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EDITORIAL

The Journal of Multidisciplinary Research (JMR) is an attempt to promote research excellence through collaborations and the incorporation of multi discipline. This issue of the journal brings together a diverse collection of studies that address timely challenges across health sciences, mathematics, social sciences, and management. Collectively, the articles reflect a strong commitment to evidence-based inquiry, theoretical advancement, and practical relevance, offering insights that respond to contemporary societal, academic, and economic concerns in both local and global contexts.

The first paper, "An Evaluation of Bacterial Profile and Antimicrobial Resistance Patterns of Infected Diabetic Foot Ulcers" by Nimnadi et al., addresses a pressing global health concern through a systematic review of bacterial pathogens associated with diabetic foot ulcers and their resistance trends. By analysing microbial profiles and antimicrobial susceptibility patterns, the study underscores the clinical implications of rising antibiotic resistance and highlights the need for evidence-based management strategies. The research makes an important contribution to medical microbiology and public health, particularly in guiding treatment protocols in hospital and community settings.

Shifting to the domain of mathematical sciences, the second paper, "Rainbow Vertex Antimagic Colouring for Square Snake Graphs and Hexagonal Snake Graphs," by Dasanayake and Perera, presents a mathematically rigorous investigation into graph colouring, an area of significant relevance to computational theory and applied mathematics. The study offers innovative approaches to rainbow vertex antimagic colourings, expanding the theoretical framework and practical applications of graph theory in fields such as network design and data structuring.

Addressing student well-being within higher education, the third paper, "An Exploration of the Prevalence, Causes, and Coping Strategies of Stress Among University Students in Sri Lanka," by Thushthika and Chathurika, sheds light on a critical psychosocial issue within higher education. This review identifies key stressors affecting university students and examines their coping mechanisms. The

findings not only add to the growing body of literature on student well-being but also suggest actionable recommendations for universities to create more supportive academic environments.

The fourth paper, “The impact of bad debt levels on the financial Performance indicators: Evidence from Sri Lanka’s Non-financial Private Sector”, by Silva M M N N, Pathiranage A, examines the impact of bad debt levels on the financial performance of non-financial private sector firms in Sri Lanka during 2020–2024. Using secondary data from 20 listed companies, the findings reveal a statistically significant negative relationship between bad debts and key performance indicators, including profitability, liquidity, efficiency, and solvency. The results underscore the critical importance of effective credit risk management and SLFRS 9-aligned practices in strengthening corporate financial resilience amid economic instability.”

The final study, “Assessment of Nutritional Status and Anthropometric Profiles of Undergraduates at NSBM Green University, Sri Lanka” by Jayalath J A S A, Thusthika A, is a cross-sectional study that assessed dietary patterns and nutritional status among 102 undergraduates at a University in Sri Lanka. Data were collected using a structured questionnaire and anthropometric measurements, including BMI and waist circumference. Findings revealed a dual burden of malnutrition, with underweight, overweight, and obesity coexisting in the population. Abdominal obesity was prevalent, particularly among females, and was significantly associated with BMI, although some students with normal BMI also exhibited central obesity. Unhealthy dietary practices, especially meal skipping and frequent snacking, were common, highlighting the need for targeted university-based nutrition interventions.

Collectively, the articles in this issue exemplify the journal’s commitment to advancing multidisciplinary research that addresses real-world challenges. They demonstrate how diverse disciplines, from microbiology and mathematics to management and psychology, can converge to generate meaningful insights and sustainable solutions.

Dr. Piyumi Wickramasinghe (Editor-in-Chief)

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AN EVALUATION OF BACTERIAL PROFILE AND ANTIMICROBIAL RESISTANCE PATTERNS OF INFECTED DIABETIC FOOT ULCERS

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Abstract

Diabetic foot ulcers represent a serious complication in diabetic patients, often leading to prolonged infections, increased morbidity, and a heightened risk of amputation. This review aims to provide an in-depth analysis of the bacterial profiles and antimicrobial resistance patterns of infected diabetic foot ulcers, with a particular emphasis on multidrug-resistant organisms and their clinical implications. A comprehensive literature search was conducted using databases such as PubMed, Scopus, and Google Scholar, covering studies published between 2010 and 2024. Relevant articles were selected based on predefined inclusion criteria focusing on microbiological analysis and resistance profiles in DFUs. The most frequently isolated pathogens in diabetic foot ulcers are Staphylococcus aureus (60%), Pseudomonas spp. (16%), and Escherichia coli (14.6%), with a particular emphasis on methicillin-resistant S. aureus (8%). Polymicrobial infections were common and showed high resistance to β-lactams and methicillin. The emergence of multidrug-resistant organisms significantly complicates the treatment of diabetic foot ulcers. These findings emphasize the need for routine microbial cultures and antibiotic susceptibility testing to guide effective therapy. The review emphasizes the critical importance of antimicrobial management, preventive patient education, and early intervention through proper foot care and glycemic control to reduce infection rates and enhance patient outcomes.

Keywords: antibiotic resistance, anti-microbial therapy, diabetic foot ulcers, diabetes mellitus, *Staphylococcus aureus*

1. Introduction

Diabetes is a non-contagious disease brought on by hyperglycemia that poses a risk to everyone worldwide. Type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), and gestational diabetes are the three types of diabetes (Nakrani et al., 2022). T1DM is an autoimmune condition in which the immune system destroys insulin-producing pancreatic cells, typically appears during infancy or adolescence and requires lifelong insulin medication (Ahmad, 2016). T2DM is the most prevalent form, results from insulin resistance or the body's inability to use insulin effectively, often linked to risk factors such as obesity, physical inactivity, and the regular consumption of processed foods. Gestational diabetes, arises during pregnancy and typically resolves after delivery (Buse et al., 2020).

The International Diabetes Federation (IDF) estimates that 8.8% of adults in the world between the ages of 20 and 79 would have diabetes in 2017 (Khan et al., 2019). In 2010, 285 million diabetic cases were reported globally, and it is expected to rise from 6.4% to 7.7% in 2030 with 439 million diabetic cases. Between 2010 and 2030, the number of adults with diabetes will rise by 69% in developing nations and 20% in developed countries (Shaw et al., 2010). In Sri Lanka, the prevalence of diabetes in the urban population has been reported at 27.6% (Kaluarachchi et al., 2020).

Diabetic foot complications remain a significant concern among the various complications of diabetes i.e., diabetic retinopathy, nephropathy, neuropathy, macrovascular disease, and cardiomyopathy (Buse et al., 2020). Diabetic foot ulcers (DFUs) are one of the most common and severe manifestations, resulting from a complex interplay of neuropathy, peripheral vascular disease, and impaired immune function. A global prevalence of 6.3% has been reported for DFUs, with the highest in North America (13.0%) and the lowest in Oceania (3.0%). Africa had a 7.2% prevalence, which was greater than that of Asia (5.5%) and Europe (5.1%) (Shi et al., 2023).

The formation of DFUs is multifactorial and involves interrelated mechanisms such as poor circulation, nerve damage, and high blood sugar levels, which together impair wound healing (Yu et al., 2022). Individuals with diabetes have a lifetime risk of 15–25% for developing DFUs (Pouget et al., 2020). If not managed effectively, DFUs can lead to serious complications including infection, gangrene, osteomyelitis, and even limb amputation.

