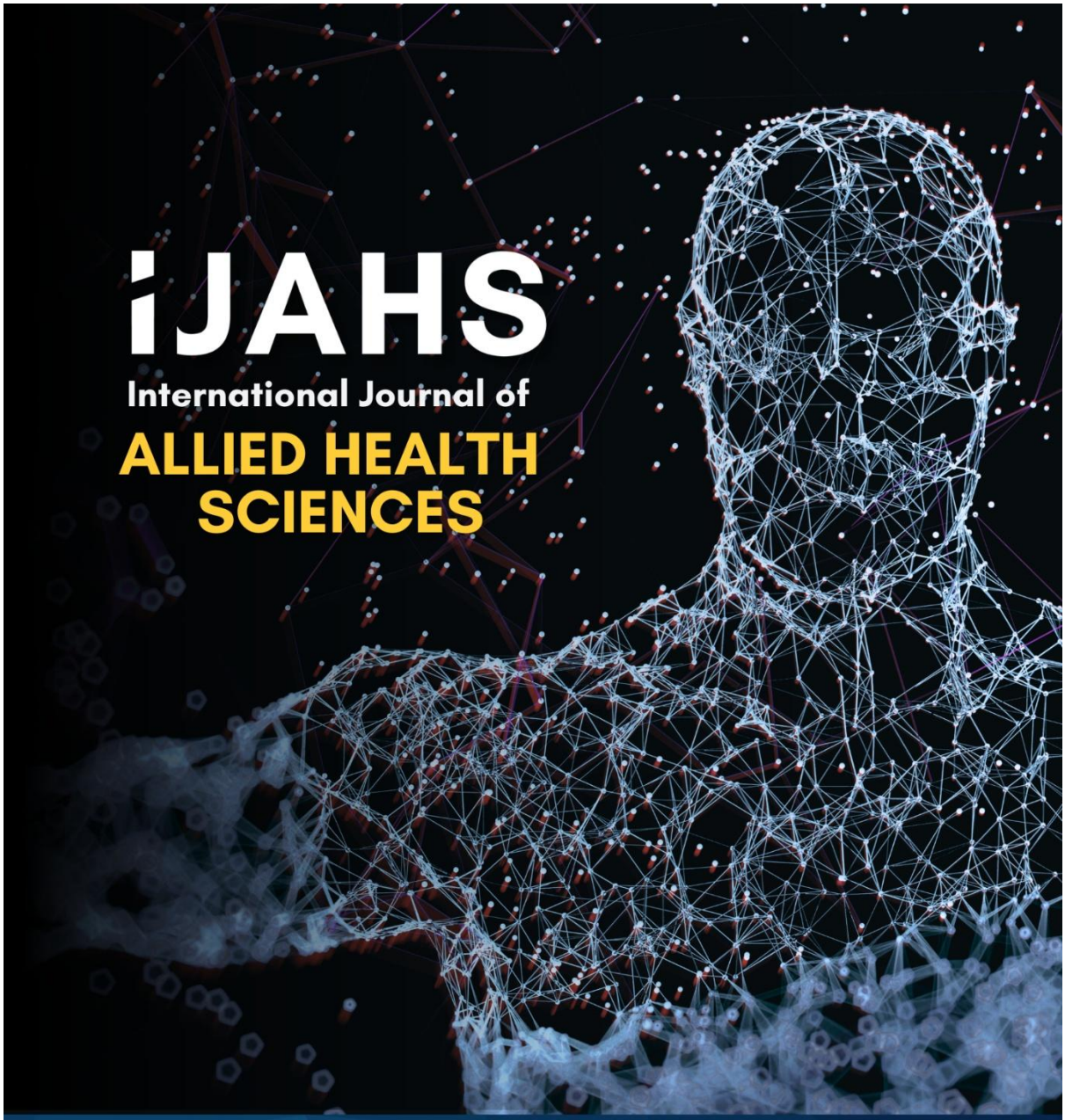

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Plastic Anxiety: Is There a Cause for Alarm?

***Suzanah Abdul Rahman*[1,*]**

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Consider this familiar morning ritual: the use of a toothbrush with synthetic bristles, coffee in a plastic-lined paper cup, and breakfast in a polymer-based container from your favourite food vendor before heading to work – each routine silently introducing invisible particles in our daily lives. Once synonymous with convenience and modern progress, this dependence on plastics has become a source of profound unease and significant public concern on long-term health implications, as scientific scrutiny reveals the pervasive presence of microplastics - plastic particles measuring less than 5 mm - and the occurrence of plastic-associated chemicals, such as bisphenol A and phthalates (Vethaak and Legler, 2021; Tang et al., 2024). Burgeoning public apprehension can be observed in daily social interactions, where individuals decline mineral water in plastic bottles or food in polystyrene containers, signifying a shift in societal behaviour that prioritises avoidance of risks over the convenience that was previously afforded by synthetic polymers. This acute risk avoidance also extends heavily into dietary choices, where many now dread seafood consumption following the growing awareness of how polymer particles and chemical additives contaminate the marine food web. Yet, the widespread anxiety often outpaces scientific understanding, as research on toxicological mechanisms and dose-response relationships of plastic exposure remains largely incomplete (Zhao et al., 2025).

Despite these concerns, plastics remain indispensable to the modern society as their polymers have transformed patient care and public health through use in sterile medical devices, diagnostic equipment, drug delivery systems, implants and personal protective equipment (Zechel et al., 2024). This essential role is a dilemma, as complete avoidance of plastics has become neither practical nor desirable. The challenge is therefore, not whether plastics should be eliminated, but whether concerns surrounding the use of plastics are proportionate to available scientific evidence to justify the general public alarm.

In the literature, the actual magnitude of risk for the human population is largely undefined, and there are critical knowledge gaps with regard to precise concentration dependencies and threshold levels required for initiation of adverse outcomes (Vethaak & Legler, 2021). Plastic particles have been shown to induce systemic physiological disturbances, including metabolic disruptions, oxidative stress, and potential interference with gastrointestinal and immune functions. Microplastics themselves are not simply inert plastic particles, as they can adsorb environmental pollutants such as heavy metals, polycyclic aromatic hydrocarbons, persistent organic pollutants and pesticides, while also carrying plastic-associated chemicals. This creates the so-called 'Trojan horse' effect that impedes hazard identification. The complexity and remarkable diversity of microplastics in terms of size, shape and polymer composition, also make it difficult to standardise toxicological studies and establish robust human health risk assessments. This scientific uncertainty presents a challenge for regional policymakers, as the current evidence is inadequate to establish dose-response thresholds for adverse health effects induced by microplastics. Consequently, this may be the reason why regional policy frameworks such as the Malaysian Roadmap towards Zero Single-Use Plastics 2018 – 2030 (MESTECC, 2018) and the Regional Action Plan for Combating Marine Debris in the ASEAN Member States 2021 – 2025 (ASEAN Secretariat, 2021), are not yet able to incorporate evidence-based exposure thresholds in their recommendations.

An objective and robust risk management that is grounded in an evidence-based framework such as the Adverse Outcome Pathway, may be able to bridge the extreme gap between public fear and scientific fact with regard to microplastics. A multidisciplinary synergy in the deployment of such framework will be able to isolate complex toxicological mechanisms, essentially differentiating intrinsic physical hazards of weathering microparticles from the extrinsic chemical threats posed by leached additives and endocrine-disrupting

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contaminants (Vethaak & Legler 2021; Tang et al., 2024; Zhao et al., 2025). It is understandable that sensationalised claims, such as the widely publicised estimation of humans ingesting a credit card's worth of plastic weekly, effectively catalyse public awareness. However, there is the more important role of risk communicators that must counter this overwhelming friction between public health warnings and unavoidable daily exposures by providing verified and standardised safety data based on exposure levels which are realistic, rather than scientifically contested generalisations (Tang et al., 2024; Zhao et al., 2025).

The ordinary citizen is not expected to solve a global crisis through personal choices such as switching to stainless steel water bottles or cloth grocery bags and through constant consumer vigilance. While individual habits matter, personal lifestyle adjustments are only a small piece of the puzzle. They would have to be backed with institutional, top-down changes such as legal caps on raw plastic manufacturing, safer and eco-friendly product redesigns and equitable and inclusive regional waste strategies. This is an ethical calling for all professionals, as well as advocates across public health and governance. Instead of allowing the public to carry the weight of risk reduction, leadership must synthesise early and alarming toxicity data into enforceable public policies and environmental protections to stop the plastic crisis and pollution directly where it begins. Ultimately, this shift from individual burden to systemic accountability will truly allay public anxiety, transforming the climate of fear into a collective, institutional security.

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ORIGINAL ARTICLE

Early Corneal Remodelling Following Topography-Guided Femtosecond LASIK: A Three-Month Retrospective Analysis

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topography-guided LASIK; femtosecond LASIK; corneal remodelling; ectasia risk

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ABSTRACT

Background: Topography-guided femtosecond LASIK (TG-Femto-LASIK) improves corneal shape uniformity while correcting refractive errors. Although visual and refractive outcomes have been widely reported, fewer studies have focused on early corneal shape changes following treatment. This study aimed to assess three-month changes in corneal remodelling following TG-Femto-LASIK. **Methods:** A retrospective study was conducted on 50 eyes of 25 patients who underwent TG-Femto-LASIK at the IIUM Eye Specialist Clinic. Preoperative and three-month postoperative values of keratometry (K1, K2), corneal astigmatism, and axial inferior–superior (I–S) index were compared using paired t-tests. Preoperative Randleman ectasia scores and postoperative residual stromal bed (RSB) thickness were recorded for contextual reference. Results were expressed as mean ± standard deviation (SD), mean difference with 95% confidence intervals (CI), and p-values. **Results**: At three months, K1 decreased by 4.22 D (95% CI: -3.85 – -4.59, $p < 0.001$) and K2 by 3.55 D (95% CI: -3.20 – -3.90, $p < 0.001$). Corneal astigmatism was reduced by 1.04 D (95% CI: -0.65 – -1.42, $p < 0.001$). The axial I–S index increased by 0.24 D (95% CI: 0.07 – 0.41, $p = 0.006$), while remaining within physiological limits. The mean preoperative Randleman score was 2.12 ± 1.49, and postoperative RSB was 346.8 ± 38.9 µm. **Conclusion:** TG-Femto-LASIK is associated with significant early corneal remodelling characterised by reduction in keratometry and astigmatism at three months. However, these findings represent short-term structural changes following stromal ablation and should not be interpreted as definitive indicators of biomechanical stability. Further longitudinal studies are required to evaluate long-term corneal behaviour and ectasia risk.

INTRODUCTION

Laser in situ keratomileusis (LASIK) is a refractive surgical procedure that corrects ametropia through corneal flap creation followed by excimer laser stromal ablation to reshape corneal curvature. The use of femtosecond laser technology has improved flap precision, reproducibility, and predictability compared to mechanical microkeratomes (Farjo et al., 2013).

Topography-guided LASIK (TG-LASIK) is a customised technique that utilises detailed anterior corneal surface data to guide stromal ablation. Unlike conventional LASIK, which is primarily based on manifest refraction, TG-LASIK aims to improve corneal surface irregularities and reduce higher-order aberrations, thereby improving optical quality (Knorz & Jendritza, 2000; Alves et al., 2022).

Early postoperative changes following TG-LASIK are mainly driven by stromal tissue ablation and epithelial remodelling, with most structural alterations occurring within the first three months (Lyra et al., 2023; Zhang et al., 2024). This period is therefore important for evaluating early corneal shape changes.

Safety remains a key concern in refractive surgery due to the risk of post-LASIK ectasia, a progressive condition characterised by corneal thinning and biomechanical weakening. The Randleman ectasia risk score and residual stromal bed (RSB) thickness are widely used as preoperative risk stratification tools (Randleman et al., 2008; Santhiago et al., 2016). However, these parameters do not directly measure postoperative biomechanical stability and cannot independently predict long-term outcomes.

Corneal shape parameters such as keratometry (K1, K2), corneal astigmatism, and the axial inferior–superior (I–S) index provide useful indicators of geometric corneal changes following stromal ablation. These parameters reflect alterations in corneal curvature rather than direct measures of biomechanical behaviour.

This study aimed to evaluate early corneal shape changes

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at three months following TG-Femto-LASIK in myopic eyes, focusing on keratometric, astigmatic, and axial I–S index changes. These parameters were analysed as indicators of corneal remodelling rather than definitive measures of biomechanical stability.

MATERIALS AND METHODS

Study Design and Setting

This retrospective study used anonymized data from routine clinical practice at the International Islamic University Malaysia (IIUM) Eye Specialist Clinic, Kuantan. Written informed consent for the use of clinical data for research and audit purposes was obtained prior to surgery. No identifiable patient information was included. In accordance with institutional policy, formal ethical approval was waived for retrospective analysis of fully anonymized data.

Participants

All patients provided written informed consent prior to surgery, including permission for the use of anonymized clinical data for research and audit purposes.

A total of 50 eyes from 25 patients who met the eligibility criteria were included. Both eyes from the same patient were analysed, and this was accounted for in the statistical analysis.

Inclusion criteria were: Age ≥18 years, stable refraction for at least one year, and suitability for LASIK based on preoperative assessment. Eyes with keratoconus, corneal scarring, ocular surface disease, prior ocular surgery, or systemic conditions affecting wound healing were excluded.

Surgical procedure

All procedures were performed by a single experienced refractive surgeon using a femtosecond laser platform for flap creation and an excimer laser with a topography-guided algorithm for stromal ablation.

Ablation depth and optical zone were individualized based on preoperative corneal topography and refractive error, following standard excimer laser nomograms. As ablation depth is directly related to refractive correction, it was inherently accounted for in the calculation of the residual stromal bed (RSB).

Flap thickness was programmed at 110 µm using the femtosecond laser system. Due to the high precision and reproducibility of femtosecond laser technology, flap thickness variability is known to be minimal, with a lower standard deviation than that associated mechanical microkeratomes.

Outcome measures

The following parameters were analysed:

- Steep keratometry (K1, D)
- Flat keratometry (K2, D)
- Corneal astigmatism (D)
- Axial inferior–superior (I–S) index (D)
- Randleman ectasia score (preoperative) – Table 2
- Residual stromal bed (RSB, µm, postoperative)

Keratometric parameters (K1, K2) and corneal astigmatism were used to quantify changes in corneal curvature following stromal ablation, reflecting refractive effects rather than biomechanical stability.

The axial I–S index was evaluated as a measure of corneal asymmetry, with values <0.8 D considered within physiological limits. However, because it was assessed at a single postoperative time point, it reflects structural change rather than progression or long-term stability.

The Randleman score and RSB were included for contextual reference as established preoperative risk stratification parameters. While RSB is biomechanically relevant, neither parameter independently predicts postoperative stability. RSB was calculated as:

RSB = Preoperative pachymetry − Ablation depth − Flap thickness (110 µm)

Preoperative and three-month postoperative values of K1, K2, corneal astigmatism, and axial I–S index were compared to assess early corneal remodelling. Refractive and visual outcomes were not evaluated and should be addressed in future studies.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 29. Continuous variables were expressed as mean ± standard deviation (SD).

Preoperative and three-month postoperative values were compared using paired t-tests. Mean differences with 95% confidence intervals (CI) were calculated. Correlation between preoperative and postoperative parameters was assessed using Pearson correlation analysis. Statistical significance was set at $p < 0.05$.

Both eyes from the same patient were included in the analysis. This may introduce inter-eye correlation and violate the assumption of independence required for parametric testing, potentially affecting statistical significance. Therefore, results should be interpreted with caution.

RESULTS

Baseline characteristics and safety parameters

A total of 50 eyes from 25 patients were analysed. The mean preoperative Randleman ectasia score was 2.12 ± 1.49 (range: 0–5). The Randleman Ectasia Risk Factor Score System and risk category classification used for preoperative risk stratification are summarized in Tables 2 and 3, respectively. The mean postoperative residual stromal bed (RSB) thickness was 346.8 ± 38.9 µm, with all eyes maintaining values above the safety threshold of 280 µm (Table 1).

Corneal remodelling at three months

At three months post–TG-Femto-LASIK, there was a significant reduction in corneal power. Detailed comparisons of preoperative and postoperative corneal parameters are presented in Table 4. Steep keratometry (K1) decreased by −4.22 D (95% CI: −4.59 to −3.85, $p < 0.001$), while flat keratometry (K2) decreased by −3.55 D (95% CI: −3.90 to −3.20, $p < 0.001$). Corneal astigmatism was also significantly reduced, with a mean change of −1.04 D (95% CI: −1.42 to −0.65, $p < 0.001$).

The axial inferior–superior (I–S) index showed a small but statistically significant increase (+0.24 D; 95% CI: +0.07 to +0.41, $p = 0.006$), although values remained within physiological limits (<0.8 D). As this represents a single postoperative time point, it does not indicate whether the observed change stabilizes, regresses, or progresses over time.

These findings represent early corneal shape changes following stromal ablation.

Table 1: Baseline Characteristics and Safety Parameters of Eyes Undergoing TG-Femto-LASIK

Parameter	mean ± SD	Range
Age (years)	29.7 ± 4.9	18 – 36
Randleman ectasia score	2.12 ± 1.49	0 – 5
Residual stromal bed (RSB, µm)	346.8 ± 38.9	281 – 449

Table 2: Randleman Ectasia Score - Ectasia Risk Factor Score System

	Points				
Parameter	4	3	2	1	0
Topography pattern	FFKC	Inferior steepening/SRA		ABT	Normal/SBT
RSB thickness µm	<240	240 – 259	260 - 279	280 - 299	>300
Age (years)		18 – 21	22 - 25	26 - 29	>30
CT (µm)	<450	451 – 480	481 - 510		>510
MRSE (D)	>-14	>-12 to – 14	>-10 to - 12	>-8 to - 10	-8 or less

Table 3: Ectasia Risk Factor Score Categories

Cumulative Risk Scale Score	Risk category	Recommendations	Comments
0-2	Low risk	Proceed with LASIK or surface ablation	
3	Moderate risk	Proceed with caution, consider special informed consent; safety of surface ablation has not been established	Consider MRSE stability, degree of astigmatism, between-eye topographic asymmetry, and family history
4 or more	High risk	Do not perform LASIK; safety of surface ablation has not been established	

MRSE = preoperative spherical equivalent manifest refraction.

Table 4: Comparison of Corneal Parameters Before and Three Months After TG-Femto-LASIK (n = 50 eyes; results interpreted with consideration of inter-eye correlation)

Parameter	**Preoperative (Mean ± SD)**	**3-Month Postoperative (Mean ± SD)**	**Mean Difference (D)**	**95% CI**	**Two-sided p-value**	**Cohen's *d***
Steep keratometry (K1, D)	44.25 ± 1.69	40.03 ± 1.78	−4.22	−4.59 to −3.85	< 0.001	3.26
Flat keratometry (K2, D)	43.03 ± 1.56	39.48 ± 1.75	−3.55	−3.90 to −3.20	< 0.001	2.91
Corneal astigmatism (D)	1.22 ± 0.44	0.18 ± 1.14	−1.04	−1.42 to −0.65	< 0.001	0.77
Axial I–S index (D)	0.29 ± 0.45	0.54 ± 0.29	+0.24	+0.07 to +0.41	0.006	0.40

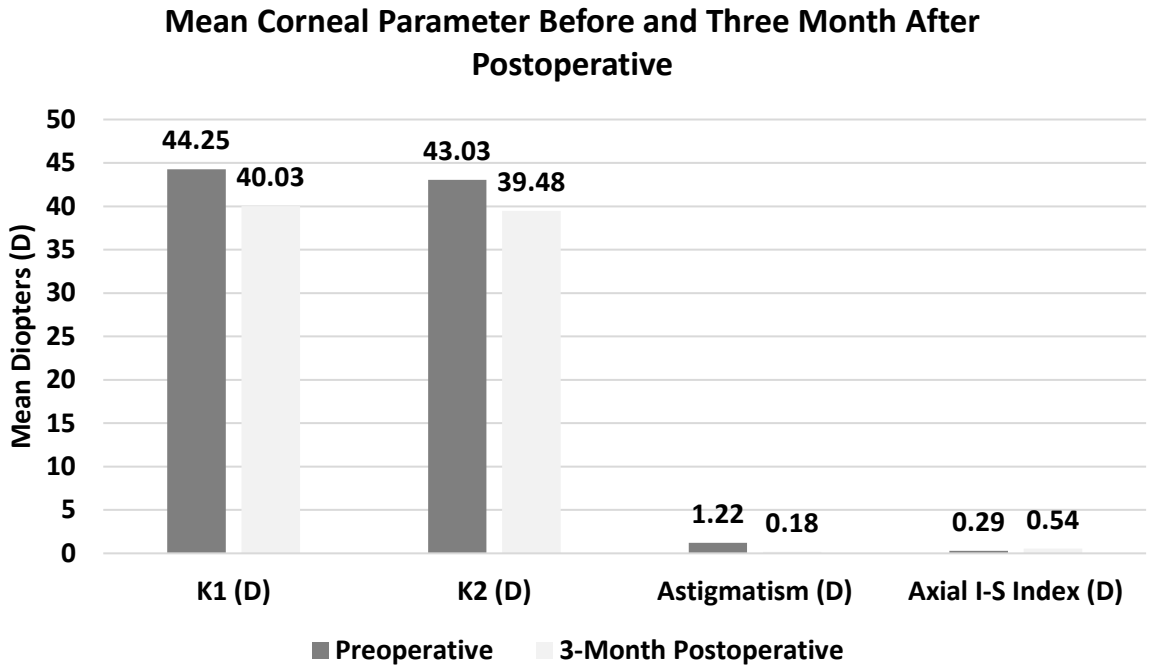

Figure 1: Mean corneal parameter before and three months after TG-Femto-LASIK

DISCUSSION

This study demonstrated significant reductions in corneal power following TG-Femto LASIK, reflected by decreases in K1 and K2, consistent with the intended refractive effect of stromal ablation and previous reports of early corneal flattening (Lyra et al., 2023; Zhang et al., 2024). Corneal astigmatism was also significantly reduced, supporting the effectiveness of topography-guided ablation in improving corneal surface regularity (Kanellopoulos, 2016; Wallerstein et al., 2019a).

A small but statistically significant increase in the axial inferior–superior (I–S) index was observed. Although values remained within physiological limits (<0.8 D), this represents a single postoperative time point and does not indicate whether the change stabilizes, regresses, or progresses over time.

Large effect sizes for keratometric changes indicate substantial refractive impact, while a moderate effect size for astigmatism reduction supports consistent cylindrical correction. The positive correlation between pre- and postoperative keratometry suggests proportional flattening rather than irregular corneal changes.

No cases of ectasia or visually significant complications were observed during follow-up. However, the Randleman score and residual stromal bed (RSB) should be interpreted as risk stratification and safety indicators rather than definitive measures of postoperative biomechanical stability. Post-LASIK ectasia is a progressive condition requiring longitudinal assessment.

Overall, TG-Femtosecond LASIK demonstrated effective corneal reshaping at three months; however, these findings reflect early postoperative changes rather than long-term structural stability.

Limitations

This study is limited by its short follow-up (three months), single postoperative time point, lack of direct biomechanical assessment, inclusion of both eyes with potential inter-eye correlation, and relatively small sample size.

Future studies with longer follow-up and incorporation of tomographic and biomechanical parameters are needed to evaluate long-term corneal stability.

CONCLUSION

Topography-guided femtosecond LASIK (TG-Femto-LASIK) demonstrated significant early corneal remodelling, with reductions in keratometry and astigmatism at three months. Corneal shape parameters remained within physiological limits; however, these findings represent short-term changes following stromal ablation rather than definitive evidence of biomechanical stability.

Given the retrospective design and single time-point assessment, results should be interpreted with caution. Further longitudinal studies incorporating tomographic and biomechanical evaluation are required to determine long-term corneal stability and ectasia risk.

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ORIGINAL ARTICLE

Evaluating the Suitability of ATR-FTIR Spectroscopy for Screening Suspected Microplastics (MPs) in Human Breast Milk (HBM)

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ABSTRACT

Background: Microplastics (MPs) are increasingly detected in human biological samples, including human breast milk (HBM), raising concerns regarding infant exposure during early development. However, analysing MPs in HBM remains challenging due to its complex composition and limited standardised detection methods. This study aimed to evaluate the suitability of Attenuated Total Reflectance Fourier-Transform Infrared (ATR-FTIR) spectroscopy for identifying MPs in HBM following enzymatic digestion and oxidative treatment. **Methods:** Processed samples were filtered, visually screened under a stereomicroscope, and analysed using ATR-FTIR. Spectral matches were compared with a polymer reference library. **Results:** Several polymer signatures were detected, including polypropylene (PP), polyvinylidene fluoride (PVDF), and chlorosulfonated polyethylene (CSPE), with match scores ranging from low to moderate confidence (0.43–0.55). These findings show that ATR-FTIR can support preliminary MP screening in HBM, but accuracy is limited by spectral resolution, library constraints and contamination risks. Improved contamination control upgraded software libraries, and integration of complementary techniques such as Raman spectroscopy and pyrolysis-GC-MS are recommended to strengthen reliability. **Conclusion:** Overall, this work provides early analytical insight into MP detection in HBM and highlights key considerations for method optimisation in future studies.

INTRODUCTION

Microplastics (MPs) are now recognised as a growing global health concern. They have been detected not only in the environment but also in complex biological samples, including human breast milk (HBM) (Zuri et al., 2023; Roslan et al., 2024). MPs are tiny plastic fragments that are formed through the breakdown of larger plastic items by processes such as photodegradation, biological degradation, and chemical reactions (Bajt, 2021). Since plastics are widely used in everyday life, their presence in the human body is becoming increasingly common. Their small size allows them to move through different media and potentially interact with human tissues, raising questions about possible health effects (Roslan et al., 2024). Infants are one of the most vulnerable groups, and they rely heavily on breast milk for healthy development. HBM contains essential nutrients and bioactive compounds that support growth, immune function, and overall well-being (Kim & Yi, 2020). Therefore, the discovery of MPs in HBM is concerning, as it may expose infants to plastic particles during a critical stage of life. Although the long-term effects of MP exposure in infants are still unclear, this issue deserves attention, given the continuing rise in plastic use and environmental contamination.

Studying MPs in HBM is challenging because breast milk is a complex biological fluid of fats, proteins, and other organic components that can interfere with analysis (Arshad et al., 2024; Saraluck et al., 2024). At present, there is no widely established standard method specifically designed for detecting MPs in HBM, and most existing protocols are adapted from environmental research. Advanced techniques like Raman spectroscopy, micro-FTIR, and ATR-FTIR have been used in previous studies, however, each method presents distinct advantages and limitations when applied to milk samples.

In this study, ATR-FTIR spectroscopy was used to detect and identify MPs in HBM after sample extraction and

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digestion. This study aimed to evaluate the reliability of this technique in identifying MPs within a complex matrix and contribute to ongoing efforts to understand and monitor MP exposure in infants.

MATERIALS AND METHODS

Ethical Approval and Sample

This study was ethically approved on 22nd March 2025 by the IIUM Research Ethical Committee (IREC), Malaysia, in accordance with the principles outlined in the Declaration of Helsinki, the International Conference on Harmonisation - Good Clinical Practice (ICH-GCP), the Malaysian Guidelines for Good Clinical Practice (Malaysia GCP), and the Council for International Organizations of Medical Sciences (CIOMS) International Ethical Guidelines (Approval ID: IREC 2025-058). Donated human breast milk (HBM) samples were obtained from Halimatussaadia Mother's Milk Centre (HMMC), Malaysia, with all samples anonymised to maintain donor confidentiality.

Chemicals

The key chemicals and reagents used in this study included hexane (HMBG Chemicals, Germany), 30% H_2O_2 solution (HMBG Chemicals, Germany), 70% ethanol (HMBG Chemicals, Germany), lipase Type VII from *Candida rugosa* with an activity of 700 units/mg solid (Sigma-Aldrich, United States), pH 7.2 buffer tablets (Sigma-Aldrich, United States), KOH pellets (Sigma-Aldrich, United States), and ultra-pure distilled water (milli-Q). All chemical and reagents used are analytical grade. The *Candida rugosa* lipase was stored at 2–4 °C prior to use, as recommended by the manufacturer, while other chemicals such as hexane, H_2O_2, and KOH were stored at room temperature in designated chemical safety cabinets.

Sample Processing

Donated HBM samples were processed following the standardized protocols of the operating milk bank and subsequently stored at −20°C to ensure preservation of compositional integrity. Upon thawing, noticeable physical variations were observed among samples, allowing classification into two primary types: Type A - high-fat milk exhibiting a thick, creamy texture with discernible lipid aggregates, and type B - low-fat milk displaying a more diluted appearance. This classification facilitated comparative analysis of digestive performance across samples differing in lipid content. A systematic sample nomenclature was adopted to streamline tracking and maintain procedural consistency throughout digestion and oxidation experiments. This consistent labelling framework minimized handling errors, improved traceability, and ensured reproducibility in subsequent data analysis.

Controls

Negative controls consisted of three samples prepared using only ultra-pure water (Milli-Q) without any HBM. These were subjected to the full digestion protocol using lipase, KOH, and H_2O_2 to detect any background contamination introduced through reagents, glassware, or environmental exposure. Positive controls were prepared by spiking HBM with known MPs: three nylon 66 (NY66) fragments (blue), three polyethylene terephthalate (PET) fragments (green), and three polypropylene (PP) fragments (pink). These polymers were selected based on their common occurrence in consumer packaging and their reported detection in breast milk and food-contact plastics (Ragusa et al., 2022; Liu et al., 2023). The positive controls were used to validate the integrity of the digestion method and to assess the compatibility of the protocol with polymer preservation under oxidative and enzymatic conditions. Both positive and negative controls were processed using the same reagent volumes, incubation durations, and temperature conditions as the experimental samples.

Digestion.

HBM samples (10 mL each) underwent a multi-step digestion protocol to remove lipids and organic matter while preserving MPs. Lipids were first reduced by hexane extraction, using 1:1 and 2:1 hexane: HBM ratios were prepared and vortexed, then left to stand for ≥2 hours until clear phase separation occurred. The lower aqueous phase (liquid matter, LM) containing proteins, MPs, and other soluble was collected for further treatment (Shang et al., 2021). Residual lipids were then enzymatically digested using a 5% lipase solution prepared in phosphate buffer (pH 7.2). Pre-warmed HBM (37 °C) was incubated with lipase at milk-to-enzyme ratios ranging from 1:1 to 20:1 at approximately 37 - 37.4 °C for 2 - 7 days, with pH monitoring, and successful digestion indicated by a final pH of approximately 4. Subsequently, protein digestion was performed with 10% (w/v) KOH, added at stepwise HBM:KOH ratios (1:1 to 1:7) and incubated at 40 - 45 °C for 2 - 4 hours. Successful protein degradation was evidenced by a dark brown colour change and decreased viscosity. Where necessary, 70% ethanol (1:1) was added to disrupt emulsions and aid filtration. Remaining organic matter was oxidised using 10% H_2O_2 at milk-to-H_2O_2 ratios of 1:1 - 1:3, typically at room temperature for approximately 12 hours, with an optional secondary oxidation at 40 - 50 °C for approximately 20 minutes until solutions became clear or

lightly coloured. After optimisation, the final protocol was applied identically to all experimental samples and to controls: negative controls to assess background contamination, and positive controls to verify MP recovery and polymer stability under the combined enzymatic, alkaline, and oxidative digestion conditions (Enders et al., 2016; Shang et al., 2021; Ragusa et al., 2022; Liu et al., 2023).

Filtration and ATR–FTIR Analysis

Following digestion, each HBM sample and all positive and negative controls were vacuum filtered using 47 mm diameter Whatman GF/C glass fibre filters (pore size 1.2 µm) (Shang et al., 2021), then dried at 60 °C for 24 hours (Prata et al., 2019). Putative MP particles retained on the filters were first screened under a stereomicroscope. Colour, shape and surface texture were used to distinguish plastic-like particles from residual organic matter, with fibrous, film-like and irregular fragment morphologies selected in line with recommended visual pre-screening criteria (Giri et al., 2024; Mariano et al., 2021). Visually suspected MPs were carefully transferred from the filters to the ATR crystal using a clean, fine-tipped metal tweezer, and each particle was placed directly onto the diamond crystal for spectral acquisition. All observable suspected MPs on each filter were subjected to ATR-FTIR analysis. Spectra were collected using a PerkinElmer Frontier (2013) FTIR spectrometer equipped with a diamond ATR accessory, operating from 4000 to 600 cm^{-1} at 4 cm^{-1} resolution with 32 co-added scans per particle. Spectra were processed in Spectrum software and matched against the commercial polymer libraries supplied by the manufacturer (e.g. Hummel Polymer and Additives Library, PerkinElmer ATR-Polymer Library). Library match scores in this study ranged from 0.42 to 0.55, below the widely accepted thresholds of ≥0.60 (reliable) and ≥0.70 (high-confidence) used for MP identification (Rathore et al., 2023). Given the reduced spectral clarity expected in lipid- and protein-rich matrices such as HBM, where residual organic matter can interfere with ATR-FTIR analysis (Ivleva, 2021; Rani et al., 2023), a pragmatic match-score threshold of 0.50 was adopted. This approach reflects the lack of universal standardisation in MP FTIR identification and the variability in spectral quality across complex matrices (Rathore et al., 2023). Therefore, spectra with scores ≥0.50 were considered tentative identifications, while lower scores were interpreted with caution and supported by morphological characteristics (Soliz et al., 2024; Giri et al., 2024). For each confirmed or suspected MP, we recorded polymer type, software match score, stereomicroscopic morphology and qualitative notes on possible contamination or artefacts, consistent with current recommendations to couple morphological and chemical descriptors when reporting MPs in complex biological samples (Dzierżyński et al., 2024; Soliz et al., 2024).

Quality Assurance

To mitigate atmospheric MP contamination, all surfaces were subjected to ethanol wiping prior to analysis. Glassware was used for all apparatus, and plastic materials were avoided except for the micropipette. Apart from that, glassware and equipment were meticulously cleansed with filtered distilled water and covered with aluminium foil (Davidson & Dudas, 2016; Li et al., 2015; Qu et al., 2017; Su et al., 2018). Every procedural step included both negative and positive controls to monitor contamination during the processes (Santana et al., 2017).

RESULTS

The ATR-FTIR analysis revealed several polymer signatures in the filtered and dried samples, as summarized in Table 1. Detected materials included polyvinylidene fluoride (PVDF), alginic acid sodium salt, polypropylene (PP), and chlorosulfonated polyethylene (CSPE). Spectral match scores obtained from the reference library ranged 0.42 - 0.55. For this study, spectra with scores ≥0.50 were considered reliable identifications, whereas values below 0.50 were interpreted as low confidence matches.

