerges as a foundational determinant of loyalty, consistent with the Commitment-Trust Theory. Sri Lankan consumers tend to respond more positively to personalised messages when brands clearly communicate how data is used, reflecting the growing local sensitivity toward data privacy and ethical AI practices. This emphasises that AI personalisation must be transparent and responsibly implemented to sustain long-term loyalty.

Customer experience also plays a decisive role, with respondents indicating higher satisfaction when AI-generated content reduces effort, improves convenience, and delivers timely solutions. In the Sri Lankan digital ecosystem, where technological adoption is uneven, AI personalisation offers value by simplifying decision-making and improving navigation across digital platforms. This aligns with global findings but highlights a unique local dimension: consumers in emerging markets particularly appreciate personalisation that reduces complexity and enhances perceived efficiency.

Relevance was identified as another strong driver of loyalty. When AI-generated recommendations and messages closely match consumer preferences, they create a sense of personal recognition and brand attentiveness. In Sri Lanka, where cultural preferences, purchasing power, and digital behaviours vary across regions, relevance becomes a powerful differentiator. The ability of AI to tailor content to these diverse preferences contributes significantly to sustained engagement and repeat interactions.

5. Conclusions and Recommendations

The research suggests that AI-based, personalised marketing content is crucial in strengthening consumers' trust, enhancing the user experience, and ensuring the relevance of marketing messaging, all of which are key factors in developing brand loyalty. Customers who receive meaningful information at the right time through an AI system will gain a stronger emotional connection and trust in the brand, driving long-term loyalty. Furthermore, the research suggests that personalised marketing effectiveness can only be achieved when utilising customer data with ethics, transparency, and genuine authenticity in customer relations.

Based on the findings of this study, the author offers several specific recommendations. Organisations must adopt AI-driven customer profiling systems that update in real-time to ensure accurate personalisation. Furthermore, Predictive analysis must be used to identify customer needs and provide proactive solutions. The Clear AI transparency indicators, such as 'Personalised by AI', also help build trust. Regular algorithm audits are also essential for preventing bias while maintaining human oversight in AI-generated content, ensuring an emotional connection with customers, and maintaining credibility.

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Thematic Track: Business & Hospitality Management

Abstract number: 224

The impact of Internet banking service quality on customer satisfaction: Special reference to Colombo district, Sri Lanka

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Abstract

The research study was conducted to find out the impact of Internet Banking Service Quality on Customer Satisfaction with Special reference to Colombo District, Sri Lanka. In the modern era of financial industry internet banking has become a key service channel, how its quality dimensions influence customer satisfaction is essential for sustaining competitiveness and customer loyalty. Therefore, it is critical to examine the impact of online banking service quality on customer satisfaction to determine the extent to which customers embrace these services and to identify opportunities for further enhancement of internet banking service quality. The research primarily focuses on three dimensions of service quality such as online customer service quality, online information system quality, and online banking service product quality and examines their combined effect on overall service quality and customer satisfaction. Main 3 hypothesis were formulated in order to effectively carry out the research work. The research is based on descriptive and correlational research design. For this study the population was online bank account holders living within the Colombo District, Sri Lanka, who are above 18 years of age. A non-probability convenience sampling method was used to collect data from the 200 online banking users. The primary and secondary data were used; the data collected was analyzed. The tool used for the data analysis was the SPSS software employing descriptive statistics, correlation, and multiple regression techniques to test the hypotheses and identify significant relationships among the variables. The findings indicate that improvements in online customer service and information system quality enhance overall service quality, which in turn increases customer satisfaction. Study concludes that the internet banking service quality of commercial banks in Colombo is generally high and contributes positively to customer satisfaction. However, online product quality did not show a significant relationship with overall service quality. The results underscore the importance of banks to invest in technologically advanced, secure, and user-friendly systems, while maintaining effective customer service to enhance user experience and satisfaction. The research provides valuable insights for bank managers and policymakers in designing strategies to improve online service quality and customer retention. Future studies are recommended to expand the geographical coverage and incorporate additional factors such as brand trust, perceived value, and user experience to enrich understanding in this area.

Keywords: Customer Satisfaction, E-Service Marketing, Information System Quality, Internet Banking, Online Service Quality

The impact of Internet banking service quality on customer satisfaction: Special reference to Colombo district, Sri Lanka

1. Introduction

Banks are the essence of the financial system and play a vital role as key financial intermediaries in promoting a country’s economic growth and development (Central Bank, 2024). The banking sector in Sri Lanka comprises 30 banks, including 24 licensed commercial banks (LCBs), which dominate the financial sector and account for 71.4% of total financial-sector assets (data.worldbank.org)

In recent years, the banking sector has experienced rapid growth in internet (online) banking, as the internet has become integral to everyday life. The convenience and benefits such as cost savings, market expansion, and 24/7 access have driven widespread adoption. Internet banking allows users to carry out transactions, check balances, pay bills, and transfer funds locally or internationally at their fingertips.

Since the service quality of technological services cannot be measured solely by general service quality dimensions, additional factors are required to assess the quality of internet banking services. Therefore, this study focuses on evaluating overall internet banking service quality and its influence on customer satisfaction. The research objectives are to:

- Determine the degree of customer satisfaction with online service quality.
- Assess the overall internet banking service quality in commercial banks.
- Examine the impact of overall internet banking service quality on customer satisfaction.
- Identify the salient dimensions of service quality and their relationship with overall internet banking service quality.

2. Methodology

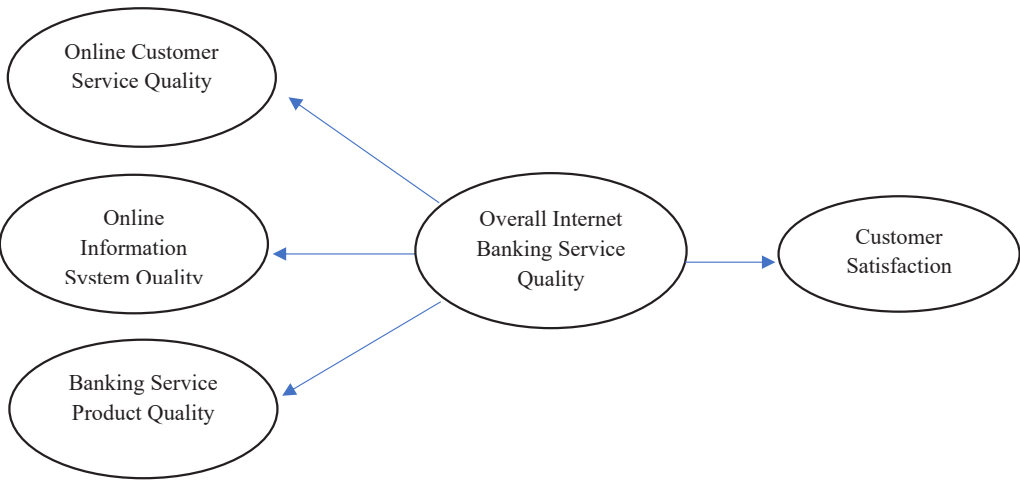


Figure 01: Conceptual Framework

This study employed a correlational, cross-sectional design to examine relationships among key variables without establishing causal links. Data were collected as a field study in a non-contrived setting over one and a half weeks, using a structured, self-administered questionnaire distributed both physically and online. The questionnaire comprised seven sections, including background information on respondents’ banks and accounts, with Sections 2–6 using a five-point Likert scale to capture perceptions. The target population included online bank account holders aged 18 and above in Colombo District, Sri Lanka. A non-probability convenience sample was used due to time and cost constraints. Of 230 questionnaires distributed, 200 valid responses were obtained, yielding a response rate of 86%.

The tested hypothesis was,

- H1** Degree of Customer Satisfaction is high
- H2** Degree of Overall Internet Banking Service Quality is high
 - H2-a There is significant relationship between online customer service quality and overall service quality
 - H2-b There is significant relationship between online information system quality and overall service quality
 - H2-c There is significant relationship between online service product quality and overall service quality
- H3** There is a significant relationship between Overall internet banking service quality and Customer satisfaction

3. Data Analysis and Results

The collected data were entered into SPSS for analysis. Descriptive, correlation, and regression analyses were conducted to test the hypothesized relationships between variables.

Correlation Analysis.

Table 01: Correlation

#	H1	P Value	Decision
1	There is significant relationship between online customer service quality and overall service quality	0.014	Accepted
2	There is significant relationship between online information system quality and overall service quality	0.034	Accepted
3	There is significant relationship between service product quality and overall service quality	0.243	Rejected

Regression Analysis

Table 02: Regression - Overall Service quality and variables

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.559 ^a	.312	.305	.313	1.907

According to the above model summary, the R² value is 0.312, indicating that 31.2% of the variation in overall customer service quality is explained by the independent variables (Online

customer service quality and Online information system quality), online customer service quality and online information system quality. This level of explanatory power is considered acceptable in behavioral and service quality research, where human perceptions and technology-based factors often show moderate predictive strength.

Table 03: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.624	2	4.312	44.029	.000 ^b
	Residual	18.999	194	.098		
	Total	27.623	196			

The ANOVA table shows a significant level of 0.000 at an F-statistic of 44.029, indicating that a significant model can be established to assess the influence of customer service quality and online information system quality on overall internet banking service quality.

Table 04: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.120	.333		3.360	.001		
	CSQ_mean	.267	.069	.231	3.863	.000	.988	1.012
	OISQ_mean	.478	.059	.484	8.081	.000	.988	1.012

The coefficient table shows that the significance values for the constant and the independent variables such as online customer service quality and overall information system quality are all below 0.05, indicating they are significant. Based on these coefficients, the following model was developed to measure the impact of customer service quality and overall information system quality on overall service quality.

$$YOSQ = 1.12 + 0.267CSQ + 0.478OISQ$$

Table 05: Regression - Overall service quality and Satisfaction

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.362 ^a	.131	.127	.39097

The model summary shows an R² value of 0.131, indicating that 13.1% of the variation in customer satisfaction is explained by the independent variable, overall service quality.

Table 06: Anova

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.578	1	4.578	29.949	.000 ^b
	Residual	30.266	198	.153		
	Total	34.844	199			

The ANOVA table shows a significance level of 0.000 at an F-statistic of 29.949, indicating that a significant model can be established to assess the influence of overall customer service quality on customer satisfaction in internet banking.

Table 07: Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.853	.195		14.597	.000		
	OSQ mean	.261	.048	.362	5.473	.000	1.000	1.000

The coefficient table shows that the significance values for the constant and independent variables are all below 0.05, indicating they are significant. Based on these coefficients, the following model was developed to measure the impact of overall online banking service quality on customer satisfaction.

$YCS = 2.853 + 0.261OSQ$

4. Discussion

The study demonstrates that online customer service and information system quality strongly influence overall internet banking service quality, which in turn enhances customer satisfaction. Customers prioritize functional and technological aspects over product features. Banks should invest in user-friendly digital platforms and responsive online support to improve service perceptions, satisfaction, and loyalty. Findings are restricted to online account holders in Colombo District, and the cross-sectional design limits causal inferences, self-reported data may present bias. Service product quality did not significantly affect overall service quality, emphasizing the importance of system reliability and usability. In summary, the findings indicate that banks should focus on enhancing online service support and improving system quality to strengthen customer satisfaction and gain competitive advantage in the digital banking sector. Investing in secure, efficient, and user-friendly digital platforms, while maintaining responsive online support services, remains essential in delivering superior customer experiences in internet banking (Palese & Usai, 2018; Rod et al., 2009).

5. Conclusions and Recommendations

The study concludes that internet banking service quality in commercial banks of Colombo District is high, effectively generating strong customer satisfaction. The technical excellence of the online information system and, to a lesser extent, customer support are the primary drivers of perceived service quality, while the quality of banking products does not significantly influence perceptions of the online channel

A validated model has been provided to predict the impact of these dimensions on overall service quality and customer satisfaction. Banks should invest in user-friendly, secure systems and maintain strong support, emphasizing ease of use, reliability, and security. Future research should expand the geographic scope, examine factors such as brand trust and perceived value, and employ longitudinal designs to track changes in satisfaction over time.