The presence of microorganisms in DFUs is common and can significantly impact the healing process. Microorganisms such as bacteria, fungi, and viruses can colonize the wound, leading to infection and delayed healing and increasing the risk of complications. Studies show that up to 80% of DFUs are infected, with *Staphylococcus aureus* being the most commonly isolated aerobic bacterium in approximately 60% of cases (Sloan et al., 2019).

Research studies conducted from 2000 to 2024 were incorporated into this review, focusing on microbial profiles and antibiotic resistance in diabetic foot infections. Literature was sourced from PubMed, ScienceDirect, and Google Scholar using relevant keywords. Studies without microbiological data were excluded. Both observational and review articles were included to inform clinical insights.

Despite available treatments, increasing antibiotic resistance among microbial isolates poses a major clinical challenge. Therefore, this review aims to evaluate the antimicrobial resistance patterns of microorganisms associated with diabetic foot ulcers, with a focus on multidrug-resistant organisms and their clinical implications in the effective management of DFUs.

2. Mechanism of diabetic foot ulceration

DFUs are associated with complex pathogenic factors in which the advanced glycation end products (AGEs) lead to several side effects. Diabetic neuropathy (sensory, motor, and autonomic) and peripheral vascular disease are the two most significant risk factors for diabetes. Figure 1 shows the mechanisms and risk factors of diabetic foot ulceration.

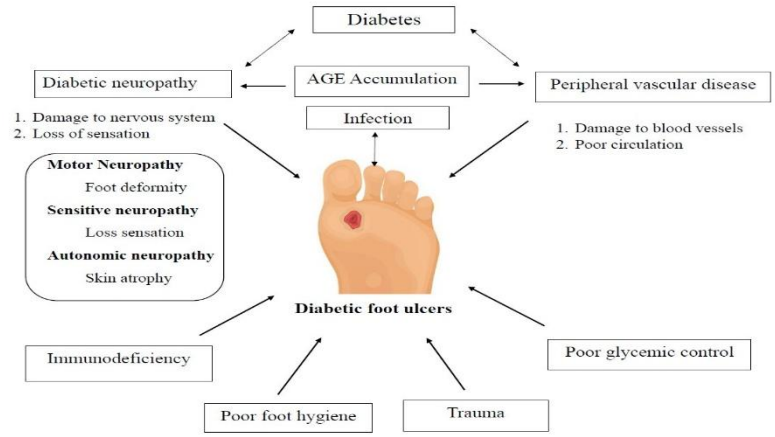

Figure 1: Mechanism of Diabetic Foot Ulceration, and Risk Factors

(AGE- advanced glycation end products)

AGEs are heterogeneous compounds that form when proteins, lipids, or nucleic acids are glycated during hyperglycemia without the use of an enzyme. In diabetes, the elevated blood glucose starts to form covalent adducts with plasma proteins through a non-enzymatic process known as glycation and form AGEs and gradually deposit on different parts of the body and are thought to be the major cause of many diabetic complications including diabetic retinopathy, diabetic nephropathy, diabetic neuropathy and macrovascular diseases (Singh et al., 2014). Further, these AGEs deposit on blood vessels & lead to reduces the blood supply which can cause wounds to heal more slowly and potentially end in gangrene (Amin & Doupis, 2016). Another factor that worsens DFUs outcomes is the impact of impaired angiogenesis, or new blood vessel formation, which is essential for supplying oxygen and nutrients to healing tissue. Diabetes-associated vascular dysfunction limits angiogenesis,

primarily due to the reduced expression of key pro-angiogenic factors, such as vascular endothelial growth factor (Velnar et al., 2009).

Accumulation of AGEs in the peripheral nerves promotes neural inflammation and impairs axonal transport & also blocks the blood vessels (Luevano-C & Chapman-N, 2010). Loss of sensation in the feet and legs due to neuropathy can make it harder for individuals to notice minor wounds or pressure points that might develop ulcers. (Boulton, 2010). Poor circulation or peripheral artery disease, which can reduce blood flow to the feet and hinder wound healing, is another cause (Armstrong et al., 2017).

Further, individuals with diabetes are more susceptible to infections, which can also contribute to the formation of DFUs. These wounds can develop into ulcers that heal slowly and can become infected if not treated, which may result in major problems like amputation. Poor glycemic control and immunodeficiency can increase the risk of bacterial infections and impair the body's ability to fight off infections. Other elements that may have played a part in DFUs development include foot deformities, poor foot hygiene, and repetitive trauma or pressure on the feet (Yu et al., 2022). Ulceration may occur as a result of trauma. Uncertain shoes are the main reason for trauma. The structure of the foot alters as a result of motor neuropathy (Reardon et al., 2020a).

Diabetic neuropathy is a common (90%) complication of both T1DM and T2DM, affecting up to 50% of people with diabetes (Alexiadou & Doupis, 2012). It is a type of nerve damage that can occur anywhere in the body. However, it usually affects the feet and legs. The blood vessels and nerves that control sensations in the feet and legs can be damaged over time by high blood sugar levels, resulting in symptoms including tingling, numbness, and discomfort. Other organs that might be impacted by diabetic neuropathy include the heart, urinary system, and digestive system (Reardon et al., 2020a). Vasodilation and reduced sweating carried on by autonomic dysfunction result in a loss of epidermal integrity and a place vulnerable to microbial invasion (Alexiadou & Doupis, 2012).

Diabetes patients have a 2-8 times higher prevalence of peripheral artery disease, which starts earlier, progresses faster and is usually more severe than in the normal population. The areas between the knee and the ankle are usually impacted. Peripheral artery disease is a predictor of foot ulcer outcome as well as an independent risk factor for cardiovascular disease. Even slight wounds in most foot ulcers have a mixed etiology (neuro ischemic), especially in patients who are elderly (Boulton, 2008). Peripheral diabetic neuropathy patients typically experience minor wounds from internal (calluses, nails, foot deformities) or external (shoes, burns, foreign objects) sources that are hidden, which can later develop into foot ulcers. This could be followed by an infection of the ulcer, which could ultimately lead to amputation of the foot, especially in patients with peripheral vascular disease (Prompers et al., 2007). The majority (60-80%) of foot ulcers will heal within 6-18 months of the initial evaluation, but 10-15% of them will remain active and 5-24% of them may ultimately cause limb amputation (Alexiadou & Doupis, 2012).

3. Identification of DFUs

Typically, DFUs can be recognized by their distinctive features and position on the foot. Ulcers usually form on the bottom of the foot and may appear as open sores or wounds that do not heal for an extended period. Some common signs and symptoms of DFUs include redness, tenderness, swelling & pain around the affected area. Besides the pus formation, discoloration of the skin around the ulcer can be seen. Also, a strong odor can be formed (Reardon et al., 2020b).