Table 1: ATR-FTIR polymer identification and match scores for HBM samples. All entries represent analysed samples (L2–L10). Procedural blank controls were conducted in parallel to assess potential contamination but are not included in this table.

Sample	Suspected Polymer Identified (Best Match)	Match Score
L2	(AP0078) Polyvinylidene fluoride (PVDF)	0.440426
L3	(AP0002) Alginic acid sodium salt	0.55236
L4	(AP0065) Polypropylene isotactic (PP)	0.420418
	AP0078 Polyvinylidene fluoride (PVDF)	0.432505
L6	AP0078 Polyvinylidene fluoride (PVDF)	0.439063

Sample	Suspected Polymer Identified (Best Match)	Match Score
L9	AP0078 Polyvinylidene fluoride (PVDF)	0.427609
L10	AP0054 Polyethylene chlorosulfonated (CSPE)	0.459408
S1	*(AP0054)* Polyethylene chlorosulfonated (CSPE)	0.429755
S2	(AP0054) Polyethylene chlorosulfonated (CSPE)	0.428505
S3	(AP0054) Polyethylene chlorosulfonated (CSPE)	0.452859

DISCUSSION

ATR-FTIR was employed in this study due to its accessibility, non-destructive nature, and proven reliability for polymer identification in complex biological and environmental matrices (Miskon et al., 2024; Ng et al., 2018). The technique operates by detecting characteristic vibrational modes of chemical bonds, which are then compared against reference spectra in polymer libraries (Ng et al., 2018).

The relatively low match scores (0.42 - 0.55) observed in this study can be attributed to several analytical and matrix-related factors. Human breast milk is a lipid- and protein-rich matrix, and residual organic matter may persist despite digestion, leading to spectral interference and reduced signal clarity (Ivleva, 2021; Rani et al., 2023). Such residual materials may hinder effective contact between particles and the ATR crystal and contribute to less distinct spectral features. In addition, the small size and irregular morphology of the particles can result in weak absorbance signals and reduced signal-to-noise ratios as well. Environmental MpPs may also undergo weathering or surface modification, further altering their spectral features compared to reference libraries (Ivleva, 2021).

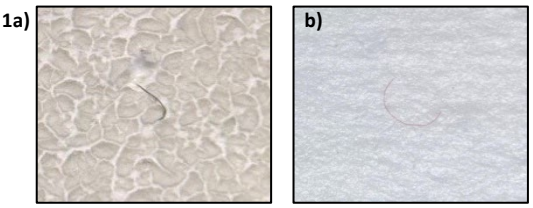

Figure 1: a) PVDF and b) PP under stereomicroscope

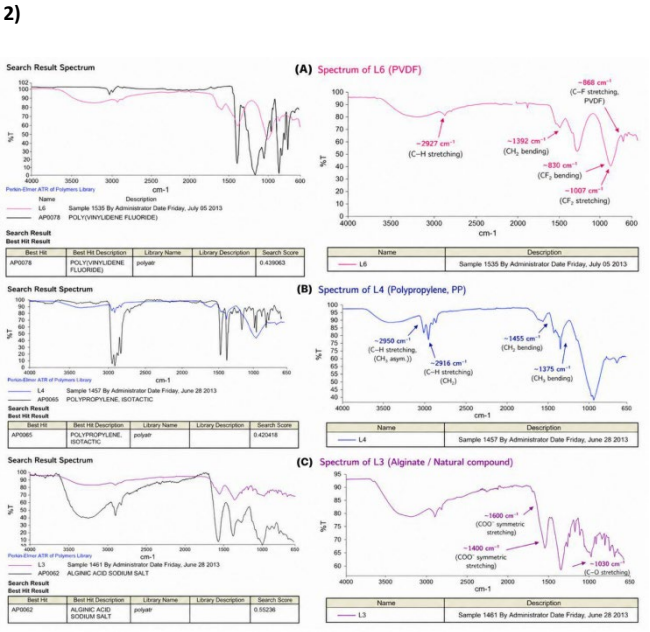

Figure 2: Composite ATR-FTIR spectra of representative samples showing polymer identification and diagnostic peak assignment. The left panels present the comparison between sample spectra and reference library spectra, where the black line represents the reference polymer and the coloured line represents the analysed sample. The right panels display the corresponding sample spectra with labelled diagnostic peaks indicated by arrows and their respective wavenumbers (cm^{-1}). (A) Sample L6 exhibiting PVDF-like features, with characteristic peaks at ~868 cm^{-1} (C–F stretching), ~830 cm^{-1} (CF_2 bending), and ~1007 cm^{-1} (CF_2 stretching), indicative of fluorinated polymers. (B) Sample L4 identified as polypropylene (PP), showing typical peaks at ~2950 and ~2916 cm^{-1} (C–H stretching), ~1455 cm^{-1} (CH_2 bending), and ~1375 cm^{-1} (CH_3 bending), consistent with an aliphatic hydrocarbon backbone. (C) Sample L3 showing alginate-like characteristics, with peaks at ~1600 cm^{-1} (COO^- asymmetric stretching), ~1400 cm^{-1} (COO^- symmetric stretching), and ~1030 cm^{-1} (C–O stretching), suggesting the presence of a naturally derived polysaccharide. Only representative and well-resolved diagnostic peaks are annotated to ensure clarity and to avoid overinterpretation of weak or non-specific signals. The significance of the labelled peaks is interpreted based on characteristic functional group vibrations to support tentative material identification.

Among the materials tentatively identified, PP is of particular interest, as shown in sample L4, as shown in Figure 1(b) and summarised in Table 1. The identification was supported by ATR-FTIR spectral matching and the presence of characteristic diagnostic peaks corresponding to C–H stretching and bending vibrations. In aquatic

environments, polypropylene (PP) has been reported to account for approximately 14% of MPs, followed by polystyrene (8.5%), polyvinyl alcohol (6%) and polyvinyl chloride (2%) (Ashrafy et al., 2023), underscoring its ubiquity in environmental matrices. Beyond marine ecosystems, PP is extensively used in food-contact materials, including microwaveable and thin-walled containers, as well as in medical and healthcare devices (Hossain et al., 2024; Kadac-Czapska et al., 2023). These applications suggest multiple potential pathways for PP to enter HBM, for instance through contact with food packaging, breast pumps, or storage containers. PP fibres and non-woven textiles are also common in consumer products due to their durability and low moisture absorption (Hossain et al., 2024). These broad applications suggest several plausible pathways for PP to reach HBM, including contact with PP-containing food packaging, breast pumps, storage containers, and clothing or nursing textiles during milk expression. Nonetheless, given the modest match scores observed, PP-like spectra in this study should be regarded as indicative of possible, rather than confirmed, PP contamination.

PVDF-like signatures were also detected in several samples such as L2, L4, L6 and L9. PVDF is a highly durable fluorinated polymer with a high melting point, strong mechanical strength, and resistance to chemicals, UV radiation, and hydrolysis (Dallaev et al., 2022). It is widely used in coatings, membranes, and components for pipelines and building materials (Dallaev et al., 2022). The biological plausibility of PVDF transfer into HBM is less straightforward than that of PP, and the detection of PVDF and CSPE in control samples strongly suggests that at least some of these signals may be attributable to airborne contamination or contact with laboratory materials rather than genuine *in vivo* exposure. It is acknowledged that polymers identified in this study, such as PVDF and CSPE, may potentially originate from laboratory-related sources (e.g., filtration membranes, tubing, or instrument components) rather than environmental contamination. Therefore, their presence should be interpreted with caution. While procedural controls were implemented, the possibility of laboratory-derived contamination cannot be fully excluded, particularly when working with complex matrices. This observation highlights the susceptibility of MP analysis to contamination and reinforces the importance of rigorous contamination-control measures, including the systematic use of field and procedural blanks.

Sample handling also influenced data quality. The formation of irregular, flaky residues on the filter surface likely impaired crystal-particle contact during ATR-FTIR measurements, contributing to weak absorbance signals and low match scores for several particles. Such manual handling artefacts are increasingly recognised as a critical source of variability in MP analysis, particularly when working close to the detection limits. Despite these limitations, the workflow applied here, combining enzymatic and chemical digestion with stereomicroscopic pre-screening and ATR-FTIR analysis, demonstrated that it is technically feasible to recover and chemically characterise particles from HBM. These findings reinforce the need for stringent contamination control measures, especially when working with trace-level MPs.

Particles identified as alginic acid sodium salt highlight the complexity of interpreting ATR-FTIR spectra in biological matrices. Unlike conventional synthetic polymers, alginate is a naturally derived polysaccharide extracted from brown algae and widely used in food and pharmaceutical applications (Sanchez-Ballester et al., 2021). It is commonly employed as a stabiliser and thickening agent in food products and as an excipient in pharmaceutical formulations (Sanchez-Ballester et al., 2021). Therefore, its detection in HBM does not necessarily indicate MP contamination but may reflect the presence of naturally derived or semi-synthetic compounds potentially originating from dietary or environmental sources.

Given that most match scores fell below commonly applied confidence thresholds (e.g. 0.6), these identifications should be regarded as tentative. In this study, such particles were not classified as confirmed MPs but were retained as ‘suspected’ materials to avoid over-interpretation of the data. Manual sample handling, particularly during drying and crystal contact, likely contributed to variability and lower reproducibility.

While ATR-FTIR remains an affordable and practical tool of MPs in biological samples, the present findings highlight several limitations of relying on this technique alone. Complementary methods such as Raman spectroscopy may provide improved sensitivity for smaller particles, whereas pyrolysis-GC-MS can offer more definitive chemical characterisation (Zhou et al., 2022; Sheriff et al., 2024; Rani et al., 2023).

Enhanced software capabilities, broader and better-curated spectral libraries, and rigorous contamination-control protocols (including field blanks and multiple procedural controls) are essential to generate robust, comparable data on MPs in HBM in the future. Such methodological improvements are a prerequisite for accurately characterising infant exposure and for informing risk assessment efforts related to early life MP ingestion. Overall, this study highlights that precise sample handling, and appropriate analytical tools are essential to confidently detect and classify MPs in biological samples.

CONCLUSION

This study evaluated the feasibility of applying ATR-FTIR spectroscopy to screen for suspected MPs in human breast milk, a complex biological matrix. By combining enzymatic and chemical digestion with microscopic pre-screening and spectral analysis, several materials, including PVDF- and PP-like polymers and the natural compound alginic acid sodium salt, were tentatively detected in HBM extracts. However, match scores were generally low, likely reflecting software limitations, restricted spectral library coverage, spectral interference from residual organic matter, and challenges in particle handling. Moreover, the occurrence of PVDF and CSPE in control samples highlights the susceptibility of the workflow to laboratory contamination and necessitates cautious interpretation of polymer assignments in HBM.

Despite these constraints, positive control experiments confirmed that the digestion protocol preserved MPs, supporting its suitability as a pre-treatment step for HBM. The findings therefore illustrate both the potential and the current limitations of ATR-FTIR as a preliminary screening tool for MPs in biological samples, particularly when working close to the detection limits. Future work should prioritise improved access to comprehensive spectral libraries, software upgrades, and rigorous contamination-control strategies, alongside the integration of complementary techniques such as Raman spectroscopy and pyrolysis-GC-MS to achieve more definitive polymer identification and characterisation. By outlining these practical considerations, this study contributes to ongoing efforts to refine analytical approaches for assessing early-life exposure to MPs and to support the development of robust biomonitoring frameworks.

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ORIGINAL ARTICLE

Wrist Pain, Technological Device Use, and Perceived Academic Performance Among Computer Studies Students in a Selected Higher Educational Institution

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ABSTRACT

Background: The increasing reliance on technological devices in higher education, particularly in computer-related academic programs, has raised concerns regarding the development of musculoskeletal complaints such as wrist pain. Prolonged use of laptops, desktops, and handheld devices may contribute to repetitive strain and discomfort, potentially affecting students' functional capacity and academic engagement. However, limited evidence exists regarding the relationship between wrist pain, device usage patterns, and academic performance among students in technology-intensive programs. This study aimed to determine the prevalence of wrist pain, identify the technological devices most frequently used, examine the association between frequency of device use and wrist pain, and determine whether a difference exists in perceived academic performance between students with and without wrist pain. **Methods:** A descriptive-correlational and comparative cross-sectional study design was employed. A structured, self-administered online questionnaire distributed via Google Forms was used to collect data from 180 computer studies students. Descriptive statistics, including frequency counts, percentages, means, and standard deviations, were used to determine the prevalence of wrist pain and describe the patterns of technology use among respondents. Spearman's rank-order correlation was used to examine the association between wrist pain and device use frequency, while an independent samples t-test compared academic performance between students with and without wrist pain. **Results:** Wrist pain prevalence among respondents was 40.55%. Laptops/desktops were identified as the most frequently used technological devices. Most students reported their perceived academic performance as "good." No statistically significant association was found between frequency of device use and wrist pain. However, a statistically significant difference in perceived academic performance was observed between students with and without wrist pain, with students without wrist pain reporting higher academic performance. **Conclusion:** Wrist pain was prevalent among computer studies students, with laptops/desktops identified as the most frequently used technological devices. Although the frequency of device use was not significantly associated with wrist pain, students with wrist pain reported significantly lower perceived academic performance compared to those without wrist pain. These findings suggest that wrist pain may negatively influence students' academic experiences and highlight the importance of ergonomic awareness and preventive strategies in technology-intensive academic environments.

INTRODUCTION

The rapid advancement of digital technology has fundamentally transformed higher education, particularly in computer-related academic programs where students rely extensively on laptops, desktop computers, tablets, and smartphones to complete academic tasks (Brohl et al., 2018). For students pursuing degrees in Computer Studies, prolonged screen exposure, repetitive typing, and sustained wrist postures have become integral components of daily academic routines. While technological integration enhances access to information and learning efficiency, it also raises concerns regarding potential musculoskeletal consequences, particularly wrist pain associated with repetitive strain and suboptimal ergonomics (Janwantanakul et al., 2008).

Computer programmers and information technology professionals routinely engage in prolonged coding, software development, and system testing (Colorado State University Global, 2021). However, improper workstation setup and sustained device use may contribute to overuse injuries (The Trustees of Princeton University, 2023). Wrist pain has been identified as a common complaint among individuals exposed to repetitive hand-intensive tasks, with established risk

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factors including repetitive motion, poor posture, prolonged computer use, inadequate rest breaks, ergonomic deficiencies, and psychosocial stressors (Mayo Clinic, 2022). Janwantanakul et al. (2008) reported an increased risk of musculoskeletal symptoms, including wrist and hand complaints, among individuals with prolonged computer exposure, while Ekşioğlu (2017) identified computer use exceeding four hours per day as a significant risk factor. Similarly, Amjad et al. (2020) found a significant association between extended mobile phone use and the development of wrist pain. These findings suggest that students in computer-intensive programs may be particularly vulnerable to wrist-related musculoskeletal symptoms.

Globally, adolescents and young adults spend substantial amounts of time engaged in screen-based activities. (Anderson & Jiang, 2018; Sampasa-Kanyinga et al., 2022). A review by Juul-Kristensen et al. (2024) highlighted the growing impact of modern technology on hand-intensive tasks and the development of overuse injuries. Bröhl et al. (2018) further emphasized that desktop computers, laptops, tablets, and smartphones have become embedded in daily life. In academic contexts, information and communication technologies (ICT) play a central role in shaping study habits. Mbah (2010) reported that 83% of students rely on computers to support, learning and perceived ICT as positively influencing their study practices. Additionally, educational technologies have been shown to enhance interactivity, accessibility, and engagement in learning environments (Ponti et al., 2017; Vyad 2022). Thus, while technological devices provide clear academic advantages, their extensive use may also introduce health-related risks.

Pain associated with wrist pathology can impair an individual's ability to perform routine tasks, including writing, typing, and manipulating devices—activities essential for academic productivity. Beyond physical discomfort, chronic or recurrent pain may influence broader aspects of school functioning. Gorodzinsky et al. (2011) demonstrated that chronic pain in children and adolescents is associated with school absenteeism, sleep disturbances, reduced concentration, emotional distress, and impaired academic competence. Logan et al. (2008) similarly reported a close association between chronic pain symptoms and decreased academic performance. Importantly, school functioning extends beyond attendance and encompasses cognitive, emotional, and social domains that influence academic outcomes (Gorodzinsky et al., 2011). Persistent wrist pain may therefore compromise not only task performance but also overall academic engagement and well-being.

Evidence suggests that musculoskeletal complaints are already present among students in information technology related fields. Sirajudeen et al. (2018) reported that 20.5% of information technology and computer science students experienced wrist and hand symptoms. Despite these findings, limited research has examined the relationship between wrist pain, patterns of technological device use, and perceived academic performance within a localized university setting. While wrist pain is prevalent in the general population and may interfere with functional activities, its potential academic implications among computer studies students remain insufficiently explored.

Given the heavy reliance on digital devices in computer-based programs, investigating the association between technological device use and wrist pain and examining whether wrist pain relates to perceived academic performance, is warranted. Therefore, this study aimed to (1) determine the prevalence of wrist pain among Computer Studies students, (2) identify the technological devices most frequently used, (3) examine the association between frequency of device use and wrist pain, and (4) determine whether a difference exists in perceived academic performance between students with and without wrist pain. The findings may inform preventive strategies, ergonomic guidelines, and health promotion initiatives to support musculoskeletal well-being and optimize academic performance in technology-intensive educational environments.

MATERIALS AND METHODS

A descriptive correlational and comparative research design was employed in this study. The descriptive component, grounded in quantitative methodology, was utilized to systematically describe the prevalence of wrist pain, patterns of technological device use, and perceived academic performance among students. This design enabled the researchers to generate accurate and relevant data aligned with the study objectives. The correlational component was used to examine the relationship between the frequency of technological device use and the incidence of wrist pain among students enrolled in the College of Computer Studies at Silliman University. This approach allowed for the investigation of associations between variables without manipulation or experimental intervention. Finally, a comparative design was incorporated to determine whether a significant difference existed in perceived academic performance between students with wrist pain and those without wrist pain. By integrating these three methodological approaches, the study was able to comprehensively describe, analyze relationships, and compare outcomes

relevant to the research problem.

The study was conducted at the College of Computer Studies of Silliman University, located along Hibbard Avenue, Dumaguete City, during the second semester of the Academic Year 2023–2024. The College is housed in the Uytengsu Foundation Computer Center, situated behind Ausejo Hall, and is equipped with modern computer laboratories, technology-enhanced classrooms, and access to comprehensive academic resources.

Silliman University is recognized for its commitment to academic excellence and holistic student development, making it an appropriate setting for investigating health-related concerns that may influence student performance. The College of Computer Studies offers undergraduate programs in computer science and related fields, where students routinely engage in prolonged use of technological devices for programming, coding, and other computer-based academic tasks.

The selection of this setting was purposive and aligned with the objectives of the study. Students enrolled in computer-related programs represent a population with high exposure to repetitive wrist movements and sustained device use, potentially predisposing them to wrist pain. The department's accessibility to the target population, availability of technological infrastructure, and supportive academic environment provided a suitable context for examining the association between wrist pain and perceived academic performance.

The study included undergraduate students enrolled in the College of Computer Studies at Silliman University during the second semester of Academic Year 2023–2024. Inclusion criteria were: (1) official enrollment in the College of Computer Studies; (2) regular use of technological devices such as laptops/desktops, tablets/iPads, or mobile phones for academic activities; and (3) voluntary consent to participate in the study. Students with recent wrist injuries due to direct trauma or those who had undergone wrist-related surgical procedures were excluded to minimize confounding effects unrelated to technology use.

The study population consisted of 430 students across four programs: Bachelor of Science in Information Technology (n = 218), Bachelor of Science in Computer Science (n = 183), Bachelor of Library and Information Science (n = 21), and Bachelor of Science in Information Systems (n = 8). The minimum sample size of 208 respondents was determined using Slovin's formula with a 5% margin of error.

Stratified random sampling was employed to ensure proportional representation of each academic program. Student lists were arranged alphabetically, and participants were selected using an online random number generator corresponding to the assigned list numbers within each stratum.

A structured survey questionnaire was used to collect data for this study. The instrument consisted of five sections: demographic profile, pre-screening criteria, wrist pain assessment, frequency of technological device use, and perceived academic performance.

The pre-screening section was designed based on the study's inclusion and exclusion criteria. Wrist pain prevalence was determined using a direct binary question: "Do you experience any form of pain or discomfort in the wrist area?" Responses were used to establish the presence or absence of wrist pain among participants.

Frequency of technological device use for academic purposes was measured using a five-point Likert scale (Always, Often, Sometimes, Seldom, and Never), corresponding to percentage usage ranges of 76–100%, 51–75%, 26–50%, 1–25%, and 0%, respectively (Likert, 1932). Prior to data collection, this section underwent face validation by four experts, including the researchers' adviser and three faculty members from the College of Computer Studies at Silliman University. Feedback from the experts primarily focused on improving grammar and clarity, while confirming the relevance and structure of the instrument.

The questionnaire also underwent pilot testing involving ten students from the Institute of Rehabilitative Sciences Physical Therapy program. The pilot testing followed recommended practices for preliminary survey testing, which suggest that small pilot sample of approximately 10-30 participants are acceptable for evaluating clarity, feasibility, and administration procedures prior to full-scale implementation (Hertzog, 2008; Johanson & Brooks, 2010). The pilot testing followed the guidelines for survey item testing and revealed no negative feedback regarding instrument administration.

Perceived academic performance was assessed using the Academic Performance Questionnaire developed by McGregory et al. (2015), an open-access instrument with demonstrated internal consistency reliability ($\alpha = 0.89$), two-week test–retest reliability ($r = 0.85$), and satisfactory concurrent validity. Total scores were computed by summing weighted responses, with performance categorized as Excellent (33–40), Good (25–32), Moderate (17–24), Poor (9–16), and Failing (0–8) based on established scoring parameters.

Prior to data collection, the research proposal was reviewed and approved by the Silliman University Research Ethics Committee (UREC) on February 23, 2024. Following ethical approval, the researchers conducted face validation and pilot testing of the questionnaire sections measuring frequency of technological device use and overall instrument reliability.

A formal correspondence was then sent to the College of Computer Studies of Silliman University to request permission for survey dissemination. Data were collected using Google Forms to facilitate efficient distribution and response recording. The survey link was sent to the official email addresses of eligible students from the Bachelor of Science in Information Technology, Bachelor of Science in Computer Science, Bachelor of Library and Information Science, and Bachelor of Science in Information Systems programs.

Informed consent was presented at the beginning of the online survey, where participants were provided with information regarding the study objectives and procedures. Participant confidentiality was strictly maintained throughout the research process.

The survey was disseminated during the second week of March 2024, with responses collected until March 30, 2024. To encourage participation, the researchers provided an incentive in the form of a raffle, offering ₱100 prizes to ten randomly selected participants.

Data encoding, analysis, and interpretation were completed by the first week of April 2024, and the study was finalized on 5thApril, 2024. Subsequent time prior to presentation was allocated for manuscript refinement and revisions.

All responses were encoded and organized using an electronic spreadsheet. The digital file used for data storage was password-protected, and access to raw data was restricted to the researchers, research adviser, and statistician to ensure data confidentiality.

Demographic characteristics including age, sex, year level, and academic program were summarized using descriptive statistics. Age was presented using range distribution, while frequencies and percentages were used to describe categorical variables such as sex, year level, and course.

Wrist pain prevalence was determined by calculating the percentage of respondents reporting the presence or absence of wrist pain. Device usage frequency across academic purposes was summarized using weighted means. Responses were measured using a five-point Likert scale, and verbal interpretations were derived by computing scale intervals using the formula (highest scale − lowest scale) ÷ number of categories, resulting in an interval width of 0.8 for scale interpretation.

Spearman's rank correlation coefficient was used to examine the relationship between frequency of technological device use and wrist pain, as the variables were ordinal in nature. Responses indicating the presence of wrist pain were coded as 1, while absence of wrist pain was coded as 0 for analysis.

Perceived academic performance was assessed using the Academic Performance Questionnaire developed by McGregory et al. (2015). Responses were scored on a five-point scale (5 = Strongly Agree to 1 = Strongly Disagree), with total scores categorized as Excellent (33–40), Good (25–32), Moderate (17–24), Poor (9–16), and Failing (0–8).

An independent samples t-test was conducted to determine whether a significant difference existed in perceived academic performance between students with and without wrist pain. Statistical analyses were performed using appropriate software, with significance levels set at conventional thresholds.

Participants were provided with an informed consent form outlining the study objectives, procedures, potential risks, and benefits to ensure voluntary and informed participation.

The researchers adhered to established ethical standards throughout the conduct of the study, prioritizing participant welfare, privacy, and confidentiality. Data collected through Google Forms were automatically encrypted, and access to the password-protected database and electronic spreadsheet was restricted to the researchers, statistician, and research adviser. Only information necessary to address the research objectives was collected, and no personally identifiable information was retained. Any personal identifiers provided by respondents were removed through data de-identification procedures.

All collected data were securely stored and will be permanently deleted after the completion and successful defense of the study to ensure respondent anonymity. Any discrepancies or issues identified in the questionnaire responses were promptly addressed.

The study also upheld the ethical principles of voluntariness and transparency in accordance with the Declaration of Helsinki. Participation was entirely voluntary, and respondents were informed of their right to

withdraw from the study at any time without consequence. Participants were also provided with information regarding the study purpose, methods, and potential risks and benefits. The researchers assumed responsibility for ensuring the accuracy and integrity of the research findings. Regular consultation with the research adviser was conducted to ensure the ethical and scientific soundness of the study.

RESULTS

Demographic Profile of the Respondents

The study included 180 eligible respondents. In terms of year level distribution, Level 1 students comprised 35.6% of the sample, followed by Level 2 students at 31.1%, Level 3 students at 22.2%, and Level 4 students at 11.1%. The respondents' ages ranged from 18 to 31 years old. In terms of sex distribution, 63.3% of the participants were male and 36.7% were female.

Wrist Pain Prevalence

Table 1 presents the prevalence of wrist pain among College of Computer Studies students. Of the 180 respondents, 73 (40.55%) reported the presence of wrist pain, while 107 (59.44%) reported absence of wrist pain. Among the respondents with wrist pain, 36 were from BS IT, 33 from BS CS, 3 from BLIS, and 1 from BSIS. The data indicate a substantial proportion of students experiencing wrist pain within the College of Computer Studies population. The prevalence ratio of approximately 2.3 suggests that for every five students in the department, two reported experiencing wrist pain.

Table 1: Prevalence of wrist pain among the students in the College of Computer Studies in Silliman University

Wrist Pain	Course				Total *n = 180*	Percent (%)	Prevalence (Ratio)
	BS IT *n = 87*	BS CS *n = 82*	BL IS *n = 8*	BS IS *n = 3*			
Presence	36	33	3	1	73	40.55%	~2:3
Absence	51	49	5	2	107	59.44%	

Frequency of Technological Device Use

Table 2 presents the frequency of technological device use among College of Computer Studies students for academic purposes. Laptops/desktops obtained the highest weighted mean (4.511), interpreted as "Always". Mobile phones followed with a weighted mean of 4.183, interpreted as "Often", while tablets obtained the lowest weighted mean (1.911), interpreted as "Seldom". These results suggest that students rely more heavily on laptops/desktops and mobile phones than tablets for academic activities such as programming, studying, and completing assignments.

Table 2: Frequency use of technological devices among the College of Computer Studies students in Silliman University

Gadget	Weighted Mean	Verbal Description
Mobile Phone	4.183	Often
Tablet	1.911	Seldom
Laptop/Desktop	4.511	Always

Scale: 4.3-5.0 Always; 3.5-4.2 Often; 2.7-3.4 Sometimes; 1.81-2.6 Seldom; 1 - 1.80 Never

Perceived Academic Performance

Table 3 shows the perceived academic performance of the respondents based on the Academic Performance Questionnaire developed by McGregory et al. (2015). The respondents obtained a mean score of 29.7, interpreted as "Good Performance", indicating that most College of Computer Studies students viewed their academic performance positively. The results may be explained using Walberg's theory of academic performance, which posits that learning outcomes are influenced by a combination of student motivation, cognitive characteristics, and environmental factors. The predominance of respondents reporting good performance suggests the presence of favorable learning attitudes and adequate academic engagement among the students.

Table 3: Perceived academic performance among the College of Computer Studies students in Silliman University

Academic Performance	Mean Score
Good Performance	29.7

Relationship Between Technological Device Use and Wrist Pain

Table 4 presents the relationship between frequency of technological device use and wrist pain among respondents. The results showed no statistically significant association between wrist pain and the use of mobile phones (rs = -0.0796, p = 0.288, tablets, (rs = -0.0941, p =

0.2088), and laptops/desktops (rs = -0.0619, *p* = 0.4094). The results suggest that device usage frequency alone may not be strongly associated with wrist pain occurrence in this population

Table 4: Test of relationship between frequency of use of technological device and presence of wrist pain

Variables	r_s values		Decision	Remarks
	Computed	P-value (a= 0.05)		
Mobile phone and wrist pain	-0.0796	0.288	Failed to reject null hypothesis	Not significant
Tablet and wrist pain	-0.0941	0.2088	Failed to reject null hypothesis	Not significant
Laptop/Desktop and wrist pain	-0.0619	0.4094	Failed to reject null hypothesis	Not significant

Difference in Perceived Academic Performance Between Students With and Without Wrist Pain

Table 5 presents the difference in perceived academic performance between respondents with and without wrist pain. The *p*-value (0.0132) indicates a statistically significant difference in perceived academic performance between the two groups. Respondents without wrist pain obtained a higher mean score (M = 30.39) compared to respondents with wrist pain (M = 28.72).

Table 5: Test of difference between perceived academic performance and presence or absence of wrist pain

Variables	t-values		Decision	Remarks
	Computed	P-value (a = 0.05)		
Difference on the perceived academic performance between respondents with wrist pain ($\bar{x}$ = 28.72) *and* without wrist pain ($\bar{x}$ = 30.39)	2.50	0.0132	Reject null hypothesis	Significant difference

DISCUSSION

The study revealed that wrist pain was prevalent among College of Computer Studies students, with approximately 40.55% reporting wrist discomfort. This finding is consistent with previous research that reported high rates of musculoskeletal symptoms among students who frequently use digital devices (Sirajudeen et al. 2018; Bubric & Hedge, 2016; Amjad et al., 2020). Prolonged typing, repetitive wrist movements, and suboptimal ergonomic positioning are recognized risk factors for musculoskeletal discomfort in technology-dependent populations (Mustafaoglu et al., 2021). The result supports the cumulative load theory, which posits that repetitive mechanical stress may gradually contribute to tissue strain and pain development (Kumar, 2001).

Students reported high reliance on laptops/desktops and mobile phones for academic activities, with laptops/desktops being the primary device used. This aligns with studies indicating that digital devices are essential tools in higher education for research, programming, and academic communication (Norries et al., 2011; Bowen & Matthew., 2012; Amjad et al., 2020). According to Walberg's theory of academic performance, learning outcomes are influenced by individual, instructional, and environmental factors. Frequent use of technology may indirectly affect academic behavior and ergonomic exposure, which may contribute to musculoskeletal risk.

The respondents generally reported good perceived academic performance (mean = 29.7), suggesting favorable academic engagement among students. This finding is supported by studies indicating that academic achievement is influenced by motivation, interest, and self-discipline (Alani & Hawas, 2021; Sikhwari et al., 2019). However, academic performance is a multifactorial outcome influenced by personal, cognitive, and environmental determinants.

Statistical analysis showed no significant relationship between frequency of technological device use and wrist pain. This result is consistent with studies reporting weak or inconsistent associations between device usage duration and musculoskeletal symptoms (Thorburn, Pope, & Wang., 2021; Xie, Szeto, & Dai., 2017). The finding suggests that wrist pain development may be influenced by factors beyond usage frequency, such as ergonomics, posture, psychosocial stress, and individual physiological differences (Xie, Szeto, & Dai., 2017; Wærsted, Hanvold, & Veiersted., 2010).

Although no significant relationship was observed between device use frequency and wrist pain, students without wrist pain demonstrated significantly higher perceived academic performance scores than those with wrist pain. Pain-related discomfort may act as a cognitive distractor, reducing attention span, learning efficiency, and productivity (Oosterman et al, 2012; Grimby-Ekman et al., 2018; Logan et al., 2008). This supports evidence that physical discomfort can negatively influence academic functioning.

Limitations of the Study

The study employed a cross-sectional design, limiting causal inference between technological device use, wrist pain, and academic performance. Data were obtained through self-reported questionnaires, which may introduce recall and response bias. The study also measured perceived academic performance rather than objective academic indicators such as official academic grades. Other potential confounding factors, including ergonomic workstation setup, duration of continuous device use, physical activity level, and psychosocial stress, were not assessed.

Implications of the Study

The findings highlight the need for ergonomic health promotion programs among students in technology-intensive academic programs. Educational institutions may consider integrating ergonomic awareness education, promoting proper posture during device use, and encouraging regular rest breaks to reduce musculoskeletal strain. Early screening for wrist discomfort may also help identify at-risk students. Future research should explore additional behavioral, environmental, and biomechanical factors affecting wrist pain and academic performance using longitudinal or experimental designs.

CONCLUSION

The study revealed that wrist pain was prevalent among College of Computer Studies students, with approximately two out of five respondents reporting the presence of wrist pain. Laptops/desktops were identified as the most frequently used technological devices for academic purposes, followed by mobile phones, while tablets were least utilized. The study found no significant relationship between the frequency of technological device use and the presence of wrist pain, suggesting that device usage frequency alone may not be a determining factor in wrist pain development among students. However, a significant difference was observed in perceived academic performance between students with and without wrist pain, with higher performance scores reported among students without wrist discomfort. These findings indicate that while technological device use frequency may not directly influence wrist pain occurrence, the presence of wrist pain may have potential implications for students' academic performance.

RECOMMENDATIONS

Based on the findings of the study, several recommendations are proposed for different stakeholders. For physical therapists, it is suggested that educational interventions be provided to promote proper ergonomic practices and increase awareness of wrist pain prevention among students. These programs may help reduce the risk of musculoskeletal discomfort and support early management of wrist-related symptoms.

For the College of Computer Studies, it is recommended that awareness campaigns, seminars, and workshops be conducted to educate students, faculty, and staff about wrist pain, its risk factors, and preventive strategies. Integrating ergonomic education into academic activities may help promote healthier technology use among students.

For students, especially those experiencing wrist pain, adopting ergonomic adjustments such as maintaining appropriate desk height, using wrist support during prolonged device use, and performing wrist-strengthening exercises is encouraged. Taking regular breaks to stretch, stand, and move during prolonged device use may help reduce wrist strain. Students without wrist pain are advised to practice preventive measures such as maintaining proper posture, setting up ergonomic workstations, and engaging in regular stretching exercises.