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**Session 06
Language, Education
& Psychology**



Thematic Track: Language, Education & Psychology

Abstract number: 81

Bridging the AI and English divide: A sustainable framework for equitable language education in Sri Lankan government schools

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Abstract

There is increasing disparity among local school students between government and private schools in both English language ability and artificial intelligence literacy of Sri Lankan local education. Whereas, private institutions are increasingly integrating AI-based solutions and English teaching through immersive learning while in government schools – the scenario is different due to lack of infrastructure, teachers being unschooled in technology and absence of digital access to match global education needs. The divide not only restricts learning and jobs opportunities for students, it also hampers the nation's vision of inclusive development and digital sustainability. The current article addresses the underlying issues that create this divide, and suggests a sustainable model for democratizing AI-driven language learning in public schooling. Data was collected through survey and interview of students and teachers from 5 government schools in the Eastern Province, as well as a comparative analysis of the digital tools used in private schools. The trial was run at one government school and saw low-cost AI language apps and bilingual teaching aids brought in for a six-week period. The indicators were such that student's engagement, vocabulary retention and confidence in spoken English improved by an average of 35% participation and a 22% increase in word retention. Teachers indicated ease of adjusting to students' various learning levels and interest in additional training. Results are indicative that any degree of AI integration, if culturally adapted and ethically deployed, can lead to a significant improvement of learning outcomes for language learning in low resource scenarios. But obstacles like patchy internet connectivity, untrained teachers and pushback against digital change need to be overcome with focused policy interventions. The paper ends with the validity that bridging the AI and English gap is not just a technological issue, but also a social one – this being the case educationists, government personnel and agents of change should join hands. It suggests pursuing a hybrid learning approach that pairs AI tools with human-led instruction and investing in teacher training programs, as well as new multilingual digital content suited to local circumstances. If we are to make Sri Lanka lead the way in inclusive and sustainable 21st century digital literacy AI education, then I'd like to think that a significant role can be played by ensuring that all students in state schools have access to language learning tools.

Keywords: Artificial intelligence, Digital equity, English education, Government schools, Multilingual learning

Bridging the AI and English divide: A sustainable framework for equitable language education in Sri Lankan government school

1. Introduction

Sri Lanka’s public education system faces a growing disparity in English language proficiency and artificial intelligence (AI) literacy between government and private school students. While private institutions increasingly integrate AI-powered tools and immersive English instruction, government schools often lack the infrastructure, trained educators, and digital access required to keep pace. This divide limits students’ academic and career opportunities and undermines national goals for inclusive development and digital sustainability. The objective of this study is to investigate the root causes of this educational gap and propose a sustainable framework to democratize AI-assisted language learning across government schools, with a focus on multilingual support, teacher empowerment, and ethical technology use.

2. Methodology

A mixed-methods approach was adopted. Quantitative data were collected through structured surveys administered to 120 students and 30 teachers across five government schools in Eastern Province. Qualitative insights were gathered via semi-structured interviews with educators, curriculum planners, and AI specialists. A comparative analysis was conducted to examine the availability and usage of digital language tools in private versus government schools. Materials included AI-based language learning applications (e.g., Duolingo, ChatGPT), bilingual teaching aids, and low-cost mobile devices. A pilot programme was implemented in one government school over a six-week period to test the proposed framework

3. Data Analysis and Results

Survey results showed only 18% of government school students to be comfortable with their English language skills, compared to 72% of students in private schools. Access to AI tools was nearly nil in public settings. Interview responses also reflected trainer training and digital infrastructure as key constraints. The pilot program showed a 35% student interest hike and a 22% improvement in vocabulary memorization when combined with traditional methods using AI tools.

Table 01. Comparison of English proficiency and AI exposure between school types

School Type	English Confidence (%)	AI Tool Usage (%)
Government School	2.9	3.9
Private School	3.3	7.0

4. Discussion

The findings confirm a growing digital and linguistic divide between private and public school students. AI can be used to enhance language acquisition, but it succeeds when it is in an environment of contextualization, teacher participation, and ethical use. The pilot demonstrated that even low-cost integration of AI has the capability to enhance learning with added culturally responsive content and multilingual support. Limitations include the short duration of the pilot and limited geographic scope. Future research should explore long-term outcomes and scalability across different locations and languages.

5. Conclusions and Recommendations

This study proposes a fair model for sustainable language learning in Sri Lankan state schools. Some of the major recommendations are the integration of AI-driven bilingual tools, the investment in teacher training programs, and the development of multilingual digital content integrated with local settings. Bridging the AI and English gap is not merely a tech problem but a social imperative. By providing government school students with equal opportunities in language education and digital skills, Sri Lanka can take a step towards a more sustainable and inclusive future in the age of artificial intelligence

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Thematic Track: Language, Education & Psychology

Abstract number: 121

Using artificial intelligence to support teachers in multilingual early childhood classrooms: Opportunities, challenges, and ethical pathways

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Abstract

The increasing linguistic diversity in early childhood classrooms presents both opportunities and challenges for teachers striving to create inclusive learning environments. This study explores how Artificial Intelligence (AI) technologies can assist teachers in managing multilingual classrooms through translation, content generation, and speech-support tools. Grounded in sociocultural and translanguaging theories, the research adopts a human-centered AI approach that prioritizes teacher autonomy and ethical practice. A mixed-method, multi-phase design is employed, beginning with a qualitative needs' assessment among 20 early childhood teachers, followed by a pilot intervention in 6–8 classrooms using an AI Toolkit, and concluding with a comparative analysis of language engagement and ethical perceptions. Preliminary findings indicate that AI supports teachers in producing multilingual learning materials and enhancing classroom interaction, though challenges remain concerning data privacy, linguistic bias, and speech-recognition reliability. The study contributes to the growing body of literature on AI in early childhood education by integrating pedagogical, technological, and ethical perspectives. It offers evidence-based recommendations for educators and policymakers to ensure that AI tools serve as inclusive, developmentally appropriate, and ethically grounded supports in multilingual early learning environments.

Keywords: Artificial Intelligence, Early Childhood Education, Multilingualism, Teacher Support, Language Development.

Using artificial intelligence to support teachers in multilingual early childhood classrooms: Opportunities, challenges, and ethical pathways

1. Introduction

Early childhood classrooms worldwide are becoming increasingly multilingual, reflecting broader trends of migration and linguistic diversity. Teachers in these classrooms play a critical role in facilitating children's emerging bilingualism and inclusive participation. However, they are often in the position of being restricted by limited linguistic resources that they have access to, time to offer individualized scaffolding, and access to materials in more than one language. Artificial Intelligence (AI) technologies—namely language models, automatic translation technologies, and speech-recognition technologies—present new opportunities to assist teachers in addressing these challenges. Nevertheless, empirical evidence on the potentiality, pedagogical value, and ethical implications of AI in early childhood multilingual education is rare. This study examines how AI can be employed to augment the pedagogical work of teachers, with an emphasis on translanguaging pedagogies, classroom communication, and management of professional workload, without compromising ethical and developmental compatibility.

2. Methodology

A mixed-method, multi-phase design is to be employed.

Phase 1 consists of a qualitative needs assessment through semi-structured interviews and classroom observations of approximately 20 linguistically diverse early childhood teachers. Teachers will identify the most pressing challenges and opportunities for AI support, and an environmental scan will map out available AI tools currently available that are suitable for these environments.

Phase 2: Pilot intervention in 6–8 classrooms. Teachers in the intervention group will receive training and be given a screened "AI Toolkit" (translation, speech-help, content-create apps). AI-infused classroom activities will be twice a week for 8–12 weeks. Data will include teacher records, child language samples, classroom observation, and post-intervention interviews.

Phase 3; a qualitative and quantitative study: children's oral language engagement changes will be examined and compared with teacher opinions regarding AI usefulness, usability, and ethical acceptability. Mixed-effects models will analyze linguistic measures, and thematic analysis will uncover emergent findings from teacher and parent narratives.

3. Data Analysis and Results

Preliminary findings indicate that AI tools enhanced teachers' ability to produce multilingual materials and fostered more inclusive classroom dialogue. Teachers valued AI's translation and content-generation functions but reported concerns about child-speech recognition accuracy, over-reliance on dominant languages, and data privacy.

Data analysis was performed following a mixed-method approach that corresponded to the three phases in the research design. Quantitative and qualitative data were triangulated to achieve a holistic perspective on how AI-supported practices influence multilingual classroom interactions and teacher experiences.

For the quantitative component, children's oral language engagement was coded from classroom video recordings using a structured observational rubric capturing frequency of verbal participation, use of home languages, responsiveness to teacher prompts, and peer interaction. Mixed-effects models were applied, with children nested within classrooms, to evaluate changes across the intervention period. Preliminary results showed that for the children in AI-supported classrooms, their multilingual engagement followed a statistically meaningful upward trend. Children showed, on average, 22-30% higher verbal participation in AI-mediated activities compared to baseline sessions. Such growth was most evident in engaging tasks like storytelling and thematic learning when AI-generated multilingual materials were employed. Teachers reported that translation apps enabled more inclusive participation from children who had not participated due to limited proficiency in the dominant language of the classroom.

Qualitative data from interviews, reflection logs, and lesson-embedded observations further underlined the pedagogical benefits and practical challenges of AI integration. Three dominant themes emerged via thematic analysis: greater multilingual scaffolding, an increase in teacher creativity, and emerging ethical tensions. Teachers described AI tools as “time-saving” and “confidence-building,” with the immediate potential to produce bilingual or trilingual materials saving planning time and enabling more focus on interactive teaching. Many reported feeling empowered to include students' home languages in ways they had not previously found possible due to limited linguistic resources.

However, several challenges quickly emerged. Across all cohorts, teachers reported speech recognition accuracy limitations for young children, especially those with developing articulation or whose home languages were underrepresented in AI datasets. This sometimes made real-time use frustrating. Secondly, a number of teachers noted the presence of algorithmic biases-such as inaccuracies in translation, or the platform's tendency to prioritize English over other languages-that risked reinforcing linguistic hierarchies the intervention sought to dismantle.

Ethical concerns formed a major part of the findings. Teachers and parents were uncertain about data privacy with children's voices or classroom interaction being processed through some or other external platform. The screened "AI Toolkit" gave assurance, but participants were more cautious, pointing out the need for clearer institutional guidelines, as well as locally developed, privacy-respecting tools. Overall, these findings suggest that when used in a critical and intentional manner, AI can support increased multilingual engagement and decreased teacher workload. Yet these same advantages must continue to be weighed against strong ethical protections, cultural responsiveness in design, and ongoing professional preparation with respect to equal and developmentally suitable uses of AI in early childhood settings.

4. Discussion

These results are in line with previous work that has placed AI as a potentially supportive but not substitutive tool in early childhood multilingual education. Mirroring the ideas posited by the sociocultural and translanguaging perspectives, the results from this study suggest that AI tools can significantly expand children's possibilities of using multiple languages within the classroom when teachers use these tools with purpose. The observed increases in multilingual engagement indicate that digital translations and AI-enabled story-generation tools can lower

the linguistic barriers for participation and foster more equal opportunities for students to engage. This strengthens the previous argument that digital tools can mediate communication and intensify child-teacher interaction in diverse learning environments.

Yet, these challenges bring forth some critical points relevant to considerations of practice and policy. The limitations around speech-recognition accuracy for young children and underrepresented languages point to technical gaps in current AI design. These are important, given that such issues risk excluding the very learners the intervention is intended to support, which suggests that AI tools need to be adapted to early childhood developmental needs rather than repurposed from adult-oriented technologies. Ethical considerations on data privacy and linguistic bias echo global debates on AI governance in educational settings. Teachers' discomfort with unclear data flows underlines the need for transparent institutional guidelines and culturally responsive AI development.

Overall, the discussion highlights that AI integration must be designed with respect for human-centered and ethically sound principles to let technology support, not override, teachers' professional judgment and inclusive pedagogies.

5. Conclusions and Recommendations

AI may enhance, not replace, teachers' multilingual pedagogies. Responsible integration is contingent upon sustained teacher professional development, transparent data policies, and AI technologies specially designed for linguistic and cultural diversity. The study contributes to the development of ethical and evidence-based AI guidelines for early childhood education.

Based on the findings, several recommendations emerge: for educators, policymakers, and developers of technology. First, teacher professional development should be prioritized, with ongoing training that helps educators critically evaluate AI outputs, integrate multilingual resources effectively, and manage ethical risks related to data use. In workshops, translanguaging-informed strategies should be foregrounded to ensure that AI tools enhance, rather than homogenize, linguistic diversity in the classroom. Second, there is a need to establish clear guidelines by policymakers with respect to data privacy, consent, and acceptable use of AI with young children. This needs to take into account international child rights frameworks and be adapted into local linguistic and cultural contexts. Third, developers should collaborate with early childhood specialists to design and adapt AI systems that are developmentally appropriate, culturally inclusive, and capable of handling a greater range of child speech patterns and minority languages. Finally, future research should investigate long-term impacts of AI-assisted multilingual pedagogies and identify sustainable models for ethical and equitable implementation across early childhood settings.