Assessment of diabetic foot can be divided into a few sections. First structural assessment, it's crucial to check the feet for structural issues such as calluses, bunions, hammertoes, claw toes, and flat feet. Excessive plantar pressures caused by limited joint mobility, especially at the ankle, subtalar, and first metatarsophalangeal joints, can lead to foot ulceration. Tools are employed to identify increased plantar pressures, including specialized mats that track plantar load distribution in bare feet and transducers in replaceable shoe insoles that record pressure inside footwear. Since

Charcot neuro-arthropathy is likely to go unnoticed by the patient until a severely malformed, insensitive foot develops that is more susceptible to ulceration, it is imperative to detect its presence (Armstrong et al., 2017). According to neuropathic assessment, a thorough examination should include looking for muscular atrophy, foot abnormalities like claw toes, hair loss, and trophic changes (Costa et al., 2022). Sensory evaluation includes testing for pressure, vibration, joint position, and pain or temperature sensations. Most patients with diabetes are likely to have atherosclerotic vascular disease. The diabetes clinic routinely feels pedal pulses, although this technique is subjective and sensitive to a variety of outside influences. Intermittent calf cramping is a rare presenting symptom in diabetic patients because the geniculate arteries that originate close to the popliteal trifurcation, a location commonly spared in diabetes-related peripheral vascular disease, supply the calf muscles with blood (Khanolkar et al., 2008). Once an ulcer appears, it's essential to monitor it. There are several classifications for foot ulcers. Grade 1 ulcers are known as superficial diabetic ulcers. Grade 2 ulcer extension involving ligament, tendon, joint capsule, or fascia with no abscess or osteomyelitis. Grade 3 refers to deep ulcers with abscesses or osteomyelitis. Grade 4 refers to the extensive gangrene of the foot which is a severe form of ulcer (Lim et al., 2017).

4. Microorganisms in DFUs

DFUs are persistent wounds commonly seen in individuals with diabetes. These ulcers are prone to infection by various microorganisms, particularly bacteria, but also fungi and viruses. Bacterial infections are the most frequent complication associated with DFUs, often worsening the condition and delaying the healing process. The most common bacteria found in DFUs include *S. aureus, Pseudomonas* sp., *Escherichia coli, and Enterococcus* species. Fungi, such as *Candida* and *Aspergillus*, can also cause infections in DFUs, although they are less common than bacterial infections. Viral infections, such as herpes simplex virus, can also occur in these ulcers, particularly in individuals with poor immune systems (Hawkins et al., 2022).

DFUs that have become microbially infected increase the risk of amputation. The presence of microbes that are resistant to therapy in DFUs makes treatment extremely difficult. The most prevalent aerobic and anaerobic microorganisms, respectively, are *S. aureus* (60%) and *Bacteroides* sp. *Pseudomonas* spp. (*P. aeruginosa)* (16%), *E. coli* (14.6%), and methicillin-sensitive *S. aureus* (13.3%) were the most prevalent species found. *Streptococcus* sp. *(Streptococcus pneumoniae)* (10.6%), *Klebsiella* spp. (8%), *Acinetobacter* spp. (8%), methicillin resistant *S. aureus* - MRSA (8%), *Proteus mirabilis* (6.6%), *Citrobacter* species, *Enterococcus* species (5.3%), and *Enterobacter* species (1.3%) were among the additional organisms that were isolated (Sloan et al., 2019).

Most chronic ulcers contain polymicrobial infections while acute ulcers contain mono-microbial infections. With time and as the ulcers develop, bacteria that colonize typically become more diverse and advanced than the skin germs that surround them (Price et al., 2020).

A type of bacteria known as *S. aureus* may result in infections in different body areas, including the skin. The natural habitat of *S. aureus* in humans is the skin and nasopharynx (Sollid et al., 2013). These ulcers are often infected, and *S. aureus* is one of the most common bacteria found in diabetic foot infections. From mild skin infections to more serious infections including sepsis and osteomyelitis, which are bloodstream infections, *S. aureus* can cause a variety of diseases. In DFUs, *S. aureus* can cause delayed healing and can increase the risk of amputation (Kalan & Brennan, 2019). Treatment of DFUs infected with *S. aureus* typically involves antibiotics. The severity of the infection, the patient's medical history, and any antibiotic resistance patterns identified in the bacterial culture will all impact the antibiotic that is selected. In addition to antibiotics, other treatments such as wound debridement (removal of dead tissue) and pressure relief may be necessary to promote healing (Dinges et al., 2000).

5. Antimicrobial susceptibility in DFUs

Antibiotics are used to treat bacterial infections. They work by killing (i.e., bactericidal) or inhibiting the growth of bacteria (i.e., bacteriostatic) that cause infections in the body. Antibiotics only work against bacterial diseases, and they do not affect viral infections like the flu or the common cold. It is important to use antibiotics only as prescribed by a healthcare professional and to finish the entire course of medication even if the patient feels better before the medication is gone. A significant public health concern is antibiotic resistance, which can be caused by the overuse and inappropriate use of antibiotics (Frieri et al., 2017).

The concept of "antibiotic resistance" refers specifically to the bacterial ability to resist the effects of antibiotics, which are drugs created with the intent of either killing or inhibiting the growth of microbes. When bacteria become resistant to antibiotics, the drugs become less effective, making it more difficult to treat bacterial infections. Antibiotic resistance is a significant public health concern because it can lead to the inability to effectively treat infections, which, in rare situations, can lead to extended hospital stays, increased healthcare costs, and even death. It is important to use antibiotics and other antimicrobial drugs responsibly and only when necessary to help to prevent the development of resistance (Du et al., 2022).

Antibiotic resistance decreases the therapeutic efficacy of antibiotics against infections that are already resistant to them or that acquire a transferable resistance from another organism in the patient's flora while being treated. The widespread use of antibiotics encourages the development of more resistant bacteria in the patient's flora. The process of "superinfection" may have significant clinical consequences, particularly for hospital patients, many of whom have a higher risk of contracting infections from organisms that rarely infect healthy people. These organisms frequently cause respiratory or septicemic problems in such patients, which may pose a larger risk than the infection for which antibiotic treatment was prescribed. The ability of prevent the further spread of resistant organisms by the selective use of

antibiotics is severely hampered by the wide spectrum of antibiotic resistance in common bacteria (Oliveira et al., 2024).

Antibiotic susceptibility testing (ABST) is an important tool in managing these infections, as it helps to identify the most effective treatment options. ABST involves exposing bacteria causing infection to a range of antibiotics to determine which ones are most effective. This can be done using different methods, including disk diffusion, broth microdilution, and automated systems. The results of the test can help to guide the choice of antibiotic therapy, as well as monitor the emergence of antibiotic resistance (Vasala et al., 2020).

It's important to remember that testing for antibiotic susceptibility should be done on an individual basis because the selection of an antibiotic depends on a variety of requirements, including the severity of the infection, the presence of underlying medical disorders, and the patient's recent exposure to antibiotics. In addition, the emergence of antibiotic resistance is a growing concern, and efforts should be made to minimize the use of broad-spectrum antibiotics to reduce the risk of further resistance development (Justesen et al., 2018).

Microorganisms can have different levels of susceptibility to different antibiotics. Some may be resistant to certain antibiotics (Table 1), meaning that the antibiotic will not be effective in killing or inhibiting their growth. Others may be susceptible, meaning that the antibiotic will be effective in killing or inhibiting their growth. In addition, some microorganisms may be intermediate in their susceptibility, meaning that the antibiotic may have some effect, but may not be the best choice for treatment (Zetola et al., 2005).