For future researchers, it is recommended to increase sample size or extend the study duration to improve statistical power and reliability of results. Expanding the study population and including additional variables such as sex, year level, duration of device use, and occupational or academic performance factors are also suggested to provide a more comprehensive understanding of the relationship between wrist pain and technological device exposure.

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ORIGINAL ARTICLE

Clinical Predictors of Abnormal Findings on Urgent CT Brain Scans in Adult Non-trauma Patients at a Tertiary Hospital

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ABSTRACT

Background: Computed tomography (CT) scan of the brain is widely used for assessing various neurological conditions and remains the imaging modality of choice in acute and emergency settings. However, CT brain examinations in non-traumatic patients have been reported to have a diagnostic yield of only approximately 15%. This study aimed to determine the prevalence of abnormal urgent CT brain performed in adult non-trauma patients in our centre and the clinical predictors associated with significant abnormal findings. **Methods:** This is an analytical cross-sectional study of urgent CT brains in patients aged 18 years or older who did not have head trauma or known intracranial pathology in Sultan Ahmad Shah Medical Centre @IIUM (SASMEC) from 1st January 2019 to 31st December 2020. A universal sampling of all urgent CT brain examinations done during the study period were traced from the Radiology Information System (RIS). Exclusion criteria included patients younger than 18 years, patients with a history of head trauma and patients with a known history of any intracranial pathology. **Results:** A total of 771 cases fulfilled the inclusion criteria. The majority of the urgent CT brain examinations for non-trauma adult patients were from the Emergency Department, which contributed to 600 cases (77.8%). Our study showed abnormal CT brain findings in 503 patients (65.2%). Our study showed age (adjusted odds ratio: 1.03; 95% confidence interval: 1.01 – 1.04; p-value: < 0.001), headache (adjusted odds ratio: 1.87; 95% confidence interval: 1.17 – 3.00; p-value: 0.009), focal neurological deficit (adjusted odds ratio 0.387; 95% confidence interval: 0.25 – 0.59; p-value: < 0.001), deranged blood pressure (adjusted odds ratio: 0.71, 95% confidence interval CI: 0.55-0.99; p-value: 0.042) and known malignancy (adjusted odds ratio 2.14; 95% CI: 1.02-4.49, p-value: 0.043) are clinical predictors of abnormal CT brain findings. **Conclusion:** Our study shows positive (abnormal) findings in 65.2% of urgent CT brain examinations among non-trauma adult patients. This suggests appropriate patient selection by clinicians in using urgent CT brain scan for neurological assessment in adult non-trauma patients. Age, headache, focal neurological deficits, deranged blood pressure and known malignancy are the significant clinical predictors for these abnormal CT brains.

INTRODUCTION

CT scan of the brain is a commonly used diagnostic imaging modality in hospitals to evaluate patients with a variety of suspected central nervous system illnesses. There are well-established criteria for the use of CT brain in traumatic patients, but no clinically valid acknowledged guideline is available to assist doctors' decisions to request CT brain for patients with no head injury. Several studies have highlighted concerns regarding the use of CT brain scans in the acute setting of non-trauma patient management due to its low yield (Brenner et al., 2007; Plasencia et al., 2023; Akhtar et al., 2023). The exponential growth of CT brain examinations has increased patient medical radiation exposure, treatment expenses, and the demand for more human resources (Covino et al., 2019; Smith-Bindman et al., 2009). Consequently, there is a rising concern regarding clinical appropriateness for the use of CT brain in urgent non-trauma adult patients. Our study aimed to identify the prevalence of abnormal urgent CT brain performed in adult non-trauma patients in our centre and the clinical predictors associated with significant abnormal findings.

MATERIALS AND METHODS

This was an analytical cross-sectional study of urgent CT brain examinations in patients aged 18 years or older who did not have head trauma or known intracranial pathology in Sultan Ahmad Shah Medical Centre @IIUM (SASMEC) from 1st January 2019 through 31st December 2020. Approval was obtained from the Kulliyyah of Medicine Research Committee, International Islamic University Malaysia (IIUM), IIUM Research Ethics Committee and Department of Education and Research, Sultan Ahmad Shah Medical Centre @IIUM (SASMEC). Informed consent

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was waived because of the retrospective nature of the study.

An urgent CT brain examination was definedas an examination that is performed on the same date of the request and/or if the word 'urgent' is mentioned on the request form. All CT brain scans performed during the study period were traced from the Radiology Information System (RIS). A universal sampling of all urgent CT brain examinations were conducted during the study period. Exclusion criteria include patients younger than 18 years, patients with history of head trauma and patients with known history of any intracranial pathological process.

CT brain examinations were performed with Siemens Somatom Definition AS 128 multi-slice CT scanner. CT brain scans were obtained in an axial plane, contiguous 4-mm axial sections from the skull base to the vertex. Imaging parameters used were 120kVp and320 mA, FOV of 195 mm, 1s/rotation, and table speed of 15mm/rotation.

Specific clinical information: patients' age, sex and clinical presentation, risk factors, medical background history and related laboratory results were retrieved from scanned request forms stored in the departmental RIS (Centricity RIS 5.11.6). The results of the CT brain were obtained from the radiologist report. Patients with an initially negative CT but a positive follow-up CT or MRI were included as positive results. Clinically non-significant CT findings that do not require acute intervention or any change in acute management are considered negative. These include chronic or age-related changes such as old lacunar infarctions, chronic small vessel disease and age-related atrophy.

The data were collected using Microsoft Excel 365. The analysis of the demographic data was performed using IBM SPSS Statistics 2.8.0.0.0 (190). Multivariable logistic regression analysis was used to identify the predictors of clinically important abnormal CT findings. The strength of association of each variable was expressed with clinically important abnormal CT findings as adjusted odds ratio (AOR), 95% confidence interval (CI) and p-value. For the statistical analysis, IBM SPSS Statistics 2.8.0.0.0 (190) was used.

RESULTS

A total of 1502 CT brain examinations were performed from 1st January 2019 until 31st December 2020 retrieved from the radiology information system (RIS). Out of the 1502 examinations, a total of 771 cases fulfilled the inclusion criteria and included into the study. From these 771 cases, 399 patients (51.8%) were males, and 372 patients (48.2%) were females. The mean age was 63.2 years with a minimum age of 18 years old and the maximum age of 98 years old, as shown in Figure 1.

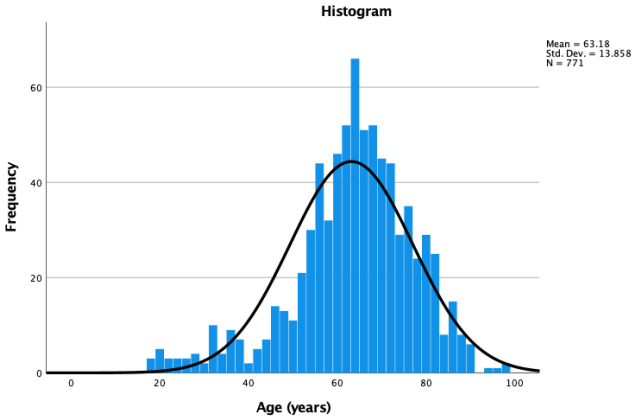

Figure 1: Distribution of patient age

Most of the urgent CT brain examinations for non-trauma adult patients were from the Emergency Department, which contributed to 600 cases (77.8%), followed by the medical wards, accounting for 108 cases (14.0%) and all other departments which contributed less than 3% each. The sources of requests for urgent CT brain scans for non-trauma adult patients are shown in Table 1.

Table 1: Sources of urgent CT brain examination requests

	Frequency (n)	Percentage (%)
Cardiac Care Unit	6	0.8
Emergency Department	600	77.8
General Surgery Wards	21	2.7
Intensive Care Unit	9	1.2
Medical Wards	108	14.0
Medical Clinic	2	0.3
Neurosurgery	2	0.3
O&G Ward	1	0.1
Operation Theatre	1	0.1
Orthopaedic Wards	10	1.3
Infectious Ward	4	0.5
Specialist Centre	6	0.8
Surgical Clinic	1	0.1
Total	771	100.0

The majority of urgent CT brain examinations were plain studies, which were 738 cases (95.7%) and only 33 cases (4.3%) were contrast-enhanced CT brain examinations.

Focal neurological deficit was the most common clinical variable, occurring in 462 cases (59.9%). It is followed by deranged blood pressure, which contributes to 344 cases (44.6%), altered mental status which contributes to 187 cases (24.3%), posterior fossa syndrome which contributes to 130 cases (16.9%), headache which contributes to 111 cases (14.3%) and nausea and/or vomiting with 86 cases (11.2%).The remaining clinical variable each accounted for less than 10% of cases. There was no case with history of drug abuse (including alcohol) in our study. The numbers and percentages of each clinical variable are shown in Table 2 below.

Table 2: Prevalence of clinical variables

Variables	**Number (n)**	**Percentage (%)**
Headache	111	14.3
Nausea, vomiting	86	11.2
Altered mental status	187	24.3
Syncope/presyncope	39	5.1
Seizure	56	7.3
Fever	47	6.1
Posterior fossa symptoms	130	16.9
Focal neurological deficit	462	59.9
Lethargy/weak	58	7.5
Deranged blood pressure	344	44.6
Seizure disorder	8	1.0
Known malignancy	35	4.5
Leukocytosis	8	1.0
Deranged coagulation profile	30	3.9

CT scan brain findings were acute cerebral infarctions (56.0%), followed by haemorrhage, and intracranial mass lesion and other intracranial pathologic entities. Other intracranial pathologies found in our study (total n=15) were skull bone lesions (n=5), intracranial arterial aneurysm (n=3), generalised cerebral oedema (n=3), white matter oedema (n=1), intracranial calcification (n=1), subdural effusion (n=1), and communicating hydrocephalus (n=1). Examples of abnormal CT findings images in 2 patients are given in Figure 2 and Figure 3.

Figure 2: Acute intraparenchymal haemorrhage in a 27-year-old male who was unresponsive preceded by severe headache. CT shows hyperdense area (arrow) in left frontoparietal lobe. Subsequent investigation shows a ruptured aneurysm as the cause of the acute bleed.

Figure 3: Acute cerebral infarction in a 63-year-old, presented with worsening dysphagia and right-sided hemiparesis. CT brain shows ill-defined hypodensities in the left corona radiata (arrow) extending to centrum semiovale in keeping with acute infarct.

Age, focal neurological deficit, headache, and derangement of blood pressure (in decreasing order) are the clinical variables with high chi-square values, signifying their association with abnormal CT brain findings. These variables also showed a statistically significant p-value of <0.05: age (p-value: <0.001), headache (p-value: 0.009), deranged blood pressure (p-value: 0.042), known malignancy (p=value: 0.043) and focal neurological deficit (p-value: <0.001). Table 3 shows the association between the clinical variables with CT brain findings.

Table 3: Association between clinical variables and CT brain findings

Variables	CT Brain Findings		Chi square	p-value
	Abnormal n (%)	Normal n (%)		
Age	503 (65.2%)	268 (34.8%)	88.813	<0.001
Gender				
Male	259 (33.6%)	140 (18.2%)	0.039	0.483
Female	244 (31.6%)	128 (16.6%)		
Headache	53 (6.9%)	58 (7.5%)	17.496	0.009
Nausea and/or vomiting	49 (6.4%)	37 (4.8%)	2.915	0.737
Altered mental status	117 (15.2%)	70 (9.1%)	0.778	0.51
Syncope or presyncope	23 (3.0%)	16 (2.1%)	0.711	0.752
Seizure	31 (4.0%)	25 (3.2%)	2.601	0.715
Fever	24 (3.1%)	23 (3.0%)	4.435	0.363
Posterior fossa symptoms	77 (10.0%)	53 (6.9%)	2.49	0.202
Focal neurological deficit	340 (44.1%)	122 (15.8%)	35.468	<0.001
Weakness, lethargy	38 (4.9%)	20 (2.6%)	0.002	0.864
Deranged blood pressure	246 (31.9%)	98 (12.7%)	10.774	0.042
Seizure disorder	3 (0.4%)	5 (0.6%)	2.743	0.863
Known malignancy	15 (1.9%)	20 (2.6%)	8.1	0.043
Leukocytosis	4 (0.5%)	4 (0.5%)	0.828	0.894
Deranged coagulation profile	18 (2.3%)	12 (1.6%)	0.378	0.975

*significant at P<0.05

Using multivariate logistic regression analysis, it was found that increasing age was a significant predictor of abnormal CT brain findings (adjusted odds ratio: 1.025, 95% confidence interval: 1.01 – 1.04, p-value: <0.001) While headache (adjusted odds ratio: 1.87, 95% confidence interval: 1.17 – 3.00, p-value: 0.009) and known malignancy (adjusted odds ratio: 2.14, 95% confidence interval: 1.02 – 4.49, p-value: 0.043) had nearly doubled the odds of abnormal CT brain findings. Meanwhile, focal neurological deficit (adjusted odds ratio: 0.387, 95% confidence interval: 0.25 – 0.59, p-value: <0.001) and derangement of blood pressure (adjusted odds ratio: 0.71, 95% confidence interval: 0.51 – 0.99, p-value: 0.042) decreased the odds for an abnormal CT brain. The multivariate logistic regression analysis is shown in Table 4 below.

Table 4: Significant clinical predictors for abnormal CT brain findings.

Variables	Abnormal CT Brain Findings				
	B	Wald	AOR	95% CI	p-value
Age	0.024	15.5	1.025	1.01 - 1.04	<0.001
Headache	0.626	6.743	1.87	1.17 - 3.00	0.009
Focal neurological deficit	-0.95	19.341	0.387	0.25 - 0.59	<0.001
Deranged blood pressure	-0.344	4.137	0.709	0.51 - 0.99	0.042
Known malignancy	0.763	4.084	2.144	1.02 - 4.49	0.043

DISCUSSION

Our study showed abnormal CT brain findings of 65.2% (n = 503), which were significantly higher than expected. Our result is almost similar to a study by Bener et al. (2008) in Hospital UKM, Malaysia with an overall scan yield of 65.8%. Another study conducted in Pakistan by Nishtar et al. (2019) showed a lower yield of 33.7% (n = 1312). However, the results from previous studies in developed countries showed much lower yield from 10.2% to 27.1% (Wang & You 2013; Bent et al., 2015 and Placencia et al, 2024). We believe that the use of urgent CT brain examinations used in our setting is appropriate, carefully selected and more selective than those reported in some developed countries. A few reasons for this include more widely available CT scanners in their settings and also due to greater medicolegal concerns.

Despite the difference regarding incidence of positive scan, our study shows almost similar patterns of abnormal CT brain findings conducted in developed and developing countries as reported by Wang & You, (2013); Bent et al., (2015), and Nishtar et al., (2019). Acute cerebral infarction shows the highest incidence followed by cerebral haemorrhage and intracranial mass lesion. Table 5 below summarises the comparison.

Table 5: Comparisons of prevalence of abnormal urgent CT brain findings with our study

	Our study	**Wang & You, (2013)**	**Bent et al., (2015)**	**Nishtar et al., (2019)**
Abnormal CT brain	65.2% (n = 503)	13.8% (n=548)	10.2% (n=51)	20.0% (n=778)
Acute infarct	56.0% (n=432)	7.2% (n=275)	6% (n=30)	14.7% (n=309)
Haemorrhage	6.9% (n=53)	4.0% (n=160)	1.6% (n=8)	11.0% (n=232)
Mass lesion	2.9% (n=22)	2.3% (n=91)	1.2% (n=6)	-
Other intracranial entities	1.9% (n=15)	0.1% (n=29)	1.4% (n=7)	-
Total sample (n)	771	3967	500	2108

We identified five independent clinical predictors (p-value < 0.05) for abnormal urgent CT brain findings for non-trauma adult patients, which were age, headache, focal neurological deficit, derangement of blood pressure, and known malignancy. Table 6 demonstrates the clinical predictors of our study compared to other published studies.

Table 6: Comparison of CT brain findings and their clinical predictors with other published studies

Study	**Results of the study**
Our study	Age (adjusted OR: 1.03; 95% CI: 1.01 – 1.04), headache (adjusted OR: 1.87; 95% CI: 1.17 – 3.00), focal neurological deficit (adjusted OR: 0.387; 95% CI: 0.25 – 0.59), deranged blood pressure (adjusted OR: 0.71; 95% CI: 0.55 – 0.59) and known malignancy (adjusted OR: 2.14; 95% CI: 1.02 – 4.49).
Rothrock et al., (1997)	Age ≥ 60 years, focal neurologic deficit, headache with vomiting, or altered mental status, was 100% sensitive (95% CI: 94-100%) and 31% specific (95% CI: 28-33%).
Bent et al., (2015)	Two clinical factors were significant: focal neurologic deficit (adjusted OR 20.7; 95% CI 9.4–45.7) and age >55 (adjusted OR 3.08; CI 1.44–6.56).
Wang & You, (2013)	Six independent clinical predictors of important abnormal findings on head CT were identified: age (adjusted OR per 10-year increase: 1.17; 95% CI: 1.08 -1.28), focal neurologic deficit (adjusted OR: 5.39; 95% CI: 3.90 -7.47), altered mental status (adjusted OR: 2.32; 95% CI: 1.66 - 3.25), history of malignancy (adjusted OR: 4.11; 95% CI: 2.28 - 7.42), nausea and/or vomiting (adjusted OR: 2.22; 95% CI: 1.14 - 4.33), and derangements in coagulation profile (adjusted OR: 1.91; 95% CI: 1.07 - 3.41).

Multiple studies have proved strong association between age with abnormal CT brain findings, which supported our results. Brown et al., 1993 showed that elderly patients presented with signs of atypical stroke and unexplained confusion have a higher yield in CT brain findings compared with younger patients when the same criteria were applied. Segard et al. (2013) Guryildirim et al. (2019) and Alsabri et al. (2025) have also included age as a risk factor for abnormal CT brain findings, particularly intracranial haemorrhage.

Our study showed that headache is a clinical predictor for significant abnormal CT brain findings. We found that most patients with significant CT findings had abnormal physical or neurologic exam or unusual clinical symptoms. Hence, the likelihood of abnormal CT brain findings is increased in the presence of other clinical variables with headache. Guryildirim et al. (2019) and Plasencia et al. (2024) have shown that focal neurological deficit, cluster-type headache, thunderclap headache and worst ever headache increased the likelihood of abnormal CT brain findings.

Our study showed focal neurological deficit as a clinical predictor for abnormal CT brain findings. Previous studies by Brown et al. (1993), Rothrock et al. (1997), Segard et al. (2013), Covino et al. (2019) and Plasencia et al. (2024) also showed similar association between focal neurological deficit with abnormal CT brain findings. While the focal neurological deficit was shown to be the strongest predictor of abnormality of CT brain findings as mentioned by Bent et al. (2015), our findings differed from previous studies with an adjusted odds ratio of only 0.387 with a low CI of less than 1 (0.25 – 0.59), which were suggestive rather than a protective value. In other words, in our study, focal neurological deficit is likely to have an association with normal CT brain findings. This is somehow inconsistent with the assumption that almost all abnormal CT brain scans are associated with focal neurological deficit. Contributing factors for this outcome can be traced at the data collection levels. The retrospective nature of our study made it impossible to ascertain a strict definition of focal neurological deficits.

Our study showed deranged blood pressure was significantly associated with abnormal CT brain findings (p= 0.042). In our study, we grouped patients as having deranged blood pressure based on the following criteria. Derangement of blood pressure (BP) is defined as either hypertension: systolic BP ≥ 140 and/ or diastolic BP ≥ 90 or hypotension: systolic BP ≤ 90 and/ or diastolic BP ≤ 60.

Known malignancy showed a higher adjusted odds ratio of 2.144 with a 95% confidence interval of 1.02 – 4.49, in keeping with a stronger association with abnormal CT brain findings with p-value of 0.043. In the acute setting, CT imaging is used as a screening tool for these patients with acute neurological deficits to rule out neurosurgical emergencies that would require immediate intervention for example presence of mass effect, haemorrhage, and hydrocephalus (Pope et al., 2018).

Derangement of coagulation profile is one of the clinical predictors of abnormal CT brain findings in non-trauma adult patients according to Wang & You (2013) and Ziai & Carhuapoma (2018). However, our study showed a weak association, most likely due to the inclusion of the organic causes of coagulopathy, for example, dengue and sepsis-related.

As expected, nausea and/or vomiting, syncope or presyncope and fever are variables with weak associations with abnormal urgent CT brain findings. These are non-specific symptoms which may be observed in non-neurological related diseases. However, our study also showed that clinical variables i.e. altered mental status and seizure, which are known to be directly associated with neurological diseases, exhibited a weak association to abnormal urgent CT brain findings with low chi-square, low confidence interval and non-significant p-value. Therefore, standardized or more objective methods are required in assessing nausea and/or vomiting, syncope or presyncope and altered mental status to determine patient selection for neuroimaging studies to have the improve diagnostic yield.

CONCLUSION

Our study shows abnormal findings in 65.2% of urgent CT brain examinations among non-trauma adult patients. This suggests good selective criteria by our clinicians in using urgent CT brain scan for neurological assessment in adult non-trauma patients. Age, headache, deranged blood pressure, known malignancy and focal neurological deficits are the significant clinical predictors for abnormal urgent CT brain scans consistent with findings reported in previous studies.

LIMITATIONS

Due to the retrospective nature of our study, patients' assessment and documentation of clinical findings were not standardized. One of the examples is headache. All headaches were grouped into a single category as no reliable distinction could be made between different types of headache based on data available in the patient's record.

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ORIGINAL ARTICLE

Association between *Piper betle's* Leaf Venation Patterns and Its Antioxidant Status – A Preliminary Study

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Piper betle, venation pattern, antioxidant, 'bertemu urat'

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ABSTRACT

Background: In Malay tradition, "sirih bertemu urat" (converging veins) and "sirih tidak bertemu urat" (non-converging veins) are terms used for betel leaves on the same plants but with different pattern. Morphologically, the converging-vein leaves exhibit the left and right veins (nerves lateral) meet at the central vein, while non-converging vein leaves lack this characteristic. Despite limited scientific evidence supporting their efficacy, Malay Traditional Medicine favors the use of *P. betle* 's converging-vein leaves for medicinal purposes. Therefore, this study aims to investigate the antioxidant status of extracts from both converging- and non converging-vein betel leaves by analyzing phenolic compounds and antioxidant activity. **Methods:** The leaves were subjected to a maceration process in an incubator shaker using 80% methanol to obtain the extract. The total phenolic content was measured using the Folin-Ciocalteu method, and antioxidant activity was evaluated through DPPH and FRAP assays. **Results:** Statistical analysis revealed significant differences ($p < 0.05$) in the phenolic content between *P. betel*'s converging- and non converging-vein leaves, "indicating that *P. betel*'s converging-vein leaves have a higher phenolic content compared to *P. betel*'s non converging-vein leaves". The results obtained from the DPPH and FRAP assays also suggested that *P. betel*'s converging-vein leaves may have higher antioxidant activity compared to the non converging-vein. **Conclusion:** The variations in leaf morphology within the same plant species might influence the leaf's total phenolic compounds which in turn reflect its antioxidant properties. Thus, for medicinal purposes, it is important for researchers and practitioners to note the variation in leaf's venetion pattern when selecting betel leaves in order to obtain the optimal outcome.

INTRODUCTION

Piper betle L. belongs to the family of Piperaceae with a hundred varieties that can be found all over the world. It is commonly known as betel leaf or betelvine. Betel leaf can be found in eastern and central Peninsular Malaysia and is known as"sirih". *P. betle* commonly used in traditional medicine as recorded in Malay medical manuscripts, traditional Chinese medicine, and the Indian Ayurvedic medicinal system. Based on Kitab Tib MS 174, betel leaves can heal coughs, remove body odor and bad breath, treat abscesses, and decrease vaginal discharge (Aziz & Yunus, 2019). Medicinal used of *P. betle* were also written in MSS 2999 Kitab Tib (Hussain, 2015) for the treatment of blurred vision, heartburn, lethargy, leucorrhea, and orthostatic hypotension. Moreover, in the Ayurvedic medicinal system, *P. betle* has historically been used to treat a variety of illnesses, including the common cold, bronchial asthma, cough, stomachalgia, and rheumatism, as well as boils, bad breath, constipation, conjunctivitis, and gum swelling (Biswas, 2022).

These traditional indications were aligned with scientific data. Jaiswal et al. (2014) showed that the leaves has a very high antioxidant content due to the presence of phenolic compounds known as hydroxyl-chavicol (4-allyl pyrocatechol). Hydroxyl-chavicol was found to be a highly effective scavenger of receiving oxygen species (ROS). Some other major phenolic compounds are eugenol and isoeugenol. Hydroxyl-chavicol, eugenol and isoeugenol were discovered to have protective properties against oxidative DNA damage and facilitate in the inhibition of lipid peroxidation. Eugenol was also mentioned by Savsani et. al (2020) to exhibit the most powerful antioxidant activity. *P. betle* also contains a variety of phytochemical compounds, including alkaloids, flavonoids, saponins, tannins, and steroids (Aara, 2020).

Moreover, it is important to note that in Malay tradition, only "sirih bertemu urat" leaves are used for the purpose of medicine. "Sirih bertemu urat" leaves referred to the leaves where the left and right veins (lateral veins) meet at the central vein (converge-vein). As for "sirih tidak bertemu urat" leaves, the left and right veins do not meet

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each other at the central veins creating the off-set pattern on the leaves (non converge-vein). Even though both types of these leaves possess different morphologies, they originate from the same plant. According to Yusoff (2017), the converge-vein leaves typically can be found in the middle section of the plant, where it is rooted for attachment. Salleh (2014) stated that in the customary engagement ceremony of Malay culture, the use of *P. betle*'s converge-vein leaves is discouraged due to their significant medicinal value, as evidenced by various Malay medical manuscripts. Various Malay medical manuscripts indicate that when using betel leaf, it is highly recommended to use converge-vein leaves as also mentioned in the treatment of eye diseases based on Ramuan Obat EAP153/9/4 (Mohd Shafri, 2021). Typically, betel leaves that deemed suitable for traditional Malay medicinal purposes are darker in color, medium in size, and positioned to face sunlight (Yusoff, 2017).

While traditional medicine attributes superior healing properties to the converge-vein leaves of *P. betle*, there is a notable lack of scientific evidence to validate these claims. Ekosari and Sugiarto (2013) reported that converge-vein leaves of *P. betle* possessed a flavonoid content 10 ppm higher than non converge-vein leaves. However, their findings are constrained by a lack of methodological transparency regarding the measurement techniques used. Consequently, a significant gap remains in the scientific literature concerning whether venation patterns truly dictate the antioxidant profile of the plant. This study, therefore, aims to investigate the impact of *P. betle* venation patterns on phenolic content, which serves as the primary driver of its medicinal and antioxidant properties."

MATERIALS AND METHODS

Sample Collection

The *P. betle* leaves were a kind gift from Encik Ganesan, owner of the *P.betle* farm where the leaves were picked [Kampung Pintu Padang, Raub (3°49'47.0"N 101°53'53.0"E)]. A total of 250 g of fresh "bertemu urat" leaves and 270 g of "tidak bertemu urat" leaves were collected. The leaf-picking were done from 11:45 am to 12:30 pm. The temperature and light intensity at the collection site were recorded respectively, using smartphone apps for temperature measurement and a lux meter (Mastech, Hong Kong) for light intensity measurement. The collected leaves were packed in plastic bags and transported to the laboratory where they were directly washed and dried.

Sample Preparation

The betel leaves were initially washed with distilled water and left to air-dry at room temperature for 10 days. During this period, the leaves were weighed daily until there was constant weight for subsequent 3 days. By using a blender (Panasonic, Japan), the leaves were grounded before the extraction process.

Extraction Process

A 2L solution of 80 % methanol was prepared using a combination of methanol and distilled water in an 8:2 ratio as the solvent extract. Each gram of powdered leaves was combined with 25 ml of the 80% methanol solution in a conical flask. The resulting mixture underwent a maceration process in an incubator shaker (Infors HT, Switzerland), set at 30°C and 200 rpm, for a duration of 18 hours. The macerated mixture was filtered twice using filter paper (Smith, USA). The samples were stored in a chiller at 4 °C until transported to the Natural Product lab, Kulliyyah of Science, for solvent drying. For solvent drying and extract concentration, a rotary evaporator (Buchi, Switzerland) was utilized. The solvent was concentrated using the rotary evaporator. The concentrated extract was subsequently stored at 4 °C until its further use.

Total Phenolic Content (TPC)

TPC was measured using the Folin-Ciocalteu (Jaiswal et. al 2014). 200 µL of the leave extracts were mixed with 1 ml of newly diluted (10-fold) Folin-Ciolateu. The mixture was incubated at room temperature for 8 minutes. 3 ml of 7.5 % sodium carbonate was added inside the mixture and was shaken vigorously, followed by incubation in the dark for 1 hour. The absorbance of the sample was measured 765 nm using UV-Vis spectrophotometer (Secomam, France). Gallic acid between 50-500 mg/l was used to create the standard curve. The test was done in triplicate. Since the extracts were in liquid form, instead of presenting the result as mg gallic acid equivalent (GAE)/g crude extract, the result was presented as mg gallic acid equivalent (GAE)/ ml extract. Total phenolic content in the samples were expressed by the following formula (Gentscheva et al., 2021):

$$\text{Gallic acid equivalent} = \left(\frac{C \ X \ Vs}{Ve}\right) \quad (1)$$

Where, C = Concentration of gallic acid from the calibration curve (mg/L)
Vs = Volume of sample used in assay (L)
Ve = Volume of extract (ml)

DPPH Radical Scavenging Activity

The assay was based on Jaiswal et al. (2014) with slight modifications. 100 ml of 2,2-Diphenyl-1-picryl hydrazyl (DPPH) solution was prepared (in 80 % methanol). A series of sample dilution was prepared. Then, 100 µL of the diluted samples were mixed with 3.9 ml of 0.004 % DPPH solution, followed by 30 minutes incubation in the dark. Absorbance were read at 515 nm using UV-Vis spectrophotometer (Secomam, France). 80% methanol was used as blank. A sample blank sample containing the same amount of methanol and DPPH was also used. Ascorbic acid was used to plot the standard curve. Since the level of antioxidant was inversely proportional to the absorbance measured, free radical scavenging activities were expressed as percent inhibition (%) based on ascorbic acid equivalent and determined using the formula below:

Percent inhibition of DPPH scavenging activity,

$$= \left(\frac{A\,c - A\,s}{Ac}\right) \text{ x } 100\% \qquad (2)$$

Where, Ac = the absorbance of control
As = the absorbance of sample.

Ferric Reducing Antioxidant Potential (FRAP) Assay

The procedure was performed based on the method described by Jaiswal et al. (2014). To prepare the FRAP assay, 200 mL of 300 mM acetate buffer (pH 3.6) was combined with 20 mL of 20 mM ferric chloride hexahydrate (dissolved in distilled water) and 20 mL of 10 mM 2,4,6-tri-(2-pyridyl)-s-triazine (TPTZ) (dissolved in 40 mM HCl). A standard graph for ferrous sulphate (FeSO4) was created using various concentrations ranging from 0.1 mM to 1 mM. To perform the assay, 0.8 mL of the FRAP solution was mixed with 24 µL of each standard or sample concentration. After a 4-minute incubation period, the absorbance at 593 nm was measured using a UV-Vis spectrophotometer (Secomam, France). The ferrous sulphate equivalent concentration was calculated using the standard graph.

Statistical Analysis

The antioxidant status between the extracts of *P.betle* "bertemu urat" and *P. betle* "tidak bertemu urat" was determined by independent t-test using SPSS statistical software version 20 for windows. The value of *p* less than 0.05 (p<0.05) was considered as statistically significant.

RESULTS

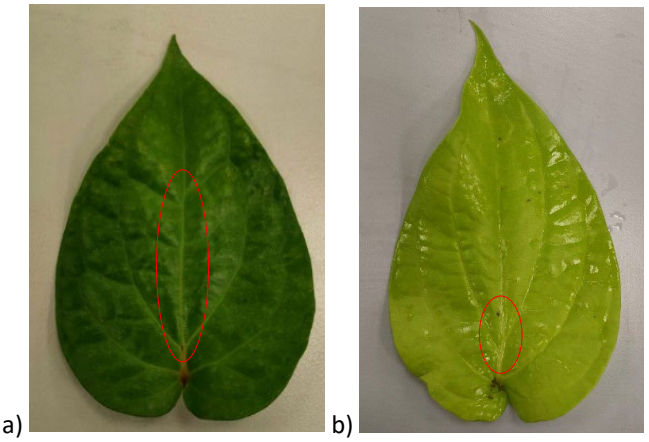

Figure 1: (a) Leaf morphology of *P. betle* "bertemu urat", that showed the left and right veins (nerves lateral) meet at the central vein; (b) Leaf morphology of *P. betle* "tidak bertemu urat", that showed the left and right vein did not meet at the central vein.(Label the central vein)

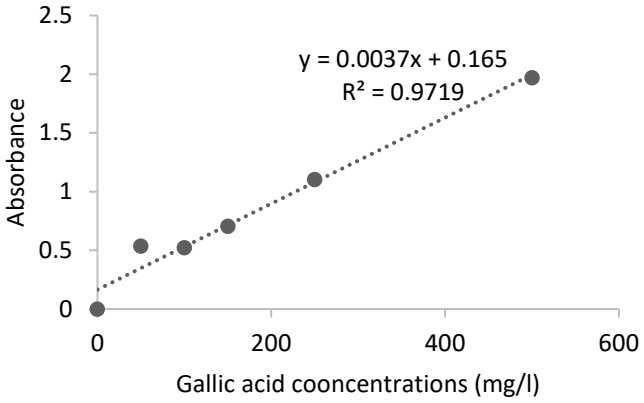

Figure 2: Gallic acid standard curve

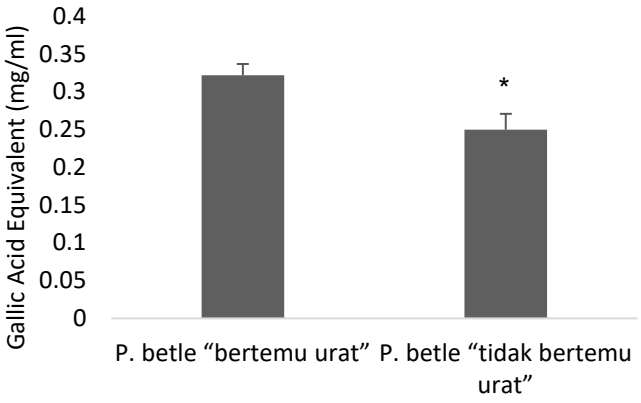

Figure 3: Total Phenolic Content (TPC) of *P. betle* leaf *extracts* expressed in gallic acid equivalent. Data are expressed as mean ± SEM. *Indicates *p*<0.05 (t-test) as compared to the bar on the left. *P. betle* 'bertemu urat' leaves contain significantly higher phenolic content as compared to the *P. betle* 'tidak bertemu urat' leaves.