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Thematic Track: Language, Education and Psychology

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Determinants of Sri Lankan mothers' decision-making on HPV vaccination for their daughters: A theory of planned behaviour with socio-psychological influences

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Abstract

Cervical cancer remains a major public health concern in Sri-Lanka, where HPV vaccination coverage is low and declining in certain regions despite its inclusion in the national immunization program. While previous studies have examined knowledge and intention regarding HPV vaccination, few have employed a comprehensive theoretical framework that integrates both psychological and socio-cultural determinants of parental decision-making. Guided by the extended Theory of Planned Behaviour (TPB), this study explored Sri-Lankan mothers' intentions to vaccinate their daughters against HPV, recognizing the pivotal role mothers play in health decisions within collectivistic societies. This study therefore aims to investigate the psychological factors - attitudes, subjective norms (SN), and perceived behavioural control (PBC) - and socio-cultural factors - religious beliefs, media exposure, knowledge, and past vaccination history - that influence Sri Lankan mothers' decisions to vaccinate their daughters, and how these factors shape vaccination intentions and behaviour. Understanding these multidimensional predictors provides valuable insights into the cognitive and cultural mechanisms shaping vaccine hesitancy and acceptance in the Sri-Lankan context. A quantitative cross-sectional survey was conducted among 152 mothers of daughters under the age of 26 years. Correlation, Mann-Whitney, and Kruskal-Wallis tests were used to examine associations, while multiple and hierarchical regression analyses identified the strongest predictors of vaccination intention. Significant associations were found for attitude ($r_s = -.29, p < .01$), PBC ($U = 1946.50, p < .001$), knowledge ($r_s = .35, p < .01$), and positive media exposure ($r_s = .35, p < .01$). Mothers with low PBC ($Mdn = 3.50, r = .27, p < .001$) and low SN ($Mdn = 3.0, r = .16, p = .044$) reported higher intention. Employment ($\chi^2(6) = 17.42, p = .008$), education ($\chi^2(8) = 18.81, p = .016$), and income ($\chi^2(3) = 8.95, p = .030$) differed, with unemployed jobseekers, diploma holders, and low-income mothers showing higher intention. Regression confirmed effects of attitude ($\beta = -.35, p < .001, R^2 = .12$), PBC ($\beta = -.29, p < .001, R^2 = .08$), knowledge ($\beta = .41, p < .001, R^2 = .17$), and positive media exposure ($\beta = .41, p < .001, R^2 = .16$); SN's were weaker ($\beta = -.19, p = .017, R^2 = .04$), education ($\beta = .20, p = .013$) and income ($\beta = .19, p = .018$) modest; religious beliefs and vaccination history were non-significant. Hierarchical regression showed knowledge and positive media exposure jointly explained 21% of variance in intention. The findings emphasize improving parental knowledge and positive media narratives to enhance HPV vaccine acceptance. Future research should address unmeasured confounders, include both mothers and fathers to capture gendered influences, and explore culturally sensitive interventions for taboo topics like sex-related communication in Sri Lankan families. In conclusion, strengthening maternal knowledge, promoting accurate media coverage, and reducing structural barriers through school and community-based initiatives are key to increasing HPV vaccination rates and lowering Sri Lanka's cervical cancer burden.

Keywords: Cross-sectional Study, HPV Vaccination, Maternal Decision-making, Sri Lankan Mothers, Theory of Planned Behaviour

Determinants of Sri-Lankan mothers' decision-making on HPV vaccination for their daughters: A theory of planned behaviour with socio-psychological influences

1. Introduction

Cervical cancer remains a major global public health concern, with almost 99% of cases caused by persistent infection with high-risk human papillomavirus (HPV) strains (Cohen et al., 2019; Okunade, 2020). Although it is largely preventable through vaccination, the disease continues to cause over 340,000 deaths annually (Singh et al., 2023). The HPV vaccine offers strong protection, particularly for girls aged 9-14 years before exposure to the virus (WHO, 2024), with population coverage of even 50% reducing incidence significantly (Drolet et al., 2019).

In Sri Lanka, approximately 1,407 new cervical cancer cases and 780 deaths occur each year (ICO/IARC HPV Information Centre, 2023). To reduce this burden, the national HPV vaccination programme was launched in 2017, targeting Grade 6 girls through a school-based schedule of two doses (FPA, 2025). However, coverage has fallen sharply - from 87% (first dose) and 55% (second dose) in 2018 to 31% and 25% in 2023 (WHO, 2023). This decline reveals a major public health concern: despite free access, many eligible girls remain unvaccinated.

The research problem therefore centres on identifying the determinants influencing mothers' decision-making regarding their daughters' HPV vaccination. In Sri Lanka's collectivistic and family-oriented culture, mothers are key health decision-makers (Wong et al., 2020). Hence, their beliefs, attitudes, and social pressures play a decisive role in vaccine acceptance.

This study addresses a critical evidence gap. While global research supports HPV vaccine effectiveness, few studies examine how cultural and psychological factors shape Sri-Lankan mothers' behavioural intentions. Understanding these factors is essential for culturally sensitive health promotion strategies to improve vaccine uptake and reduce cervical cancer. Guided by the Theory of Planned Behaviour (Ajzen, 1991), it examines attitudes, SN, and PBC, alongside cultural beliefs, media exposure, and religious norms, in shaping mothers' vaccination intentions.

2. Methodology

This study adopted a quantitative cross-sectional design with a predictive correlational approach, administered online via Qualtrics. The design was selected for its efficiency, cost-effectiveness, and ability to generalise findings across a larger population (Carr, 1994; Wang & Cheng, 2020). Data collection followed ethics approval and Open Science Framework (OSF) registration to ensure transparency and credibility.

A total of 203 participants were initially recruited; however, 51 were excluded due to incomplete responses, ineligibility, or failure of attention checks. The final sample comprised 152 Sri-Lankan mothers aged 18-60 years ($M = 43.78$, $SD = 7.31$), each having at least one daughter under 26 years and fluent in English. A minimum sample size of 146 was estimated via G*Power for linear regression, ensuring adequate statistical power ($\alpha = .05$, $1-\beta = .95$). Volunteer sampling was employed as the most feasible method within the project timeline.

Measures were adapted from validated instruments, including the Carolina HPV Immunisation Attitudes and Beliefs Scale (CHIAS) for attitude and intention (McRee et al., 2010), the Duke University Religion Index (DUREL) for religiosity (Koenig & Büssing, 2010), and the HPV Knowledge Scale (Waller et al., 2013). Additional scales assessed PBC, SN (Wijayanti et al., 2021), and media exposure (Margolis et al., 2019; Zhang et al., 2023). Cronbach's alpha values ranged from .24 to .84, reflecting varying internal consistencies across constructs.

Data were collected through an online Qualtrics survey containing consent, demographic, and scale sections, followed by a debriefing sheet and support resources. Ethical approval was granted by the University of West London Ethics Committee, adhering to the British Psychological Society (BPS, 2021) guidelines. Descriptive and inferential analyses, including hierarchical regression, were conducted using IBM SPSS Version 30 to identify significant predictors of mothers' HPV vaccination intentions.

3. Data Analysis and Results

Data were analysed using SPSS (version 30) through descriptive, inferential, and exploratory statistical techniques. Prior to analysis, categorical variables with more than two levels were dummy-coded. Regression assumptions were checked and satisfied using the Shapiro-Wilk test for normality, scatterplots for linearity and homoscedasticity, Durbin-Watson for independence, and VIF/tolerance values for multicollinearity. No influential outliers were identified based on standardised residuals, Cook's distance, leverage, and Mahalanobis distance.

3.1 Descriptive Analysis

The sample included 152 Sri-Lankan mothers aged 26-58 ($M = 43.78$, $SD = 7.31$) with daughters aged 2-26 ($M = 15.55$, $SD = 5.89$). Most were married (90.8%), had one daughter (55.3%), were full-time employed (63.2%), held a bachelor's degree (40.8%), and reported high household income (75%; Rs.188,946-203,633). Vaccination intention was moderate ($M = 3.19$, $SD = .75$). Most mothers (56.6%) and daughters (70.4%) lacked previous vaccination history. Over half had low PBC (55.3%) and low SN (58.6%). Mothers showed reduced negative attitudes ($M = 2.20$, $SD = .34$), low knowledge ($M = 4.61$, $SD = 2.96$), and were moderately religious ($M = 18.66$, $SD = 4.36$). They also reported slightly more exposure to positive than negative HPV media ($M = 1.49$ vs. 1.28).

3.2 Inferential Analysis

Due to non-normality, non-parametric tests were used. Spearman's correlations showed vaccination intention was positively related to knowledge ($r_s = .35$, $p < .01$) and positive media ($r_s = .35$, $p < .01$), but negatively to attitude ($r_s = -.29$, $p < .01$); age, religious belief, and negative media were not significant. Mann-Whitney U tests indicated higher intention among mothers with low PBC ($Mdn = 3.50$, $r = .27$, $p < .001$) and low SN ($Mdn = 3.0$, $r = .16$, $p = .044$). Kruskal-Wallis H tests showed no differences by number of daughters ($\chi^2(3) = 7.29$, $p = .063$) or marital status ($\chi^2(3) = 1.51$, $p = .681$), but differences emerged for employment ($\chi^2(6) = 17.42$, $p = .008$), education ($\chi^2(8) = 18.81$, $p = .016$), and income ($\chi^2(3) = 8.95$, $p = .030$), with unemployed, diploma holders, and low-income mothers showing highest intention.

Linear regression showed attitude ($\beta = -0.35, p < .001$), SN ($\beta = -0.19, p = .017$), and PBC ($\beta = -0.29, p < .001$) negatively predicted intention, while knowledge ($\beta = .41, p < .001$) and positive media ($\beta = .41, p < .001$) positively predicted it; negative media ($p = .521$) and religious belief ($p = .844$) were non-significant. Among demographics, only education ($\beta = .20, p = .013$) and income ($\beta = .19, p = .018$) predicted intention. Mediation analysis (Baron & Kenny, 1986) showed mothers' vaccination history did not mediate the link between maternal intention and daughters' HPV vaccination.

3.3 Exploratory Analysis

Hierarchical multiple regression identified that, after controlling for demographics, adding psychological and socio-cultural factors improved prediction ($\Delta R^2 = .22, p < .001$). The final model explained 21% of variance in vaccination intention (Adjusted $R^2 = .21$). Significant predictors were positive media exposure ($\beta = .17, p = .047$) and knowledge ($\beta = .21, p = .020$), whereas attitude and PBC remained negative predictors. Overall, findings highlight the importance of informational exposure and knowledge enhancement while addressing psychological barriers to improve HPV vaccination uptake among Sri-Lankan mothers.

4. Discussion

This study examined the determinants of Sri-Lankan mothers' intentions to vaccinate their daughters against HPV using an extended TPB framework. The findings showed that knowledge and positive media exposure significantly increased intention, while attitude and PBC negatively predicted vaccination intention.

Mothers with safety concerns were less likely to intend vaccination, aligning with prior research highlighting attitudinal barriers (Catalano et al., 2017; Han & Son, 2021). However, when knowledge was considered, attitude lost predictive power, indicating that increasing awareness can mitigate negative perceptions. Contrary to expectations, SN's were negatively associated with intention, suggesting that some mothers prioritise personal judgement over social approval. This may reflect a growing autonomy among Sri Lankan mothers in health decision-making, influenced by online and educational resources.

Interestingly, higher PBC correlated with lower intention, likely due to the structured, school-based vaccination system (Debellut et al., 2024), where mothers play a limited logistical role. Consistent with international evidence (Abay et al., 2025; Alshehri et al., 2023), knowledge emerged as the strongest predictor, while positive media exposure significantly enhanced vaccination intention. Negative media exposure showed no effect, perhaps due to limited misinformation within the Sri Lankan context. Socio-demographic factors and religion showed minimal influence, reinforcing that psychological and informational factors are more decisive.

The findings emphasise that improving maternal knowledge and fostering trust through credible media communication are key to increasing HPV vaccine uptake. Health campaigns must balance factual accuracy with cultural sensitivity to counter myths and hesitancy.

A key strength of this study is the integration of socio-psychological factors within a TPB model tailored to the Sri Lankan context. However, its cross-sectional design limits causal inference, and self-report measures may introduce response bias. The exclusion of fathers and

non-English-speaking mothers limits generalisability, and the mediation analysis had reduced statistical power.

5. Conclusions and Recommendations

This study concludes that knowledge and positive media exposure significantly enhance HPV vaccination intention, while attitude and PBC act as barriers. Health authorities should prioritise awareness campaigns using schools, clinics, and digital platforms to disseminate reliable information. Strengthening mothers perceived control through flexible access and community outreach is vital.

Future research should adopt longitudinal designs and include both parents to capture family-level influences. Enhancing accurate knowledge dissemination and positive media engagement remains essential to improving vaccination coverage and preventing cervical cancer in Sri Lanka.