Bacteria	Resistant antibiotics
Staphylococcus aureus	• Beta lactam antibiotics – penicillin • Methicillin
Pseudomonas spp.	• Penicillin, Aminopenicillin • First and second generation of cephalosporins
Escherichia coli	• Penicillin, Aminopenicillin
Methicillin-sensitive *Staphylococcus aureus*	• Penicillin, Erythromycin
Methicillin-resistant *Staphylococcus aureus*	• Methicillin • Beta lactam antibiotics
Acinetobacter spp.	• Beta lactam antibiotics

Table 1: Antimicrobial Resistance of Bacterial Isolates

In the case of DFUs, the most common bacterial pathogens are *S. aureus, Streptococcus* sp., *Enterococcus* species, and Gram-negative bacilli such as *Pseudomonas* species, *Proteus mirabilis*. To assist in selecting the best ABST should be carried out on isolates from these diseases. This is especially important in cases where the infection is severe or has not responded to initial treatment (Sloan et al., 2019).

One of the most influential and adaptable human infections is *S. aureus*, which can acquire mechanisms for developing antibiotic resistance and pathogenic determinants (Zetola et al., 2005). Clinicians nowadays face an obstacle when treating *S. aureus* infections since *S. aureus* is resistant to several kinds of antimicrobial drugs. *S. aureus* developed resistance to numerous antibiotics because of its recurrent adaptation to various antibiotics used in clinical practice over time. MRSA, which causes several untreatable infections in humans, is defined as any strain of *S. aureus* that has developed resistance to methicillin and other beta-lactam drugs. The *Staphylococcal* chromosomal cassette mec (SCCmec) mobile gene element (MGE) contains the mecA gene, which codes for the penicillin-binding protein 2a (PBP2a), which is generated by *S. aureus* and is resistant to methicillin. Beta-lactam medications have a low affinity for PBP2a (Akanbi et al., 2017).

Infections with *Streptococcus* continue to be one of the major issues in modern medicine. According to the World Health Organization (WHO), *Streptococcus pneumoniae* accounts for most pneumonia cases worldwide (Sollid et al., 2013). Isolates of the *P. aeruginosa* and *Acinetobacter* spp. that are completely or nearly completely resistant to b-lactam antibiotics. *P. aeruginosa* and, to a lesser extent, *Acinetobacter* spp. frequently cause hospital-associated conditions. Infections brought on by these organisms most frequently cause ventilator-associated pneumonia. If the organism infects healthy individuals, it typically does so in the gastrointestinal tract and moist body regions such as the throat, nasal mucosa, axillary skin, and perineum. In the microbial flora of healthy individuals, the organism is hardly ever found (Iwata et al., 2012).

It is significant to remember that the exact bacterial strain causing the infection, as well as other aspects including the patient's immune system and any underlying medical issues, can all affect the results of an ASBT. Therefore, it is important for healthcare providers to carefully consider all available information when selecting antibiotics for the treatment of DFUs (Yerlikaya et al., 2021).

6. Discussion

This review elucidates the complex microbial environment and the rising challenge of antimicrobial resistance identified in DFUs. The persistent occurrence of pathogens, including MRSA, *P. aeruginosa*, and *Enterococcus* spp., as evidenced by numerous studies, underscores their significant contribution to chronic infections (Sloan et al., 2019; Du et al., 2022). It is important to highlight that the patterns of antimicrobial resistance indicate an increase in the prevalence of multidrug-resistant organisms, particularly in relation to widely utilized antibiotics such as beta-lactams and methicillin. This trend complicates treatment decisions and is associated with prolonged healing times and heightened risks of amputation (Akanbi et al., 2017; Du et al., 2022).

Recent research, encompassing various geographic regions, illustrates the diversity in bacterial prevalence and the trends in resistance observed. For instance, MRSA and extended-spectrum beta-lactamases (ESBL) producing *E. coli* are frequently observed in Asian contexts, whereas *Enterococcus* spp. and *Acinetobacter* spp. exhibit elevated resistance levels in specific European research findings (Shi et al., 2023). The observed variations underscore the necessity for localized antibiograms, and treatment guidelines tailored to specific regions.

In spite of the heightened focus on infections associated with diabetic foot ulcers, there continue to be significant gaps in the existing research. A significant number of studies primarily emphasize aerobic bacteria, often leading to an underrepresentation of anaerobic bacteria and fungi. Moreover, methods that rely on culture may not adequately represent the polymicrobial characteristics inherent in chronic ulcers. Emerging advanced tools, including molecular diagnostics and biofilm studies, are currently not extensively utilized in routine clinical practice.

While conventional therapies remain prevalent in existing treatment protocols, innovative strategies such as agents aimed at biofilms, antimicrobial peptides, and stem cell therapies are currently under investigation (Yu et al., 2022). These methods demonstrate promise; however, they necessitate additional clinical validation prior to their broad implementation.

The implementation of advanced microbial surveillance, the enhancement of diagnostic capabilities, and the establishment of antimicrobial stewardship programs are crucial for mitigating the burden of infections and enhancing patient outcomes in DFUs.

7. Conclusion

This analysis emphasizes the essential significance of determining the microbial makeup and antibiotic resistance profiles in DFUs, which continue to pose a considerable worldwide health challenge. The predominant bacterial strains *S. aureus*, *Pseudomonas* spp., and *Enterococcus* spp. exhibit escalating resistance to primary antibiotics, such as beta-lactams and methicillin, resulting in extended infections, increased treatment expenses, and a heightened risk of lower limb amputation. Comparative analyses of research indicate geographical disparities in pathogen distribution and resistance patterns, emphasizing the necessity for localized surveillance and region-specific treatment protocols. Despite progress in bacterial profiling, significant research deficiencies remain, especially regarding the role of anaerobic bacteria, fungus, and biofilm-associated infections in chronic DFUs. The dependence on culture-based diagnostic approaches restricts the identification of polymicrobial and fastidious species, indicating the necessity for incorporating quick molecular or metagenomic tools into clinical practices.
Subsequent research should concentrate on assessing the clinical effectiveness of alternative therapeutics, including biofilm-targeted medicines, antimicrobial peptides, and regenerative medicine strategies. Furthermore, systematic global data collection and multicenter real-world studies would enhance the evaluation of treatment effects and resistance trends.
The integration of routine microbial culture, susceptibility testing, patient education, and preventive foot care is crucial for enhancing outcomes in DFUs. Addressing these research and clinical deficiencies will be crucial for formulating more effective, targeted, and sustainable methods for managing infections in diabetic patients.

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RAINBOW VERTEX ANTIMAGIC COLORING FOR SQUARE SNAKE GRAPHS AND HEXAGONAL SNAKE GRAPHS

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Abstract

Rainbow vertex antimagic coloring is a novel area of graph theory that com- bines two important concepts, rainbow coloring and antimagic labeling. This study explores these concepts specifically for square snake graphs and hexagonal snake graphs. A graph is said to have a rainbow vertex antimagic coloring if there exists a vertex labeling that makes the edge labeling unique, and the resulting vertex colors induce rainbow paths between any two vertices. The minimum number of colors required to achieve this coloring is known as the rainbow vertex antimagic connection number, denoted as rvac(G). In this research, we analyze for square and hexagonal snake graphs, leveraging their unique structural properties, and compare the difference of rainbow vertex antimagic connection number. These graphs are interesting because of their geometric arrangement and their role in modeling applications in biology, chemistry, and network design. By assigning unique edge labels and ensur- ing each vertex labeling satisfies the rainbow vertex antimagic connection number, we construct rainbow paths that establish a vertex-antimagic rainbow coloring. This study develops new general formulas including some general terms where we can increase or decrease the total number of edges in the graph and use the same formula for graph labeling of that particular graph family under all the necessary conditions to be rainbow vertex antimagic colored graphs. The findings contribute to a broader understanding of rainbow vertex antimagic coloring.