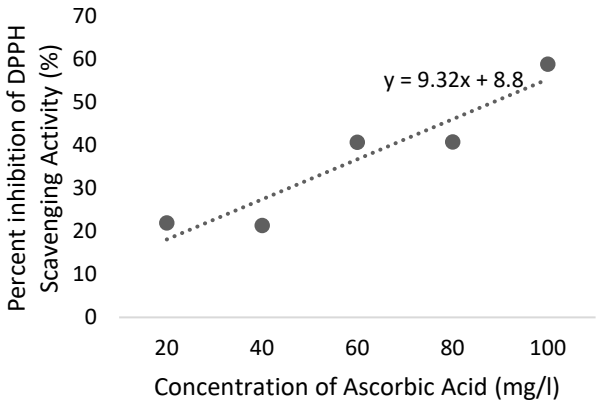

Figure 4 : Ascorbic acid's standard curve

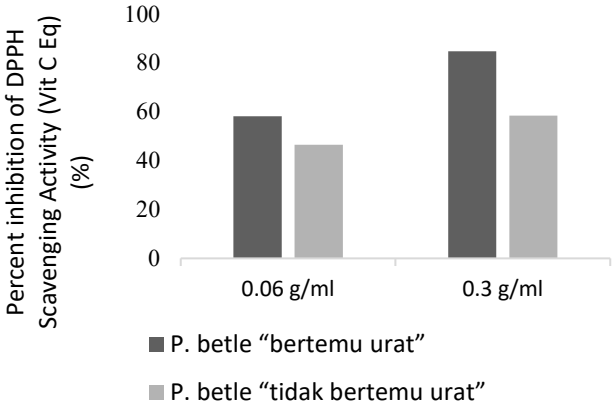

Figure 5 : Percent inhibition of DPPH radicals scavenging activities of *P. betle extracts* expressed in ascorbic acid equivalent

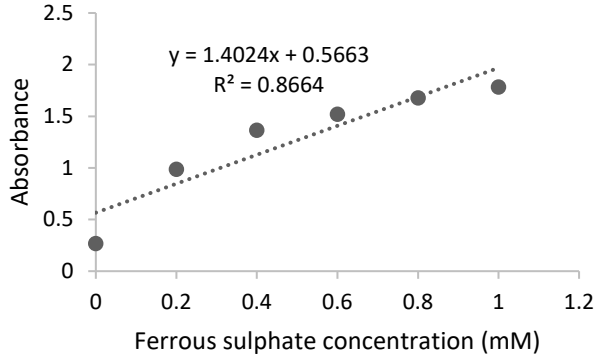

Figure 6 : Ferrous sulphate calibration curve

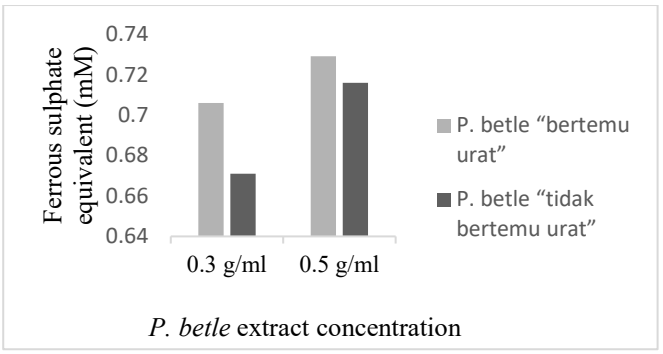

Figure 7 : Antioxidant activities of *P. betle extracts* expressed in ferrous sulphate equivalent

DISCUSSION

In this study, 80 % methanol was used as solvent to extract the phytochemicals. Previous study (Jaiswal et al., 2014) had shown that 80% methanol was the most effective solvent for extracting total phenolic content because the addition of 20% water improved the extraction efficiency and yielded higher antioxidant compounds. In order to remove the solvents after maceration, we used the rotary evaporator that removed all the methanol. Due to some limitations, the extracts were not freeze-dried in order to remove the water content. Thus, the precise extraction yield could not be determined. The initial concentration of the extracts were determined based on the dry-weight of *P. betle* after grounding (the volume of ethanol added for maceration is based on the weight) in total volume of the extracts gained after the rotary evaporator method. Thus, this could lead to inaccuracy in our data.

As for initial comparison, we observed the morphological differences between the leaves of *P. betle* converge- and non converge-vein. The two type of leaves exhibit notable differences in morphology, as documented by Ekosari & Sugiarto (2013). The authors describe the converge-vein leaves of *P. betle* as having a symmetrical shape, where the veins on both sides meet at the main vein, while the veins of non converge-vein leaves do not converge at the main vein. This indicates that the observation of this study aligns with their findings. Furthermore, the non converge vein of *P. betle* leaves have an oblong shape, often longer and with a slender tip, typically displaying a length-to-width ratio of 1:7. On the contrary, *P. betle* "bertemu urat" leaves have a sharper and slightly curved (cuspidate) tip, with a length-to-width ratio of 1:5.

Then, the biochemical assays were conducted. The total phenolic content (TPC) assay used the Folin-Ciocalteau reagent that reacts with the hydroxy group in phenolic ions, reducing heteropoly acid (phosphomolybdate-phosphotungstate) and forming a dark blue molybdenum-

tungsten complex that has the absorbance of 765 nm (Martono et al., 2019). Thus, the presence of phenolic contents in the test samples were corresponded to the increase of the absorbance. To quantify the total phenolic compounds in the sample extracts, gallic acid was used as a standard (Figure 1) due to its purity and stability as a phenol (Hilma et al., 2018). As shown in figure 2, extract of *P.betle* converge-vein leaves showed higher phenolic content as compared to non converge-vein leaves.

Previous studies suggested that total phenolic content in *P. betle* varies based on the species and also the geographical origin of the plant sample (Jaiswal et al., 2014; Makarova et al., 2021). Additionally, other factors that may influence the phenolics compound and antioxidant properties of the plants include the individual chemotypes, environmental changes, the harvesting stage (floral budding stage, blooming stage, or fruit set stage), geographical origin, and the age of the plant (Al-Rimawi et al. 2014, Makarova et al., 2021). Moreover, these plant properties may also be influence by light intensity and temperature that highly associated with geographical region. In addition to that, this study aim to determine whether leaf's venation pattern also could affect the biochemical properties of plant sample. This is of particular importance because variations in total phenolic content could be the factor that lead to variations in antioxidant activity of plant extracts. Further biochemical assays, DPPH and FRAP assays showed this pattern.

In DPPH assay, the absorbance of the extracts was compared to that of ascorbic acid's standard and the DPPH radical scavenging activities were expressed in ascorbic acid equivalent. Ascorbic acid was used as the standard because it is a natural occurring effective antioxidant with the ability to donate hydrogen atom to form a relatively stable ascorbyl free radical (Olszowy-Tomczyk, 2021). DPPH compound are free radicals. The compound is colored and has maximum absorbance at 517 nm. Compound with antioxidant properties able to transfer electron to DPPH radicals and cause discoloration of the solution. Thus, lower absorbance value is relative to higher antioxidant properties of a test compound. Our result showed that extract of *P. betle*'s converge-vein leaves showed a trend of higher free radicals scavenging activities as compared to non converge-vein leaves at both concentrations tested (0.06 g/ml and 0.3 g/ml) (Figure 4).

As for FRAP assay, it was based on the ability of antioxidant to reduce the complex of ferric ions (Fe^{3+})-ligand to the intensely blue ferrous complex (Fe^{2+}). The blue complex has absorbance at 593 nm. Increase in absorbance of the samples indicate increase in antioxidant activity (Munteanu and Apetrei, 2021). Antioxidant activities of the *P. betle* extracts were expressed as ferrous sulphate equivalents of Fe^{2+} based on the ferous sulphate calibration curve. Based on our result, the extract of *P. betle'*s converge-vein leaf extractshowed a trend of higher free radicals scavenging activities as compared to non converge-vein leaf extract at both concentrations tested (0.3 g/ml and 0.5 g/ml) (Figure 7).

Based on previous studies, the arrangement of the lateral veins (leaf venation patterns) on a plant leaf is associated with several physiological function of the plants such as water and nutrient transport (Review: Roth-Nebelsick, 2001), the utilization of water by the leaf (Kawai and Okada, 2015) and photosynthesis (Brodribb et al., 2007). Thus, leaf with different vein pattern, such as symmetrical or asymmetrical pattern as shown *P. betle*, could have different function or biochemistry activities that could lead to differences in the productions of the phytochemicals.

IC_{50} for the *P. betle* extracts were unable to be determined due to the limitations mentioned earlier. Nevertheless, Uddin et al. (2015) reported an IC_{50} value of 151.36 (mg/L), while Nur Sazwi et al. (2013) obtained an IC_{50} value of 179.5 ± 93.1 (mg/L) for *P.betle* leaf extract. Conversely, Phongpaichit (2007) recorded IC_{50} value of 9.04 ± 0.09 mg/L for ascorbic acid. This indicate that *P. betle* extract has much lower antioxidant capacity as compared to vitamin C. Medicinal properties of *P. betle* were recorded not only in Malay Medical Manuscript but also in many of the scientific literatures encompassing a wide area of pathological conditions (Biswas et. al. 2022).

It is possible that there are other properties of *P. betle* extract that contributes to its medicinal properties apart from its radical scavenging activities. One possible aspect is signal transduction. Several scientific articles on natural products reported that certain phytochemicals have anticancer properties by inhibiting the MAPK-signaling pathway. The pathway regulates many of mammalian cell's physiological functions including proliferation and differentiation and is one of the targets for anticancer drug development (Shi et al. 2024).

CONCLUSION

In conclusion, results from this preliminary study might suggest that *P. betle* extract from leaves that are converge-vein had higher antioxidant properties as compared to non converge-vein. Further studies need to be done to validate this data but hopefully this result will pave the way to further explore the medicinal potential of *P. betle* and give more insight to researchers on relationship between leaf venation patterns and medicinal properties.

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ORIGINAL ARTICLE

The Association Between Internet Addiction and Physical Activity Level among IIUM Students in Kuantan

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ABSTRACT

Background: Internet addiction (IA) has emerged as a major concern among university students and has been associated with prolonged screen time and physical inactivity—both recognised behavioural risk factors for non-communicable diseases (NCDs). Although several studies have examined the impact of IA among university students, limited research has been conducted on the association between IA and the physical activity (PA) level. This study aimed to analyse the association between IA and PA levels among students at the International Islamic University Malaysia (IIUM), Kuantan Campus, Pahang. **Methods:** This cross-sectional study recruited 113 students using a convenience sampling method. Data were collected through an online questionnaire that included socio-demographic characteristics, patterns of internet use, the Internet Addiction Test (IAT), and the International Physical Activity Questionnaire-Short Form (IPAQ-SF). Descriptive statistics and the Chi-square test were performed. **Results:** The findings revealed that the prevalence of IA among students was 31.9%. A total of 34.5% of students had a low PA level, 47.8% had a moderate level, and only 17.7% had a high PA level. No significant association was found between IA and PA levels (p = 0.963). **Conclusion:** Despite the absence of a significant association between IA and PA, the relatively high prevalence of IA and physical inactivity underscores the need for targeted health promotion strategies. Awareness campaigns focusing on responsible internet use, reduction of sedentary behaviour, and promotion of regular PA are recommended to mitigate long-term NCD risk and improve overall health among university students.

INTRODUCTION

Non-communicable diseases (NCDs) are widely recognised as a major public health concern. Their causes are multifactorial, arising from a combination of underlying determinants, modifiable behavioural risk factors, and non-modifiable risk factors (Manning et al., 2021). Behavioural risk factors for NCDs are commonly observed among young adults, particularly university students, among whom the prevalence of these risk factors is notably high. This trend is largely driven by reduced physical activity (PA), rapid urbanisation, increased screen-based behaviours, and other lifestyle-related factors (Alobaid et al., 2023; Cicekli & Gokce Eskin, 2025; Ouyang et al., 2025).

With regard to the PA level, nearly one-third of adults globally were insufficiently physically active, with a prevalence of 31.3% in 2022 (Strain et al., 2024). In Malaysia, data from the National Health and Morbidity Survey (NHMS) 2019 reported that 25.1% of adults were physically inactive (Lim et al., 2025). Among university students, varying levels of PA have been reported across different university settings worldwide.

A study conducted in northern India found that 14.5% of 4,586 university students were classified as physically inactive (Verma et al., 2022). In contrast, a study from Tamil Nadu reported that among 454 university students, 346 (76.2%) were physically inactive (Kumar et al., 2021). Similarly, a study conducted in Spain reported that over 80% of 2,216 university students were physically inactive, while a substantial 40.5% were classified as extremely sedentary (Garcia-Lorenzo et al., 2024). Similar variations physical activity patterns have also been observed among local undergraduate students. A study among 167 students at Universiti Teknologi MARA (UiTM) Perlis reported that only 1% of participants were classified as having low-levels PA, as the vast majority engaged in high (59%) or moderate (40%) levels of activity (Nurfatehah et al., 2024). Likewise, a study at a public university in Selangor found that 56.7% of the 120 respondents demonstrated a good PA level (Sook et al., 2019).

Although studies from Malaysia generally report higher levels of PA, increased screen-based behaviours driven by

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rapid technological development have emerged as a growing concern that may contribute to physical inactivity among young people. This is largely due to the substantial amount of time spent using the internet for academic purposes and entertainment as a means of stress relief (Samaha & Hawi, 2016). Prolonged and excessive internet use may contribute to the development of internet addiction (IA), which has become a major issue among university students and has been associated with reduced levels of PA. Supporting this concern, a previous study involving Thai and United States university students reported that high levels of smartphone use may act as a barrier to PA (Penglee et al., 2019).

Although several studies have examined the impact of IA among university students, limited research has focused on the association between IA and PA levels, particularly within the Malaysian context. Therefore, this study aimed to analyse the association between IA and PA levels among students at the International Islamic University Malaysia (IIUM), Kuantan Campus, Pahang.

MATERIALS AND METHODS

A cross-sectional study was conducted over a five-month period from June to November 2022. Based on a single population proportion sample size calculation, utilising an expected IA prevalence (P) of 36.9% among Malaysian medical students (Ching et al., 2017) and incorporating a 25% non-response buffer—the minimum target sample size was determined to be 124 participants recruited via convenience sampling. The inclusion criteria comprised all IIUM Kuantan students who had been using the internet regularly during the preceding months and who voluntarily agreed to participate in the study. Students who were unable to engage in PA during the previous month due to injury or health-related conditions were excluded.

Upon receiving institutional ethical approval (ref: IIUM/310/G/13/4/4), an online questionnaire was distributed via Google Forms. Participants provided electronic informed consent after reading the study information sheet and selecting a mandatory agreement checkbox prior to accessing the survey. The questionnaire consisted of four sections: (1) socio-demographic characteristics; (2) features of internet use, including daily duration of internet use, purpose of use, and methods and locations of internet access; (3) the Internet Addiction Test (IAT); and (4) the International Physical Activity Questionnaire–Short Form (IPAQ-SF).

IA was assessed using the IAT, a validated 20-item questionnaire rated on a five-point Likert scale ranging from 0 (not applicable) to 5 (always) (Servidio, 2017). The total IAT score ranges from 0 to 100, with a score of 43 or higher serving as the optimal cut-off point for classifying individuals with IA (Guan et al., 2012).

The levels of PA were assessed using the IPAQ-SF, which evaluates PA over the previous seven days (Lee et al., 2011). PA was expressed as metabolic equivalent task (MET)-minutes per week, calculated by multiplying activity intensity by duration, using standard MET values of 3.3 for walking, 4.0 for moderate-intensity activity, and 8.0 for vigorous-intensity activity (Fogelholm et al., 2006). Total PA was obtained by summing MET-minutes/week from walking, moderate, and vigorous activities. Participants were subsequently categorised into low, moderate, or high PA levels according to the IPAQ-SF scoring guidelines.

Data were analysed using the Statistical Package for the Social Sciences (SPSS), version 29.0 for Windows. Total IA scores and PA levels were calculated. Descriptive statistics were used to determine the prevalence of internet use, IA, and PA levels among IIUM students. The association between IA and PA level was assessed using the Chi-square test, with statistical significance set at $p < 0.05$.

RESULTS

Of the 122 questionnaires completed by students at IIUM Kuantan, 113 were included in the final analysis, yielding a response rate of 92.62%. The remaining questionnaires were excluded due to incomplete data. The mean age of the respondents was 22.06 ± 2.24 years. Table 1 summarises the demographic characteristics of the respondents.

Table 1: Demographic characteristics of the respondents (n=113)

Demographic	Frequency	Percentage (%)
Gender		
Male	34	30.1
Female	79	69.9
Kulliyyah		
Medicine	14	12.4
Dentistry	17	15.0
Pharmacy	4	3.5
Nursing	18	15.9
Science	23	20.4
Allied Health Science	37	32.7
Level of Study		
Undergraduate	106	93.8
Postgraduate	7	6.2
Year of Study		
Year 1	11	9.7
Year 2	24	21.2
Year 3	13	11.5
Year 4	54	47.8

Year 5	4	3.5
Masters	6	5.3
PhD	1	0.9

Table 2 presents the features of internet use. The most common purpose of internet use was social networking (96.5%), followed by streaming audio and video content (92.9%) and educational activities (92.0%). In addition, 55.8% of respondents reported using the internet for online shopping, while 53.1% used it for e-banking services. Online gaming was the least common activity, reported by only 26.5% of respondents.

Table 2: Features of internet use

Features	Frequency	Percentage (%)
Duration spent on using internet per day		
< 2 Hours	1	0.9
2-5 Hours	26	23.0
6-10 Hours	48	42.5
> 10 Hours	38	33.6
Method of internet access		
Wi-Fi	62	54.9
Mobile Data	51	45.1
Location of internet access		
Home	79	69.9
Hostel	32	28.3
Faculty	2	1.8

Among the 113 students, 36 (31.9%) were classified as having IA, defined by an IAT score of ≥43, while 77 (68.1%) were classified as non-addicted users. Table 3 presents the distribution of MET-minutes/week according to the IPAQ-SF. About 34.5% of respondents reported low PA, 47.8% moderate PA, and only 17.7% high PA levels. The Chi-square test indicated no significant association between IA and PA levels among the students ($\chi^2(2, n = 113) = 0.074$, $p = 0.963$).

Table 3: The distribution of MET-minutes/week

PA	Median	IQR
MET-minutes/week		
Vigorous	120.00	960.00
Moderate	120.00	480.00
Walking	297.00	676.50
Total PA	1049.50	1454.25

DISCUSSION

In this study, most students reported spending between 6 and 10 hours per day using the internet (42.5%), while 33.6% reported spending more than 10 hours daily. These findings are consistent with previous research. Radeef and Faisal (2019) reported that 47.9% of 257 dental students from the IIUM Kuantan used the internet for 20–40 hours per week, with 29.2% of students classified as pathological internet users and a further 12.5% identified as being at high risk of IA. Similarly, Rosliza et al. (2018) found that 44.7% of 322 students from Universiti Putra Malaysia (UPM) spent 4–10 hours per day online, with 25 respondents (7.8%) categorised as addictive internet users.

The high prevalence of prolonged internet use among university students indicates a substantial risk for the development of IA. Consistent with this, the present study found that 36 students (31.9%) met the criteria for IA. Prolonged screen time may also contribute to increased sedentary behaviour, potentially displacing time that could otherwise be spent on PA and thereby increasing the risk of physical inactivity.

Consistent with these findings, most respondents were categorised as having a moderate PA level (47.8%), followed by 34.5% with a low PA level. These findings are consistent with previous studies conducted among university students. For instance, Goje et al. (2014) at UPM and Sahin and Lok (2018) in Turkey reported that the majority of students were classified as having moderate levels of PA (58.3% and 43.9%, respectively). Similarly, Balaraman et al. (2017), in a study among university students in Negeri Sembilan, Malaysia, reported that 35.9% of students had low levels of PA, which aligns closely with the findings of the present study.

Despite the high prevalence of IA and low-to-moderate PA levels, this study found no significant association between IA and PA levels among the participants. This finding is consistent with the study by Dang et al. (2018), which also reported no correlation between IA and PA. The absence of an association among Malaysian medical and health sciences undergraduates could be attributed to several overriding confounding factors. Firstly, heavy academic workloads and busy class schedules often impose substantial time constraints, directly limiting their opportunities for PA regardless of internet habits (Al-Asousi & El-Sabban, 2016). Secondly, poor sleep quality following a modified lifestyle can deplete their energy levels, further discouraging physical exertion (Saat et al., 2020). Beyond these individual constraints, environmental factors such as limited accessibility of sports facilities can restrict PA across the entire student population (Alkhawaldeh et al. 2024).

However, several previous studies have demonstrated a significant association between IA and PA levels, including

studies conducted in Pakistan (Khan et al., 2017), Turkey (Alaca, 2020; Bener et al., 2019), and Taiwan (Chang & Sun, 2020). The discrepancies between these established findings and the present study may be attributed to several distinct factors beyond differences in sample size and statistical power. Critically, variations in the measurement tools used to assess IA and PA may contribute to inconsistent findings across studies, particularly because different studies employ varying cut-off scores to determine and categorise IA levels.

Several limitations should be considered when interpreting the results of this study. Response bias may have influenced the findings, as data were collected using self-reported questionnaires. Such bias is inherent in many survey-based studies, as respondents may underreport IA or overestimate PA due to social desirability or recall bias. Additionally, participants' responses regarding PA may have been influenced by their prior responses to questions on IA, which could have affected the observed association between IA and PA. To address these limitations and achieve more conclusive data, future research should employ longitudinal study designs to better capture long-term behavioural trends. Furthermore, utilising objective PA measures such as accelerometers or pedometers alongside self-reported tools will be crucial to mitigate subjective reporting bias and resolve the inconsistencies found across existing literature.

CONCLUSION

In conclusion, this study demonstrated a relatively high prevalence of IA among university students at IIUM Kuantan, suggesting that this population may be particularly vulnerable to problematic internet use. Although no significant association was observed between IA and PA levels, the coexistence of high IA prevalence and suboptimal PA remains a public health concern. Both excessive internet use and physical inactivity are recognised behavioural risk factors for NCDs. Therefore, these findings underscore the importance of continued monitoring and the implementation of targeted interventions aimed at promoting healthy internet use, reducing sedentary behaviour, and encouraging active lifestyles among university students to mitigate long-term risks of NCDs.

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ORIGINAL ARTICLE

Conceptual Integration of Social Cognitive and Self-Determination Theories in Promoting Physical Activity Among Pre-Frail Older Adults: A Narrative Review

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ABSTRACT

Background: Physical inactivity among pre-frail older adults contributes to accelerated progression toward frailty, disability, and mortality. Given the influence of psychological and motivational barriers, behavioural theories offer valuable insights into initiating and sustaining physical activity (PA). Social Cognitive Theory (SCT) highlights cognitive regulators such as self-efficacy, outcome expectations, goal setting, and behavioural reinforcement, while Self-Determination Theory (SDT) emphasises motivation driven by autonomy, competence, and relatedness. Integrating both perspectives may provide a more comprehensive foundation for designing effective PA interventions for pre-frail populations. **Methods:** A narrative review was conducted using literature retrieved from PubMed, Scopus, and Google Scholar. Searches were conducted for English-language publications from 2000 to 2025 using keywords related to "pre-frailty," "older adults," "physical activity," "exercise," "Social Cognitive Theory," "self-efficacy," "Self-Determination Theory," "autonomy," "competence," "relatedness," and "motivation." Publications were included if they examined SCT, SDT, or related behavioural and motivational constructs in relation to PA among older adults, particularly those relevant to pre-frailty. Publications were excluded if they were unrelated to older adults, PA behaviour, or theory-informed intervention development. A total of 19 key publications were included in the final narrative synthesis. **Results:** SCT-based approaches may support PA initiation by enhancing self-efficacy, encouraging goal setting, strengthening self-regulation, and reinforcing perceived health benefits. Meanwhile, SDT-based approaches support long-term adherence by strengthening autonomous motivation, competence, emotional well-being, and social connectedness. Evidence suggests that interventions combining SCT and SDT constructs may improve adherence, resilience, psychological well-being, and overall quality of life among older adults. However, current evidence remains limited by the lack of longitudinal and culturally contextualised studies, particularly in Southeast Asia, restricting broader applicability to pre-frail populations.
Conclusion: Integrating SCT and SDT may provide a synergistic behavioural framework capable of addressing both external and internal determinants of PA participation in pre-frail older adults. To advance healthy ageing strategies, future research should develop hybrid, community-based interventions tailored to cultural and social contexts, particularly within Malaysian ageing populations. Strengthening both behavioural capability and motivational quality may optimise resilience and support sustained active ageing trajectories.

INTRODUCTION

Physical inactivity remains a major public health concern among older adults, particularly those in the pre-frail stage. Pre-frailty is a potentially reversible condition that affects approximately 35–60% of community-dwelling older adults in Asia, with a prevalence of 41.6% reported among urban Malaysian populations (Norazman et al., 2020). Given its association with functional decline and adverse health outcomes, early theory-informed strategies are needed to promote physical activity and prevent frailty progression.

Behavioural theories provide valuable frameworks for understanding physical activity behaviour. Social Cognitive Theory (SCT) emphasises self-efficacy, goal setting, outcome expectations, and self-regulation as key determinants of behavioural initiation (McAuley et al., 2007). In contrast, Self-Determination Theory (SDT) focuses on autonomy, competence, relatedness, and motivational quality, which are important for sustaining long-term engagement in physical activity (Deci & Ryan, 2000; Teixeira et al., 2022). Although both theories have been widely applied in physical activity research, their integrated application among pre-frail older adults remains insufficiently explored.

The integration of SCT and SDT is particularly relevant for pre-frail older adults, who often experience both physical and motivational barriers to physical activity. SCT-based

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strategies may facilitate behavioural activation, whereas SDT-informed approaches may enhance long-term adherence. Together, these theories offer a complementary framework for addressing both the initiation and maintenance of physical activity behaviour.

In Malaysia, physical activity participation among older adults is influenced by environmental, social, and cultural factors (Alias et al., 2022; Tan et al., 2018). Regional evidence further highlights the importance of self-efficacy, social support, accessibility, and motivation in shaping physical activity behaviour among physically vulnerable populations (Manaf et al., 2021; Hisham et al., 2022).

Therefore, this narrative review aims to conceptually integrate SCT and SDT to explain how physical activity can be initiated and sustained among pre-frail older adults. By synthesising evidence from global and Malaysian perspectives, this review proposes an integrated SCT–SDT pathway that links behavioural activation with motivational maintenance and provides a foundation for culturally responsive physical activity interventions.

MATERIALS AND METHODS

Study Design and Conceptual Approach

This study employed a theory-driven narrative review to synthesise evidence on Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) in promoting physical activity among pre-frail older adults. A narrative review approach was chosen to conceptually integrate theoretical constructs and explore how SCT and SDT may complement one another in explaining physical activity initiation and long-term adherence across diverse literature sources.

Search Strategy and Data Sources

A structured literature search was conducted using PubMed, Scopus, and Google Scholar to identify relevant English-language publications published between 2000 and 2025. Search terms included keywords related to pre-frailty, older adults, physical activity, SCT, SDT, self-efficacy, motivation, autonomy, competence, and relatedness. Relevant Malaysian and regional studies were also considered when they provided contextual evidence related to physical activity participation and adherence.

Eligibility Criteria

Publications were included if they examined SCT, SDT, or related behavioural and motivational constructs in relation to physical activity among older adults. Empirical studies, intervention studies, qualitative studies, theoretical papers, and review articles relevant to theory-informed physical activity promotion were considered. Publications unrelated to older adults, physical activity behaviour, or behavioural theory integration were excluded.

Study Selection Process

Titles, abstracts, and full texts were screened for relevance to physical activity, pre-frailty, SCT, and SDT. A total of 19 publications met the eligibility criteria and were included in the final narrative synthesis. The selection process is summarised in Figure 1.

Conceptual Extraction and Synthesis

Included publications were examined for recurring theoretical constructs, behavioural mechanisms, motivational processes, and practical implications related to physical activity promotion among pre-frail older adults. Particular attention was given to SCT constructs (e.g., self-efficacy, outcome expectations, and self-regulation) and SDT constructs (e.g., autonomy, competence, relatedness, and intrinsic motivation). Publications were evaluated based on their conceptual relevance and contribution to SCT–SDT integration.

Framework Development Procedure

Synthesised themes were used to develop a conceptual integration of SCT and SDT. SCT was positioned as supporting the initiation of physical activity through confidence-building, goal setting, feedback, and behavioural reinforcement, whereas SDT was positioned as supporting long-term adherence through autonomy, competence, relatedness, and internalised motivation. The integrated framework therefore explains how behavioural capability and motivational quality may interact to promote sustained physical activity among pre-frail older adults.

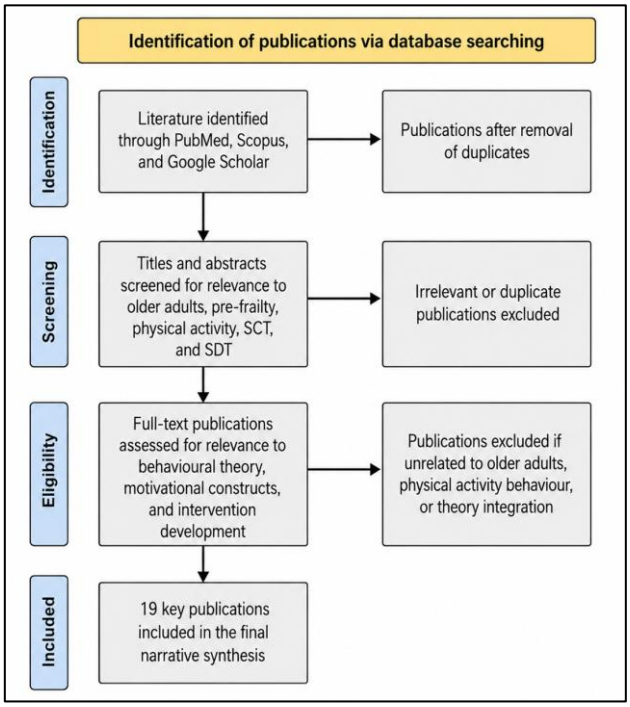


Figure 1. Simplified PRISMA-guided flow diagram ilustrating the selection of publications for narrative review

RESULT

Overview of Theoretical Models

This section outlines how Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) explain physical activity behaviour among pre-frail older adults and inform intervention development. SCT primarily explains behaviour initiation through confidence-building, behavioural capability, and self-regulation, whereas SDT focuses on sustaining behaviour through motivation and psychological need satisfaction.

Social Cognitive Theory, developed by Bandura, proposes that behaviour results from the interaction between personal, behavioural, and environmental factors (McAuley et al., 2007). Key SCT constructs relevant to physical activity include self-efficacy, outcome expectations, self-regulation, observational learning, reinforcement, and environmental support. Together, these factors may enhance confidence, perceived benefits, and behavioural skills, helping older adults overcome barriers to physical activity participation (Conn et al., 2014; Umstattd et al., 2008). Figure 2 illustrates the SCT constructs relevant to physical activity initiation among pre-frail older adults.

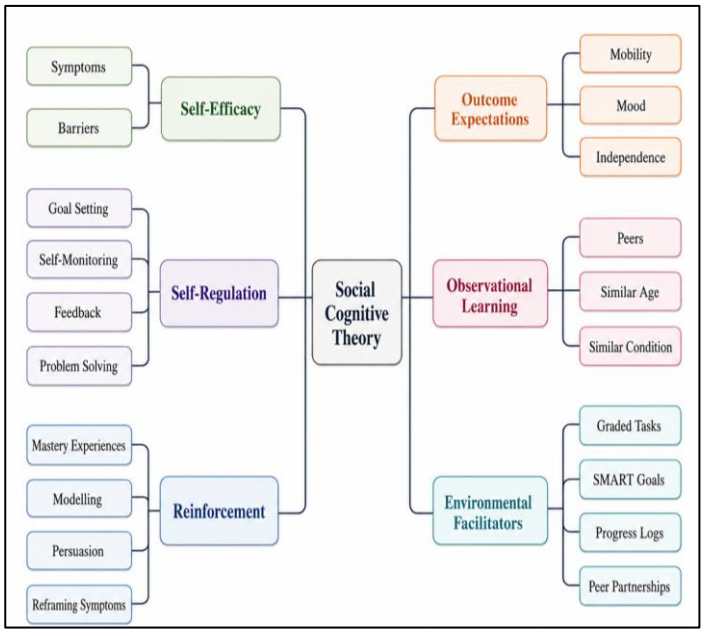


Figure 2. Social Cognitive Theory

In pre-frail populations, SCT-based strategies such as goal setting, self-monitoring, peer modelling, graded activities, and positive feedback may strengthen self-efficacy and support early behavioural activation. However, additional motivational mechanisms may be required to sustain long-term adherence.

Self-Determination Theory (SDT), proposed by Deci and Ryan (2000), emphasises the quality of motivation through the satisfaction of three psychological needs: autonomy, competence, and relatedness. Fulfilment of these needs promotes autonomous motivation, whereby physical activity becomes personally meaningful and self-endorsed (Ng et al., 2012). Figure 3 presents the SDT cycle relevant to physical activity maintenance among pre-frail older adults.

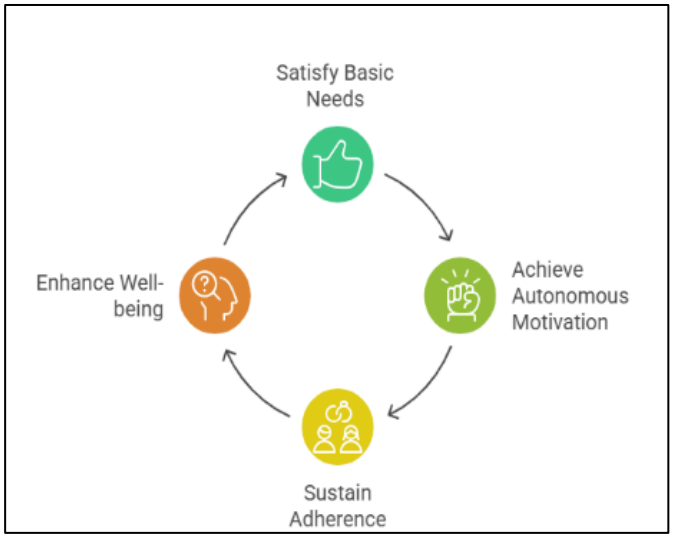


Figure 3. The Self-Determination Theory Cycle

For pre-frail older adults, SDT highlights the importance of providing meaningful choices, achievable progression, supportive feedback, and opportunities for social connection. Strategies such as co-created activity plans, group-based activities, and motivational interviewing may strengthen long-term adherence by aligning physical activity with personal goals (Cotter et al., 2024).