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Thematic Track: Language, Education and Psychology

Abstract number: 227

Study on the navigation of special needs education in international schools of Colombo district in Sri Lanka

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Abstract

The 21st century is still transforming and the school has to keep up with new technology, international relations and a more varied student body. In this case, it is highly essential to ensure that every learner, particularly with disabilities, stands equal learning opportunities. This paper examines the efforts of international schools of the Colombo District in Sri Lanka to involve all students in the learning process. These schools accommodate both the local and the foreign families and use different study programs and hence inclusion is more difficult. The primary aim of the study is to discover the way these schools implement inclusion, how teachers are oriented to work with special-needs students, and what are the issues in the areas of teacher training and school support. The research methodology is mixed method research. It consists of data generated by teachers by interview and questionnaire, and the secondary data by reports of National Education Commission and published studies. The findings indicate that despite the fact that the international schools within the Colombo District are very effective in terms of promoting the idea of inclusive education, there exist still significant variations regarding the process of training teachers, the availability of assistive technologies, and the level of utilization of Individualized Education Plans (IEPs). A lot of the teachers are left to rely on their own and the assistance of other teachers as there is not enough school training or support. Another finding of the study was that schools having the encouragement of the continuous teacher learning process and flexible approaches to teaching instruction are more effective in establishing inclusive classrooms and raising student participation. The study concludes that maintaining the inclusive education on a high level requires enhancement of the skills of teachers as well as the introduction of the inclusive values in the school policy as well as appropriate support by all school management tiers. It demonstrates that educators, families, and experts should collaborate in order to address the various needs of students in a successful manner. Some of the suggestions in the study would be to provide teachers with frequent special education training, more assistive technology, explicit and consistent IEP plans, and the creation of a school climate in which everyone feels part of it and has the desire to perform their best. The study provides valuable suggestions that can be used in training teachers, making leadership choices, and planning school policies within the Colombo District by relating classroom practice with school policies. The findings can also be used by the international schools in other countries to establish equitable, enabling and adaptable learning environments that are beneficial to both the teachers and students.

Keywords: Educational challenge, Inclusive learning, International schools, Special Educational Needs, Teacher training.

Study on the navigation of special needs education in international schools of Colombo district in Sri Lanka

1.Introduction

Education is changing quickly because of globalization, new technology, and the growing diversity of students. In this situation, inclusive education for students with special needs has become very important. This study looks at the challenges and opportunities faced by international schools in the Colombo District of Sri Lanka, an area that is developing fast and has many different cultures. It focuses on how these schools meet the needs of students with special educational needs (SEN). Since teachers play a key role in creating inclusive classrooms, the study also looks at how well teachers are trained to support students with different learning needs. By studying teacher readiness, current practices, and school policies, this research aims to help promote inclusive education that gives every student an equal chance to learn in international schools.

2. Methodology

The research methods applied in this study were quantitative and qualitative. Teachers in the Colombo District working in international schools were used as the source of data. A questionnaire consisting of 20 structured online questions was distributed among teachers in five selected schools and aimed to provide the information concerning their training, methods of teaching and the problems with special education. Also, personal interviews were conducted to get insights on personal experience and opinion of the teachers. The simple statistical methods of charts and tables were used to analyze the quantitative data whereas the answers of the interviews were analyzed with the thematic method to find out prevalent concepts. The attention on international schools provided a deeper insight into why inclusive education becomes more difficult to achieve with the consideration of cultural and language differences.

3. Data Analysis and Results

The outcomes revealed that 71 percent of teachers lacked formal education on special education indicating a major disparity in teacher preparation. But, 93 percent of teachers were in favor of the use of Individualized Education Plans (IEPs) and instructional approaches that are tailored to the requirements of students. Teachers indicated that they employed flexible lesson plans, assistive technology and collaborated with special educators to help students with special needs. The majority of teachers thought inclusive education will benefit everyone - it will enhance the learning and socialization abilities of students with special needs and their peers. The primary obstacles that were noted were language and cultural barriers, the absence of special support personnel, and the unavailability of school resources.

Table 01. Teacher preparation in special education in international schools in Colombo.

Teacher Preparation	Percentage
Formal Training	29%
No Formal Training	71%

4. Discussion

The paper has discovered that a quick solution is needed in terms of effective teacher training programs that aim at special needs education. The attitude of the teachers is significant in assisting the students to acquire confidence, as well as create a positive learning environment. The advantages of inclusive education help the international objective to achieve equality and integration in education. Nonetheless, inclusion is challenging because of the absence of training, the insufficient cooperation, and the inability to effectively implement national policies in the area of special education. The solution to these issues requires ongoing training of teachers, improved resources and teaching strategies that will not violate cultural diversity.

5. Conclusions and Recommendations

The research concludes that special education teacher training plays a key role in the development of successful special classrooms in the international schools in Colombo. It suggests that schools should pay attention to the enhancement of teacher qualification with the help of formal training, constant workshops, collaboration of teachers. The schools too should be sufficiently equipped with resources, such as assistive technology and trained personnel to meet the various learning needs. The policy-makers need to enhance the support systems and make sure that the inclusion education policies are implemented accordingly. Other areas can be studied and inclusion implications of long-term teacher training investigated in future studies. In sum inclusion education is not only beneficial to students with disabilities but it also causes a more robust supportive learning community among all students.

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**Session 03
Civil & Built Environment**



Thematic Track: Construction & Built Environment

Abstract number: 73

Impact of soil type and moisture on corrosion behavior in reinforced concrete: Experimental insights

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Abstract

Reinforced Concrete (RC) foundation bases and beams in coastal regions are exposed to chloride-rich and moisture-saturated soils, which accelerate steel corrosion through chloride ingress and prolonged humidity, thereby reducing the durability and structural integrity of the foundation elements. This study quantifies how soil type (sand, clay, silt) and moisture state (dry, optimum moisture content, saturated) influence chloride uptake, electrical resistivity, bar mass/diameter loss, and residual flexural capacity in RC beams. Thirty three prismatic beams (300×150×150 mm) were fabricated; 27 underwent impressed-current accelerated corrosion while surrounded by soils dosed to 5% chloride. Compared to the unexposed control, seawater reduced flexural capacity around 51%, clay produced the most severe corrosion in dry and medium moisture conditions, while in saturated condition, corrosion levels in clay and sand became comparable, reflecting similar availability of chloride ions under full saturation. Resistivity decreased with moisture and tracked corrosion severity (e.g., seawater 3.8 kΩ·cm vs control 32.8 kΩ·cm), aligning with commonly cited probability bands. Free/total chloride profiles (surface and 40 mm depth) were measured per standard procedures; resistivity, rust production, bar diameter reduction, and four-point flexure were evaluated. Saturation increased chloride uptake, reduced resistivity, exacerbated bar loss, and decreased flexural strength within each soil class ; however, the difference in performance between clay and sand narrowed in the saturated state. The evidence supports soil selection and moisture-management strategies for foundations and below-grade RC in chloride-bearing environments and offers actionable thresholds for design and condition assessment.

Keywords: Accelerated corrosion, chloride ingress, flexural degradation, reinforced concrete, soil–structure interaction.

Impact of soil type and moisture on corrosion behavior in reinforced concrete: Experimental insights

1. Introduction

Corrosion of steel reinforcement remains the dominant durability limit state for Reinforced Concrete (RC) infrastructure, particularly in marine and saline soil environments, where chloride-induced corrosion can initiate even before visible signs emerge (Pushpakumara, 2025; Pushpakumara and Bandara, 2025; Ann and Song, 2007). The ingress of chlorides through concrete cover and the establishment of a critical threshold at the steel-concrete interface leads to depassivation and active corrosion, which compromises bond strength, reduces cross-sectional area of rebars, and induces cracking in the surrounding concrete (Pushpakumara and Weerasinghe, 2024; Tang et al., 2015; Poursaei, 2016). While marine splash zones and tidal exposures are well-documented, subgrade soil environments pose a parallel but less visible risk, especially for RC foundations, retaining walls, and below-grade beams (Maslehuddin et al., 2007; Norhazilan et al., 2012). Alongside cover, mix design, and exposure control, materials innovations such as graphene-oxide (GO) additions have also been shown to enhance corrosion resistance by refining pore structure and delaying steel depassivation (Oshadhi and Pushpakumara, 2025). Soil type significantly affects these moisture dynamics. Clay, due to its fine particles and high water retention, may exhibit high moisture content but also high ionic binding capacity and low permeability. Sand, on the other hand, allows rapid drainage but may also promote chloride transport in capillary pores (Li et al., 2019). Silt, with intermediate pore structures, may behave differently depending on its plasticity and compaction state. Despite the evident complexity, there is a shortage of side-by-side experimental data that isolates the combined effect of soil type and moisture state on corrosion performance under constant chloride exposure. Prior studies have either focused on simulated solutions (Ann and Song, 2007; Dang and François, 2013), laboratory-prepared soils without moisture variation (Maslehuddin et al., 2007), or natural field conditions without controlled boundary environments (Costa and Appleton, 2002). This study addresses that research gap by implementing a compact, instrumented laboratory program that evaluates corrosion development in RC beams embedded in three soil types (i.e. sand, clay, and silt) each subjected to three moisture states: dry, Optimum Moisture Content (OMC), and saturated.

The primary objectives of this study are: (i) to quantify how clay, sand, and silt differ in chloride ingress, resistivity, and corrosion damage under dry, OMC, and saturated states; (ii) to derive empirical relationships connecting electrochemical indicators to residual flexural strength; and (iii) to propose guidance for soil selection, moisture control, and detailing in coastal or chloride-bearing RC foundation design. This experimental approach and its outcomes provide both novel insight and practical guidance for integrating soil–moisture influences into the durability design and assessment of submerged or buried RC elements.

2. Methodology

2.1 Specimens

Thirty-three prismatic RC beams (300×150×150 mm; Grade 25) were cast with conventional aggregates. A deformed steel bar was centered and wired for electrochemical connection. Curing proceeded under water for 28 days. Three specimen remained unexposed (control), three was immersed in seawater, and 27 were embedded in soils (sand, clay and silt) under three moisture states (dry, OMC and saturated). All soils used for corrosion testing were dosed to 5% chloride.

2.2 Soils

Soils were classified under the AASHTO M 145 standard for highway and soil-aggregate mixtures (AASHTO M 145-91) (AASHTO, 1991). For each soil sample, sieve analyses and Atterberg tests (LL and PI) were conducted, and the resulting indices (Sand: LL $\approx$ 19 %, PI $\approx$ 3.9 %; Silt: LL $\approx$ 38.5 %, PI $\approx$ 13.4 %; Clay: LL $\approx$ 66.5 %, PI $\approx$ 35 %) were used to assign each soil into its AASHTO group. Because the group index values for these soils were comparatively low, the classification was simplified into the broad categories: Sand; granular (A-2 or related subgroup), Silt; intermediate (A-4 / A-5), and Clay; fine-grained clay group (A-6 / A-7). Compaction tests were performed via the Standard Proctor (ASTM D 698 / AASHTO T99) method to determine Optimum Moisture Content (OMC) and maximum dry density. Using the determined OMC, soils were conditioned to dry, OMC, or saturated states for corrosion testing.

2.3 Accelerated Corrosion Test (ACT)

Each test beam was embedded in the conditioned soil (or seawater) and connected to a DC power supply with the steel bar as the anode and a copper electrode in the surrounding medium. An impressed current of 0.05 A was applied continuously for 40 days under controlled ambient conditions: the temperature was maintained at 25 °C $\pm$ 2 °C and the relative humidity at 60 % $\pm$ 5 %. This controlled environment enables the electrochemical reactions to approximate long-term chloride-induced corrosion within a shortened timeframe.

2.4 Measurements

Measurements were conducted on 33 beam specimens as summarized in Table 1, which lists the exposure media (soil or seawater), moisture state (dry, OMC, or saturated), and chloride conditioning (5% for all soils; natural for seawater). The uncorroded control (00) and seawater-exposed specimens (01) serve as the reference extremes.

The three soils used for embedding the beam specimens were selected to represent distinct geotechnical categories: sand, silt, and clay. Their index properties, including liquid limit (LL), plastic limit (PL), and plasticity index (PI) were determined via laboratory testing and are shown in Table 2.

Table 01: Specimen matrix for exposure and testing

Label	Soil/Medium	Moisture State	Chloride in Soil
00	Control (no ACT)	—	—
01	Seawater	—	—
A1	Sand	Dry	5% Cl ⁻
A2		OMC	
A3		Saturated	
B1	Clay	Dry	
B2		OMC	
B3		Saturated	
C1	Silt	Dry	
C2		OMC	
C3		Saturated	

Table 02: Index properties used for soil classification

Property	Sample 01	Sample 02	Sample 03
Liquid Limit (%)	19	38.5	66.5
Plastic Limit (%)	15.1	25.1	42.3
Plasticity Index (%)	3.9	13.4	35
Maximum Dry Density (kg/m ³)	1489.4	1918.2	2350.6
Optimum Moisture Content (%)	8.7	10.15	15.18
AASHTO Classification	Sand	Silt	Clay

3. Data Analysis and Results

3.1 Chloride Ingress

Chloride ingress was assessed by measuring both free chloride and total chloride at two depths (i.e. surface and 40 mm) for all specimens. The results are summarized in Table 3. As expected, specimen 01, which was fully immersed in seawater, recorded the highest chloride concentrations at both depths (free Cl⁻: 0.835 kg/m³ surface; 0.384 kg/m³ at 40 mm). Among the soil-embedded specimens (all dosed to 5% Cl⁻), clay showed somewhat higher chloride uptake than sand in dry and OMC states, likely due to clay’s higher surface area and ion retention near interfaces, while in saturated conditions sand slightly surpasses clay in uptake, as free ion mobility becomes dominant. Silt remained the lowest in both states. Moisture state significantly influenced chloride ingress. In each soil type, free chloride increased progressively from dry → OMC → saturated conditions. The data confirm that saturation facilitates chloride migration, particularly in clay due to its ion binding effects.