Keywords: Antimagic Vertex Coloring, Rainbow Connection, Graph Labeling Theory, Square and Hexagonal Snake Graphs, Combinatorial Graph Structures

1. Introduction

Graph theory is a dynamic field with applications in diverse areas such as network design, biology, chemistry, and optimization problems. Among its many topics, graph labeling is a prominent area of research. Antimagic labeling, introduced by Hartsfield and Ringel (1990) [4], involves assigning labels to the edges of a graph so that the sum of edge labels incident to each vertex is unique. This labeling creates a structure in which no two edges share the same labeling, making it a valuable concept in both theory and applications.

Rainbow coloring, introduced by Chartrand et al. (2008) [2], focuses on assigning colors to graph edges or vertices such that any two vertices are connected by a path where all edges or vertices along the path have different colors. The minimum number of colors required for such connectivity is termed the rainbow connection number. Combining these ideas, researchers developed rainbow vertex antimagic coloring, where an edge labeling function ensures unique vertex sums and induces rainbow paths between vertices.

In this study, we explore the rainbow vertex antimagic coloring of two specific graph families, square snake graphs, and hexagonal snake graphs. Snake graphs, known for their repeating geometric patterns, represent useful models for molecular structures and network topologies. Using these graphs, we aim to calculate their rainbow vertex an- timagic connection number (rvac(G)). Building on recent studies, such as those by Dafik et al. (2023) [3] and Joedo et al. (2022) [6], this research provides algorithms for vertex labeling to square and hexagonal snake graphs.

1.1 Definitions

1.1 .1 Rainbow Vertex-Connection Graph

In a rainbow vertex connection coloring of a graph G, we assign colors to the vertices of G in such a way that for every pair of vertices u and v, there is a path between u and v such that all internal vertices of this path are colored differently from each other. The path connecting u and v is called a rainbow path if all internal vertices on the path have different colors. [Budi, Dafik, Tirta, Agustin, & Kristiana, 2021]

1.1.2 Antimagic Coloring

A graph G is called antimagic if there is a bijection $f : E(G) \rightarrow \{1, 2, 3, \ldots, |E(G)|\}$, so every vertex has distinct weight, where the node-weights of v vertices are the sum of the labels of all edges adjacent to v. [Marsidi, Agustin, Dafik, & Kurniawati, 2021]

1.1.3 Rainbow Vertex Antimagic Coloring

For a bijective function $f : E(G) \rightarrow \{1, 2, 3, \ldots, |E(G)|\}$, the associate weight of a vertex $v \in V(G)$ against f is,

$$W_f(v) = \sum_{e \epsilon E(v)} f(e),$$

where $E(v)$ is the set of edges incident to v. If for every two vertices u and v, there is a rainbow path between u and v, then f is called the rainbow vertex antimagic labeling of G. Then the graph G is called rainbow vertex antimagic coloring when each $u - v$ edge has a vertex weight color $W_f(v)$. [Marsidi, Agustin, Dafik, & Kurniawati, 2021]

2. Literature Review

The study of rainbow antimagic and rainbow vertex antimagic colorings has recently become an active research area in graph theory, combining the ideas of color connectivity and unique label assignments. Budi et al. (2021) initiated the investigation of rainbow antimagic coloring of graphs, introducing fundamental definitions and demonstrating how specific graph structures influence the existence of such labeling. Their work established the groundwork for later studies on the interaction between rainbow and antimagic properties. Marsidi et al. (2021) expanded this concept by defining rainbow vertex antimagic coloring**,** a new notion that focuses on assigning labels to vertices rather than edges. This development opened new directions for studying how vertex labeling can simultaneously satisfy antimagic and rainbow conditions.

Joedo et al. (2022) advanced the field by exploring vertex amalgamation of graphs, analyzing how combining two or more labeled graphs affects the ability to obtain rainbow antimagic colorings. Their findings are particularly useful for research on composite or modular graph families, such as snake-type graphs. Dafik et al. (2023) contributed further by examining rainbow antimagic colorings on several special graph families, providing constructive examples, existence results, and methods for building these labeling systematically. Their study identifies which graph classes have been solved and which remain open for investigation.

More recently, Ayu et al. (2023) studied rainbow vertex antimagic coloring of shell-related graphs, presenting labeling constructions and computing the rainbow vertex antimagic connection number for graphs with regular, shell-like structures. Their approach, which combines structural decomposition and systematic labeling, provides a valuable methodological reference for analyzing graphs with repeating geometric patterns. Collectively, these studies by Budi et al. (2021), Marsidi et al. (2021), Joedo et al. (2022), Dafik et al. (2023), and Ayu et al. (2023) highlight the progressive development of rainbow antimagic and vertex antimagic colorings across

different graph classes. Together, these works unify three threads the theory of rainbow connection, classical labeling and antimagic ideas and modern combinations of rainbow and antimagic properties applied to specific families of graphs.

However, the literature lacks a focused study of rainbow vertex antimagic coloring for snake graphs with square and hexagonal tiles. Snake graphs are widely used as geometric models in chemistry and network design, and their repeated structure nature suggests the possibility of general labeling formulas, but explicit results for the rainbow vertex antimagic connection number ($rvac(G)$) in these families are not available in the cited works.

This research addresses that gap by, defining and adapting rainbow vertex antimagic coloring to square and hexagonal snake graphs, producing constructive labeling and general formulae that work when the number of edges is increased or decreased while maintaining the required properties and comparing $rvac(G)$ values between the two graph families to reveal how geometry affects labeling complexity.

3. Methodology

This research starts with a detailed review of existing studies on antimagic labeling and rainbow coloring in graph theory. We try to understand the key ideas and theories developed by important researchers such as N. Hartsfield, G. Ringel, Chartrand, Johns, McKeon, Zhang, and others.

In rainbow vertex antimagic coloring, edges are assigned a unique label from the set $\{1, 2, \ldots, p\}$, where p is defined as the number of edges in a graph. For vertex labeling, we take the sum of the adjacent edge labeling. The edge labeling should be adjusted until we obtain the minimum number of distinct vertices labeling, and this number is called the rainbow antimagic connection number.

For both square and hexagonal graphs, n is taken as the total number of squares in the graphs, and the vertex labeling is discovered after generating a pattern. By classifying vertices into several sets, general formulas for vertex labeling are

obtained, and the labeling is denoted as $f(u_i)$, $f(v_i)$, and $f(w_i)$, according to the position.

3.1 Square Snake Graphs

General Square Snake Graph (with one-vertex overlap) is a connected graph formed by attaching multiple square units (4 cycles), where each new square shares exactly one vertex with the previous one. For n squares, the graph has $3n + 1$ vertices and $4n$ edges. This structure resembles a snake-like path of squares.