Although both theories emphasise self-regulation and supportive environments, they differ in focus. SCT primarily supports behaviour initiation through confidence-building and behavioural skills, whereas SDT facilitates maintenance through motivational quality and psychological need satisfaction (Teixeira et al., 2022). Integrating both theories therefore offers a comprehensive framework in which SCT-based strategies initiate physical activity and SDT-based approaches sustain long-term engagement. This integration may be particularly beneficial for pre-frail older adults, who often require both structured support and motivational reinforcement to maintain active lifestyles (Si et al., 2024; Larsen et al., 2021; Hamid et al., 2018; Zainudin et al., 2020).

Application in Older Adult Physical Activity

Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) have been widely applied in studies examining physical activity among older adults, including pre-frail populations. SCT primarily explains behaviour initiation through constructs such as self-efficacy, outcome expectations, goal setting, and self-regulation, whereas SDT focuses on sustaining behaviour through autonomy, competence, relatedness, and intrinsic motivation.

Evidence supporting SCT indicates that self-efficacy is a key determinant of physical activity participation. McAuley et al. (2007) reported that higher exercise self-efficacy was associated with greater goal-setting and persistence, while Yu et al. (2025) found that self-efficacy and outcome expectations were the strongest predictors of exercise behaviour among frail older adults. These findings suggest that confidence and perceived benefits are critical during the early stages of behaviour change.

SDT-based approaches contribute to long-term adherence by promoting autonomous motivation. Studies have shown that interventions incorporating autonomy support, competence building, and social connectedness improve physical activity engagement, quality of life, and adherence among older adults (Si et al., 2024; Cotter et al., 2024). Such findings indicate that sustained participation is more likely when physical activity aligns with personal values and psychological needs.

Research integrating SCT and SDT demonstrates complementary benefits. For example, Larsen et al. (2021) showed that combining motivational interviewing with activity-monitoring strategies improved movement, self-efficacy, and adherence among older adults. Together, these theories suggest that SCT-based strategies may facilitate behaviour initiation, while SDT-based approaches support long-term maintenance.

For pre-frail older adults, practical interventions may combine goal setting, self-monitoring, feedback, and peer modelling with autonomy-supportive strategies, social connectedness, and motivational interviewing. Such an integrated approach provides a structured pathway for increasing physical activity participation and sustaining engagement over time.

Overall, SCT explains the cognitive mechanisms underlying behaviour initiation, whereas SDT explains the motivational processes that maintain behaviour. Integrating both theories offers a comprehensive framework for promoting sustained physical activity and healthy ageing among pre-frail older adults.

Critical Appraisal of Included Evidence

The included publications provide valuable theoretical and empirical support for integrating Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) in promoting physical activity among older adults. The literature encompasses diverse study designs, including theoretical papers, qualitative studies, cross-sectional studies, intervention trials, protocols, and review articles. While this diversity enriches conceptual understanding from multiple perspectives, it limits direct comparison due to variations in populations, intervention approaches, outcome measures, and follow-up periods.

A major strength of the evidence is the consistent identification of self-efficacy, goal setting, autonomy, competence, relatedness, and social support as key determinants of physical activity behaviour (McAuley et al., 2007; Ng et al., 2012; Teixeira et al., 2022). Intervention studies further demonstrate that behavioural and motivational strategies can enhance adherence, confidence, and quality of life (Larsen et al., 2021; Si et al., 2024). Malaysian and regional studies also provide useful contextual insights into barriers and facilitators of physical activity among physically vulnerable populations (Manaf et al., 2021; Hisham et al., 2022a, 2022b; Ong et al., 2024).

However, several limitations remain. Many studies involve general older adult populations rather than specifically pre-frail individuals. Some Malaysian studies were conducted among people with spinal cord injury or physical disabilities and were therefore included only as contextual evidence. In addition, the evidence base varies in methodological strength. Cross-sectional studies cannot establish causality, qualitative studies may have limited generalisability, and intervention studies often involve short follow-up periods and heterogeneous designs. Furthermore, culturally contextualised evidence from Malaysia and Southeast Asia remains limited.

Overall, current evidence supports the conceptual relevance of SCT–SDT integration, but further longitudinal and theory-driven intervention studies involving clearly defined pre-frail populations are needed to evaluate its effectiveness in promoting sustained physical activity and improving health outcomes.

DISCUSSION

Synthesis and Comparative Analysis

Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) offer complementary perspectives for understanding physical activity behaviour among pre-frail older adults. While SCT emphasises behavioural initiation through self-efficacy, outcome expectations, self-regulation, and reinforcement, SDT focuses on sustaining behaviour through autonomy, competence, relatedness, and intrinsic motivation (Deci & Ryan, 2000; McAuley et al., 2007; Ng et al., 2012). Integrating both theories therefore provides a comprehensive framework that addresses both the initiation and maintenance of physical activity.

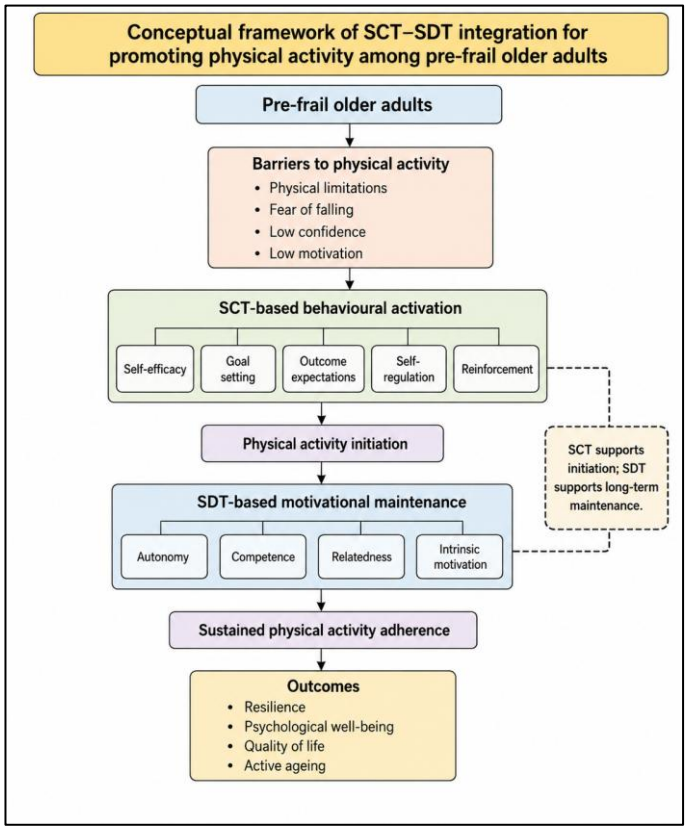
Evidence supports this theoretical complementarity. Studies have shown that autonomy-supportive approaches combined with behavioural strategies such as self-monitoring, feedback, and activity tracking improve physical activity participation, self-efficacy, and adherence among older adults (Larsen et al., 2021; Si et al., 2024; Cotter et al., 2024). These findings suggest that SCT-based constructs may facilitate behavioural activation, whereas SDT-based constructs support long-term engagement through internalised motivation and psychological need satisfaction.

Based on the reviewed evidence, SCT and SDT can be conceptualised as sequential and complementary mechanisms. SCT constructs, including self-efficacy, goal setting, outcome expectations, and self-regulation, may support early participation in physical activity, while SDT constructs, including autonomy, competence, relatedness, and intrinsic motivation, may enhance long-term adherence. This integrated SCT–SDT pathway provides a theoretical basis for developing interventions that combine structured behavioural support with motivational maintenance. The proposed SCT–SDT integration pathway is illustrated in Figure 4.

The proposed framework is particularly relevant for pre-frail older adults, who may require external guidance and confidence-building to initiate physical activity before gradually transitioning towards more autonomous and self-directed engagement. Such an approach may help address common barriers such as fear of falling, low confidence, and uncertainty regarding exercise participation.

Nevertheless, the evidence base remains limited. Much of the literature is derived from general older adult or rehabilitation populations rather than clearly defined pre-frail samples. In addition, SCT-focused studies often place less emphasis on motivational quality, whereas SDT-based studies may provide less guidance on structured behavioural techniques required during the initiation phase. Further empirical research is therefore needed to evaluate integrated SCT–SDT interventions specifically among pre-frail older adults.

Figure 4. Conceptual framework of SCT-SDT intergration for promoting physical activity among pre-frail older adults



Cultural adaptation may further strengthen this framework. In collectivist contexts such as Malaysia, family involvement, social support, and community participation may enhance both behavioural and motivational processes (Hamid et al., 2018; Zainudin et al., 2020). Incorporating culturally relevant and community-based approaches may therefore improve the effectiveness of theory-informed physical activity interventions.

Overall, SCT and SDT should be viewed as complementary rather than competing theories. Their integration offers a practical and theoretically grounded framework for promoting sustained physical activity among pre-frail older adults and provides direction for future intervention development and evaluation.

Implications for Practice

Integrating Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) provides a practical

framework for promoting physical activity among pre-frail older adults. SCT may support behaviour initiation through self-efficacy, goal setting, self-monitoring, reinforcement, and peer modelling, whereas SDT may facilitate long-term adherence by strengthening autonomy, competence, relatedness, and intrinsic motivation (Deci & Ryan, 2000; McAuley et al., 2007; Teixeira et al., 2022).

In clinical practice, healthcare professionals may apply SCT-based strategies such as SMART goal setting, self-monitoring, graded activity progression, and positive feedback to enhance confidence and encourage physical activity participation. Combining these approaches with motivational interviewing may further support autonomy and intrinsic motivation, particularly among older adults experiencing fear of falling, fatigue, or low confidence (Larsen et al., 2021).

At the community level, programmes such as peer-led exercise groups, walking clubs, and community-based activities may promote self-efficacy through observational learning and reinforcement while fostering relatedness and competence through social participation. Providing opportunities for older adults to select preferred activities and participation settings may further enhance autonomy and support sustained engagement (Ng et al., 2012; Cotter et al., 2024).

At the programme and policy level, interventions should adopt a phased and theory-informed approach that combines behavioural activation with motivational maintenance. In collectivist settings such as Malaysia, culturally adapted strategies involving family support, community engagement, accessible facilities, safe environments, and affordable group-based activities may help reduce participation barriers while strengthening both behavioural and motivational determinants of physical activity.

Bridging SCT and SDT in Practice

Motivational interviewing represents a useful bridging technique because it may support both self-efficacy and autonomy. It helps older adults explore ambivalence, identify personally meaningful reasons for being active, and set realistic activity goals. When combined with self-monitoring tools, feedback, and gradual progression, motivational interviewing may align behavioural activation with internal motivation, thereby supporting both physical activity initiation and maintenance (Larsen et al., 2021; Si et al., 2024). This integrated approach may be especially relevant for pre-frail older adults, who often require both structured support and motivational encouragement to sustain active ageing behaviours.

RECOMMENDATION FOR FUTURE RESEARCH

Future research should move beyond theoretical discussion and empirically evaluate integrated SCT–SDT approaches for promoting physical activity among pre-frail older adults. Intervention studies should clearly incorporate SCT-based strategies, such as goal setting, self-monitoring, feedback, and reinforcement, alongside SDT-based components including autonomy support, competence-building, relatedness, and motivational interviewing.

Longitudinal and intervention-based studies are needed to determine whether integrated SCT–SDT approaches can support both physical activity initiation and long-term adherence. Future research should also examine potential behavioural and psychological mediators, including self-efficacy, self-regulation, autonomy, competence, relatedness, motivation, psychological well-being, and quality of life, to better understand the mechanisms underlying behavioural change.

In addition, culturally contextualised research is needed in Malaysia and other Asian settings. Factors such as family involvement, collectivist values, environmental accessibility, and community support should be considered when designing and evaluating physical activity interventions (Hamid et al., 2018; Zainudin et al., 2020).

Finally, implementation studies should explore the feasibility, acceptability, sustainability, and real-world application of integrated SCT–SDT programmes within clinical and community settings. Such research may facilitate the translation of theoretical frameworks into effective strategies for promoting active ageing and preventing frailty progression among pre-frail older adults.

CONCLUSION

This narrative review highlights the value of integrating Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) to promote physical activity among pre-frail older adults. SCT may support behavioural initiation through self-efficacy and self-regulation, whereas SDT may facilitate long-term adherence through autonomy, competence, relatedness, and autonomous motivation. The proposed SCT–SDT pathway provides a framework linking behavioural activation with motivational maintenance.

Theory-informed interventions should combine structured confidence-building strategies with autonomy-supportive and socially engaging activities. Future research should

evaluate integrated SCT–SDT interventions using longitudinal and intervention-based designs to determine their effectiveness in promoting sustained physical activity among pre-frail older adults.

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AUTHOR'S CONTRIBUTION

Mahirah Kamaron (MK) conceptualised and designed the study, conducted the literature search, synthesised data, and prepared the manuscript draft. Azliyana Azizan (AA) provided supervision, conceptual direction, and critical revisions to refine the analysis and presentation. Both authors reviewed, edited, and approved the final version of the manuscript.

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ORIGINAL ARTICLE

Exploring the Anti-Melanoma and Anti-Breast Cancer Potential of *Mitragyna speciosa* (Korth.) Havil. Leaf Constituents Using *In Silico* Approaches

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ABSTRACT

Background: The incidence of melanoma and breast cancer globally are increasing at an alarming rate. However, many existing anticancer drugs are losing efficacy due to increasing drug resistance and are often accompanied by unavoidable side effects. This growing challenge underscores the urgent need for novel and selective anticancer therapies. Traditional medicinal plants, such as kratom (*Mitragyna speciosa* (Korth.) Havil.), offer promising avenues for drug discovery in this regard. **Methods:** This study explored the *in silico* anticancer potential of compounds identified in *M. speciosa* leaf extract using quadrupole time-of-flight liquid chromatography-mass spectrometry (Q-ToF-LCMS) analysis, alongside their physicochemical and pharmacokinetic parameters, to determine their suitability as lead candidates for anticancer drug development. A crude extract was prepared from kratom leaves using 100% methanol through ultrasound-assisted extraction yielding a 100% methanolic ultrasound-assisted extract with a recovery rate of 26.14%. The compounds were then screened *in silico* against two cancer-related proteins (PDB IDs: 3OG7 and 3ERT) to evaluate their potential against melanoma and breast cancer. **Results:** The identified phenolic, flavonoid, and alkaloidal compounds showed strong binding interactions with the melanoma target. Physicochemical and absorption, distribution, metabolism, excretion, and toxicity (ADMET) predictions revealed the potential of scopolin and 17-O-acetylajmaline as lead molecules for the development of new anticancer drugs to treat melanoma and breast cancer. **Conclusion:** The current study has identified promising lead compounds for the development of novel anticancer agents, providing a basis for future research on kratom-based anticancer drug discovery.

INTRODUCTION

Cancer is caused by abnormal cell division, affecting any organ in the body. It is considered one of the main causes of death across the globe (Bordoloi et al., 2018, Priatna et al., 2023). According to international statistics, twenty million new cancer cases and 9.7 million cancer-related fatalities were documented in 2022. Among these, skin melanoma ranked 17th in incidence, with 331,647 new cases and 58,645 deaths (Bray et al., 2024). Melanoma, often caused by ultraviolet exposure and carcinogenic BRAF mutations, is an aggressive form of skin cancer known for its rapid metastasis and progression (Banerjee et al., 2024, Umar et al., 2020). In contrast, breast cancer remains the most common malignancy among females globally. Approximately 70-80% of patients with early-stage, non-metastatic disease can be cured with current therapies. In contrast, advanced breast cancer characterised by distant organ metastases is regarded as incurable with currently accessible treatment options. At the molecular level, breast cancer is highly heterogeneous, with key characteristics including overactivation of human epidermal growth factor receptor 2 (HER2, encoded by ERBB2), hormone receptor signalling (oestrogen and

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progesterone receptors), and/or mutations in BRCA genes (Harbeck et al., 2019).

Current cancer treatments, such as chemotherapy, impose a significant financial burden on patients (Smith et al., 2019) and are responsible for a range of deleterious effects due to their lack of selectivity towards cancer cells and the issue of multidrug resistance (Wang et al., 2019). Vemurafenib has been a preferred drug for treating melanoma; however, resistance to vemurafenib has already been reported (Banerjee et al., 2024). Similarly, toremifene is a drug of choice to treat breast cancer and has been found to be associated with cross-resistance to another anti-breast cancer drug, tamoxifen (Favoni & de Cupis, 1998).

Consequently, the development of new anticancer drugs has become a pressing need. Traditional medicinal plants, such as *Mitragyna speciosa* (Korth.) Havil. (locally known as kratom), offer promising anticancer compounds. This native plant of Southeast Asia is well-regarded by locals for its effectiveness in treating and preventing various diseases and disorders (Figure 1) (Begum et al., 2025a).

The anticancer potential of *M. speciosa* extracts and their constituents has been evaluated in various studies. For example, Goh et al. (2014) explored the properties of mitragynine and its silane-reduced analogue on erythroid leukaemia and colon carcinoma cell lines. Another study evaluated the cytotoxicity of hexane, dichloromethane (DCM), and methanol extracts of kratom against lung, colon and breast cancer cell lines (Rahman et al., 2022). Additionally, Zailan and coworkers (2019) assessed the cytotoxicity and cytokine inhibitory effects of the methanol extract on SW480 cells. Furthermore, Bayu et al. (2024) demonstrated that combining crude or alkaloid kratom extract with doxorubicin produced synergistic anticancer activity on the human lung cancer cell line (A549).

To date, only one *in silico* study has evaluated the anti-breast cancer activity of kratom alkaloids against estrogen receptor alpha (ERα) and P53 proteins, revealing their significant potential (Priatna et al., 2023). Kratom contains various compounds beyond alkaloids and evaluating different classes of these compounds against oncogenic protein targets can provide deeper insight. Therefore, an *in silico* study of kratom's identified compounds against mutant B-Raf Kinase protein in melanoma and against human estrogen receptor alpha in breast cancer would offer valuable information for both kratom and cancer treatment sectors. The aim of this study was to explore, through *in silico* approaches, the anticancer potential of compounds identified from *M. speciosa* leaf extracts. In addition, the study was also designed to characterise the physicochemical and pharmacokinetic characteristics of these compounds to explore their suitability as lead constituents for the development of novel anticancer agents.

Figure 1: A mature leaf of the kratom plant.

MATERIALS AND METHODS

Collection and Preparation of Plant Material

M. speciosa leaves were procured from Kedah, Malaysia. Species identification and authentication were performed at the KOP, IIUM, and a voucher specimen (voucher number PIIUM 0358) was deposited. The leaves were carefully cleaned and subsequently dried at 40 °C for 72 hours. Subsequently, the dried leaves were then pulverised using a Universal Cutting Mill (FRITSCH Pulverisette19, Germany) to obtain powdered kratom leaf material.

Preparation of Extract by Ultrasound-Assisted Extraction Method

Ultrasound-assisted extraction was performed to obtain a 100% methanolic ultrasound-assisted extract (100% US extract) of *M. speciosa* leaves. Briefly, 5 g of dried powdered leaf material was mixed with 50 mL of 100% methanol and placed in an ultrasonic extractor (UC-10, Jeio Tech Co., Ltd., Daejeon, Republic of Korea) for 30 minutes to obtain the ultrasonic extract (Figure 2). The resulting mixture was carefully filtered twice, and the resultant filtrate was concentrated under reduced pressure using a rotary evaporator. This process was repeated three times to ensure maximum yield. Lastly,

the percentage yield of the resultant extract was determined (Begum et al., 2025b).

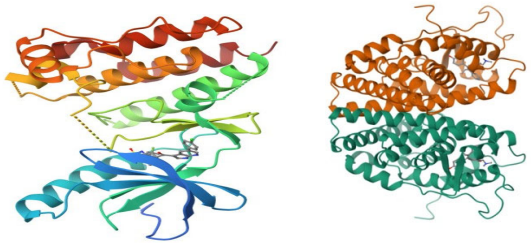
Figure 2: Preparation of 100% US extract by ultrasound-assisted extraction method.

Identification of Compounds in the 100% US extract of *M. speciosa* leaf through Quadrupole Time-of-Flight Liquid Chromatography-Mass Spectrometry (Q-ToF-LCMS) analysis

The extract was analysed using an LC-MS/QTOF system (Agilent 1200 LC with an ESI source). Firstly, 1 mg of extract was dissolved in 250 µL of liquid chromatography grade methanol and subsequently vortexed and sonicated, and further mixed with 250 µL of distilled H_2O. The mixture was subjected to centrifugation for 15 minutes, and the supernatant was carefully transferred to a glass vial after filtration. Chromatographic separation was performed in a positive ionisation mode using two different mobile phases. The first phase consisted of 0.1% formic acid in water and the second phase consisted of 0.1% formic acid in acetonitrile. However, in negative ionisation mode, the first mobile phase consisted of 0.1% ammonium formate in water and the second consisted only of acetonitrile. The gradient program for both modes was: 0.0-18 min, 5-95% B; 18-23 min, 95% B; 23.01 min, 5% B. The total run time was 30 minutes, with a 2-minute re-equilibration before each injection. 2 µL was injected, and 0.25 mL/min was the flow rate of the mobile phase. The optimised conditions for the mass spectrometer were set as follows: gas flow 11 L/min, nebuliser pressure 35 psi and gas temperature 325 °C. Data files were processed using Agilent MHQA B.05.00 software (Agilent Technologies, SA, United States of America) (Begum et al., 2025c).

Molecular docking analysis

Q-ToF-LCMS analysis of the 100% ultrasonic methanolic extract of *M. speciosa* leaves identified several key phytoconstituents which were further investigated using *in silico* molecular docking. Chemical structures of the reference drugs (dabrafenib and toremifene) and the test compounds were retrieved from the PubChem database (https://pubchem.ncbi.nlm.nih.gov/). For docking studies, the human estrogen receptor alpha ligand-binding domain (PDB ID: 3ERT) (Shiau et al., 1998) and the BRaf kinase mutant (PDB ID: 3OG7) (Bollag et al., 2010) (Figure 3) were selected as target proteins and obtained from the Protein Data Bank (http://www.rcsb.org). Protein structures were prepared by removing water molecules and native ligands, followed by the addition of polar hydrogens. Redocking of the native ligand (vemurafenib) into 3OG7 was performed using grid points (X, Y, Z) set to 46, 16, and 36, respectively, with grid centre coordinates (X, Y, Z) at 2.643, -2.28, and -19.403, ensuring a root-mean-square deviation (RMSD) < 2. For 3ERT, redocking of the native ligand (OHT600) was carried out using grid points (X, Y, Z) set to 28, 28, and 28, with grid centre coordinates (X, Y, Z) at 30.01, -1.913, and 24.206, also ensuring RMSD < 2. AutoDock Tools 1.5.7 and AutoDock Vina were used for docking simulations (Trott et al., 2010), and Discovery Studio was used for visualisation and interaction analysis. Binding interactions were examined through both 2D and 3D representations to provide detailed insights (Umar et al., 2020).



A **B**

Figure 3: 3D structures of two selected proteins: PDB ID 3OG7 (A) and PDB ID 3ERT (B) along with their respective native ligands retrieved from the Protein Data Bank.

Physicochemical and Pharmacokinetic Properties

The assessment of physicochemical and pharmacokinetic properties is a critical step in predicting drug disposition, maximising therapeutic outcomes, and safeguarding patient safety. Accordingly, the bioactive compounds identified from the 100% ultrasonic methanolic extract of *M. speciosa* leaves by Q-ToF-LCMS analysis were further assessed for their pharmacokinetic/physicochemical properties to investigate drug-likeness and other parameters including absorption, distribution,

metabolism, excretion, and toxicity (ADMET) profiles by utilising the SwissADME web server (accessed on 10 May 2026; http://www.swissadme.ch/index.php) and pkCSM web server (accessed on 10 May 2026; https://biosig.lab.uq.edu.au/pkcsm/prediction) (Ahmed et al., 2026).

RESULTS AND DISCUSSION

Yield of 100% US extract

Ultrasound-assisted extraction is widely recognised as an environmentally sustainable and highly efficient technique. By reducing or eliminating the use of organic solvents, it minimizes environmental impact while maintaining safety. Moreover, this method has been shown to markedly enhance the recovery of target bioactive compounds, making it an attractive and increasingly adopted approach in both research and industrial applications (Shen et al., 2023). Consequently, the 100% US extract of *M. speciosa* leaf was selected because of these advantages and was carefully prepared to support efficient extraction of bioactive compound. Therefore, the extract demonstrated a good yield, with a yield of 26.14%. This notable yield indicates the efficiency of the ultrasound-assisted extraction process in obtaining bioactive compounds from *M. speciosa* leaves.

Q-ToF-LCMS analysis

Q-ToF-LCMS afforded a robust basis for the identification of key phytoconstituents in the 100% ultrasonic methanolic extract of *M. speciosa* leaves. The analysis revealed a diverse range of metabolites, including phenolic compounds, flavonoids, and alkaloids (Table 1). Chromatograms obtained in both negative and positive ionisation modes offered a comprehensive overview of the extract's chemical profile (Figure 4). Representative chemical structures of selected identified compounds are presented in Figure 5.

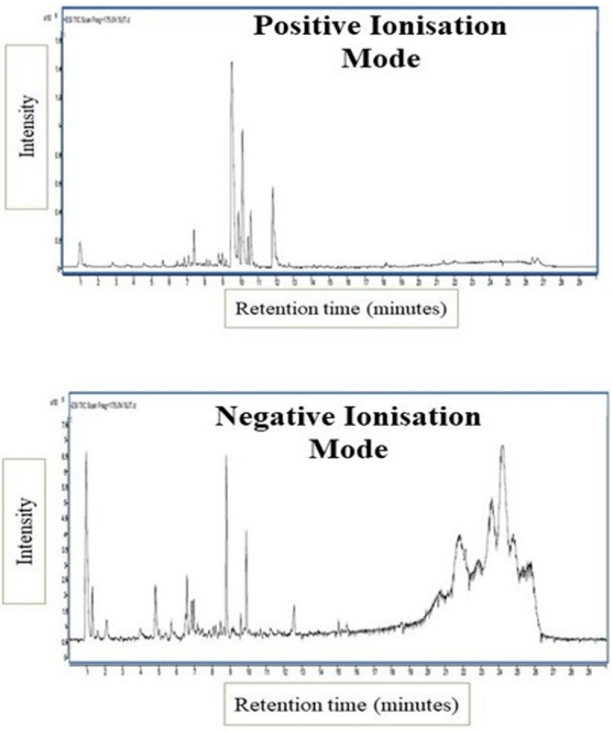


Figure 4: The Q-ToF-LCMS chromatograms of the 100% US leaf extract of *M. speciosa* in both negative and positive ionization modes.

Phenolic and flavonoid compounds are important plant secondary metabolites widely recognised for their significant biological properties (Chen et al., 2021). Flavonoids exert anticancer effects by halting cell division, invasion, and metastasis, as well as initiating apoptosis and cell-cycle arrest in cancer cells (Çetinkaya et al., 2022). Among the alkaloids, the anticancer properties of mitragynine have already been proven (Goh et al., 2014). Identified compounds such as scopolin can be converted into scopoletin in biological system, and reserpic acid and methyl respirate can be converted into reserpine. The anticancer properties of scopoletin and reserpine have been documented in several studies (Tian et al., 2021, Abdelfatah et al., 2025).

Table 1: The compounds identified in the 100% US extract of *M. speciosa* leaves through Q-ToF-LCMS analysis.

Putative Compounds	Molecular formula	Observed RT (min)	Score (%)	Observed *m/z*	Exact Mass (Da)	Mass Error (ppm)	Annotation Level
Scopolin	$C_{16}H_{18}O_9$	2.832	96.67	355.1032	354.09509	2.1	Level 2
Epifisetinidol-4alpha-ol	$C_{15}H_{14}O_6$	4.831	97.34	289.0715	290.07904	3.1	Level 2
Robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol	$C_{45}H_{38}O_{18}$	5.199	93.06	867.2115	866.20582	−2.5	Level 2

Formononetin 7-O-glucoside-6''-O-malonate	$C_{25}H_{24}O_{12}$	5.701	97.51	515.119	516.12678	0.1	Level 2
Robinetin 3-rutinoside	$C_{27}H_{30}O_{16}$	6.466	98.94	611.1612	610.15339	2.0	Level 2
5,6,7,3',4'-Pentahydroxy-8-methoxyflavone 7-apioside	$C_{21}H_{20}O_{12}$	6.743	99.11	465.1023	464.09548	−2.2	Level 2
8-Hydroxyluteolin 8-glucoside	$C_{21}H_{20}O_{12}$	6.856	94.97	463.0873	464.09448	5.3	Level 2
Luteolin 7-rhamnosyl(1-6)galactoside	$C_{27}H_{30}O_{15}$	7.079	97.5	595.1662	594.15848	0.4	Level 2
Reserpic acid	$C_{22}H_{28}N_2O_5$	7.895	98.57	401.2075	400.199823	0.6	Level 2
Methyl reserpate	$C_{23}H_{30}N_2O_5$	8.789	98.78	415.2234	414.215473	0.2	Level 2
17-O-Acetylajmaline	$C_{22}H_{28}N_2O_3$	9.187	99.09	369.2177	368.20999	−0.3	Level 2
Mitragynine	$C_{23}H_{30}N_2O_4$	9.893	96.14	399.2288	398.22056	1.0	Level 2

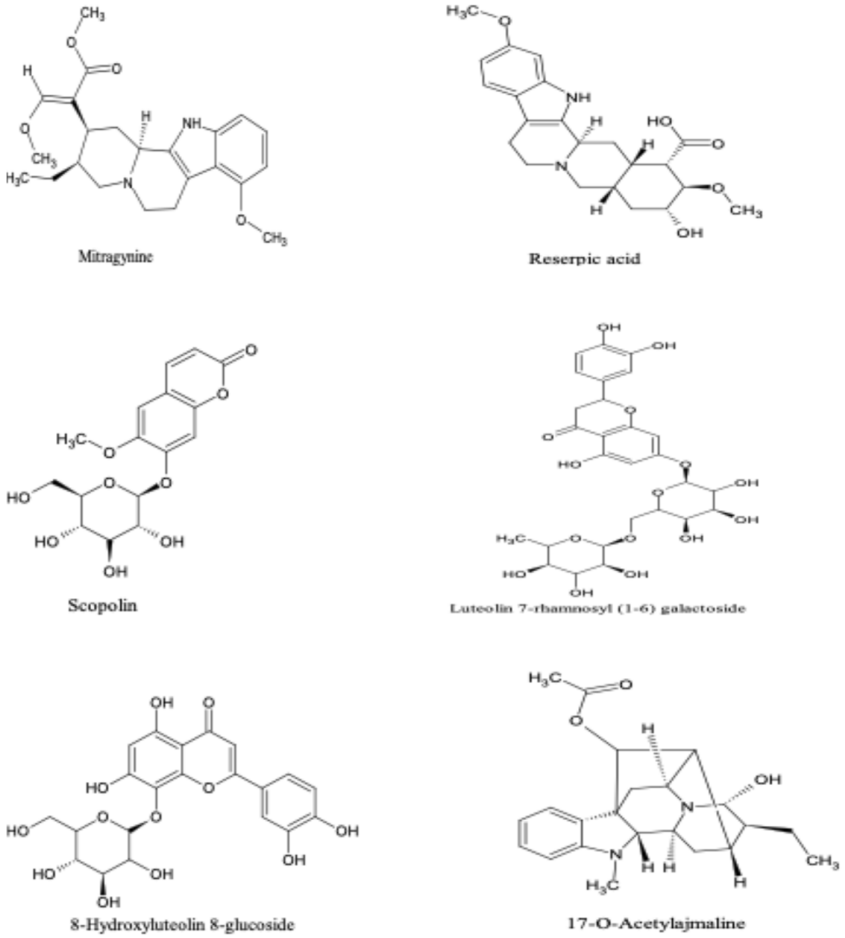


Figure 5: The chemical structures of some compounds identified by Q-ToF-LCMS analysis of the *M. speciosa* leaf's 100% US extract.

Table 2: Interaction profile of compounds from the 100% US extract of *M. speciosa* leaves with 3OG7 protein.