Table 03: Free and total chloride concentrations after exposure (mass % of concrete powder)

Specimen	Free Cl ⁻ (surface) (kg/m ³)	Free Cl ⁻ (40 mm) (kg/m ³)	Total Cl ⁻ (surface) (kg/m ³)	Total Cl ⁻ (40 mm) (kg/m ³)
00	0.12	0.092	0.165	0.121
01	0.835	0.384	0.995	0.482
A1	0.526	0.237	0.711	0.436
A2	0.548	0.258	0.731	0.453
A3	0.569	0.273	0.755	0.485
B1	0.540	0.147	0.760	0.362
B2	0.580	0.166	0.800	0.380
B3	0.481	0.194	0.674	0.407
C1	0.408	0.116	0.576	0.305
C2	0.42	0.125	0.589	0.323
C3	0.431	0.136	0.604	0.34

3.2 Steel Corrosion and Bar Loss

Steel corrosion was quantified by measuring both rust mass and bar diameter reduction ($\Delta\Phi$). Results are presented in Table 4. The most significant corrosion occurred in Specimen 01 (seawater), which produced 4.278 g of rust and a 3.95 mm loss in bar diameter. Among the soil groups, clay exhibited greater corrosion than sand in both dry and OMC conditions as seen from higher bar losses in B1 and B2 relative to corresponding sand specimens. In the saturated condition, bar losses in sand and clay became comparable (e.g., $\Delta\Phi = 3.15$ mm for A3 vs 2.05 mm for B3), consistent with convergence in ionic conductivity once full saturation is reached. Silt consistently displayed the least steel loss, with $\Delta\Phi$ ranging from 0.38 mm (dry) to 1.10 mm (saturated), highlighting its lower permeability and chloride mobility. Notably, while saturation worsens corrosion in all soils, it reduces the relative difference between clay and sand, supporting the hypothesis that under saturated conditions, corrosion becomes more chloride-driven than soil-dependent.

Table 04: Rust production and bar diameter loss after accelerated corrosion

Specimen	Rust mass (g)	Bar diameter Φ (mm)	Reduction $\Delta\Phi$ (mm)
00	0.325	11.74	0.26
01	4.278	8.05	3.95
A1	3.886	8.58	3.42
A2	3.795	8.72	3.28
A3	3.642	8.85	3.15
B1	4.125	8.48	3.26
B2	3.860	8.60	3.14
B3	2.108	9.95	2.05
C1	0.585	11.62	0.38
C2	0.965	11.25	0.75
C3	1.265	10.9	1.1

3.3 Concrete Resistivity

Concrete resistivity was measured post-exposure as an indirect indicator of corrosion potential. The results are plotted in Figure 1, while Table 5 summarizes widely accepted resistivity ranges for interpreting corrosion risk.

As expected, Specimen 00 (control) had the highest resistivity (32.8 kΩ·cm) and lowest corrosion level (16.2%). In contrast, Specimen 01 (seawater) exhibited very low resistivity (3.8 kΩ·cm), indicating a very high probability of corrosion, and correlating with the highest corrosion observed.

Among soil-exposed specimens:

- Clay: resistivity ranged from 8.5 → 7.5 kΩ·cm (dry → saturated)
- Sand: slightly higher resistivity, from 9.3 → 7.6 kΩ·cm
- Silt: higher overall, from 18.2 → 15.1 kΩ·cm

This pattern reflects that clay, though more compact, shows lower resistivity than sand, likely due to its moisture retention and ionic binding effects at intermediate and high moisture states. Saturation universally lowered resistivity across all soils, enhancing corrosion probability. .

These trends are plotted in Figure 1, which includes horizontal threshold lines marking resistivity categories:

- <5 kΩ·cm = very high corrosion risk
- 5–10 kΩ·cm = high risk
- 10–20 kΩ·cm = moderate
- >20 kΩ·cm = low

Table 05: Commonly cited resistivity ranges for corrosion probability

Resistivity ρ (kΩ·cm)	Qualitative corrosion probability
< 5	Very high probability
5–10	High probability
10–20	Moderate to low probability
> 20	Low probability

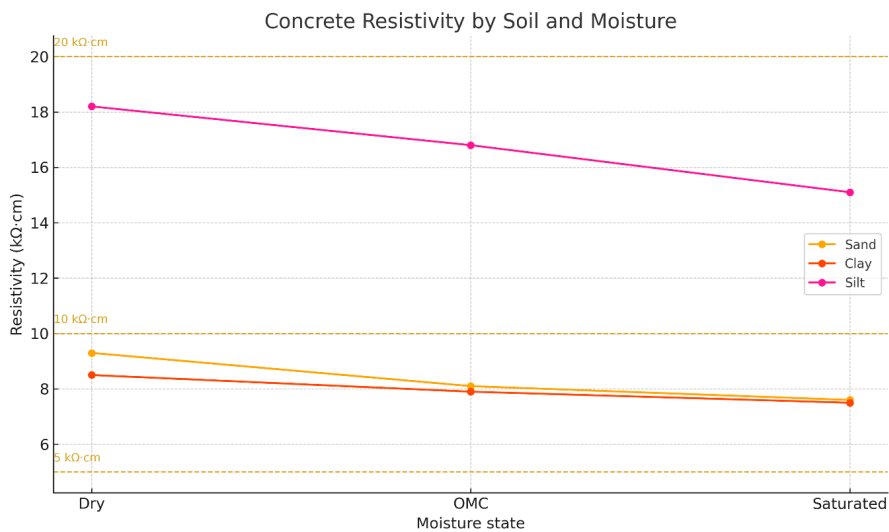


Figure 01: Concrete resistivity vs moisture for each soil with commonly cited probability thresholds.

3.4 Flexural Strength Reduction

Residual structural performance was assessed through four-point flexural strength tests. The control specimen (00) achieved a strength of 9.58 (units to be confirmed as MPa or kN·m). In contrast, Specimen 01 (seawater) showed the most significant deterioration, with strength reduced to 4.68, a ~51% decrease.

Among the soil-exposed specimens:

- Clay showed greater degradation than sand in dry and OMC conditions: strength decreased from 6.44 (dry) to 5.66 (saturated)
- Sand showed slightly better retention: 6.60 → 5.62
- Silt preserved the most capacity: 8.98 → 8.06

Moisture again had a worsening effect on all soils. These outcomes are clearly depicted in Figure 2, where flexural strength is plotted against moisture condition for each soil. The curve for clay shows more severe degradation at lower moisture states compared to sand, supporting

the conclusion that corrosion effects manifest earlier in clay despite its higher resistivity in some cases.

The results correlate well with the previously observed chloride ingress, resistivity, and corrosion levels, validating the multi-indicator approach to evaluating durability.

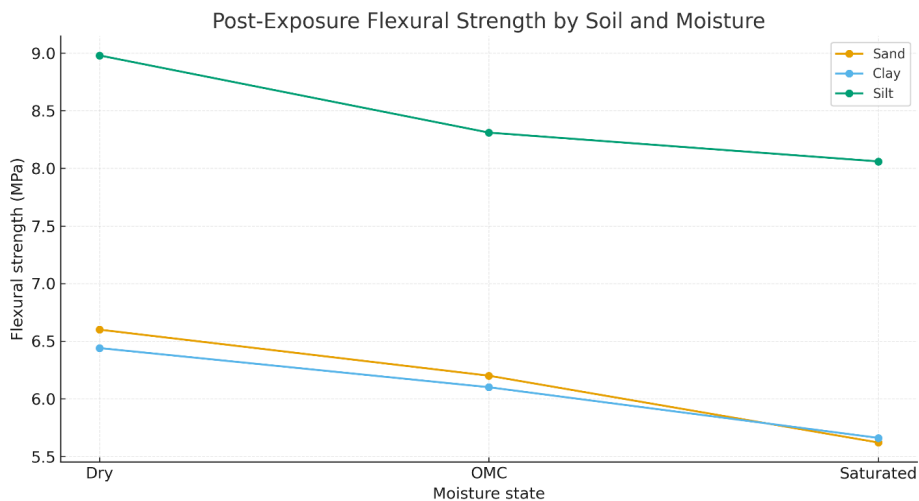


Figure 02: Post-exposure flexural strength vs moisture for each soil.

4. Discussion

Findings corroborate the central role of moisture in chloride-induced corrosion of buried RC. Resistivity trends aligned with widely used probability bands and mirrored chloride profiles and steel loss, supporting resistivity as a rapid field indicator (Rossi et al., 2022; Azoor et al., 2019). Clay’s greater severity at lower moisture states likely reflects higher water retention and localised chloride concentration near the steel, intensifying anodic activity and differential aeration; under saturation, enhanced ionic continuity reduces soil-texture effects, narrowing the gap to sand. Silt’s consistently higher resistivity and lower chloride mobility translated to the least damage, reinforcing the value of silt-like or engineered fills for durability. The mechanical reductions tracked electrochemical damage, demonstrating a practical linkage between diagnostics and performance, consistent with prior corrosion–mechanics observations in RC (Daku et al., 2019; Sing et al.,2013).

5. Conclusions and Recommendations

Moisture content is the dominant accelerator, increasing chloride uptake, lowering resistivity into high-risk bands for sand and clay, increasing steel loss and reducing flexural strength. Under a fixed chloride dose, relative corrosiveness followed clay ≥ sand >> silt, with clay–sand differences less pronounced at saturation, indicating the primacy of ionic continuity at high moisture. Resistivity provided a reliable, rapid indicator that tracked chloride and mechanical degradation. Use higher-resistivity fills or engineered backfills; implement drainage and moisture barriers; specify low-permeability concretes and protective

reinforcement for saturated or sandy exposures; and adopt routine resistivity screening with confirmatory chloride tests for condition assessment.

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Thematic Track: Construction & Built Environment

Abstract number: 124

Enhancing urban resilience through AI-supported fire risk assessment of office buildings in Colombo city area

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Abstract

Urban resilience relies on the functionality, safety, and reliability of the built environment in addition to ecological integrity and sustainable land use. In Sri Lanka, office building fire safety is an essential but frequently disregarded aspect of sustainable urban development. High-rise office buildings are increasing due to rapid vertical urban growth; however, many of these buildings have inadequate fire protection systems and only partially comply with national fire regulations. This study examines 10 representative office buildings in Colombo and uses a semi-quantitative, AI-compatible fire risk assessment tool developed specifically within Sri Lanka's prescriptive regulatory framework. The tool incorporates 221 regulatory and managerial attributes across five domains, as confirmed by over 50 prior case studies and published works: means of escape, structural fire protection, detection systems, suppression systems, and fire safety management. The study identifies the most significant deficiencies influencing fire risk using the Relative Importance Index (RII) method and a four-level compliance scoring model. The results showed that passive fire safety measures averaged 48% below the required standard, while active protection systems, including hydrants, hose reels, extinguishers, and alarms, achieved 48.5% compliance. Overall, there was 50% compliance with international standards and 51% compliance with national (CIDA) fire regulations. Thirty percent of the evaluated buildings were classified as high risk, forty percent as moderate risk, and ten percent of them received a "low risk" rating. The study identifies the main reasons for poor performance as severe regulatory enforcement gaps, fragmented legal frameworks, and inadequate resource allocation. To strengthen urban resilience, the study recommends modernizing fire codes and stabilizing proper enforcement mechanisms, ensuring periodic compliance audits, integrating AI-assisted risk assessment tools, and embedding fire safety within broader sustainability frameworks. By connecting risk-informed design, regulatory compliance, and AI-supported predictive analytics, this research underscores fire safety as a foundational element of sustainable city design and climate-resilient infrastructure in Sri Lanka.

Keywords: Fire Risk Assessment, Office Buildings, Regulatory Compliance, Sustainable Fire Safety, Urban Resilience,

Enhancing urban resilience through AI-supported fire risk assessment of office buildings in Colombo city area

1. Introduction

The reliability, safety, and continuity of built infrastructure, especially office buildings that accommodate substantial workforces and support economic activity, are closely related to urban resilience. Although risk-informed urban planning is becoming increasingly important in global sustainability frameworks, fire safety is still considered a separate technical field in Sri Lanka rather than a key element of sustainable development. (Bosher et al., 2007; Barua & Han, 2025). Enforcement gaps in laws and regulations are the main root cause of fire safety issues in Sri Lankan office buildings (Gunarathna, Fernando and Sridarran, 2014). Major shortcomings in fire detection, suppression systems, means of escape, and management procedures can be found in many office buildings built before the introduction of fire regulations in 1997 (Liyanapeli *et al.*, 2025a).