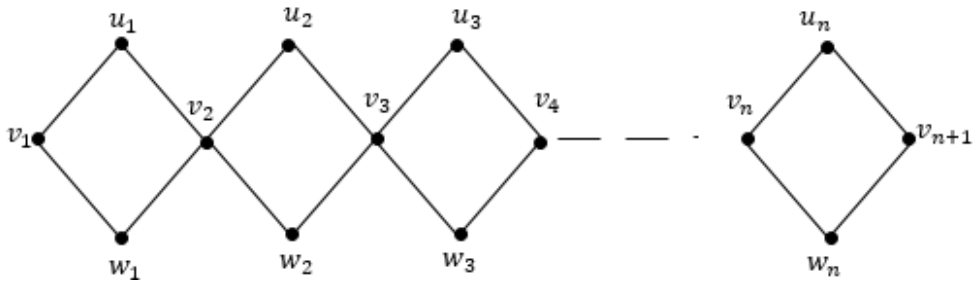


Figure 01: General Square Snake Graph

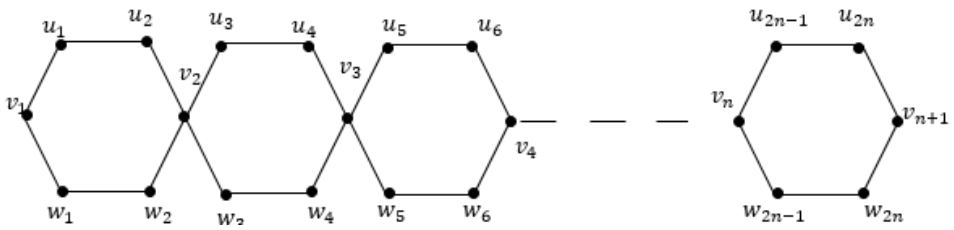
$$f(u_i) = \{4n + 1 \text{ for } i = 1,2, \dots, n$$

$$f(v_i) = \begin{cases} 4n & \text{for } i = 1 \\ 8n + 2 & \text{for } i = 2,3, \dots, n \\ 4n + 2 & \text{for } i = n + 1 \end{cases}$$

$$f(w_i) = \{4n + 1 \text{ for } i = 1,2, \dots, n$$

3.2 Hexagonal Snake Graphs

A General Hexagon Snake Graph (with one-vertex overlap) is a connected graph made by attaching multiple hexagon units (6 cycles), where each new hexagon shares exactly one vertex with the previous one. For n hexagons, the graph has $5n + 1$ vertices and $6n$ edges. This snake-like structure is useful for labeling problems such as Rainbow Vertex Antimagic Coloring.



$$f(u_i) = \begin{cases} 8n+1 & \text{for } i = 1,3,\dots,2n-1 \\ 4n-1-2i & \text{for } i = 2,4,\dots,2n \end{cases}$$

$$f(v_i) = \begin{cases} 4n+1 & \text{for } i = 1 \\ 8n+2 & \text{for } i = 2,3,\dots,n \\ 4n+1 & \text{for } i = n+1 \end{cases}$$

$$f(w_i) = \begin{cases} 4n+1+2i & \text{for } i = 1,3,\dots,2n-1 \\ 8n+1 & \text{for } i = 2,4,\dots,2n \end{cases}$$

Figure 2: General Hexagonal Snake Graph

4. Findings and Discussion

4.1 Square Snake Graphs

For square snake graphs, the results indicate that the rainbow vertex antimagic connection number (denoted as $rvac(G)$) remains constant regardless of the number of squares (polygons) in the graph. After assigning edge labels and calculating the corresponding vertex weights, we observe that the vertex labeling consistently produces only four distinct values that are sufficient to ensure rainbow connectivity between all vertex pairs. This leads to the conclusion that $rvac(G) = 4$ for all square snake graphs, regardless of the number of connected squares.

This consistency highlights the symmetric and repetitive structure of square snake graphs, which allows for efficient and minimal coloring schemes. The result demonstrates that square snake graphs possess a stable labeling pattern that simplifies

the construction of rainbow vertex antimagic colorings, making them ideal candidates for applications that require predictable and low-color connectivity pattern.

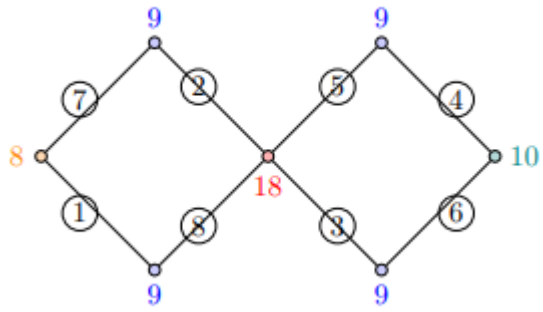


Figure 3: RVA colored square snake graph of $\boldsymbol{n = 2}$

- $rvac(G)$ is 4 since the labeling contains 8,9,10 and 18 as the vertex labeling.

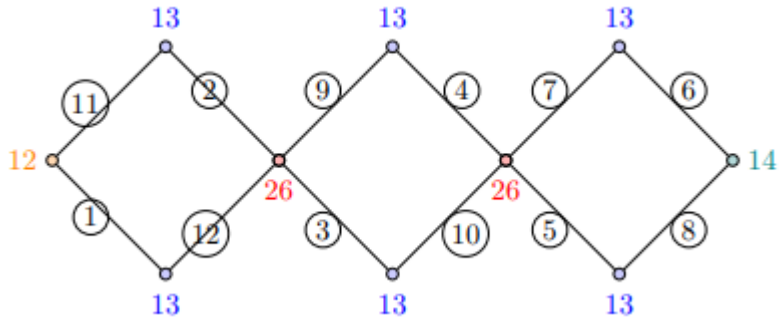


Figure 4: RVA colored square snake graph of $\boldsymbol{n = 3}$

- $rvac(G)$ is 4 since it contains 12,13,14 and 26 for the vertex labeling.

4.2 Hexagonal Snake Graphs

In contrast to square snake graphs, hexagonal snake graphs exhibit a varying $rvac(G)$ that increases with the number of hexagons (n) in the graph. Through vertex labeling based on edge weights, the study reveals that the number of distinct vertex labels required to maintain rainbow vertex antimagic connectivity increases linearly. Specifically, the observed pattern leads to the generalized result $rvac(G) = n + 3$, where n is the number of hexagons in the snake graph.

This linear growth arises from the more complex geometric structure of hexagonal snake graphs, which introduces additional vertex connections and labeling overlaps as the graph expands. Therefore, unlike square snake graphs, hexagon structures demand more colors to preserve the rainbow path property, making their analysis more dynamic and sensitive to structural expansion. The contrast in behavior between the two graph families provides valuable insight into how polygonal structure affects labeling complexity and color requirements. It also reinforces the need for customized algorithms when designing rainbow vertex antimagic labeling for different graph types.