Compounds	Ligand binding energy (kcal/mol)	Binding Interactions	
		H bond interactions with bond distance (Å)	Other bond interactions with bond distance (Å)
Scopolin	-8.2	ASN 581: 2.89; CYS 532: 2.46; SER 465: 2.49	CYS 532: 4.70; TRP 531: 5.50; ALA 481: 4.21 & 5.18; LEU 514: 5.47 & 5.27; VAL 471: 4.42; PHE 583: 4.45 & 4.36
Epifisetinidol-4alpha-ol	-8.4	CYS 532: 2.85; ASP 594: 2.03	PHE 583: 3.91; CYS 532: 5.45; VAL 471: 5.30; LYS 483: 3.85
Robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol	-13.3	CYS 532: 2.33 & 3.16; LYS 483: 3.00; SER 465: 2.24; LYS 473: 2.01; TRP 531: 2.16; HIS 539: 2.51	HIS 539: 4.97; TRP 531: 5.91 & 3.65; ILE 463: 3.77
Formononetin 7-O-glucoside-6''-O-malonate	-9.2	SER 536: 2.00; CYS 532: 1.97; LYS 483: 2.61	LYS 483: 4.01; VAL 471: 3.58 & 3.92; LEU 514: 5.39 & 5.33; LEU 505: 3.94; ILE 527: 5.21; LEU 514: 5.39 & 5.33
Robinetin 3-rutinoside	-9.1	SER 536: 2.69 & 1.84; CYS 532: 2.49; SER 465: 1.82; ASN 580: 2.28; ASN 581: 1.93	VAL 471: 3.79 & 4.39; ALA 481: 5.47
5,6,7,3',4'-Pentahydroxy-8-methoxyflavone 7-apioside	-8.9	ILE 527: 2.28; CYS 532: 2.10; SER 536: 2.21; ASN 580: 2.46 & 2.85	LYS 483: 4.81; ALA 481: 4.68 & 4.76; VAL 471: 4.62, 4.79 & 5.47; ILE 463: 5.32; TRP 531: 5.59 & 5.81; PHE 583: 4.52 & 4.69
8-Hydroxyluteolin 8-glucoside	-10.4	ASN 580: 3.22; ASN 581: 3.36; GLN 530: 3.30; ALA 481: 3.12; THR 529: 3.21; ILE 527: 2.99	ASP 594: 4.96; VAL 471: 5.49, 4.36 & 5.15; TRP 531: 5.36; PHE 583: 4.48; CYS 532: 5.26; ALA 481: 4.59
Luteolin 7-rhamnosyl(1-6)galactoside	-10.5	CYS 532: 2.62 & 3.03; ASP 594: 2.52; LYS 483: 2.76; ASN 580: 2.22; LYS 578: 2.76	-
Reserpic acid	-8.6	ASN 581: 2.32; ASN 580: 2.74	ALA 481: 5.14; LYS 483: 3.95; ILE 527: 4.72; VAL 471: 3.58 & 4.42
Methyl reserpate	-9.1	SER 536: 2.74 & 2.69	VAL 471: 3.91 & 4.43; ALA 481: 5.06 & 3.72; PHE 583: 4.59 & 4.43; LEU 514: 4.50; CYS 532: 3.84
17-O-Acetylajmaline	-8.1	SER 536: 2.88	ALA 481: 5.16; VAL 471: 3.78
Mitragynine	-8.6	-	PHE 583: 3.93; 5.21 & 4.85

Native Ligand (Vemurafenib)	-11.1	GLN 530: 2.24; GLY 596: 2.21; PHE 595: 2.68	ILE 463: 4.66; TRP 531: 5.93; CYS 532: 5.00; LEU 505: 4.06; LYS 483: 4.10; PHE 583: 4.75; LEU 514: 4.83; ALA 481: 3.79; PHE 595: 4.59
Standard drug (Dabrafenib)	-9.0	ASP 594: 2.60; ASN 590: 1.83	PHE 468: 5.09; LYS 578: 4.27; SER 465: 3.27; ASN 580: 3.29; ASP 594: 3.13; ASN 581: 3.57; VAL 471: 4.70 & 5.07; TRP 531: 5.02; PHE 583: 4.50 & 3.53

Molecular Docking Analysis

To investigate the potential anticancer activity of the Q-ToF-LCMS identified compounds, molecular docking was performed against two therapeutically relevant targets associated with melanoma and breast cancer. The first target, BRAF kinase (PDB ID: 3OG7), is a serine/threonine protein kinase, which functions as a key regulator of growth signal transduction. It plays a central role in the mitogen-activated protein kinase (MAPK)/ERK signalling pathway signalling pathway, influencing cellular processes such as cell division, differentiation, and secretion. The oncogenic BRAF V600E mutation results in constitutive activation of downstream signalling, promoting uncontrolled cell proliferation, increased cancer aggressiveness and reduced chemotherapy efficacy, as they diminish tumour responsiveness to anticancer agents. Consequently, direct inhibition of the mutated B-Raf kinase has emerged as an effective therapeutic strategy and a significant advance in oncology. The crystal structure 3OG7 contains the clinically approved inhibitor vemurafenib bound within the ATP-binding catalytic pocket, a well-characterized and highly druggable site that has been successfully utilized for the development of targeted melanoma therapies (Hassan et al., 2022; Tsai et al., 2008; Davies et al., 2002; Bollag et al., 2010; Cope et al., 2019). Therefore, this structure was selected as a biologically relevant model for evaluating the binding affinities of the identified compounds toward a validated melanoma target.

The docking analysis of 3OG7 protein revealed that the native ligand (vemurafenib) showed an RMSD of 0.594, with an affinity binding energy of -11.1 kcal/mol. Moreover, standard (dabrafenib) exhibited a binding score of -9.0 kcal/mol. Among the identified compounds, robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol demonstrated the highest binding affinity (-13.3 kcal/mol), while 17-O-acetylajmaline exhibited the lowest binding affinity (-8.1 kcal/mol) (Table 2). The binding interactions of the native ligand, dabrafenib, formononetin 7-O-glucoside-6''-O-malonate, robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, scopolin, and 17-O-acetylajmaline with the 3OG7 are illustrated in Figure 6a. Moreover, the binding interaction of the other compounds are provided in Figure 6b.

The molecular docking results revealed that the compounds, including the controls, interacted with the protein via various types of bonds. For the native ligand, three amino acids were responsible for conventional hydrogen bonds: GLN 530, GLY 596, and PHE 595, along with hydrophobic interactions with ILE 463, TRP 531, CYS 532, LEU 505, LYS 483, PHE 583, LEU 514, ALA 481, PHE 595.

In the case of robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, conventional hydrogen bonds were observed with CYS 532, LYS 483, SER 465, LYS 473, TRP 531, and HIS 539, and hydrophobic interactions with HIS 539, TRP 531, and ILE 463. Moreover, luteolin 7-rhamnosyl (1-6) galactoside formed conventional hydrogen bonds with CYS 532, ASP 594, LYS 483, ASN 580, and LYS 578.
Conversely, 17-o-acetylajmaline, which had the lowest binding interaction, was involved with SER 536 through hydrogen bonding and with ALA 481 and VAL 471 through hydrophobic interactions. Additionally, in the case of scopolin, ASN 581, CYS 532, and SER 465 were responsible for conventional hydrogen bonds and CYS 532, TRP 531, ALA 481, LEU 514, VAL 471, and PHE 583 were responsible for other interactions.

The standard drug, dabrafenib interacted with ASP 594 and ASN 590 via hydrogen bonding and with PHE 468, LYS 578, SER 465, ASN 580, ASP 594, ASN 581, VAL 471, TRP 531, and PHE 583 for other hydrophobic interactions. Thus, the compounds and the standard drug interacted with the catalytic site of the PDB ID: 3OG7 with amino acids similar to those of the native ligand. CYS 532, LYS 483, TRP 531, and ALA 481 were the amino acids most commonly present in their interactions. Thus, the compounds identified from the 100% ultrasonic methanolic extract demonstrated strong binding affinities, along with the interaction at the catalytic site of the protein, suggesting their potential to inhibit oncogenic B-Raf kinase activity.

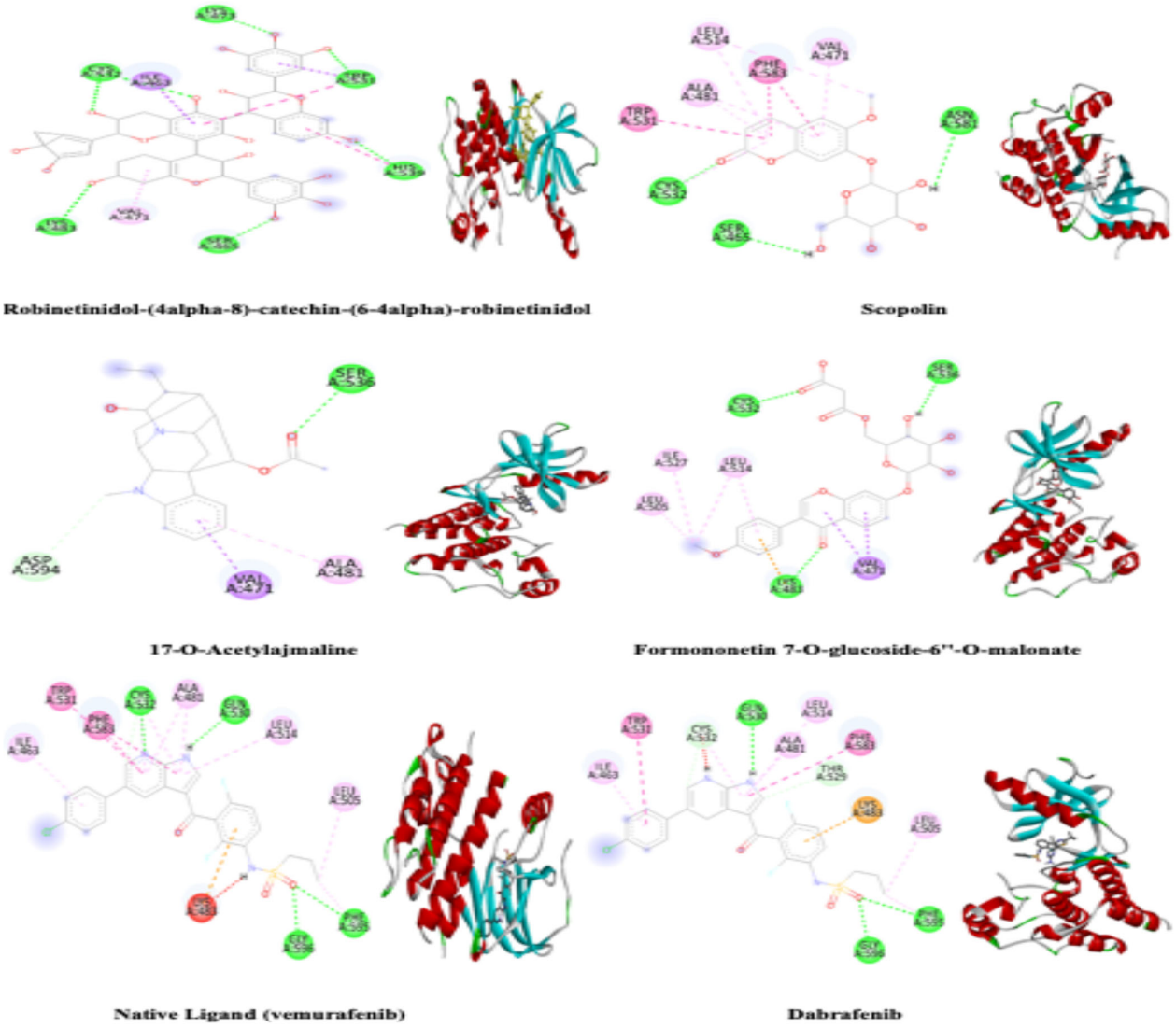


Figure 6a: Binding interactions of robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, scopolin, 17-O-acetylajmaline, and formononetin 7-O-glucoside-6''-O-malonate along with the native ligand and dabrafenib with the 3OG7 protein.

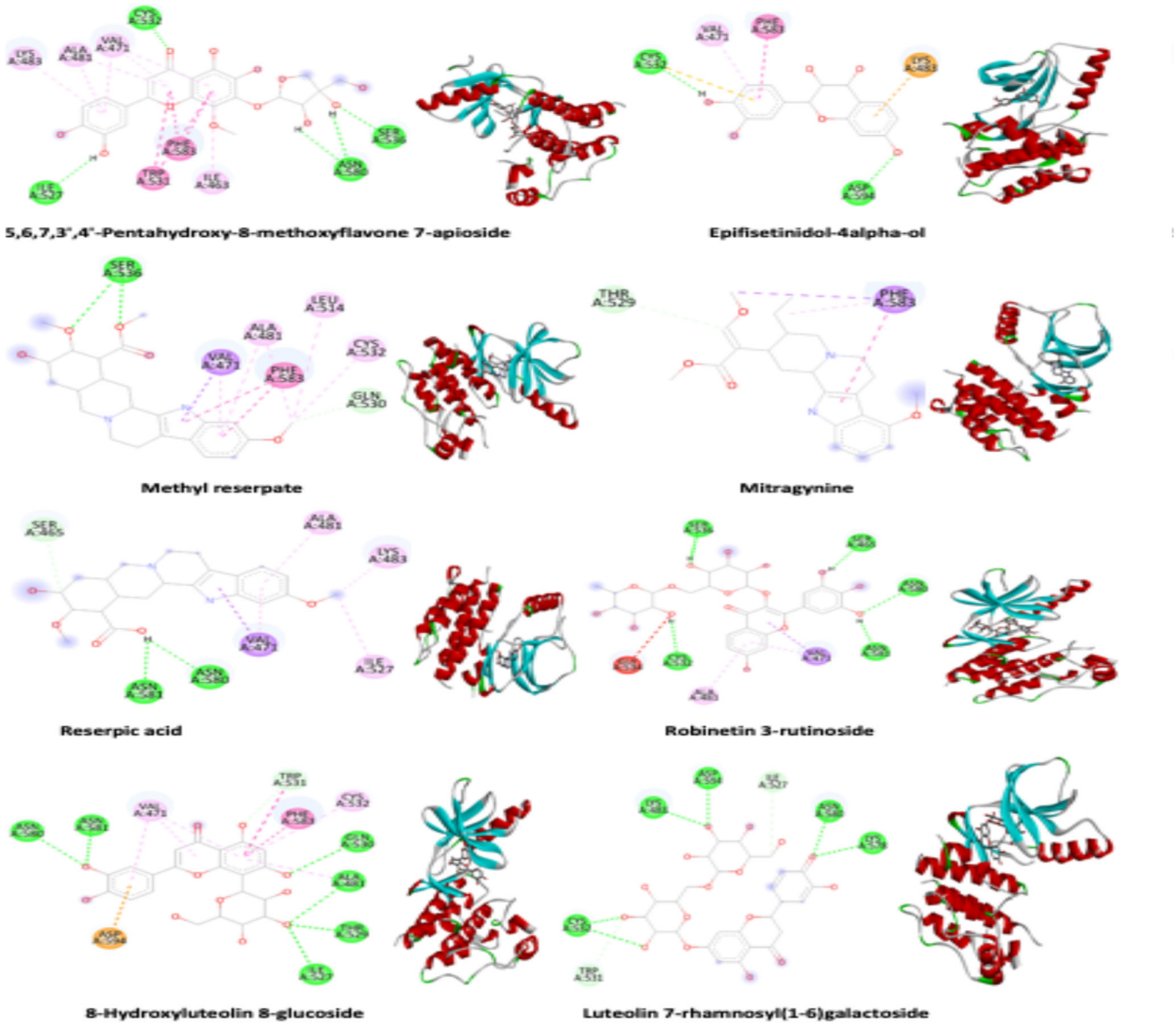


Figure 6b: Binding interactions of other compounds with the 3OG7 protein.

The second protein target, estrogen receptor alpha (ERα) (PDB ID: 3ERT), is a ligand-activated nuclear receptor that functions as a DNA-binding transcription factor that regulates gene expression and diverse cellular processes. ERα is expressed in approximately 70% of all human breast cancers and clinical evidence strongly supports a role of ERα in breast cancer. The crystal structure 3ERT contains 4-hydroxytamoxifen bound to the receptor's canonical ligand-binding (orthosteric) pocket, a therapeutically validated site targeted by several endocrine therapies used in breast cancer treatment (Shiau et al., 1998; Shanle & Xu, 2010). Owing to its established role in breast cancer progression and proven druggability, ERα was selected as an appropriate target for virtual screening and molecular interaction studies.

Likewise, for the 3ERT protein, the native ligand (OHT600) and toremifene (standard drug) exhibited binding energies of -9.9 and -8.7 kcal/mol, respectively. Among the identified compounds, robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol exhibited the strongest binding energy (-11.3 kcal/mol), followed by formononetin 7-O-glucoside-6''-O-malonate (-8.7 kcal/mol), luteolin 7-rhamnosyl (1-6)galactoside (-8.6 kcal/mol) and 17-O-acetylajmaline (-8.4 kcal/mol). Among the compounds, mitragynine showed the lowest binding energy (-7.0 kcal/mol). Table 3 contains the binding interactions of all the identified compounds against the 3ERT protein. The binding interactions of robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, scopolin, 17-O-acetylajmaline, and formononetin 7-O-glucoside-6''-O-malonate along with the native ligand and dabrafenib with the 3ERT protein are shown in Figure 7a. Moreover, the binding interactions of the rest of the compounds are presented in Figure 7b.

Table 3: Interaction profile of compounds from the 100% US extract of *M. speciosa* leaves with 3ERT protein

Compounds	Ligand binding energy (kcal/mol)	Binding Interactions	
		H bond interactions with bond distance (Å)	Other bond interactions with bond distance (Å)
Scopolin	-7.5	-	LEU 346: 5.42; ALA 350: 4.71 & 4.77; MET 343: 5.33, 4.71 & 5.04; LEU 525: 3.91 & 4.69; MET 421: 4.69
Epifisetinidol-4alpha-ol	-8.0	ARG 394: 2.00; GLU 353: 2.16; THR 347: 2.30	MET 343: 4.92; LEU 346: 4.65; LEU 525: 3.87; ALA 350: 5.48 & 4.12; LEU 391: 4.97; LEU 387: 4.32
Robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol	-11.3	VAL 534: 3.24; VAL 533: 3.22; LEU 536: 2.45; CYS 530: 3.44; MET 528: 3.35	MET 528: 3.87; CYS 530: 5.08; MET 522: 5.29; TYR 526: 5.01; LEU 536: 5.46; ALA 350: 5.29; LEU 525: 4.40
Formononetin 7-O-glucoside-6''-O-malonate	-8.7	HIS 524: 2.16; GLY 420: 2.93; CYS 530: 2.06	CYS 530: 5.38; VAL 533: 4.86; LYS 529: 3.88; ALA 350: 4.00; LEU 346: 5.02; LEU 525: 3.64; MET 343: 5.05 & 5.02
Robinetin 3-rutinoside	-8.0	CYS 530: 2.19; ASP 351: 2.43; MET 522: 2.68	MET 522: 3.98; LEU 525: 4.49 & 4.49; LYS 529: 5.44
5,6,7,3',4'-Pentahydroxy-8-methoxyflavone 7-apioside	-7.9	MET 522: 2.14	LEU 536: 5.28; MET 343: 4.96; ALA 350: 3.97 & 5.01; LEU 525: 5.34 & 4.65
8-Hydroxyluteolin 8-glucoside	-8.2	MET 528: 2.91; CYS 530: 1.90; MET 343: 3.62	MET 343: 5.08; LEU 525: 3.92; ALA 350: 4.03 & 4.87; ASP 351: 3.46 & 3.63
Luteolin 7-rhamnosyl (1-6)galactoside	-8.6	LEU 525: 3.21; LEU 536: 1.96 & 2.69; CYS 530: 2.22	MET 522: 5.33
Reserpic acid	-7.9	ASP 351: 2.53	MET 522: 3.98 & 4.04
Methyl reserpate	-7.5	-	ALA 350: 5.17, 4.09 & 3.85; LEU 525: 3.91 & 3.86; LEU 346: 4.75 & 4.75; MET 343: 5.91 & 5.08
17-O-Acetylajmaline	-8.4	-	MET 522: 4.64; TYR 526: 4.94; LEU 536: 4.07
Mitragynine	-7.0	-	LEU 536: 4.88; LEU 525: 5.46 & 5.25; ALA 350: 4.71 & 4.07; LEU 354: 3.89; TRP 383: 4.33
Native Ligand: OHT600	-9.9	GLU 353: 2.50	LEU 346: 4.98 & 4.94; MET 421: 4.77 & 5.24; LEU 525: 4.88 & 4.78; ALA 350: 4.12; LEU 387: 5.01
Standard drug: Toremifene	-8.7	-	ALA 350: 4.02 & 4.41; LEU 387: 5.10; LEU 346: 4.71; LEU 525: 4.68 & 4.90; LEU 391: 4.61; MET 388: 3.57; LEU 428: 4.48; MET 421: 5.13

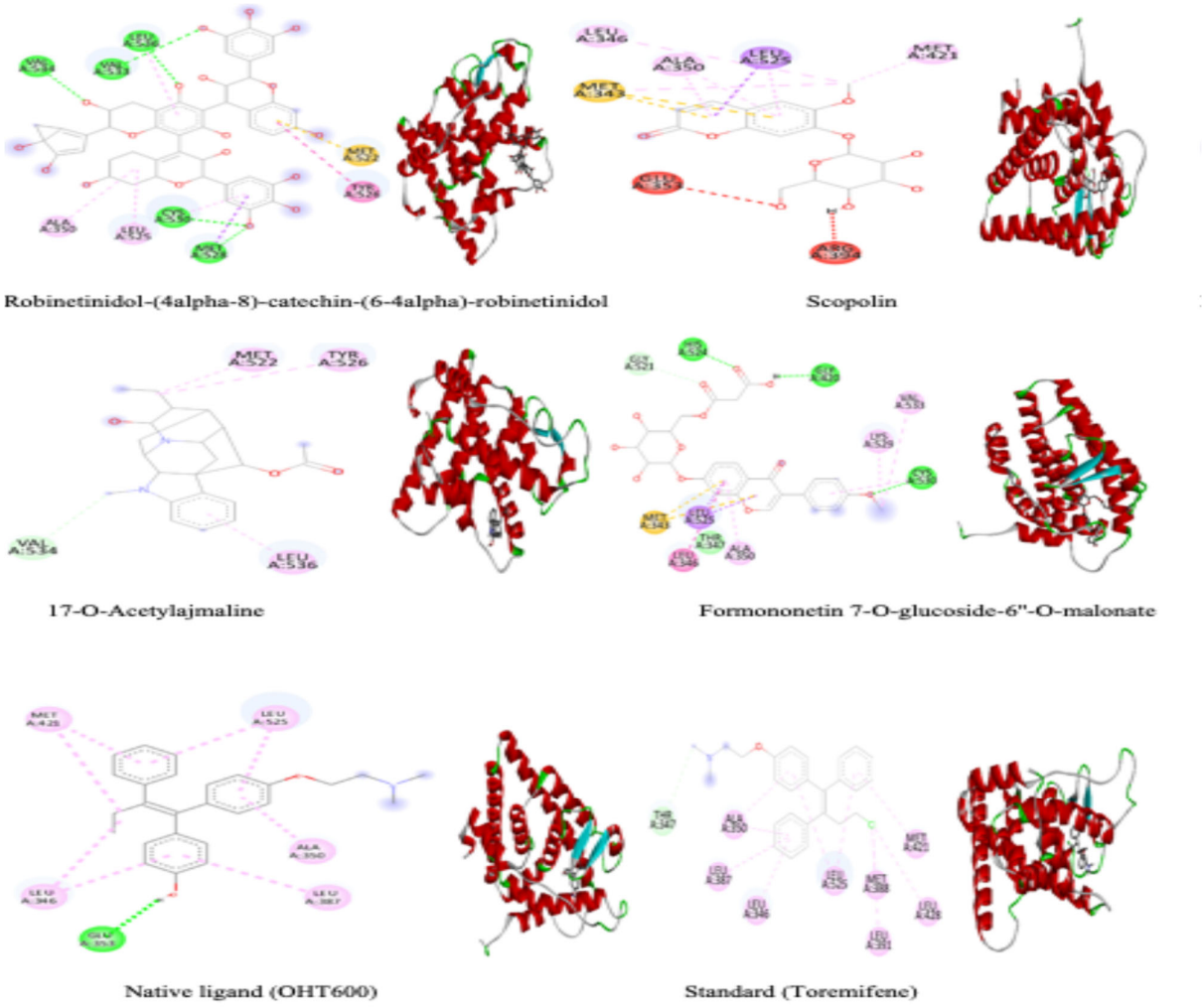


Figure 7a: Binding interactions of robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, scopolin, 17-o-acetylajmaline, and formononetin 7-O-glucoside-6''-O-malonate along with the native ligand and toremifene with 3ERT protein.

The native ligand (OHT600) formed a hydrogen bond with GLU 353 of 3ERT, while additional interactions were observed with LEU 346, MET 421, LEU 525, ALA 350, and LEU 387. Robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol showed hydrogen bonds with VAL 534, VAL 533, LEU 536, CYS 530, and MET 528. Moreover, other binding interactions were observed with MET 528, CYS 530, MET 522, TYR 526, LEU 536, ALA 350, and LEU 525. Formononetin 7-O-glucoside-6''-O-malonate showed hydrogen bonds with HIS 524, GLY 420, and CYS 530, as well as other interactions with CYS 530, VAL 533, LYS 529, ALA 350, LEU 346, LEU 525, and MET 343. Luteolin 7-rhamnosyl (1-6) galactoside formed hydrogen bonds with LEU 525, LEU 536, and CYS 530. Scopolin exhibited hydrophobic interactions with LEU 346, ALA 350, MET 343, LEU 525, and MET 421. Moreover, LEU 536, LEU 525, ALA 350, LEU 354, and TRP 383 were involved in the non-hydrogen bond interactions, in the case of mitragynine. Furthermore, the standard drug, toremifene showed diverse interactions with amino acids, including ALA 350, LEU 387, LEU 346, LEU 525, LEU 391, MET 388, LEU 428, and MET 421. Overall, the tested compounds demonstrated comparable amino acid involvement to that observed with both the native ligand and the standard drug, and ALA 350 and LEU 525 were found to be the common amino acids. The standard drug, toremifene, a selective estrogen receptor modulator, exerts mixed estrogenic and anti-estrogenic effects. In breast tissue, it competes with estrogen for receptor binding sites, thereby producing antiestrogenic and antitumor effects (Martinkovich et al., 2014). Since the identified compounds showed similar interactions as the toremifene, they might also possess a great potential as anti-breast cancer agents. Estrogen receptors (ERs) are nuclear

receptors located in the cytoplasm that function as DNA-binding transcription factors, regulating gene expression and diverse cellular processes. Two isoforms of the human estrogen receptor exist, ERα and ERβ, both of which have been implicated in breast cancer pathogenesis. Structurally, ERs comprise three major domains: the DNA-binding domain, the ligand-binding domain, and the transactivation domain (McGee et al., 2008).

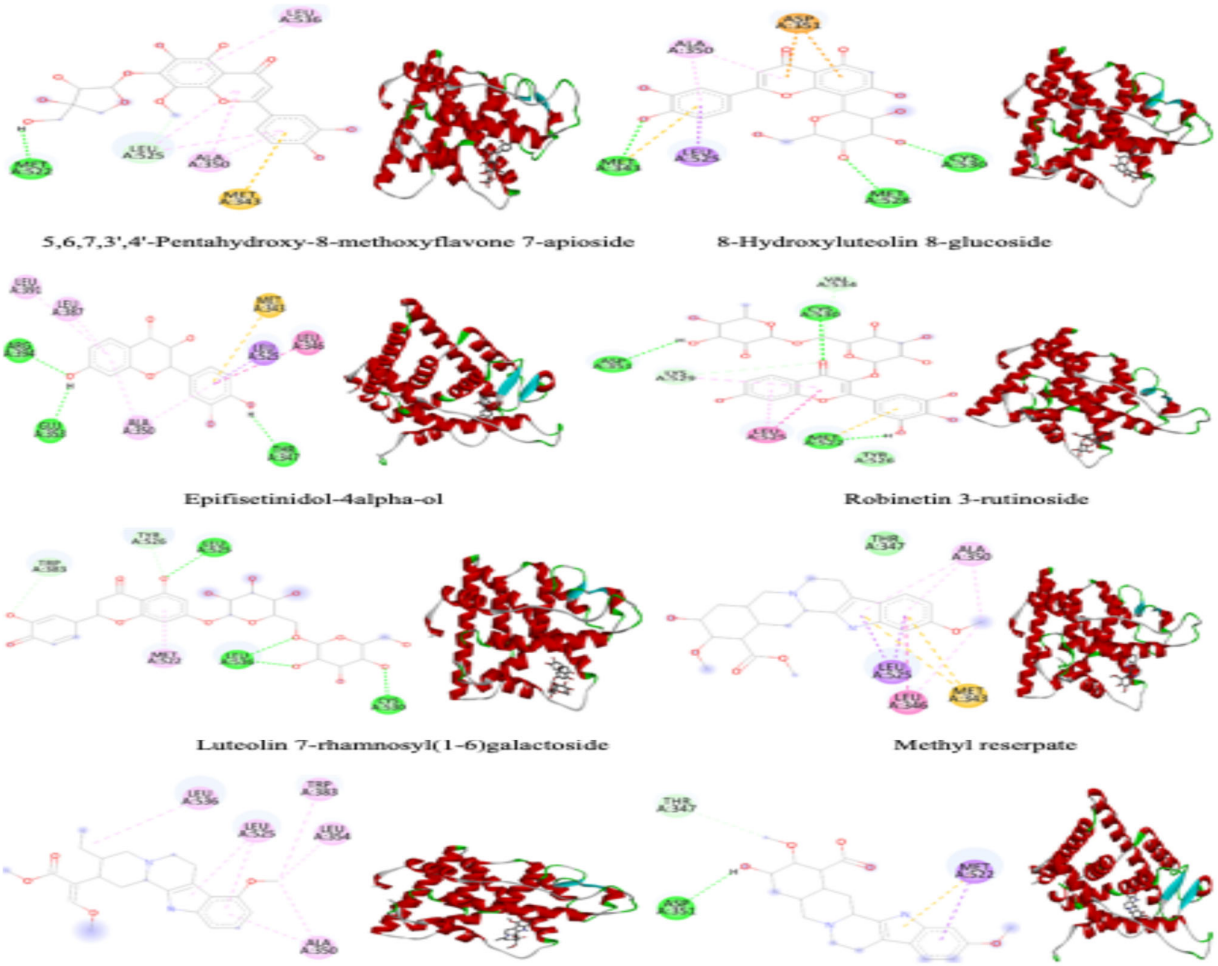


Figure 7b: Binding interactions of other compounds with 3ERT protein.

Table 4: The physicochemical and ADMET parameters of the compounds from the methanol extract of *M. speciosa* leaves.

Compound	Properties										
	Physicochemical						ADMET				
	MW	Log P	NHA	NHD	NLV	DL	IA	CLR	HET	AM	ROAT
5,6,7,3',4'-Pentahydroxy-8-methoxyflavone 7-apioside	464.38	-2.32	12	7	2	No	41.382	0.439	No	No	2.61
Epifisetinidol-4alpha-ol	290.27	-0.02	6	5	0	Yes	65.555	0.003	No	Yes	2.45
17-O-Acetylajmaline	368.47	3.00	4	1	0	Yes	97.092	0.896	No	No	2.886
8-Hydroxyluteolin 8-glucoside	464.38	-2.59	12	8	2	No	33.475	0.384	No	No	2.562
Luteolin 7-rhamnosyl (1-6)galactoside	594.52	-3.43	15	9	3	No	27.777	0.251	No	Yes	2.734

Mitragynine	398.50	2.02	5	1	0	Yes	92.967	0.859	Yes	No	3.157
Formononetin 7-O-glucoside-6''-O-malonate	516.45	-1.06	12	4	2	No	40.995	0.333	No	No	2.617
Reserpic acid	400.47	1.08	6	3	0	Yes	61.972	0.433	Yes	No	2.1
Robinetin 3-rutinoside	610.52	-3.89	16	10	3	No	20.596	-0.377	No	No	2.49
Methyl reserpate	414.49	1.30	6	2	0	Yes	93.519	48.119	Yes	No	2.93
Scopolin	354.31	-1.23	9	4	0	Yes	48.119	0.716	No	No	2.391
Robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol	866.77	-1.11	18	15	3	No	33.083	33.083	No	No	2.482

Note: MW: molecular weight, gram/mole; Log P: predicted octanol/water partition coefficient; NHA: number of hydrogen bond acceptors; NHD: number of hydrogen bond donor; D: drug-likeness; NVL: number of Lipinski's rule violations; IA: intestinal absorption, %; CLR: clearance; (log ml/min/kg); HET: hepatotoxicity; AM: AMES toxicity; ROAT: rat acute oral toxicity, mol/kg.

Physicochemical and Pharmacokinetic Profiles of Compounds from *M. speciosa* leaf Methanol Extract

The drug discovery and development is a challenging, time-consuming, intricate, and costly endeavour, often associated with uncertainty regarding clinical success. To streamline these processes, predicting the ADMET (Absorption, Distribution, Metabolism, Excretion, and Toxicity) properties of a compound before it enters clinical trials allows potential issues to be indentified early in the development process (De Carlo et al., 2024). In this context, predicting the physicochemical and pharmacokinetic parameters of the identified compounds from the 100% US extract, which also showcased potent inhibition of the oncogenic B-Raf Kinase protein, could be highly beneficial. This approach may aid in the development of new selective anticancer drugs against melanoma based on these compounds. Thus, the physicochemical and pharmacokinetic parameters of the compounds from *M. speciosa* leaf's methanol extract were thoroughly evaluated (Table 4).

The physicochemical profiling of the 12 identified compounds revealed that 6 exhibited drug-like properties, with minimal violations of the Lipinski Rule of Five (Salihu et al., 2024). Subsequent ADMET evaluation indicated that among these, scopolin and 17-O-acetylajmaline demonstrated promising potential as lead candidates for the development of selective anticancer agents. These compounds showed favourable intestinal absorption rates of 48.119% and 97.092%, respectively, and were free from both hepatotoxicity and AMES toxicities. To improve the intestinal absorption or mitigate toxicity risks, several strategies in drug design have proven effective, including particle size reduction, surface area enhancement, and prodrug formation (Alagga et al., 2025, Jornada et al., 2015). Conversely, mitragynine and methyl reserpate demonstrated high intestinal absorption rates of 92.967% and 93.519%, respectively, but were associated with hepatic toxicity. Moreover, ent-fisetinidol-4beta-ol and reserpic acid, showed moderate intestinal absorption yet also presented hepatic toxicity concerns.

Importantly, robinetinidol-(4alpha-8)-catechin-(6-4alpha)-robinetinidol, luteolin 7-rhamnosyl (1-6)galactoside, 8-hydroxyluteolin 8-glucoside, formononetin 7-O-glucoside-6''-O-malonate and robinetin 3-rutinoside showed strong binding affinities in molecular docking analyses. Despite their promising interactions with target proteins, these compounds lacked drug-likeness due to their high molecular weights and high polarity, which significantly hindered their absorption across biological membranes. To enhance their pharmacokinetic profiles, the incorporation of hydrophobic moieties has been suggested as a viable strategy to increase lipophilicity and facilitate systemic absorption, thereby increasing their suitability for drug development (Begum et al., 2025b).

Comprehensive evaluation through Q-TOF LC-MS profiling, molecular docking, and physicochemical and pharmacokinetic assessments revealed that the 100% US extract of *M. speciosa* leaf contains a diverse array of phenolic, flavonoid, and alkaloidal compounds. Among these, only scopolin and 17-O-acetylajmaline demonstrated favourable drug-like properties and ADMET profiles, positioning them as promising lead candidates for the development of selective anticancer therapeutics.

CONCLUSION

The biological activities of plant extracts and their individual compounds can differ markedly due to the complex nature of phytochemical interactions. Extracts typically contain complex mixtures of compounds that

may synergise or antagonise each other's effects. Consequently, the therapeutic potential of certain bioactive constituents may be masked or diminished when assessed within the whole extract. Therefore, the identification and isolation of potent compounds from crude extracts represent a strategic approach in the discovery and rational design of novel drug candidates. Currently, many available anticancer drugs lack selectivity and are associated with significant adverse effects. This limitation underscores the urgent need for the development of new, selective anticancer drugs derived from natural sources. Based on the findings of the current study, scopolin and 17-O-acetylajmaline have emerged as promising lead compounds for the development of anticancer drugs against melanoma and breast cancer. The findings of this study are hypothesis-generating and suggest that the identified compounds may represent promising candidates for further investigations rather than confirmed anticancer leads. Future studies should prioritise experimental validation through biochemical target-binding assays, *in vitro* cytotoxicity testing against relevant melanoma and breast cancer cell lines, and preliminary ADME evaluations to verify the computational predictions and establish their therapeutic potential.