Although baseline compliance criteria have been established by the Construction Industry Development Authority (CIDA), the Urban Development Authority (UDA), and the fire service department bylaws, enforcement remains inadequate, and monitoring systems are dispersed (Liyanapeli *et al.*, 2023). Even though they provide structured inspection methods, globally accessible digital risk assessment tools such as SafetyCulture, FireMate, and GoAudits are expensive, data-intensive, and incompatible with Sri Lankan regulatory frameworks (Twigg *et al.*, 2017) (Cleef *et al.*, 2024). The Fire Risk Management Tool (FRMT), a semi-quantitative, checklist-based framework that can operate offline and is intended for future AI integration to enable automated data analysis and predictive scoring, was developed to close this gap (Liyanapeli *et al.*, 2025b).

Using a semi-quantitative model in line with Sri Lanka's regulatory framework, this study was carried out to (1) evaluate fire safety compliance and risk levels in office buildings; (2) identify critical deficiencies that constitute the primary cause of elevated fire risks and assess their implications for urban resilience and sustainability; and (3) explore the potential of AI-assisted fire risk assessment as a proactive tool for assisting building management, policymaking, and sustainable urban governance.

2. Methodology

A mixed-method, semi-quantitative approach was used to evaluate the risk levels and fire safety compliance of Sri Lankan office buildings.

Table 01: Distribution of Selected Sample

Number	Office Building	Height Category	Government /Private
1	A	Medium rise	Government
2	B	High rise	Government
3	C	Super high-rise	Private
4	D	High rise	Government
5	E	Low rise	Private
6	F	Medium rise	Private
7	G	Medium rise	Private
8	H	High rise	Private
9	I	High rise	Private
10	J	High rise	Government

Using Sri Lanka's prescriptive regulatory framework, mainly the requirements of the Construction Industry Development Authority (CIDA), Fire Service Department, and the Urban Development Authority (UDA), a structured fire risk assessment tool was developed. The tool integrates both active and passive fire protection factors together with management requirements in the lifecycle of the buildings within five domains: means of escape, structural fire protection, detection systems, suppression systems, and fire safety management. Over fifty prior case studies and published papers were used to validate the tool. Ten office buildings representing a wide variety of ages, occupancy levels, and design types were deliberately selected from the Colombo city area. Site inspections, document reviews, and interviews with facility managers and fire safety officers were carried out to collect data on compliance with relevant fire safety regulations. 221 attributes were evaluated using a transparent scoring system across four compliance levels: non-compliant, partially compliant, compliant, and fully compliant. Critical risk factors were prioritized, and the importance of individual deficiencies was determined using the Relative Importance Index (RII) method. Descriptive statistics were thereafter employed to compare and analyze the semi-quantitative results to evaluate the overall fire risk and determine compliance levels. In addition to ensuring reproducibility, the methodology sets foundations for future integration with AI-assisted prediction models for proactive fire risk management.

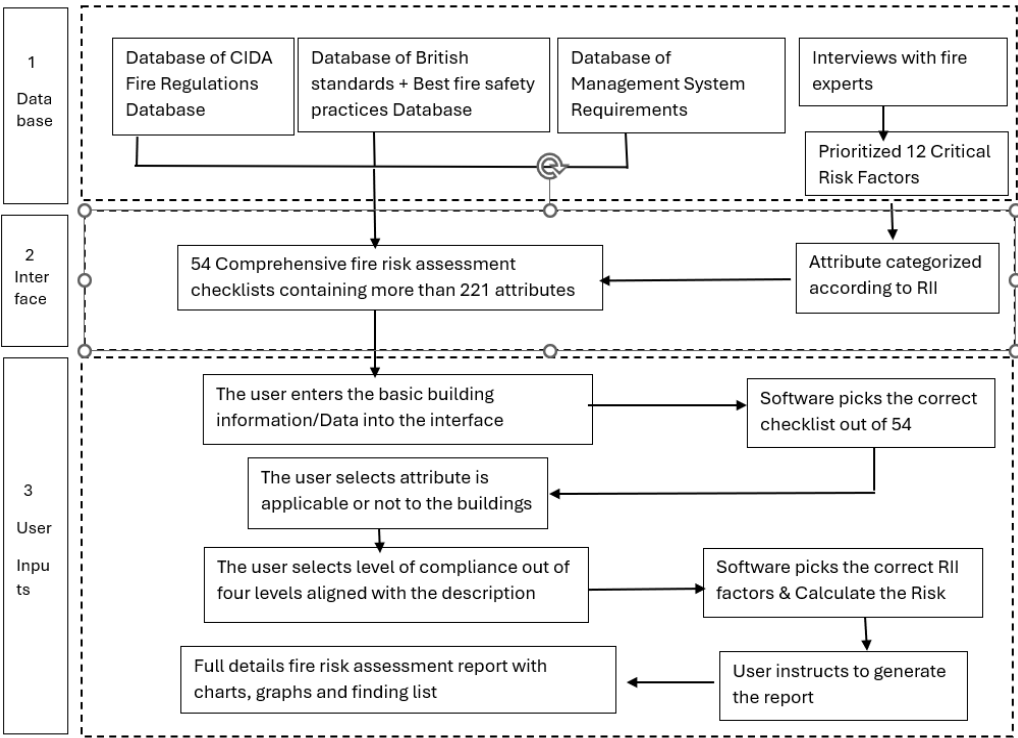


Figure 01: Process of functioning of the new FRMT

3. Data Analysis and Results

Significant gaps in compliance with active and passive fire safety measures were found by the analysis. While passive measures like compartmentation, structural protection, and escape provisions averaged 48 % below the minimum requirements, active systems such as alarms, extinguishers, hose reels, hydrants, and sprinklers only showed an average compliance of 48.5%. Overall, building compliance was 50% when compared to international best practices and 51% when compared to Sri Lanka's CIDA regulations. Thirty percent of the buildings were categorized as high risk, forty percent as moderate risk, and twenty percent as low risk; Only ten percent received a "low risk" classification. The lowest levels of compliance were found in older buildings built prior to the introduction of modern fire regulations, especially in the areas of fire safety management, detection, means of escape, and suppression systems. The analysis found that the main factors affecting fire risk were a lack of periodic inspections, a lack of means of escape, and a fire detection systems and fire protection systems. To improve proactive fire safety governance and strengthen urban resilience in Sri Lanka, the results highlight the pressing need for regulatory reform, uniform enforcement, and the incorporation of AI-assisted fire risk assessment tools.

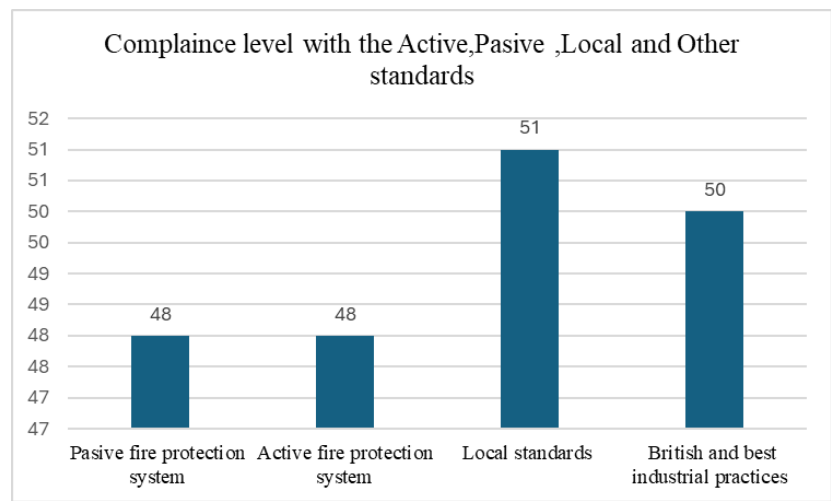


Figure 02: Compliance levels with passive, active, and British & best industrial practices

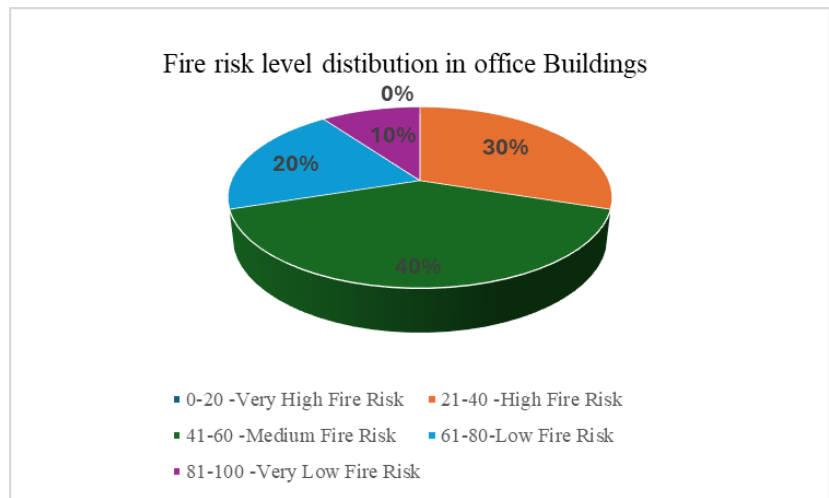


Figure 03: Fire risk level distribution in office buildings

4. Discussion

The results highlight a recurring discrepancy between the intention and execution of regulations in Sri Lanka's office building sector. Active and passive protection systems, the first lines of defense in the event of a fire, are consistently inadequate in office buildings. Authorities appear to prioritize visible structural conformity over operational aspects, as evidenced by the moderate compliance with means of escape and active fire protection systems. Consistent enforcement is hampered by agencies' divided responsibilities and a lack of technical capability. This study shows how semi-quantitative frameworks can transform conventional inspections into data-driven decision tools by implementing RII-weighted scoring. Early detection of compliance gaps, benchmarking, and predictive maintenance may all be made possible by the incorporation of AI-assisted analysis. By improving decision-making and resource

efficiency, integrating fire risk assessment into urban governance supports the global trend toward AI-enabled sustainable cities.

5. Conclusions and Recommendations

The overall performance, averaging only 50–51% of the required standards, indicates that fire safety compliance in Sri Lankan office buildings remains severely insufficient. Urban resilience is weakened by redundant regulations, weak enforcement, and inadequate managerial supervision. Older buildings are more vulnerable due to inadequate implementation of both active and passive systems. Modernizing regulations together with enforcing mechanisms, requiring regular audits, increasing capacity, and implementing AI-assisted risk monitoring are all crucial to overcoming these obstacles. Predictive analytics integration will support climate-resilient and sustainable urban development by enabling proactive safety governance. The Fire Risk Management Tool should be improved in the future to include dynamic elements like energy consumption, occupancy density, and sensor-based data for real-time monitoring.

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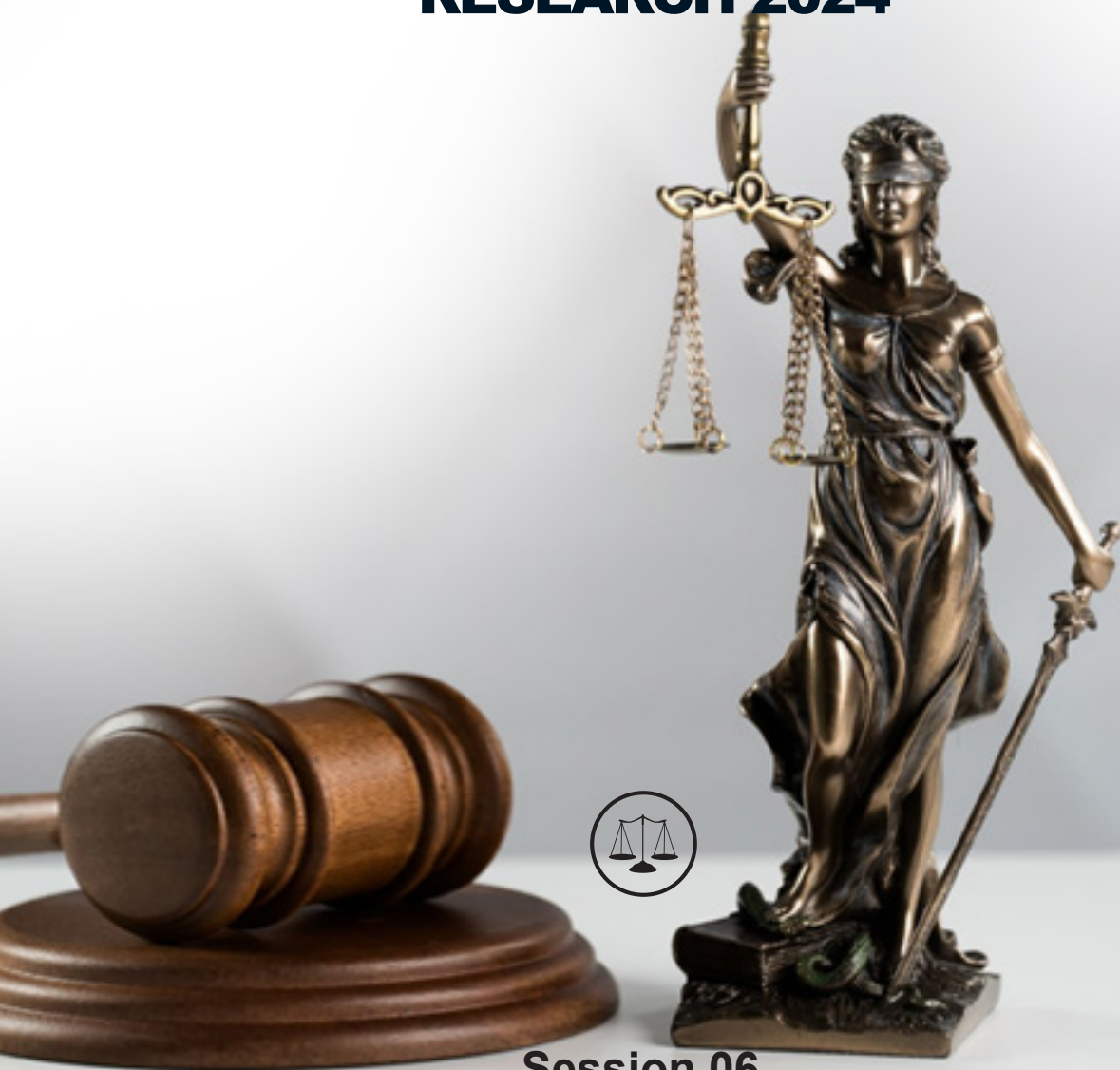