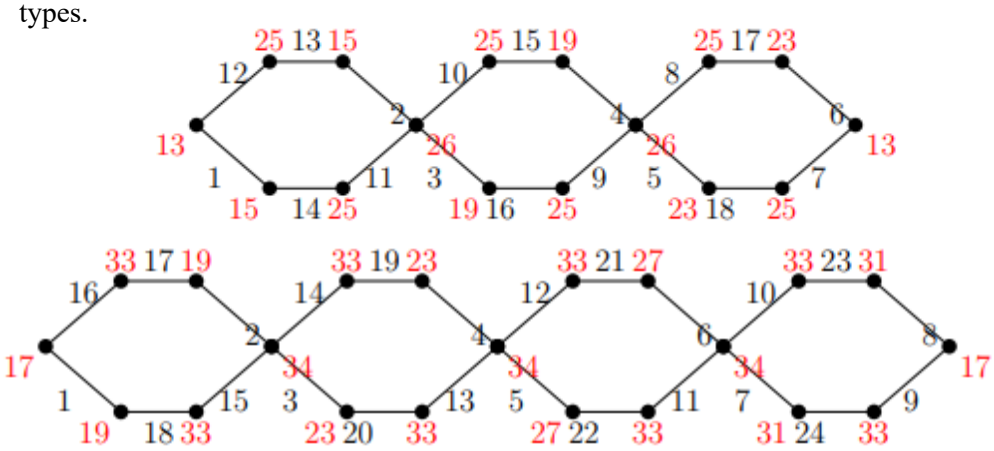


Figure 5: RVA colored hexagonal snake graph of $\boldsymbol{n = 3}$

- $rvac(G)$ is 6 since it contains 13,15,19,23,25 and 26 for the vertex labeling.

Figure 6: RVA colored hexagonal snake graph of $\boldsymbol{n = 4}$

- $rvac(G)$ is 7 since it contains 17,19,23,27,31,33 and 34 for the vertex labeling.

5. Limitations and Recommendations for Future Researchers

This study is limited to square and hexagonal snake graphs with one-vertex overlaps, and the results were obtained mainly through structural analysis and manual verification for small values of n. The research does not cover other polygonal snake graphs or irregular structures, and computational validation for larger graphs was not conducted due to complexity.

Future researchers are encouraged to extend this work to other families of snake graphs, such as triangular or mixed-type forms, and to develop algorithms for automated labeling and verification. Further studies can also explore connections between the rainbow vertex antimagic connection number and other graph parameters, as well as potential applications in network design, chemistry, and cryptography.

6. Conclusion

This study focuses on understanding and developing rainbow vertex antimagic coloring for square and hexagon snake graphs. By assigning unique labels to edges and ensuring vertices induce rainbow paths, we calculate the rainbow vertex antimagic connection number ($rvac(G)$). As we can see in the results $rvac(G)$ for square snake graph is always 4 and it does not depend with the total number of polygons in the graph while hexagon snake graphs do. $rvac(G)$ for hexagon snake graph is $n + 3$ where n denotes the number of polygons (hexagons for these graph families) in the graph. General formulas applicable to these graph families under varying conditions are derived, providing a framework for analyzing and applying rainbow vertex antimagic coloring to structured graph families.

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AN EXPLORATION OF THE PREVALENCE, CAUSES, AND COPING STRATEGIES OF STRESS AMONG UNIVERSITY STUDENTS IN SRI LANKA

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Abstract

Perceived mismatch between external pressures and an individual's capacity to manage them is generally referred to as stress. It can be either short-term or long-term in duration. The stress often leads to academic struggles and difficulties in social adjustment. Among university students in Sri Lanka, it is evident that stress has a notable impact on both academic performance and mental well-being. This literature review explores the levels of perceived stress, its underlying causes, resulting effects, and the coping mechanisms employed by students during their time at university. A comprehensive search of scholarly databases such as Google Scholar, PubMed, and ScienceDirect led to the identification of twenty relevant studies conducted in Sri Lanka from 2014 to 2024. These studies reveal varying degrees of stress among students across different disciplines, with common stressors including intense academic workloads, exam pressure, gender related differences, and concerns about physical health. Although moderate stress can sometimes drive motivation, excessive stress is strongly linked to adverse outcomes such as anxiety, depression, and reduced academic achievement. The research also highlights a range of coping strategies used by students, from effective methods like time management, planning, and seeking social support to less constructive ones like avoidance and substance use. Understanding these trends is essential for developing targeted interventions aimed at improving student wellbeing and academic performance in Sri Lankan universities, thereby contributing to the success of future generations.

Keywords: *factors, Sri Lanka, stress, university students*

1. Introduction

Stress is characterized as the state of mental strain that occurs as a result of various challenging circumstances faced by an individual in their in the day today life. Stress arises when there is a perceived gap between environmental demands and an individual's ability to meet those demands. These environmental demands are generally defined as stressors (Damayanthi, 2014; Wanigasinghe & Rathnayaka, 2019). Stress can also be described as a stimulus that poses a threat to an individual's well-being (S. Senarath, 2020).

Stress has become a significant concern across various domains, including employment, social environments, and academic settings (Peris et al., 2021). University education is widely regarded as a crucial component of an individual's life, as it provides an individual with future employment opportunities and helps in enhancing skills and attitudes that are needed to become a productive citizen in society (Hewage & Ponnamperuma, 2023). This period of university life can be stressful for many students as they are in the process of adapting to an unfamiliar environment. Additionally, the transition from adolescence to adulthood during university years can also be a significant source of stress (Walpola et al., 2020). As a result of this, the university students are prone to various academic, psychological, and social challenges (Peris et al., 2021).

Not all types of stress adversely affect an individual's health (Peris et al., 2021; S. Senarath, 2020). Stress can be either short-term or long-term. Both types of stress exhibit a variety of symptoms in the individuals (Peris et al., 2021). Long-term stress can be particularly harmful if not identified and treated on time, potentially leading to long-term physical and behavioral complications such as depression, back pain, increased blood pressure, headaches, skin disorders, bowel problems, and peptic ulcers. Identifying stress among students earlier and directing them to available supportive services at the university level are crucial for managing its harmful effects

timely manner, which will be crucial in creating a healthy university life for the students (Walpola et al., 2020).

Therefore, it is well understood that the assessment of the stress levels among university students is very crucial. A literature search was conducted in the databases such as Google Scholar, PubMed, and ScienceDirect and twenty relevant studies conducted in Sri Lanka from 2014 to 2024 were identified. The results of the studies were synthesized in this literature review which aims to identify the perceived stress levels, factors affecting perceived stress, outcomes of the stress and the coping mechanisms employed by university students in Sri Lanka. The findings will be instrumental in formulating necessary interventions to address the harmful outcomes of stress and in fostering the development of productive citizens for Sri Lanka.

2. Level of perceived stress among university students

Several studies have examined the perceived stress levels among university students in Sri Lanka, those from both state and non-state sectors. Research has also been conducted among students from health-related and non-health-related disciplines to assess perceived stress levels. These studies illustrate a diverse range of levels of perceived stress among Sri Lankan university students, influenced by their specific study programs and various socio-demographic factors such as age, gender and family size.

A study conducted among nursing undergraduates in the Faculty of Allied Health Sciences at the University of Peradeniya using the Depression, Anxiety and Stress Scale - 21 (DASS-21) revealed that 25% of students reported moderate levels of stress, while 21.7% reported severe levels of stress. In addition to this, 17.4% of the students were classified as having normal stress levels (Rathnayake & Ekanayaka, 2016). In contrast to this study, another study among the same population at the University of Sri Jayewardenepura using the Perceived Stress Scale (PSS) by Cohen indicated that half of the sample experienced high stress levels (Ilankoon & Warnakulasooriya, 2014). This contrast opinion in the result may not only reflect true

differences in stress levels between the two populations but also differences in measurement tools and how they conceptualize and measure the perceived stress. Furthermore, the time the studies were conducted, the university environment, academic workload of the students, the type of assessment and academic support systems available in the university could also influence these results.