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AUTHOR CONTRIBUTIONS

Conceptualization, Q.U.A.; M.M.A.K.K.; T.B.; methodology, T.B.; Q.U.A.; resources, Q.U.A.; M.H.A.; data curation, T.B.; M.S.R.; S.A.A.S.; F.O.; writing-original draft preparation, T.B.; writing-review and editing, Q.U.A.; M.M.A.K.K.; M.N.S.; visualization, Q.U.A.; A.B.M.H.U.; M.N.S.; M.R.M.; supervision, Q.U.A. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY

Data will be made available on reasonable request.

ETHICAL APPROVAL

Not applicable.

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ORIGINAL ARTICLE

Clinical Profile and Refractive Outcomes of Medennium Phakic Intraocular Lens (MPL) Implantation: A Prospective Case Series

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ABSTRACT

Background: This study aims to report the clinical profile and refractive results of Medennium Phakic Intraocular Lens (MPL) in patients with mild to high myopia who are not suitable for laser refractive correction. **Methods**: This prospective, single-centre case series included patients who underwent MPL implantation at IIUM Eye Specialist Clinic from February to August 2024. Manifest refraction, uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), intraocular pressure, and endothelial cell density were analysed at 1 month after surgery. Complications during the intraoperative and postoperative periods were also recorded. **Results**: This study included 30 eyes from 15 patients, with a mean age of 30.2 ± 5.23 years. The spherical equivalent of manifest refraction was -10.01 ± 3.99 diopters (D) (range: -3.63 to -18) preoperatively and 0.02 ± 0.57 D (range from +1.25 to -1.13) at 1 month. Postoperative uncorrected visual acuity (UCVA) of logMAR 0.5 achieved in 1 eye (3%), 0.2 in 5 eyes (17%), 0.1 in 6 eyes (20%) and 0.0 in 18 eyes (60%). Factors contributing to suboptimal outcomes included residual astigmatism, amblyopia and monovision correction. No intraoperative complications occurred. Postoperative complications include high intraocular pressure (2 eyes), glare (2 eyes) and a statistically significant reduction in mean endothelial cell counts at 1 month (p=0.045). **Conclusion**: MPL implantation demonstrates effective refractive outcomes in the treatment of myopia at one month. However, due to a small sample size and short follow up, further studies is required to assess its long-term safety and efficacy.

INTRODUCTION

Myopia is the most common refractive error affecting both children and adults worldwide (Durajczyk et al., 2021). It is the second leading cause of blindness worldwide (Holden et al., 2015). The prevalence of myopia has risen steadily over recent decades and is projected to affect nearly 50% of the world population by 2050, including in Southeast Asia (Holden et al., 2016). Myopia is generally classified as mild (-0.50 D to -3.00 D), moderate (-3.00 D to -6.00 D), and high myopia (≥ -6.00 D). The conventional non-surgical correction of myopia includes spectacles and contact lenses, which remain the standard treatment options (Ang & Wong, 2020). For patients with stable refractive error seeking long term correction, surgical management may be considered.

There are three principal surgical approaches, including laser refractive surgery, phakic intraocular lens (IOL) implantation, and refractive lens exchange. Among these three options, phakic intraocular lens has emerged as an effective alternative, particularly for patients with moderate to high myopia who may not be suitable for corneal refractive surgery due to thin corneas, high refractive error or risk of postoperative ectasia (Jonker et al., 2020). Unlike refractive lens exchange and laser refractive surgery, phakic IOL implantation is a reversible procedure. It also preserves the natural crystalline lens and patient's accommodation. Hence, for younger patients, implanting phakic IOL is a reasonable option.

Phakic intraocular lens implantation for correction of myopia has been started since 1953 by Strampelli (Jonker et al., 2020). Although the refractive outcome was promising, there were reported complications including cataract formation, endothelial cell loss, elevated

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intraocular pressure, pigment dispersion, pupillary block, and vault-related complications (Jonker et al., 2020). These concerns have driven the development of newer generation phakic intraocular lens to improve intraocular biocompatibility and long-term safety such as the Medennium Phakic Intraocular Lens (MPL; Medennium Inc, California, United States, CE 0459, GC4247923-154518).

Medennium phakic intraocular lens is the newly available phakic lens in Malaysia, featuring plate haptics for sulcus support. Its self-centering and self-buoyant design allow it to float within aqueous humour. This feature is intended to optimise vault predictability and reduce the risk of touching with surrounding structures such as crystalline lens and iris. It is made from hydrophobic silicone to minimize mechanical irritation. Unlike other phakic lens, MPL is available in only two sizes, MPL 100 and MPL 101, which simplifies the selection process using standard white-to-white measurements. Despite increasing interest in this newer phakic intraocular lens in our market, evidence regarding the safety, efficacy and long-term stability of the MPL remains scanty.

This prospective, interventional case series represents the early clinical experience in Malaysia. We aim to report on the clinical profile and refractive outcomes of Medennium Phakic Intraocular Lens (MPL) that were implanted in our patients, specifically focusing on patient's demographic, visual outcomes, refractive predictability, and its safety.

MATERIALS AND METHODS

Study design

A prospective case series of patients who underwent MPL implantation at IIUM Eye Specialist Clinic from February to August 2024 was undertaken. Patient demographic data, preoperative and postoperative uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), subjective refraction, optical biometry, intraocular pressure, and corneal endothelial cell density were collected.

Inclusion and exclusion criteria

Patient who included in the study met the following criteria: age ≥18 years old, stable refractive error (refractive change ≤0.50 D in past year), cylinder power ≤2.0 diopters, anterior chamber depth ≥3.0 mm, endothelial cells count ≥2000, intraocular pressure <20mmHg and keen for MPL inplantation for refractive correction. Exclusion criteria were previous intraocular surgery, glaucoma, cataract, active ocular infection and anterior chamber depth <3.0 mm.

Clinical examination

All patients had a complete preoperative ophthalmic examination, including slit lamp microscopy for anterior segment assessment, applanation tonometry for intraocular pressure measurement, indirect ophthalmoscopy for posterior segment status, corneal topography, pachymetry, optical biometry and specular microscopy. Manifest and cycloplegic refraction was performed by optometrist. Uncorrected and spectacle-corrected visual acuity was performed using MS Smart System 20/20 (M&S Technologies, USA). The optical biometry was performed using IOL Master 700 (Zeiss, Germany). Endothelial cell count was taken using Konan Specular Microscopy (Konan medical, Japan).

The MPL with appropriate power was calculated by furnishing the required parameters from IOL Master data to the company. The lens power was calculated based on formula which included data of patient's axial length, anterior chamber depth, manifest refraction and keratometry value. The type of MPL implanted will be determined by patient's white-to-white parameter measured, either MPL 100 (WTW <11.3 mm) or MPL 101 (WTW ≥11.3 mm) measured from IOL Master 700 (Zeiss, Germany).

Post operatively, patients will be reviewed at day 1, 1 week and 1 months. Patient safety and tolerability were evaluated at each follow up through objective clinical examinations including slit lamp examination, intraocular pressure, endothelial count, measurement of manifest refraction, UCVA and BCVA as well as active elicitation of patient-reported symptoms.

Surgical technique

All operations were performed by a single surgeon (K.K). Prior to the surgery, cyclopentolate 1% and phenylephrine 2.5% were used to dilate the pupil. MPL was implanted under intracameral anesthesia through a 3 mm clear temporal corneal incision. The anterior chamber was filled with a viscoelastic agent.

The lenses were manually loaded into the cartridge and implanted via injector. Both lens haptics were placed under the iris. Viscoelastic materials were removed from anterior chamber and exchanged with balanced salt solution. The corneal wound was self-sealing.

Postoperatively, the patient was given topical antibiotic and corticosteroid drops (Fluomethalone 0.1% and Moxifloxacin 0.5%) prescribed four times daily for 1 week and dose was tapered for another 4 weeks.

Statistical analysis

Statistical analysis was performed using SPSS software version 30.0 (SPSS Inc, Chicago, Illinois). Normality of data distribution was assessed using the Shapiro–Wilk test and analysed using paired *t*-test or Pearson correlation, when appropriate to assess differences in visual and adverse outcomes. Results were presented as mean ± standard deviation. P value <0.05 were considered statistically significant.

RESULTS

Patient demographics

A total of 30 eyes from 15 patients were included in the study. All patients were implanted with MPL lens. Preoperative ocular characteristics are summarized in Table 1. The patient's mean preoperative UCVA and postoperative UCVA were measured in logMAR.

Table 1: Demographic characteristics of patients

Characteristics	Result
Age (years)	30.2 ± 5.23
Gender	Male: 7 (46.7%) Female: 8 (53.3%)
Laterality	Right eye: 15 (50%) Left eye: 15 (50%)
Preoperative UCVA (logMAR)	1.39 ± 0.30 (range: 0.8-2.10)
Preoperative BCVA (logMAR)	0: 21 (70%) 0.1: 4 (13.3%) 0.2: 2 (6.7%) 0.3: 3 (10%)
Spherical equivalent (D)	- 10.01 ± 3.99 (range SE: -3.63 to -18.0) (range sphere:-3.0 to -18.0)
Astigmatism (D)	- 0.80 ± 0.54 (range: 0-1.75)
AXL at baseline (mm)	27.36 ± 2.47 (range: 23.62-32.37)
ACD at baseline (mm)	3.65 ± 0.25
CCT at baseline (μm)	511 ± 39.78
WTW at baseline (mm)	12.0 ± 0.38 (range: 10.9-12.4)
Indication	
High myopia	10
Steep cornea	1
Low pachymetry	4

Refractive outcomes

Visual outcome

Postoperatively at 1 month, UCVA improved from 1.39 ± 0.30 logMAR preoperatively to 0.06 ± 0.08 logMAR. The BCVA of patient's at 1 month was summarised in Table 2.

Overall, at 1 month, 20 eyes (67%) maintained preoperative best corrected visual acuity, 5 eyes (17%) gained at least ≥ 1 line, 3 eyes (10%) reduce 1 line, 2 eyes (7%) reduce ≥ 2 lines. The patient who had reduce ≥ 2 lines was due to having minimal inflammation (1 eye) and received monovision treatment of 1.5 D (1 eye). Despite this, the above data indicates that MPL phakic IOL implantation not only effectively corrected refractive error but also maintained and improved visual function in majority of patients.

Table 2: UCVA and BCVA at baseline and 1 month

	Number of eyes		
Characteristics (logMAR)	**BCVA at baseline**	**UCVA at 1 month**	**BCVA at 1 month**
0	21 (70%)	18 (60%)	22 (73%)
0.1	4 (13.3%)	6 (20%)	5 (17%)
0.2	2 (6.7%)	5 (17%)	3 (10%)
0.3	3 (10%)	-	-
0.5	-	1 (3%)	-

Refractive accuracy

The mean spherical equivalent improved from -10.0 ± 3.99 Diopter (D) preoperatively to 0.02 ± 0.57 Diopter (D), p value <0.001.The predictability of the procedure was high, with 16 (53%) of eyes within ±0.50 D and 11 (37%) within ±1.00 D of the target refraction. However, 3 (10%) eyes were within ±2.00 D target. The mean residual astigmatism remained 0.71 ± 0.50 Diopter (D) (range: 0 to -1.75), p = 0.291.

Complications

Endothelial count

The mean endothelial count preoperatively was 2855 ± 220 (cells/mm²) and 1 week was 2739 ± 363 (cells/mm²) with correlation (r = 0.358), 4% reduction, p = 0.084. While mean endothelial count at 1 month was 2708 ± 368 (cells/mm²) with correlation (r =0.229), 5.1% reduction, p = 0.045.

Table 3: Endothelial count at baseline and 1 month

	Result	
Characteristics	**Baseline**	**1 month**
Mean endothelial count (cells/mm^2)	2855 ± 220	2706 ± 387

Intraocular pressure

The mean intraocular pressure preoperatively was 11.9 ± 2.3 mmHg and 1 week was 15.9 ± 2.7 mmHg, p <0.001. While mean intraocular pressure at 1 month was 16.79 ± 2.9 mmHg, p <0.001. A transient rise in IOP (>21 mmHg) was observed in both eyes of similar patient (6.7%), which was controlled with topical medication. No cases of persistent ocular hypertension or secondary glaucoma were noted.

Other complications

No intraoperative complications were reported. Post operatively, 2 eyes experienced glare which was tolerable, 1 eye had mild anterior chamber inflammation during early postoperative period, which resolved with topical corticosteroid. At 1 week and 1 month, no eyes reported experienced cataract formation, IOL decentration, rotation or pupil ovalization.

DISCUSSION

In this study, we evaluated the refractive outcomes and safety profile of MPL phakic intraocular lens implantation. Our results suggest that MPL implantation is suitable for patients with mild to high myopia, providing predictable refractive correction and visual improvement. We observed that 90% of eyes achieved a postoperative spherical equivalent within ±1.00 D of the intended target refraction, which is consistent with outcomes reported in previous studies (Jongsareejit, 2006). Residual astigmatism, monovision correction and existing amblyopia were identified as contributing factors to suboptimal outcomes. This is an important limitation to current lens design, as the absence of a toric option prevents direct correction of pre-existing corneal astigmatism. These factors may limit functional visual improvement despite accurate refractive correction. Thus, meticulous preoperative counseling is essential, including clear addressing of patient expectations and potential visual limitations, alongside careful patient selection.

Previous reports have described complications associated with phakic IOLs, including elevated intraocular pressure, halos, cataract formation, endothelial cell loss, and pigmentary dispersion (Jonker et al.,2020; Stein & Stein, 2023; Jongsareejit A, 2006; Verdeet al., 2007; Hoyoset al., 2002; Pérez-Cambrodíet al., 2013). In our study, we observe clinically significant endothelial cell changes and slightly increase in intraocular pressure at 1 month. This is consistent with previous finding by Subudhi et al. They found a significant reduction in the endothelial cell count at the end of 1 month. However, the endothelial cell count was found to remain stable with no significant reduction at the end of 12 months. Nevertheless, the observed early endothelial cell loss should be interpreted with caution as postoperative corneal changes, measurement variability, and transient surgical trauma may have contributed to the apparent reduction. Further studies with longer follow up are warranted. As for high intraocular changes, Jongsareejit also reported similar finding at 1 month and the pressure returned to preoperative level at 3 months. Hence, close monitoring is important.

In this study, we did not encounter cataract formation or pigmentary dispersion. This difference is likely attributable to the relatively short duration of follow-up**,** as such complications often develop over longer periods. In addition, vault assessment and anterior segment imaging were not performed, limiting our ability to evaluate lens position, vault and cornea-lens-iris relationship which are important factors associated with cataract formation, pigment dispersion and other phakic IOL related complications. Therefore, although the short-term safety profile of MPL phakic IOLs appears favourable, these findings should be interpreted with caution. A continuous long-term monitoring is essential to detect delayed complications and to confirm the sustained efficacy of the lens. Future studies with extended follow-up will be necessary to fully establish the long-term safety, particularly regarding endothelial health, lens vault stability, and the potential for cataract development.

CONCLUSION

In summary, MPL phakic IOL implantation demonstrated acceptable early refractive accuracy with generally favourable short-term visual outcomes in the majority of eyes. However, endothelial cell loss, transient IOP elevation and reduction in best corrected visual acuity in a subset of eyes, together with methodological limitations including potential inter-eye dependence, require further evaluation. Longer-term follow-up is required to ensure continued safety and are needed before definitive comparisons with corneal refractive surgery can be made.

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ORIGINAL ARTICLE (ORIGINAL ARTICLE)

Association between Fear of Falling and Balance in Elderly with Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis (KOA) is a prevalent musculoskeletal disorder among older adults that often leads to impaired balance and an increased risk of falls. Fear of falling (FOF) is a common psychological concern within this population, further limiting mobility and diminishing quality of life. This study aimed to examine the association between FOF and balance among elderly individuals with KOA, emphasizing how these factors influence fall risk. **Methods:** A cross-sectional study was conducted involving 43 older adults diagnosed with KOA. FOF was assessed using the Modified Falls Efficacy Scale (MFES), while balance and fall risk were evaluated using the Timed Up and Go Test (TUG). Descriptive statistics were applied to summarize demographic data using counts and percentages for categorical variables. The Chi-Square test was employed to assess the association between FOF and fall risk. **Results:** The findings revealed that 88.3% of participants did not experience significant FOF, while 11.6% reported fear. Regarding fall risk, 65% were categorized as having normal risk, 21% were at risk, and 14% had a high risk. A significant association was observed between FOF and fall risk, $\chi^2(2, N = 43) = 21.37$, $p < 0.001$, indicating that higher fear levels were linked to impaired balance and significant fall risk. **Conclusion:** The findings suggest that greater FOF is associated with poorer balance and an increased risk of falls among older adults with KOA that may adversely impact daily activities and functional mobility among elderly individuals with KOA. The observed association between FOF and balance impairment highlights the need for targeted rehabilitation strategies aimed at improving confidence, stability, and fall prevention in this population.

INTRODUCTION

Knee osteoarthritis (KOA) is the most prevalent musculoskeletal disease globally (Langworthy & Dasa, 2024), with an estimated prevalence of 374.7 million and 30.8 million incident cases reported in 2021, and the numbers are projected to rise further by 2045 (Ouyang & Dai, 2025). In Malaysia, the Malaysian Community Oriented Programme for the Control of Rheumatic Diseases (COPCORD) study reported that 64.8% of joint complaints involved the knee, with over half showing clinical symptoms of osteoarthritis (OA) (Veerapen et al., 2007).

The alarming increase in KOA prevalence is primarily attributed to population growth and aging demographics (Langworthy & Dasa, 2024; Yeap et al., 2021). Aging is the strongest risk factor, with individuals aged 55–64, 65–74, and ≥75 years showing 2.91-, 2.78-, and 3.44-fold higher risks of KOA, respectively, compared to those under 55 years (Ji et al., 2023). In fact, the prevalence of KOA among the elderly ranges from 22% to 47% globally (Daniel et al., 2025; Hawker & King, 2022; Postler et al., 2018), while the Malaysian Elders Longitudinal Research (MELoR) study reported that 27% of older adults experience KOA symptoms (Yeap et al., 2021).

In the context of elderly people, falls are a major public health concern, with prevalence in Malaysia ranging from 4% to 74% (Shaharudin et al., 2020). Falls lead to serious physical, psychological, and economic consequences, including injuries, reduced quality of life, and higher healthcare costs. Previous studies have identified that OA is a key contributing factor to fall incidence among the elderly (Salari et al., 2022; Zhang et al., 2023). Impairments related to KOA such as impaired balance responses, are associated with an increased risk of falls, the leading cause of hospitalization among older adults, often resulting in fractures, soft-tissue injuries, loss of independence, and morbidity (Liu et al., 2017; Zhang et al., 2023). Given this heightened vulnerability, assessing balance impairment in individuals with KOA is crucial.

Additionally, psychological factors, particularly fear of

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falling (FOF) arising from a history of previous falls, may further exacerbate fall risk among older adults (Leong Joyce et al., 2020; Yeong et al., 2016). The coexistence of KOA-related functional limitations and FOF may further compound fall susceptibility (Huang et al., 2025; Zhang et al., 2023). However, local studies evaluating these variables remain limited.

To date, the MELoR study has pioneered this topic by investigating the interplay between knee pain, FOF, and fall incidence. In their prospective analysis of community-dwelling older adults, knee pain at baseline was significantly associated with a 1.76-fold increased risk of developing FOF at a 12-month follow-up (Mat et al., 2020). Building upon this established framework, this study aimed to examine the association between FOF and balance among elderly individuals with KOA, emphasizing how these factors can influence fall risk. Elucidating this specific relationship is vital for expanding current clinical knowledge, as it highlights the critical necessity of integrating targeted balance training into rehabilitation protocols for older adults with KOA, ensuring that therapeutic interventions address both physiological instability and its underlying psychological barriers.

MATERIALS AND METHODS

A cross-sectional study was conducted at a local government hospital. Participants were included if they met the following criteria: (1) aged 65 years and above, and (2) diagnosed with unilateral or bilateral radiographic KOA. Respondents were excluded if they had: (1) any uncontrolled non-musculoskeletal diseases such as chronic obstructive pulmonary disease (COPD) or congestive heart failure; (2) a pre-existing neurological disorder affecting lower-limb strength, balance, or ambulation (e.g., poliomyelitis, stroke); (3) any musculoskeletal or orthopedic diseases that may impair ambulation (e.g., rheumatoid arthritis); or (4) dementia or mild cognitive impairment.

The sample size was calculated using G Power 3 analysis, specifically applying a Chi-Square Test of Independence (df=1). Assuming a large effect size (w=0.61), 28 participants was estimated to provide 90% power with a risk of type 1 error of 0.05. Thus, a final sample size of 34 participants was targeted after considering a 20% attrition rate. Participants were recruited using convenience sampling, and the study protocol was approved by the university ethics committee (FERC/FSK/MR/2022/0225). A consent form was provided to eligible participants to obtain their willingness to participate in the study. Participants then completed a questionnaire that included demographic data, fall history, and other comorbidities.

The 14-item Modified Falls Efficacy Scale (MFES) questionnaire was used to assess FOF (Yin et al., 2023). The questionnaire was administered in English and completed by the participants with the assistance of the researcher to ensure clarity and accurate comprehension of the items. In its original psychometric evaluation, Cronbach's alpha was used to demonstrate the internal consistency of the items on the questionnaire, yielding a value of 0.95, while the overall intraclass correlation coefficients (ICCs) for the MFES was 0.93 (Hill et al., 1996). All items were scored on a 10-point visual analog scale (VAS), where 0 = not confident at all, 5 = fairly confident, and 10 = completely confident (Yin et al., 2023). An average score below 8 categorized the participant as Fearful, whereas a score of 8 or above classified the participant as Not Fearful.

To assess balance and fall risk, the Timed Up and Go (TUG) test was performed. A priori research had demonstrated that the test had good to excellent test-retest reliability (ICCs ranging from 0.86 to 0.92) when administered five times with a one-minute rest interval (Collado-Mateo et al., 2019). Participants were instructed to rise from the chair, walk three meters, turn around, and return to the chair (Collado-Mateo et al., 2019). Timing began when the participant's buttocks was lifted off the seat and stopped when they sat down again (Collado-Mateo et al., 2019; Herman et al., 2011). Participants were instructed to walk at their normal pace. If a walking aid was typically used at home, it was also permitted during the test (Collado-Mateo et al., 2019). Completion times were classified into three risk categories: Normal (< 12 seconds), At Risk of Falling (12–13.9 seconds, reflecting minor gait impairment or early frailty), and High Risk of Falling (14 seconds or more).

Descriptive statistics were used to summarize demographic data, with counts and percentages for categorical variables. The Chi-square test was employed to assess the association between FOF and fall risk.

RESULTS

Characteristics of the Participants

A total of 43 participants were recruited for this study. Most participants (60.5%) were aged 65 to 70 years, and the majority were female (72.1%). The most common health problems reported were non-communicable diseases (NCDs), with diabetes mellitus (DM) and hypertension (HPT), affecting 39.5% of participants. Most participants were diagnosed with bilateral knee OA (81.4%), and 32.6% had experienced a fall within the past year (Table 1).

Table 1: Characteristics of the Participants

Variable	Number	Percentage (%)
Age Group:		
65-70	26	60.5
70-75	12	27.9
75-80	4	9.3
80-85	1	2.3
Gender:		
Male	12	27.9
Female	31	72.1
Diagnosis:		
Unilateral KOA	8	18.6
Bilateral KOA	35	81.4
Comorbidities:		
NCD-DM/HPT/HD	17	39.5
HDL	3	7
HPT/Dyslipidemia	5	11.6
Others	5	11.6
NKMI	13	30.2
Falls History:		
Yes	14	32.6
No	29	67.4

DM: Diabetes Mellitus; HD: Heart Disease; HDL: High-Density Lipoprotein; HPT: Hypertension; NCD: Non-Communicable Diseases; NKMI: No Known Medical Illness

The Level of Fear of Falling and Balance

About 88.3% of participants reported no FOF, while a smaller proportion (11.6%) expressed fear, as assessed using the MFES. Based on the TUG test results, 65.1% were categorized as having normal mobility with no significant fall risk, whereas 20.9% were identified as at risk of falling, and 14% were classified as having a high risk of falling.

Association between Fear of Falling and Balance

A Chi-Square analysis revealed a significant association between FOF and balance/fall risk, $\chi^2(2, N = 43) = 21.37$, $p < 0.001$. The effect size for this relationship was large (Cramer's V = 0.71), indicating a strong link between higher fear levels and impaired objective balance in this population. Table 2 shows the cross-tabulation between FOF and fall risk.

Table 2: Cross-tabulation between FOF and fall risk

FOF	Normal (Low Risk)	At Risk of Falling	High Risk of Falling	Total
Not Fearful	28 (73.7%)	8 (21.1%)	2 (5.3%)	38 (100.0%)
Fearful	0 (0.0%)	1 (20.0%)	4 (80.0%)	5 (100.0%)
Total	28 (65.1%)	9 (20.9%)	6 (14.0%)	43 (100.0%)

DISCUSSION

In this study, the majority of participants (88.3%) reported no significant FOF, while only 11.6% exhibited fear. This finding may reflect that participants with KOA were relatively active older adults who attended hospital-based physical assessments and participated in early rehabilitation programs, which are known to help prevent functional decline (Martinez-Velilla et al., 2016). Furthermore, most participants (67.4%) had no history of falls, supporting the notion that regular participation in rehabilitation activities may help maintain balance and confidence in this population.

Despite having KOA, most participants (65%) demonstrated a normal fall risk, possibly due to adequate muscle strength after actively engaging in knee rehabilitation that enables lower-limb muscles to contract under the regulation of the central nervous system to generate corrective torques for maintaining joint stability and balance control (Shen et al., 2024). Moreover, higher levels of fall efficacy is associated with better balance performance and a reduced risk of falls (Arnold et al., 2011; Hicks et al., 2020).

This study also found a significant correlation between FOF and balance, corroborating previous articles by Walankar and Jain (2017) and Fernandes et al. (2024). This finding is consistent with the fear-avoidance model theory, which explains how individuals with musculoskeletal pain may limit activity due to fear, leading to loss of confidence and an increasing fear of pain (Rosadi et al., 2022). Furthermore, high-fear KOA patients often adopt protective movement strategies by reducing weight bearing on the affected side and increasing stress on the contralateral limb. This compensatory mechanism may explain the subsequent development of bilateral KOA following an initial unilateral presentation (Duan et al., 2025). Ultimately, this behavior drives activity avoidance, resulting in reduced mobility and a reinforcing cycle of muscle atrophy, gait disorders, and physiological instability (Delbaere et al., 2010; Mat et al., 2019). This situation strengthens the necessity of evaluating psychological barriers alongside physical impairments in this population.

The recent study by Alkhamis et al. (2026) further reported that elderly patients with KOA with a history of falls presented with poorer TUG performance. A study by Aljuhani et al. (2025) also found that despite having

undergone total knee arthroplasty (TKA), FOF remains prevalent in this population, even at three months following surgery, compromising their rehabilitation progress. These findings underscore the critical need for a more holistic approach to geriatric orthopedic care. Recognizing FOF as a major barrier to functional recovery allows clinicians to screen vulnerable patients early. Consequently, this shifts the therapeutic focus from isolated joint-focused protocols toward a comprehensive, dual-targeted management strategy that concurrently addresses both objective physical balance impairments and cognitive-behavioral barriers to movement.

This study has several limitations. First, the use of a cross-sectional design means that data were collected at a single point in time, which inherently prevents us from establishing causal relationships between FOF and balance. Second, our reliance on a convenience sampling strategy and a relatively small sample size may limit the generalizability of the findings to the broader population of older adults with KOA. Larger studies utilizing randomized sampling techniques are needed to identify other factors influencing the relationship between FOF and balance. Furthermore, the study did not include a comparison group of older adults without KOA, which limits the ability to determine the relative impact of KOA on fall risk. In addition, the study focused exclusively on KOA and did not account for other comorbidities such as hip OA, cognitive impairment, visual deficits, or muscle weakness, that may also influence balance and fall risk. Future research should involve larger, more diverse samples, employ longitudinal designs, and consider these variables to provide a more comprehensive understanding of fall risk in older adults with KOA.

CONCLUSION

This study highlights a significant association between FOF and balance among elderly individuals with KOA. The findings indicate that although most participants exhibited relatively good balance and a low fall risk, FOF can markedly affect both mobility and postural stability. The analysis further demonstrates a strong association between higher FOF levels and poorer balance performance, underscoring the psychological factors that contribute to fall risk in this population.

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ORIGINAL ARTICLE

The Relationship Between the Axial Length to Corneal Radius of Curvature Ratio and Refractive Status in Young Malay Adults

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ABSTRACT

Background: Myopia is increasing worldwide and is closely linked to structural changes in the eye. While axial length (AL) and corneal radius (CR) are commonly measured in clinical practice, evaluating their relationship provides a more complete understanding of refractive status. The ratio between AL and CR reflects the balance between eye elongation and corneal shape. This study aimed to evaluate the relationship between the AL to CR ratio and spherical equivalent refraction (SER) in young Malay adults. **Methods:** A cross-sectional study was conducted involving 94 young Malay adults (86.2% female) aged between 20 and 30 years. Participants were included if they were emmetropic or myopic and had no history of ocular disease, surgery, or recent myopia control treatment. AL was measured using the Haag-Streit Lenstar LS900 optical biometer, while corneal radius of curvature (CR) was measured using the Oculus Keratograph 5M (OK5M). The AL to CR ratio was calculated by dividing AL by CR. Refractive error was determined through objective and subjective refraction, and spherical equivalent refraction (SER) was calculated accordingly. Pearson correlation and linear regression analyses were used to examine the relationship between the AL to CR ratio and SER. **Results:** The mean SER was −3.64±2.35 dioptres, and the mean AL to CR ratio was 3.23±0.16. A very strong negative correlation was found between the AL to CR ratio and SER ($r=-0.902$, $p<0.001$). Linear regression analysis showed that the ratio explained 81.3% of the variation in refractive error ($R^2=0.813$, $p<0.001$), indicating that higher ratios were associated with greater levels of myopia. **Conclusion:** The AL/CR ratio serves as a robust structural indicator strongly associated with the refractive status in young Malay adults. These findings highlight its utility as an objective biometric marker for clinical assessment and screening, particularly in environments where cycloplegic refraction is restricted.

INTRODUCTION

Refractive errors represent an emerging domain in ophthalmology, with growing recognition of their importance and impact on vision (Cruickshank & Logan, 2018; Marinescu et al., 2025). Myopia is the refractive error with the most rapidly increasing prevalence (Marinescu et al., 2025; Baird et al., 2020; Holden et al., 2016). The World Health Organization projects that 52% of the world's population will be myopic by 2050 (Holden et al., 2016; World Health Organization-Brien Holden Vision Institute, 2015). Data from Asian countries highlight a substantial challenge (Zhang et al., 2023). For instance, research has shown that myopia was reported in over 91% of first-year university students in Taiwan as early as 2005 (Wang et al., 2009). In another study, 96% of army recruits in South Korea had myopia, of which over 20% were classified as high myopia (Jung et al., 2012).

High myopia is a well-established risk factor for sight-threatening pathologies, including myopic macular degeneration and retinal detachment (Du et al., 2021; Wang et al., 2021; Zhang et al., 2024). Crucially, even low levels of myopia can significantly elevate these risks, emphasising the need for early identification of at-risk individuals through robust biometric monitoring (Haarman et al., 2020; Bullimore et al., 2021). An eye with a refractive error of −3.00 dioptres (D) has a threefold higher risk of retinal detachment compared to an eye with −1.00 D, a risk level closely associated with progressive changes in ocular biometric ratios (Marinescu et al., 2025; Haarman et al., 2020). Myopic macular degeneration remains the leading cause of blindness among myopic patients (Fricke et al., 2018). Another chronic disease associated with myopia is primary open-angle glaucoma, for which the risk is 2.26 times higher than in the general population (Wu et al., 2021; Choquet et al., 2022).

During normal ocular development, a process known as emmetropization maintains clear vision by balancing axial elongation with corresponding changes in corneal

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curvature and crystalline lens power (Grosvenor, 1988; He et al., 2015). This coordinated growth helps ensure that images remain focused on the retina despite ongoing structural changes within the eye (He et al., 2015). During myopic progression, axial length (AL) increases, and compensatory corneal flattening may occur (Marinescu et al., 2025; Grosvenor, 1988). However, when axial elongation exceeds the eye's ability to compensate through these refractive adjustments, the focal point shifts anterior to the retina, resulting in myopia (Marinescu et al., 2025). Recent research has focused on the ratio of AL to corneal radius of curvature (AL/CR) as a valuable biometric parameter (He et al., 2015; Jong et al., 2018; Omoto et al., 2020). The AL/CR ratio provides a structural assessment of the eye by indicating the proportionality between AL and corneal curvature (Mu et al., 2022; Fan et al., 2024).

Previous studies have shown that the AL/CR ratio increases with myopia severity. Emmetropic eyes typically exhibit ratios close to 3.0, whereas myopic eyes generally demonstrate higher ratios (Grosvenor, 1988; Ojaimi et al., 2005; Scheiman et al., 2016). The AL/CR ratio has been reported to be more strongly associated with refractive error than AL alone (He et al., 2015; Ojaimi et al., 2005). Although AL remains the gold standard for monitoring axial elongation, the AL/CR ratio provides additional information regarding the structural status of the eye (Cruickshank & Logan, 2018). Recent studies have further highlighted the clinical utility of the AL/CR ratio as an indicator of refractive status and myopia risk (Chen et al., 2025; Marinescu et al., 2025; Wang et al., 2026). However, data on the association between the AL/CR ratio and refractive status in young Malay adults remain limited. Furthermore, evidence from the Malaysian population is scarce. Therefore, this study aimed to determine the relationship between the AL/CR ratio and spherical equivalent refraction (SER) among young Malay adults in Malaysia.

MATERIALS AND METHODS

This study utilised a cross-sectional methodology to investigate the biometric profiles of young adults. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the International Islamic University Malaysia Research Ethics Committee (Reference: IIUM/504/14/11/2/IREC-2025-191).

Participants

A total of 94 young Malay Malaysian adults were included in the final analysis, comprising 13 males (13.8%) and 81 females (86.2%). This gender distribution likely reflects the demographic profile of the student population from which participants were recruited via purposive sampling from the International Islamic University Malaysia (IIUM) community in Kuantan, Pahang. Inclusion criteria were age between 20 and 30 years, spherical equivalent refractive error (SER) of emmetropia (0.00 to −0.25 D) and myopia (SER≤−0.50 D) in both eyes, generally healthy, and willingness to undergo a comprehensive ocular examination. Written informed consent was obtained from all participants prior to their enrolment in the study. Participants were excluded if they presented with a history of ocular surgery or trauma, active ocular disease, or current use of myopia control treatments (e.g., orthokeratology and atropine) within the previous year.