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**Session 06
Legal Studies**

Thematic Track: Legal Studies

Abstract number: 140

A legal analysis on the need to amend Sri Lankan defamation laws to address AI-generated deepfake content

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Abstract

Artificial intelligence (AI) has enabled the creation of "deepfakes," or remarkably realistic spoof voices, images, and videos that can make people appear to say or do things they never did. Research indicates that approximately 96% of deepfakes globally are pornographic, targeting women and violating their dignity, making the problem especially serious for them. These changes bring up a pressing legal issue: can Sri Lanka's current defamation laws adequately address the harms caused by deepfake technology? The purpose of this study is to assess how well Sri Lanka's defamation laws handle false information produced by artificial intelligence, find any legal loopholes, and suggest changes that strike a balance between free speech and reputation protection. In addition to international statutes like the UK Defamation Act 2013, AI Act, and U.S. deepfake laws, the study employs a qualitative doctrinal approach, examining legal texts such as Sri Lankan defamation laws and the Online Safety Act (OSA) 2024 and Penal Code. We also looked at secondary data, such as human rights reports and legal journals. The study concludes that Sri Lanka's defamation law needs to be updated immediately. Reforms should define criminal liability for malevolent creators, create platform accountability under judicial supervision, define fast-track injunctions, and specifically include AI-generated media as defamatory. Legal aid procedures, awareness campaigns, and forensic standards should also be created to guarantee that victims particularly women get prompt and equitable redress. In the digital age, these reforms would help Sri Lanka preserve its dignity and reputation while defending the right to free speech.

Keywords: Artificial Intelligence, Regulation, Deepfakes, Defamation Law, Online Safety Act

A legal analysis on the need to amend Sri Lankan defamation laws to address AI-generated deepfake content

1. Introduction

Deepfakes are fake videos, images, and voices that look and sound very real. For instance, a fake video of businessman Dhammika Perera was spread online to get people to invest in a fake business. (Dinithi Pelithanthrige, 2025). But the worst thing is that it hurts women the most. Fake sexual pictures of Sri Lankan actresses, journalists, and even regular women have been spread online, which has made them feel ashamed and scared. These abuses raise an important question: Is Sri Lanka's current defamation law strong enough to deal with the risks of deepfakes?

Defamation laws were made for a time when lies were spread through newspapers and speeches, not AI-generated media. The problem now is that the law hasn't kept up with technology, so victims have very little real protection.

Researchers and lawyers around the world agree on two conflicting needs: 1. Protecting people's reputations from false or manipulated content, and 2. Protecting freedom of speech and creativity online. (Jodka, 2024)

First Amendment in the United States gives people a lot of freedom of speech. Lies are usually safe unless they clearly turn into defamation, fraud, or another crime. When states like Texas and Minnesota tried to make it illegal to use deepfakes in elections, courts said the laws were too broad and violated free speech rights. (brianbuchanan, 2024)

The UK, on the other hand, depends on the Defamation Act of 2013, which mandates that victims demonstrate "serious harm" to their reputation. If a deepfake causes significant harm to someone's reputation, it may pass this test. Enforcement is challenging, though, as victims must track down the person who created or posted the fake, which is frequently concealed behind phony accounts overseas, and demand that platforms remove it. This is a gradual and unpredictable process.

By introducing the AI Act, the European Union (EU) is taking things a step further and requiring transparency tools on AI-generated content, such as watermarks or labels. This makes it easier for people to spot fake. Countries all over the world are revising their legal frameworks to address deepfakes. There is a clear trend: while new tools are necessary, laws that are too general may restrict free speech. (Mishcon de Reya LLP, 2025)

Research Objectives

1. The first goal of this study is to determine the shortcomings of Sri Lanka's current defamation law and assess its ability to handle AI-generated deepfakes.
2. Examine how defamation pertaining to deepfakes is handled in other nations (such as the UK, EU, USA, etc.).
3. Examine how human rights principles can be applied to strike a balance between freedom of speech and reputation protection.
4. Make recommendations for legal changes that uphold free speech, such as precise definitions, expedited resolutions, and responsibility for those who create or disseminate deepfakes.

2. Methodology

This is a qualitative doctrinal study. The research reviews Sri Lankan defamation laws and case law alongside the Online Safety Act 2024; compares foreign frameworks such as the UK's Defamation Act 2013 and Online Safety Act 2023, the EU's AI Act, and relevant U.S. state and federal deepfake laws; and synthesizes insights from legal journals and reports produced by human rights organizations and subject-matter experts.

3. Data Analysis and Results

Article 14 (1) a of the Sri Lankan Constitution provides the right of free speech; somehow it can be restricted in the case of defamation. Sri Lanka's existing criminal laws contain strong provisions against the obscene publication of images or videos, especially those involving females and children. The Obscene Publications **Ordinance** criminalizes the creation, distribution, or possession of obscene materials such as writings, drawings, photographs, or films. The Online Safety Act, Section 20, makes it an offense to publish or share private information online with the intent to harass another person, punishable by up to five years' imprisonment or a fine of up to five hundred thousand rupees, with increased penalties for repeat offenses. Similarly, Section 286A of the Penal Code addresses child exploitation by prohibiting the use, coercion, or involvement of children in any indecent photographs, films, or exhibitions and punishes offenders with imprisonment ranging from two to ten years and possible fines. It also requires developers of such materials to report obscene content involving children to the police. However, none of these laws specifically address the modern issue of AI-generated or deepfake images, leaving a legal gap in dealing with digitally manipulated content that can harm individuals' dignity and reputation.

In terms of civil law remedies, if a defamatory image of a person is published, he or she may file a defamation case in the District Court and seek compensation. To succeed in such a claim, the following elements must be proven:

- 1.The statement must be defamatory
- 2.It must refer to the plaintiff
- 3.It must be published
- 4.*Animus injuriandi* on the part of the defendant

In the case of *De Villiers vs Vels* 1921 OPD 55 it was held that mere expression of abuse cannot be considered as defamation unless that image of words refer hatred, laugh at them unfairly, or to diminish the willingness of others to associate with him. Also, in the case of *MGP Perera vs A V Peiris* (1947) it was held that *animus injuriandi* of the defendant should be proved to claim damages for defamation

Since deepfakes convey a false statement about someone, Sri Lanka's defamation law may theoretically apply to them, but it is ineffective.

There are three primary gaps:

1. Jurisdiction and anonymity: Deepfake creators frequently post from overseas or use fictitious names, making it very difficult to bring legal action against them.

2. No quick takedowns: Civil cases are moving too slowly, but victims need content removed quickly. Social media companies are not required by law to remove dangerous deepfakes.

3. High burden of proof: victims have to demonstrate that the fake is untrue, which calls for costly expert analysis.

Therefore, victims have no prompt or efficient remedy, even though the current defamation law may technically apply. Deepfakes have not yet been specifically addressed in any Sri Lankan court case.

The comparative study shows that various legal systems have taken different stances when it comes to dealing with deepfakes. The Defamation Act of 2013 in the United Kingdom makes deepfakes that cause significant harm actionable, and victims can get court orders to identify the anonymous perpetrators, something Sri Lanka does not yet have. Although victims may file a lawsuit in the US for defamation or "false light," their options are limited because online platforms such as YouTube are protected from liability for user-generated content by Section 230 of the Communications Decency Act.

4. Discussion

Defamation laws in Sri Lanka were never intended for an AI-fake world. Today's victims have limited opportunities for immediate relief. Although preserving one's reputation is still the main objective of defamation, deepfakes make lies more plausible and dangerous than ever.

Justice for digital harm will proceed too slowly if laws stay the same. However, laws that are too rigid may also restrict free expression. Reform must therefore strike a balance between quick civil remedies and extensive censorship.

Any speech restrictions must be appropriate and necessary in accordance with Article 19 of the ICCPR. Accordingly, criminal defamation ought to be reserved for the most dire circumstances. Emphasis should be on civil remedies, such as court orders and damages. The study also points out that deepfakes infringe upon human dignity and privacy, which are legally protected, in addition to reputation. Defamation is still the victims' most practical legal option, though.

The two main enforcement issues that Sri Lanka needs to address for reforms to be successful are anonymity and content removal. Platforms should be obliged to remove verified fakes under an open "notice and action" system akin to the EU model, while courts should have the authority, as in the UK's Norwich Pharmacal Orders, to force platforms to identify the authors of defamatory deepfakes. Importantly, an impartial entity must supervise this procedure to guarantee equity and avoid political abuse.

The legal question in the case of *Megan Thee Stallion v. Milagro Cooper* (2025, Miami Federal Court), which is presently pending in the United States, is whether or not someone who disseminates or promotes an AI-altered video is legally liable for the harm it causes in the real world. Megan claimed that Cooper had amplified a deepfake video to harm her reputation and career. The law pertaining to media defendants, the handling of deepfake cases in the future, and limitations on free speech and online commentary will all be shaped by this case.

5. Conclusions and Recommendations

The study comes to the conclusion that deepfake harms are not adequately covered by Sri Lanka's antiquated defamation laws. Victims must deal with lengthy legal proceedings, the burden of technical proof, and the lack of an immediate solution to stop fraudulent content. Although deepfakes may technically be considered defamatory, there are no enforcement tools available.

To improve Sri Lanka's response to defamation caused by deepfakes, I suggest a number of specific reforms. AI-generated or manipulated media should be specifically recognized as defamatory when they damage someone's reputation, according to an amendment to the civil defamation law. Victims should be able to quickly obtain takedown or injunction orders against harmful deepfakes through a fast-track court process. It should also be noted that “joke” can be raised as a defense in defamation cases. Therefore, a perpetrator might claim that the deepfake image was shared merely as a joke in order to avoid civil liability for defamation. So, these unintentional sharing should be protected, while those who purposefully produce or disseminate malicious deepfakes should be punished by a limited criminal offense. With safe harbor protection for those acting in good faith, online platforms should be legally obligated to remove deepfakes upon court order. By creating forensic standards, educating legal professionals, and amending the Evidence Ordinance to accept digital proof, the law must also improve technical and evidentiary capacity. Lastly, legal aid and public awareness initiatives should inform the public about deepfakes and guarantee that victims, particularly women, have access to prompt assistance and reporting channels.