Ocular Measurements

Ocular biometry was performed to evaluate the primary structural variables of the eye. The AL was measured using the Haag-Streit Lenstar LS900 optical biometer (Haag-Streit AG, Köniz, Switzerland), and the mean of five consecutive automated measurements was used for analysis (Lal et al., 2024). The CR was measured using the OCULUS Keratograph 5M corneal topographer (OCULUS Optikgeräte GmbH, Wetzlar, Germany), which employs a Placido ring-based system to obtain corneal curvature measurements (Zhang et al., 2025). For each eye, three consecutive scans were obtained, and the average keratometry value was used for statistical analysis. The AL to CR ratio (Equation given below) was subsequently calculated by dividing AL (mm) by the average corneal radius of curvature (mm) (Marinescu et al., 2025).

$$\mathrm{AL/CR} = \frac{Axial\ length\ of\ the\ eye\ (AL{-}measured\ in\ mm)}{Corneal\ curvature\ radius\ (CR{-}measured\ in\ mm)} \quad (1)$$

Refractive status was determined through objective and subjective refraction. Refraction (Rx) was performed without cycloplegia, as the study sample comprised adults aged 20 to 30 years and the study aimed to evaluate the relationship between refractive status and ocular biometric parameters under routine clinical conditions. Cycloplegic refraction was therefore not considered essential for achieving the study objectives. Spherical equivalent refraction (SER) was calculated as the spherical power plus half of the cylindrical power. Participants were classified as emmetropic or myopic based on their refractive status.

Statistical analysis was conducted using SPSS version 27 (IBM Corp., Armonk, NY, USA). The normality of the data was verified using the Shapiro–Wilk test (Shapiro & Wilk, 1965). Descriptive statistics were generated for all biometric and refractive parameters. Pearson's correlation

coefficient was computed to evaluate the strength of the relationship between the AL/CR ratio and SER (Mukaka, 2012). A linear regression analysis was also performed to determine the predictive capacity of the AL/CR ratio for SER (Roustaei, 2024).

RESULTS

The normality of the study variables was assessed using the Shapiro–Wilk test to ensure the appropriateness of subsequent parametric analyses. Results indicated that SER demonstrated a statistically significant deviation from normality (p=0.019), whereas the AL/CR ratio was normally distributed (p=0.685). Despite the deviation from normality in SER values, parametric analyses were employed due to the sufficient sample size (n=94) and the inherent robustness of these tests for continuous ocular biometric data (Ghasemi & Zahediasl, 2012; Ashby, 1991). Consequently, parametric tests were used for all subsequent statistical analyses.

Table 1 summarises the demographic and refractive characteristics of the study population. A total of 94 young Malay Malaysian adults were included in the final analysis, comprising 13 males (13.8%) and 81 females (86.2%). The overall mean age was 21.32±1.29 years (range: 20–27 years). Male participants were significantly older than female participants; however, this difference was not clinically meaningful, with mean ages of 22.46±1.20 years and 21.14±1.18 years, respectively (t(92)=−2.81, p=0.006). All participants were either emmetropic or myopic, with SER errors ranging from 0.00 D to −9.25 D and a mean of −3.64±2.35 D. Comparison of mean SER between genders showed no statistically significant difference (t(92)=−0.14, p=0.895). The AL/CR ratio was also comparable between males and females.

As shown in Table 2, the mean AL was 25.03±1.20 mm, while the mean CR was 7.75±0.23 mm. The population had a mean AL/CR ratio of 3.23±0.16, ranging from 2.87 to 3.62.

Pearson correlation analysis demonstrated a very strong negative correlation between the AL/CR ratio and SER (r=-0.902, p<0.001), as shown in Table 3 and Figure 1. This indicates that an increase in the AL/CR ratio is directly correlated with a decrease in SER values, reflecting a higher degree of myopia (Figure 1). The strength of this correlation suggests a robust linear relationship between the structural AL/CR ratio and refractive status.

Linear regression confirmed that the AL/CR ratio is a robust predictor of refractive status, explaining 81.3% of the variance in spherical equivalent (R^2=0.813, p<0.001). The model yielded a significant negative coefficient (β=-13.25, p<0.001), indicating that a one-unit increase in the AL/CR ratio results in a 13.25 D myopic shift. This relationship is mathematically defined by the regression equation: SER=39.19 - 13.25x (AL/CR ratio).

Table 1: Demographic and refractive characteristics of the study population

Characteristic	Male (n=13)	Female (n=81)	Overall (n=94)	t(df)	p-value
Age (years)	22.46±1.20	21.14±1.18	21.32±1.29	−2.81 (92)	0.006
SER (D)	−3.98±2.99	−3.79±2.23	−3.64±2.35	−0.14 (92)	0.895

Table 2: Descriptive statistics of study variables

Variable	Mean±SD	Minimum	Maximum
SER (D)	−3.64±2.35	−9.25	0.00
AL (mm)	25.03±1.20	22.76	28.40
CR (mm)	7.75±0.23	7.06	8.44
AL/CR ratio	3.23±0.16	2.87	3.62

Table 3: Correlation between AL/CR ratio and SER

Variable Pair	r (Pearson)	p-value
AL/CR ratio vs SER	−0.902	<0.001

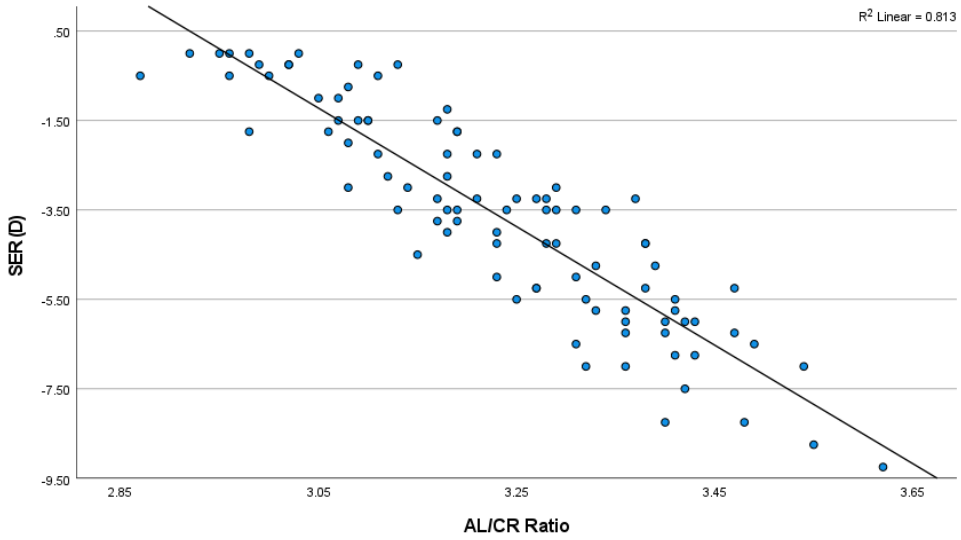

Figure 1: Correlation Between AL/CR Ratio and SER in Young Malay Adults

DISCUSSION

The primary objective of this study was to evaluate the relationship between the AL/CR ratio and spherical equivalent refraction in a sample of young Malay adults in Malaysia. The results demonstrated a very strong negative correlation (r=−0.902) between these two parameters, confirming that the AL/CR ratio is a highly reliable structural indicator of refractive status. This finding aligns with established literature suggesting that the AL/CR ratio provides a more comprehensive assessment of the eye's refractive state than AL alone (He et al., 2015; Foo et al., 2016).

The mean AL (25.03±1.20 mm) and mean CR (7.75±0.23 mm) observed in this study are consistent with the structural characteristics typically found in myopic eyes. Although both measurements fall within clinically expected ranges, the relatively longer AL reflects the axial elongation commonly associated with myopia development (Grosvenor, 1988; Marinescu et al., 2025). Grosvenor (1988) proposed that emmetropic eyes exhibit a balanced relationship between AL and CR, resulting in an AL/CR ratio of approximately 3.0. In contrast, the mean AL/CR ratio observed in the present study was 3.23±0.16, which is consistent with the predominantly myopic refractive profile of the study population. This finding supports the concept that myopia is associated with disproportionate axial elongation relative to corneal curvature, leading to an increase in the AL/CR ratio beyond the emmetropic threshold (Grosvenor, 1988; Cruickshank & Logan, 2018; Marinescu et al., 2025). Recent studies have further demonstrated that the AL/CR ratio is more strongly associated with refractive status and myopia risk than AL alone, highlighting its value as a robust biometric marker for the detection and monitoring of myopia progression (Chen et al., 2025; Wang et al., 2026).

The exceptionally strong correlation observed in the present study (r=-0.902) exceeds the r=-0.817 reported by Hashemi et al. (2013). This discrepancy may be attributed to the ethnic homogeneity and narrow age range of this Malay sample, which reduces biometric variance compared to more diverse populations.

Linear regression analysis revealed that the AL/CR ratio accounted for 81.3% of the variance in spherical equivalent refraction. This high R^2 value (0.813) demonstrates the strong association between the AL/CR ratio and SER within the study population. Given the cross-sectional design of the present study, these findings should be interpreted as reflecting a structural relationship between ocular biometry and refractive status rather than a causal or predictive association. In clinical environments where pharmacological cycloplegia is contraindicated or impractical, the AL/CR ratio may serve as a useful adjunctive measure for assessing refractive status (Marinescu et al., 2025). The regression equation derived in this study provides a mathematical framework for estimating refractive error based on biometric data. This is particularly relevant as the AL/CR ratio serves as a useful indicator of the relationship between axial elongation and corneal curvature. In emmetropic eyes, these components remain proportionally balanced to maintain retinal focus. However, when axial elongation exceeds the compensatory influence of corneal curvature, the AL/CR ratio increases, resulting in the development of myopia (Marinescu et al., 2025; Grosvenor, 1988; He et al., 2015).

Interestingly, no statistically significant gender differences were observed in the AL/CR ratio or SER, despite males being statistically significantly older than females in this sample. This suggests that the structural relationship

between AL and CR remains relatively stable during early adulthood (He et al., 2015; Hashemi et al., 2013). However, the high prevalence of moderate to high myopia (63.9%) in this university-aged population reflects the growing trend of myopia in Southeast Asia (Holden et al., 2016; Wang et al., 2021). Such a trend necessitates the use of robust biometric markers, such as the AL/CR ratio (Cruickshank & Logan, 2018; Grosvenor, 1988; He et al., 2015), to monitor structural changes that increase the risk of sight-threatening pathologies (Holden et al., 2016; Haarman et al., 2020; Wu et al., 2021).

Several limitations must be acknowledged. The cross-sectional nature of the study precludes the determination of causal relationships over time. In addition, the sample exhibited a marked gender imbalance, with females accounting for 86.2% of participants. This distribution likely reflects the demographic profile of the student population at the International Islamic University Malaysia Kuantan campus, from which the purposive sample was recruited. Although no significant differences in the AL/CR ratio or SER were observed between males and females, the relatively small number of male participants (n = 13) may limit the generalisability of gender-specific findings. Furthermore, the use of non-cycloplegic refraction introduces the potential for residual accommodation; however, the high level of agreement between the subjective refraction and the purely structural biometric ratio suggests that the influence of accommodation was minimal in this adult cohort (Hashemi et al., 2013). Future longitudinal studies should be conducted to determine how the AL/CR ratio changes over time during myopic progression in this specific demographic (Marinescu et al., 2025). Nevertheless, the findings highlight the clinical utility of the AL/CR ratio as a key metric for optometrists and ophthalmologists in assessing myopic risk (Cruickshank & Logan, 2018; Marinescu et al., 2025).

CONCLUSION

In conclusion, the AL/CR ratio demonstrates a strong association with SER and serves as a reliable structural indicator of refractive status in young Malay adults. These findings highlight its potential utility as an objective biometric marker for clinical assessment and screening, particularly in settings where cycloplegic refraction may not be feasible. However, the cross-sectional nature of this study precludes conclusions regarding causality or prediction. Future longitudinal studies are warranted to further evaluate the role of the AL/CR ratio in monitoring refractive changes over time.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the author used ChatGPT by OpenAI to assist in polishing the English language, improving sentence structure, and enhancing academic writing clarity. All generated content was carefully reviewed, revised, and approved by the author, who accepts full responsibility for the final version of the manuscript.

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ORIGINAL ARTICLE

SmartTasjeel: A GPS-Based Automated Attendance Tracking System for Medical Education Built on Microsoft PowerApps

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ABSTRACT

Background: Attendance in medical undergraduate programmes is consistently associated with academic performance, which makes accurate per-session tracking essential for early identification of at-risk students. At the Department of Basic Medical Sciences, Kulliyyah of Medicine, International Islamic University Malaysia, the previous biometric thumbprint system captured only twice-daily entries and excluded students with dermatological conditions affecting fingerprint recognition. This made per-session attendance percentage calculations impossible to automate. **Methods:** We report a descriptive operational deployment and systems evaluation of SmartTasjeel, a GPS-based attendance system built entirely on free Microsoft 365 Education licences using PowerApps, SharePoint Online, and Excel with Power Query. The system uses geofencing validation with a 0.001-degree tolerance (approximately 110 metres at the campus latitude) and matches each time-in to a session pulled from track-specific timetables. It was deployed for 285 students across three curriculum tracks. **Results:** Per-session attendance processing dropped from 30 minutes (paper) or 10 minutes (biometric queues) to under 15 seconds which a reduction of approximately 99.2% versus the paper-based baseline and 97.5% versus the biometric-queue baseline. Weekly percentage calculations dropped from around 2 hours of manual computation to under 30 minutes of automated dashboard review. Data granularity increased from a maximum of 10 weekly capture points (biometric) to 20–25 per student (per-session). No attendance calculation errors were identified during routine coordinator review across two academic semesters. Hardware cost dropped from RM3,500–7,000 (biometric machines) to zero. Students previously excluded by fingerprint recognition issues were able to participate. **Conclusion:** SmartTasjeel demonstrates that GPS-based automated attendance tracking can be implemented using only free Microsoft 365 Education licences, with no premium connectors, no custom code, and no additional hardware purchase, making it especially relevant for resource-constrained medical and health education institutions. The architecture is transferable to other institutions and the per-session data structure supports policy enforcement, warning-letter workflows, and student self-monitoring. Future work should formally evaluate whether real-time attendance feedback influences student attendance behaviour and academic performance.

INTRODUCTION

Attendance among medical undergraduates is one of the more consistent predictors of academic success in the literature. A systematic review by Doggrell (2020) covering 32 courses in the human biosciences found a positive association between lecture attendance and academic outcomes in 75% of courses overall, rising to 82% among courses for dental and medical students. Meanwhile, Al Shenawi et al. (2021) reported a positive correlation between attendance and performance in undergraduate surgical clerkship ($r = 0.360$, $p < 0.01$), with excellent performers maintaining a mean attendance rate of 83.16% compared with 47.95% among weak performers. These findings make accurate attendance tracking a meaningful operational concern in medical education, not just an administrative formality.

At the Department of Basic Medical Sciences, Kulliyyah of Medicine, International Islamic University Malaysia (IIUM), attendance for 285 students across three curriculum tracks initially relied on paper signatures. The risk of signature forgery prompted the transition to biometric thumbprint systems. However, biometric tracking introduced its own set of problems such as long queues formed at peak times. Additionally, students with dermatological conditions affecting fingerprint recognition were also excluded. Data transfer from biometric device also required manual transfer using thumb drives, which were unreliable. Most critically, the biometric system captured only twice-daily time-ins rather than per-session entries. This made it impossible to calculate accurate per-

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session attendance percentages, which is very important to the department because the need to issue warning letters at specific thresholds and for barring students who fall below minimum attendance requirements.

Several GPS-based and geofencing attendance systems have been described in higher education contexts, including dedicated Android applications (Babatunde et al., 2022) and Microsoft PowerApps-based platforms for medical education (Rajaram et al., 2022), and purpose-built GPS-based attendance tracking systems in engineering education contexts (Ravikumar et al., 2026). What is less well documented is whether a complete attendance ecosystem consisting of an interface, geofencing logic, relational database, per-session matching, and analytics dashboard that can be built end-to-end using only free Microsoft 365 Education licences, with no premium connectors and no custom programming. Analytics dashboards integrated into such systems have been shown to increase student engagement and support self-directed attendance monitoring in higher education (Ramaswami et al., 2023). This is very important as digital transformation in tertiary education has been described as a means to replace traditional administrative methods with cost-effective technological solutions in resource-constraint institutions (Althubaiti et al., 2022; Anisimova et al., 2024; Truong & Diep, 2023). Hence, the gap between this general framing and a working, replicable institutional deployment is rarely closed in published reports.

Babatunde et al. (2022) describe a dedicated Android application requiring device installation and custom programming, and Rajaram et al. (2022) implement a Microsoft PowerApps-based platform in medical education. Both studies do not report a zero-cost, fully integrated ecosystem that eliminates manual attendance processing, which is from student check-in to coordinator dashboard in a single, automated workflow. SmartTasjeel addresses this gap by combining GPS-based geofencing, automated per-session matching, and real-time analytics within a free Microsoft 365 Education licence, deployed in a resource-constrained Malaysian medical institution without custom programming or premium connectors.

In this paper, we describe SmartTasjeel ("Smart Registration" in Arabic), a GPS-based attendance system built on free Microsoft 365 Education licences. The system uses geofencing validation, captures per-session attendance with automatic curriculum detection, and provides students with real-time self-monitoring of their attendance percentages. This paper is presented as a descriptive operational deployment evaluation, drawing on deployment data rather than experimental or behavioural testing; formal user-experience evaluation is identified as a direction for future work.

MATERIALS AND METHODS

System Architecture

SmartTasjeel uses a four-layer cloud-based architecture: a PowerApps mobile application as the user interface, GPS geofencing with automatic curriculum detection as the application logic layer, SharePoint Online with eight relational lists as the data layer, and an Excel dashboard synchronised through Power Query as the analytics layer (Figure 1). The SharePoint database consists of TimeInData (timestamped attendance records), three timetable lists corresponding to the curriculum tracks (Year 1 Semester, Year 1 Block, and Year 2 Block), an Authorised Student List with curriculum assignments, a LocationMasterList containing venue GPS coordinates, and PBL group assignment lists. This structure allows the system to detect each student's curriculum track and match the time-in to the correct session without any manual coordinator intervention.

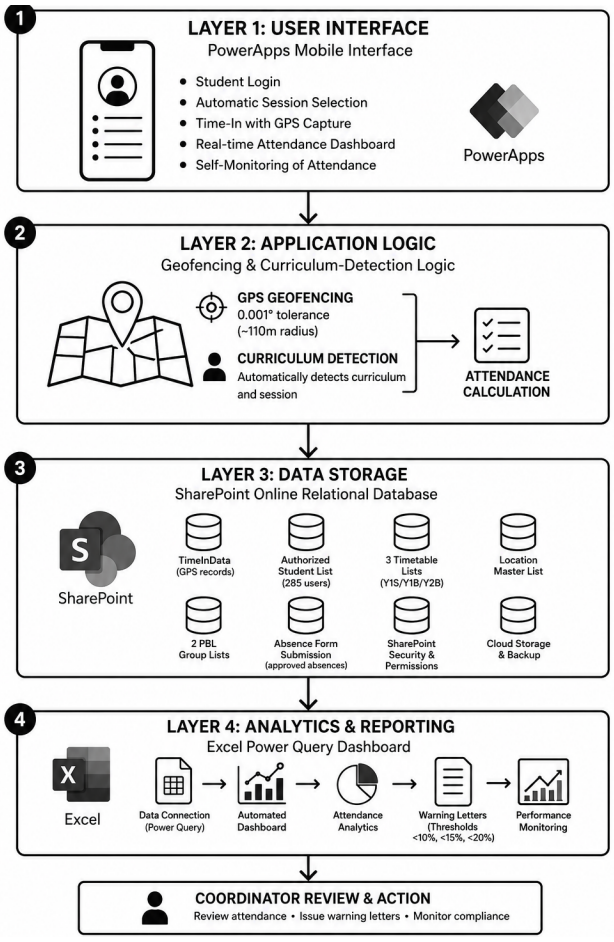


Figure 1: The four-layer cloud-based architecture of SmartTasjeel showing the PowerApps mobile interface, the geofencing and curriculum-detection logic layer, the SharePoint Online relational database, and the Excel/Power Query analytics dashboard.

The whole system was developed using only the components available in free Microsoft 365 Education licences. No premium connectors, no Power Automate workflows, and no third-party purchases were required. Record counts in each SharePoint list stayed below the PowerApps 500-record delegation threshold, so no delegation workarounds were needed. Total development cost was zero.

GPS Geofencing

The verification mechanism compares each student's GPS coordinates against the LocationMasterList using a 0.001-degree tolerance threshold, which corresponds to approximately 110 metres at the latitude of IIUM Kuantan campus. This precision is tight enough to prevent dormitory-based fraudulent time-ins but generous enough to accommodate legitimate venue proximity (for example, students standing just outside a packed lecture hall). For sessions designated as virtual, the system bypasses GPS verification automatically so that remote learning days do not register as false absences. This tolerance value was determined through manual on-site boundary testing, calibrated to approximately cover the full footprint of the Kulliyyah of Medicine building. A wider radius than a single lecture hall was required because sessions are conducted not only in lecture halls but also in dissection halls, laboratories, and seminar rooms distributed across the building. Version 1.0 of SmartTasjeel was deployed and operated for over six months prior to this report with no reported geofencing failures, providing operational validation of the threshold. The system creates no record for an out-of-range time-in attempt and does not log failed attempts by design; only successful time-ins are recorded. There are therefore no false positives by design. The rate of failed time-in attempts cannot be quantified retrospectively; this is identified as a system limitation.

Student Interface

The application has three screens: a login screen, a time-in screen, and an attendance monitoring screen. The login screen automatically displays the student's name and matriculation number based on the university Microsoft 365 credentials account. From the login screen, the student navigates to the time-in screen, which displays a dropdown for the semester or block, a topic selection that auto-populates from the timetable, and real-time GPS location verification. The time-in logic prevents duplicate records for the same session.

Version 2.0 added a self-monitoring feature that shows real-time attendance percentages calculated as (sessions attended ÷ total sessions conducted) × 100. The percentages are presented in three categories: Total Attendance, On-Time Attendance, and Late Attendance. All are colour-coded as Green (≥90%), Orange (≥80%), and Red (<80%) (Figure 2). The intention behind this feature is to shift students from passive end-of-block notification to active self-awareness of their own attendance status in real-time.

Coordinator Workflow

Attendance coordinators can review an Excel dashboard with Power Query. The Excel dashboard automatically refreshes from the SharePoint database. The mid-block review of student attendance percentage takes approximately 30 minutes or less. The coordinators also need to cross-reference the automated percentages with the absence approval database before finalising the net percentage and therefore can issue a warning letter. Student training required only brief demonstrations of the four-step time-in process. Timetable updates are currently performed manually by the system administrator directly within the SharePoint timetable lists. The block or year coordinators must inform the administrator of any session timing or venue changes for manual entry. The interface was designed for rapid use, with an estimated time of under 15 seconds from app launch to confirmed time-in.

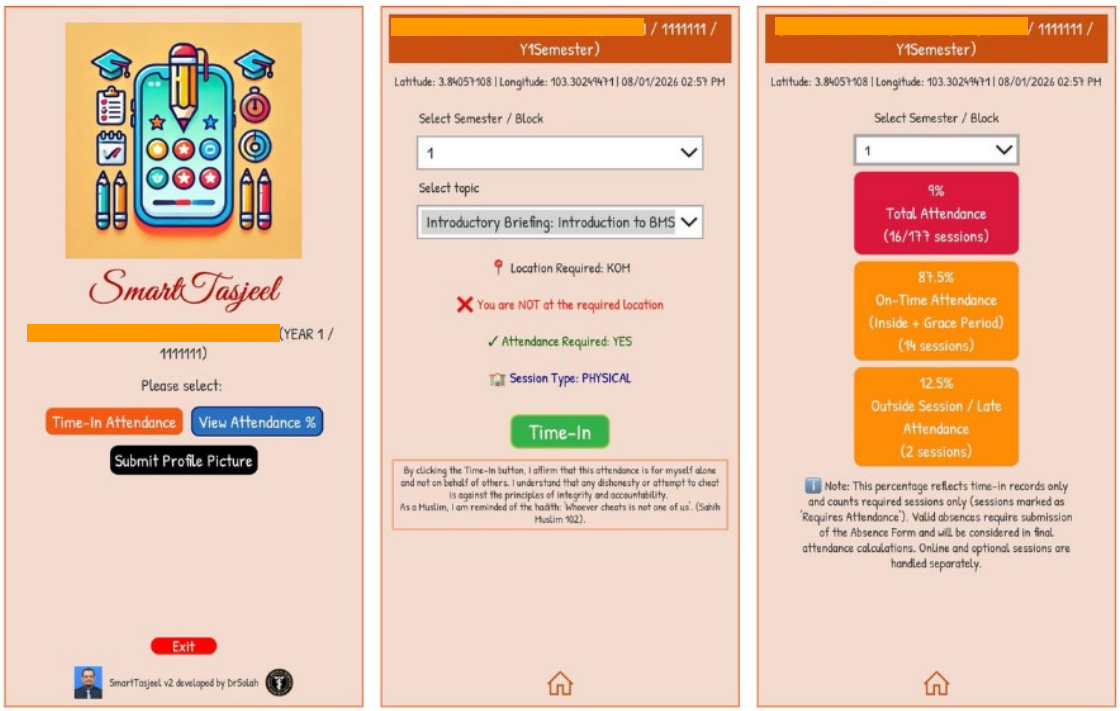
Data Security and Privacy

Student authentication is handled through institutional Microsoft 365 single sign-on. Therefore, no separate credentials are created or stored within SmartTasjeel itself. GPS coordinates are captured only at the moment of time-in and are not used for continuous or background location tracking. Access to the SharePoint lists is restricted to attendance coordinators and the system administrator via SharePoint permission groups, and all data transmission occurs over Microsoft's standard encrypted HTTPS connections within the IIUM Microsoft 365 Education tenant. External or third-party accounts are not involved at any point in the data workflow.

Statistical Analysis

As this study reports operational deployment outcomes rather than an experimental comparison, descriptive statistics (totals and percentages) were used to summarise system performance; inferential statistical testing was not undertaken and was not appropriate for the available data. Processing times are practical estimates rather than formal time-motion measurements, as actual time varies with individual device performance and campus WiFi connection speed at each venue. Failed time-in attempts (GPS location outside the authorised geofence, or use of a

device without enabled location services) are not separately logged by the current system; only successful time-ins are recorded. Consequently, the rate of failed attempts and GPS rejection events cannot be quantified retrospectively; this is identified as a system limitation. Across both cohorts, a total of 900 timetabled sessions were conducted (412 sessions across two semesters for Year 1; 488 sessions across four blocks for Year 2). A total of 38,931 attendance records were processed (24,568 for Year 1; 14,363 for Year 2), with all 285 enrolled students recorded in the system. As no duplicate time-ins are permitted, each record represents one unique successful student time-in event.



Login screen | Time-In screen | Attendance monitoring screen

Figure 2: The Version 2.0 include the first page for login, second screen for student to time-in for each session, and monitoring screen for self-monitoring screen. The monitoring screen showing colour-coded real-time attendance percentages across the three tracking categories.

RESULTS

SmartTasjeel produced measurable improvements across three areas: efficiency, accuracy, and inclusivity.

Efficiency

Table 1 compares the three attendance methods across key operational dimensions. Per-session attendance processing time fell from 30 minutes (paper signatures) or 10 minutes (biometric queueing) to under 15 seconds per student. Weekly attendance percentage calculations fell from approximately 2 hours of manual computation to under 30 minutes of automated dashboard review per mid-block period. Post-session data processing, which previously required 1 hour for thumbprint data transfer, now happens in real time through automatic SharePoint synchronisation. Specifically, per-session processing time was reduced by approximately 99.2% relative to the paper-based baseline (from 30 minutes to under 15 seconds) and approximately 97.5% relative to the biometric-queue baseline (from 10 minutes to under 15 seconds). Across both cohorts, a total of 900 timetabled sessions were conducted (412 sessions across two semesters for Year 1; 488 sessions across four blocks for Year 2), with 38,931 attendance records processed in total (24,568 for Year 1; 14,363 for Year 2). All 285 enrolled students were recorded in the system, with each record representing one unique successful time-in event.

Accuracy and Data Granularity

The system substantially reduced the calculation errors inherent in manual percentage computation. The previous biometric system captured a maximum of 10 data points per student per week (twice-daily time-ins), whereas SmartTasjeel captures 20 to 25 data points per week through per-session tracking. It is a 2 to 2.5 times increase in granularity. Over two academic semesters of deployment, no attendance calculation errors were

reported by coordinators during routine review, which involved cross-referencing the automated Excel dashboard against the absence-approval database at mid-block intervals. No formal independent audit was conducted; this statement reflects coordinator-reported operational experience. GPS verification reliably captured attendance at authorised venues while preventing remote fraudulent time-ins.

Feature	Paper-based	Biometric thumbprint	SmartTasjeel (GPS)
Technology	Manual sign-in sheets	Thumbprint scanner hardware	PowerApps + GPS geofence on student smartphones
Data capture	Manual (pen & paper)	Hardware-based scan	Automated GPS check-in via PowerApps
Processing time	~30 min/session	~10 min/session (queueing)	<15 sec/student; real-time SharePoint sync
Hardware cost	RM 0 (paper only)	RM 3,500-7,000 per unit	RM 0 (uses existing smartphones & M365 Education licences)
Student inclusivity	Universal	Excludes students with dermatological conditions affecting fingerprint recognition	Universal (smartphone-based)
Real-time monitoring	None	None	Live SharePoint dashboard with automated attendance percentage
Coordinator workload	High (~2 hr manual tallying/week)	Moderate (~1 hr data transfer/session)	Low (~30 min automated dashboard review per mid-block period)
Scale (Year 1 & 2)	Not applicable	Not applicable	900 sessions; 38,931 records; 285 students

Table 1: Comparison of attendance recording methods: paper-based, biometric thumbprint, and SmartTasjeel GPS-based system.

Inclusivity and Cost

SmartTasjeel also eliminated the hardware footprint of the biometric approach, which previously required approximately seven machines at RM500–1,000 each (RM3,500–7,000 total). The cloud-based architecture supports additional students at zero marginal cost. Students with dermatological conditions affecting fingerprint recognition, who were effectively excluded from biometric tracking, can now participate equally.

DISCUSSION

The progression from paper signatures to biometric systems to GPS-based automation reflects a sequence of solutions to successive limitations: first forgery prevention, then capacity and inclusivity, and finally per-session accuracy. SmartTasjeel addresses all three within a zero-cost platform.

The most operationally significant outcome is per-session capture, which the previous biometric system could not provide. Per-session data is what makes accurate attendance percentages possible, and accurate percentages are what make warning-letter and barring-from-examination workflows defensible. Without that granularity, the department had to rely on manual reconciliation, which was slow and error-prone.

The Version 2.0 self-monitoring feature is conceptually distinct from the administrative gains. Learning analytics dashboards that give students visibility into their own progress have been associated with improvements in motivation, engagement, and grades in higher education settings (Jayashanka et al., 2022; Ramaswami et al., 2023). The SmartTasjeel self-monitoring screen falls into this same category of intervention: it shifts students from passive end-of-block notification by attendance coordinator to active awareness of their percentage of attendance status percentage. Furthermore, the colour coding is designed to make the gap between actual and required attendance immediately readable. Whether this real-time awareness translates into changed attendance behaviour at our institution has not yet been formally evaluated, and that will be a direction for future work.

SmartTasjeel's architecture is transferable to any institution holding Microsoft 365 Education licences. It requires no premium connectors, no custom coding, and no specialised hardware beyond the mobile devices students already own. In our experience, the development required familiarity with the Microsoft Power Platform but not formal programming expertise. A lecturer with applied IT skills working alongside academic coordinators was sufficient. We acknowledge that this observation is based on a single development team and would benefit from independent replication in other institutional contexts. The approach is consistent with cost-effective digital transformation strategies described for tertiary education

(Althubaiti et al., 2022; Truong & Diep, 2023). These studies provide a worked example of how those general principles can be translated into a functioning operational system, particularly for institutions operating under resource constraints.

SmartTasjeel has several limitations. The application requires a smartphone or tablet (GPS is unavailable on most laptops) and an active internet connection. The coordinator workflow still involves manual SharePoint interaction for absence approvals; a dedicated coordinator-facing interface remains a future development priority. Timetable changes not updated in SharePoint can produce inaccurate session records, though this is a workflow coordination rather than a technical issue. Critically, the data presented are operational rather than experimental: formal evaluation of user satisfaction and the behavioural impact of the self-monitoring feature on attendance are needed and represent clear priorities for further research.

On privacy, SmartTasjeel captures location only at the moment of time-in rather than continuously, limiting data minimisation concerns relative to continuous tracking approaches (Durodolu et al., 2026). All data are stored within institutional IIUM Microsoft 365 accounts under the same governance framework. GPS coordinate data is comparatively less sensitive than biometric identifiers and no external or third-party accounts are used. Future deployments should communicate these governance arrangements to students in advance and establish a formal data retention schedule.

CONCLUSION

SmartTasjeel demonstrates that GPS-based automated attendance tracking can be implemented for medical education using only free Microsoft 365 Education licences, with no premium connectors, no custom code, and no additional hardware purchase. The system reduced per-session processing time by approximately 97.5–99.2% (depending on baseline), substantially reduced manual calculation errors based on coordinator review, and enabled per-session tracking, which is essential for early identification of at-risk students and for defensible warning-letter and barring workflows. Its zero-cost development, scalability, and inclusivity make it especially relevant to other medical and health education institutions operating under resource constraints. Future work should formally evaluate whether the real-time self-monitoring feature changes student attendance behaviour and academic performance.

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ETHICAL CONSIDERATIONS

SmartTasjeel was developed and deployed as an operational attendance management system within the Department of Basic Medical Sciences, Kulliyyah of Medicine, IIUM. The system processes attendance data that the department already collected through previous paper and biometric systems for the same operational purpose. No experimental procedures were conducted on students, no human subjects research was undertaken, and no identifiable personal data beyond standard institutional attendance records was used. This report describes the system's design and operational outcomes; formal ethics approval will be sought separately for any future study evaluating student behavioural or learning outcomes attributable to the system.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used Claude (Anthropic) to assist with language editing, citation verification through the Scite AI and Consensus integrations, and formatting alignment to the journal template. The authors subsequently reviewed, revised, and approved all content and accept full responsibility for the final manuscript.

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