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Thematic Track: Legal Studies

Abstract number: 144

From silence to recognition: A socio-legal comparison of marital rape laws and cultural perceptions in Sri Lanka and the United Kingdom

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Abstract

Marriage is conventionally regarded as a social institution grounded in mutual respect, equality, and partnership. Nevertheless, in many societies, including Sri Lanka, marriage continues to be influenced by patriarchal structures that position men as dominant figures within the family unit. One of the most critical manifestations of this inequality is the legal and social tolerance of marital rape, defined as non-consensual sexual intercourse by a husband with his wife. In Sri Lanka, marital rape remains unrecognized as a criminal offense. The Penal Code explicitly excludes it from the legal definition of rape, except in instances where the spouses are judicially separated. This exemption signifies that sexual intercourse within marriage, even without consent, is not regarded as rape under existing legislation. Such a provision has generated substantial concern among legal scholars, human rights advocates, and medical professionals, as it undermines fundamental principles of bodily autonomy, gender equality, and personal dignity. International human rights instruments have long affirmed the equality of spouses within marriage. Article 16(1) of the Universal Declaration of Human Rights (UDHR), Article 23(4) of the International Covenant on Civil and Political Rights (ICCPR), and Article 16(1) (c) of the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) collectively recognize that men and women are entitled to equal rights in marriage and at its dissolution. The continued exemption of marital rape from criminal prosecution in Sri Lanka thus reflects a profound inconsistency between domestic law and international human rights obligations. In contrast, the United Kingdom represents a jurisdiction that has successfully reformed its approach to marital rape. The landmark decision in *R v R (1991)* abolished the long-standing marital rape exemption, establishing that marriage does not constitute irrevocable consent to sexual relations. This judicial development marked a pivotal moment in aligning domestic law with the principles of consent and equality, illustrating a progressive recognition of women's sexual autonomy within marriage. Despite the global shift toward criminalization, Sri Lanka's reluctance to reform its Penal Code continues to perpetuate gender inequality and normalize coercive sexual practices within marriage. Deeply entrenched socio-cultural attitudes further reinforce the misconception that marriage confers sexual rights upon husbands, thereby silencing victims and obstructing access to justice. Accordingly, this research titled "From Silence to Recognition: A Socio-Legal Comparison of Marital Rape Laws and Cultural Perceptions in Sri Lanka and the United Kingdom" undertakes a comparative socio-legal analysis to examine how differing legal frameworks and cultural perceptions shape the recognition of marital rape. Ultimately, this study underscores the urgent necessity for comprehensive legal reform and policy intervention to ensure the full protection of women's human rights, bodily integrity, and equality within the institution of marriage.

Keywords: Marital Rape, Consent, Sri Lanka, United Kingdom, Gender Justice

From silence to recognition: a socio-legal comparison of marital rape laws and cultural perceptions in Sri Lanka and the united kingdom

1. Introduction

1.1 Background

Marriage is often described as a relationship built on mutual respect, shared responsibilities, and equality. Yet, in many South Asian societies including Sri Lanka, this ideal is frequently overshadowed by long-standing patriarchal traditions that grant husbands greater authority within the home. One of the most damaging outcomes of these unequal power dynamics is the continued existence of marital rape, where a husband engages in sexual intercourse with his wife without her consent. Under Section 363(e) of the Sri Lankan Penal Code, marital rape is not recognized as an offence unless the couple is legally separated. This legal exemption reinforces the outdated notion that marriage automatically grants permanent sexual consent, restricting women's autonomy and conflicting directly with global human rights standards. International frameworks such as the UDHR, ICCPR, and CEDAW emphasize equality within marriage and the fundamental right to bodily integrity, yet Sri Lanka's laws do not fully reflect these commitments. The idea that a husband cannot rape his wife can be traced back to a 17th-century statement by Sir Matthew Hale, whose view heavily influenced many Commonwealth legal systems during the colonial era. The United Kingdom eventually rejected this doctrine through the landmark ruling in *R v R* (1991), which affirmed that marriage does not erase a woman's right to refuse consent. Against this backdrop, marital rape becomes more than a legal concern; it is a complex socio-legal issue shaped by cultural expectations, religious beliefs, gender norms, and evolving understandings of human rights. This study therefore explores the gap between Sri Lanka's current legal position and its international obligations, while drawing comparisons to the United Kingdom's more progressive reforms.

1.2 Research Problem

Despite growing global support for women's bodily autonomy and stronger movements advocating gender equality, Sri Lanka still does not fully criminalize marital rape, except in situations where a judicial separation is in place. This stands in clear contrast to the United Kingdom, where marital rape is recognized as a criminal offence regardless of marital status. The core research problem, therefore, lies in the gap between Sri Lanka's limited legal recognition of marital rape and the UK's comprehensive criminalization of the offence, and how this gap affects victims' rights, law enforcement practices, and broader standards of gender justice.

1.3 Research Objectives

- To examine the legal framework governing marital rape in Sri Lanka and the United Kingdom.
- To analyze cultural and societal perceptions shaping attitudes toward marital rape.
- To assess gaps between Sri Lanka's domestic law and its international human rights obligations.
- To recommend legal and policy reforms to ensure criminalization and recognition of marital rape in Sri Lanka.
- To analyze statutory provisions and case law related to marital rape in both jurisdictions.
- To propose strategies for harmonizing Sri Lanka's legal standards with global best practices.

2. Methodology

This study adopts a qualitative and comparative legal research methodology. The focus is on analyzing statutory frameworks, judicial decisions, international human rights instruments, and scholarly literature to understand how marital rape is conceptualized and regulated in Sri Lanka and the United Kingdom.

2.1 Research Design

A qualitative research approach is used to analyze legal rules and principles governing marital rape. Comparative analysis between the two jurisdictions highlights how consent and autonomy are legally interpreted within marriage.

2.2 Data Collection

Secondary data were extracted from:

Primary Legal Sources

- Sri Lanka's Penal Code (Sections 363(e), 393)
- *R v R (1991)*
- Sexual Offences Act 2003 (UK)
- *Attorney-General v Piyadasa (Sri Lanka)*

International Instruments

- UDHR – Universal Declaration of Human Rights (1948)
- ICCPR – International Covenant on Civil and Political Rights (1966)
- CEDAW- Convention on the Elimination of All forms of Discrimination Against Women (1979)

Secondary Sources

Scholarly articles, legal commentaries, law reform commission reports, UN publications.

3. Data analysis and results

- Case law analysis - Comparative review of key decisions including *R v R* (UK) and Sri Lankan cases.
- Comparative analysis - Identifying divergences in legal approaches and cultural attitudes.
- Thematic analysis - Understanding the influence of patriarchal norms on legislative outcomes.

Case Law Analysis

The UK's landmark decision in *R v R* removed the marital rape exemption and firmly established that marriage cannot override consent. Sri Lankan case outcomes, however, show judicial reluctance to expand criminal liability within marriage except in exceptional circumstances. This contrast demonstrates that UK courts actively support recognition of marital rape, whereas Sri Lankan courts reinforce the limited statutory framework.

Comparative Analysis

Across both jurisdictions, key differences emerge in legal approach and cultural expectations. The UK treats marital rape as a human-rights violation, supported by law-enforcement and judicial practice. Sri Lanka's approach is shaped heavily by cultural norms

emphasizing family harmony and marital duty, leading to restrictive legal interpretation and weaker institutional responses.

Thematic Analysis

The thematic patterns highlight that patriarchal attitudes strongly influence Sri Lanka's legal and social treatment of marital rape. Themes such as marital privacy, victim-blaming, and fear of social stigma create barriers to recognition and reporting. In the UK, while challenges remain, societal and legal norms increasingly support survivors' autonomy. Overall, patriarchal norms serve as a major factor explaining why Sri Lanka remains hesitant to fully criminalize marital rape.

3.1 Scope and Limitations

The scope of this study is limited to a legal and socio-legal analysis of marital rape in Sri Lanka and the United Kingdom. It excludes empirical research such as interviews or fieldwork due to ethical and sensitivity concerns. The study relies solely on documentary and textual sources to develop a theoretical understanding. Although the use of secondary data presents certain limitations, it is appropriate for a comparative doctrinal approach.

3.2 Ethical Considerations

As this study does not involve direct human participation, ethical compliance is maintained through the responsible and accurate use of legal and academic sources. All materials are properly acknowledged to ensure intellectual honesty and prevent plagiarism. Given the sensitive nature of sexual violence, the research upholds objectivity, respect, and confidentiality, ensuring that discussions surrounding marital rape are presented with due academic and ethical sensitivity.

4. Discussion

The findings of this study reveal that Sri Lanka's legal stance on marital rape remains fundamentally inconsistent with constitutional principles of equality and international human rights standards. The marital rape exemption under Section 363(e) of the Penal Code reflects entrenched patriarchal attitudes that interpret marriage as implying continuous consent, rather than a union based on mutual respect and individual autonomy. This approach stands in clear contradiction to the principles upheld by the UDHR, ICCPR, and CEDAW, all of which guarantee equal rights for men and women within marriage. In contrast, the United Kingdom's legal evolution, beginning with *R v R (1991)* and consolidated through the Sexual Offences Act 2003, demonstrates a progressive shift towards recognizing sexual autonomy and consent as core human rights. This reformative approach not only aligns with international human rights frameworks but also offers a valuable model for nations that continue to uphold outdated marital exemptions. Furthermore, the study identifies that Sri Lanka's failure to criminalize marital rape extends beyond legal shortcomings and reflects deep-rooted socio-cultural barriers, including traditional gender norms and societal silence on sexual violence. Achieving genuine reform therefore requires a multidimensional approach encompassing legislative change, public awareness, judicial training, and institutional strengthening to ensure effective implementation.

5. Conclusion and recommendations

5.1 Conclusion

This research concludes that the non-criminalization of marital rape in Sri Lanka represents a critical gap in the protection of women's fundamental rights and an enduring reflection of patriarchal legal traditions. The analysis of Section 363(e) of the Penal Code reveals that the exemption granted to husbands perpetuates gender inequality and undermines the principles of consent, autonomy, and human dignity. Despite Sri Lanka's obligations under international human rights instruments such as the UDHR, ICCPR, and CEDAW, the state continues to fall short in ensuring equal protection for married women under criminal law.

In contrast, the United Kingdom's legal evolution, culminating in the abolition of the marital rape exemption through *R v R (1991)* and the Sexual Offences Act 2003, demonstrates a strong commitment to upholding sexual autonomy within marriage. The comparative analysis highlights that Sri Lanka's current legal stance is inconsistent with international standards and modern human rights jurisprudence, reflecting an urgent need for reform.

Ultimately, the study reaffirms that marriage does not negate the requirement of consent in sexual relations. Recognizing marital rape as a criminal offense is not merely a legal necessity but a moral imperative to safeguard women's equality, dignity, and bodily integrity within marriage.

5.2 Recommendations

- Legislative Reform of the Penal Code - Amend Section 363(e) of the Penal Code to remove the marital rape exemption and explicitly recognize marital rape as a criminal offense where consent is always required.
- Incorporation of International Human Rights Obligations - Align domestic laws with CEDAW, ICCPR, and other international treaties to uphold gender equality and meet global human rights commitments.
- Judicial and Law Enforcement Training - Provide specialized, gender-sensitive training for judges, prosecutors, and police to ensure fair and effective handling of marital rape cases.
- Public Awareness and Education - Conduct nationwide campaigns to challenge myths of perpetual marital consent and integrate education on sexual rights and equality into schools and community programs.
- Victim Support Mechanisms - Strengthen counseling, medical, and legal support services for survivors; establish confidential reporting systems and safe shelters.
- Engagement of Civil Society and Religious Leaders - Partner with NGOs, women's groups, and faith leaders to promote cultural change, dialogue, and advocacy for consent and equality in marriage.

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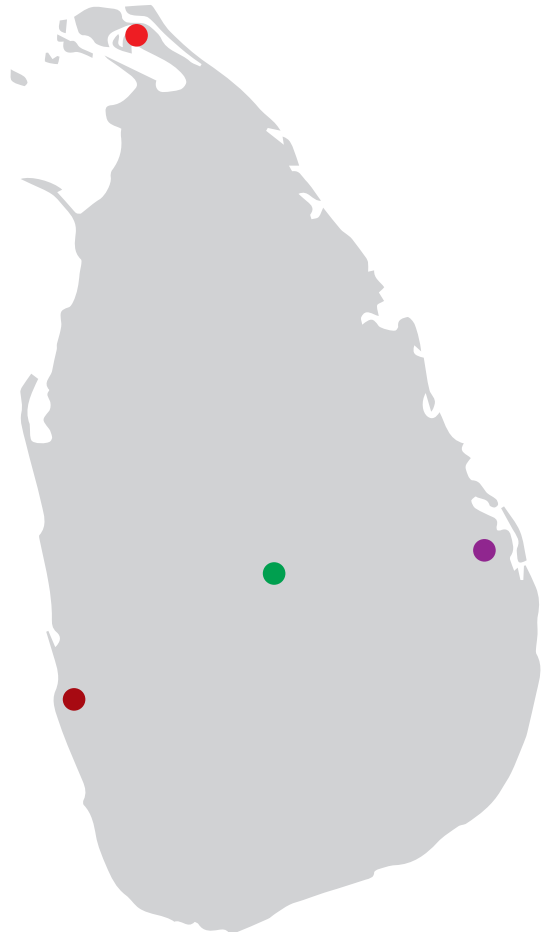
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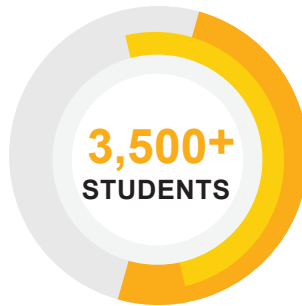
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