During the university experience, students encounter various stressful periods, with examinations being particularly well-known for inducing stress. A study (M. Senarath et al., 2017) assessed the stress levels of physiotherapy students at the University of Peradeniya during their examination period. The mean stress score was 44.3 ± 11.77, with values ranging from 21 to 72. Additionally, male students reported experiencing higher levels of stress compared to female students.

Healthcare-related students from universities in Sri Lanka are expected to be key contributors to the country's health sector in the future. Therefore, understanding their stress levels and coping strategies is crucial for ensuring they can deliver quality and efficient healthcare. A study conducted among health-related students (Allied Health Sciences and Medical) at the University of Ruhuna found that the majority (98.8%) of students were affected by stress, with 20.1% reporting that they always suffer from stress (Peris et al., 2021). Additionally, a survey of medical students at the University of Colombo revealed that the mean stress level of 5th year students was significantly lower compared to that of 2nd and 3rd year students (Ranasinghe et al., 2017). This could be because of several factors such as senior students may have developed better coping mechanisms over time, or their academic environment may offer more clarity, practical engagement and support and they may get adapted to the new environment, which can reduce uncertainty and pressure. In contrast, students in earlier years might be struggling with academic transitions, high expectations, or unfamiliarity with the demands of medical education.

Few studies have compared stress levels between medical and non-medical science students. One study found that medical students experienced higher levels of

psychological distress compared to their non-medical counterparts (Liyanage, 2017). Conversely, a study conducted among 1st year students from four faculties at the University of Colombo revealed that law faculty students had higher stress levels compared to medical faculty students (Nakandalage et al., 2014). This contradicts the common assumption that medical students consistently face the highest academic stress than other disciplines students. This suggests that discipline alone is not a sufficient predictor of students' perceived stress level. Instead, stress is likely shaped by a complex interplay of many factors such as curriculum demands, coping resources, peer pressure, personal expectations and support system available.

Additionally, a study at Uva Wellassa University, which included 1st to 4th year students from three faculties, reported that the majority (48%) had elevated levels of perceived stress, while 35% had moderate stress levels and 17% had low stress levels (Herath, 2019) .

While it is commonly assumed that students in Open Distance Learning (ODL) systems face elevated stress levels generally due to the need to struggle between academic obligations alongside employment and family commitment, a study by Gamage and Herath (2021) reveals a different result. Their findings show that the majority of Open University students reported normal to mild levels of perceived stress, and only a very small percentage (1.63%) experienced extremely severe stress.(Gamage & Herath, 2021). The result shows that the students of the ODL system may have adopted good time management and coping strategies to manage their academic and life commitments. In addition to this, many ODL students tend to be mature students who may possess greater emotional resilience compared to their younger counterparts in conventional universities. Unlike traditional university students, ODL students are not usually required a transition into an unfamiliar physical and social environment, such as moving away from home or adapting to on campus hostel or boarding life. This lack of environmental transition may contribute to lower stress levels, as students remain within familiar surroundings and support systems while pursuing their studies.

Additionally, a survey assessing perceived stress levels among students at a non-state university in Sri Lanka found a mean stress score of 20.72 ± 4.96, which was comparatively higher than the stress levels reported in a study of 2nd year medical students at the University of Colombo (Ranasinghe et al., 2017; Walpola et al., 2020).

3. Factors affecting stress among university students

Numerous studies in Sri Lanka have identified a range of factors influencing the prevalence of stress among university students, with findings varying based on study settings and samples. These factors include personal, academic, and environmental dimensions. The literature provides a comprehensive examination of the relationship between these factors and stress levels.

3.1 Socio demographic characteristics and stress

It is well known that sources of stress may originate from environmental or individual factors (S. Senarath, 2020). In a study conducted among nursing students, the age of the students was not found to be associated with stress levels (Rathnayake & Ekanayaka, 2016). Conversely, research at Sri Jayewardenepura University revealed there was an association between age and perceived stress among students in the Faculty of Medical Sciences (p=0.042).

However, age did not show a statistically significant association with stress levels among students in the Faculties of Humanities and Social Sciences and Applied Sciences (Wanigasinghe & Rathnayaka, 2019). Additionally, another study reported that students aged 18-21 experienced higher levels of stress (54%) compared to those aged 22-24 (23%) (Nakandalage et al., 2014). The inconsistency across studies also highlights the importance of discipline-specific analyses. The influence of age on stress could not be simply to generalize without considering academic culture, support systems, and personal circumstances unique to each faculty or institution.

Another widely studied factor is gender. Numerous studies have found no significant association between gender and stress levels among students (Ilankoon &

Warnakulasooriya, 2014; Jayasena & Abeysinghe, 2023; Liyanage, 2017; Ranasinghe et al., 2017; Rathnayake & Ekanayaka, 2016; Walpola et al., 2020; Wanigasinghe & Rathnayaka, 2019). However, one study conducted during the examination period found that male students experienced higher levels of distress compared to female students (M. Senarath et al., 2017) . Supporting this finding, it was observed that among 1st year students, males were more distressed than females. This highlights a potential concern regarding the development of coping strategies among males and a lack of evidence regarding bodily harm events among Sri Lankan male students (Nakandalage et al., 2014). In addition to this one possible explanation to this result could be the male students may be less likely to develop or employ adaptive coping mechanisms or may face cultural expectations that discourage help-seeking behaviors.

Across various samples and settings, most studies have concluded that demographic factors such as family type, ethnicity, religion, area of residence, monthly family income, parents' education and employment status, and marital status are not significantly associated with the prevalence of stress (Ilankoon & Warnakulasooriya, 2014; Liyanage, 2017; Ranasinghe et al., 2017; Rathnayake & Ekanayaka, 2016; Walpola et al., 2020).

At the University of Sri Jayewardenepura, the stress levels of students from the Faculty of Humanities and Social Sciences were found to be associated with family size ($p=0.008$) and family type ($p=0.025$). Additionally, for students in the Faculty of Management Studies and Commerce, whether they lived at home or not was significantly associated with stress levels ($p=0.001$) (Wanigasinghe & Rathnayaka, 2019).

3.2 Academic related factors and stress

Academic-related examinations are widely regarded as a major factor influencing stress levels among students due to their significant impact on future careers (Tiwari et al., 2012). While some stress during exams is normal, excessive stress can diminish a student's efficiency(S. Senarath, 2020). A study among physiotherapy students found that stress levels increased with each academic year, potentially due to the growing workload associated with clinical placements and practical work (M. Senarath et al., 2017). However, other studies found no significant association between academic year and stress levels (Rathnayake & Ekanayaka, 2016; Walpola et al., 2020) which is consistent with the results of (Ranasinghe et al., 2017) , where the mean stress scores for 2nd and 4th-year medical students were 19.9 ± 5.1 and 19.6 ± 5.6, respectively. These mixed results suggest that academic year alone is not a predictor of stress. The nature of assessment, the presence of clinical or field practice, faculty expectations, support systems available, and personal coping mechanisms likely play significant roles.

For nursing students, satisfaction with their program was not significantly associated with stress levels ($p=0.065$). In contrast, for medical undergraduates at the University of Colombo, program satisfaction was significantly associated with stress levels ($p <0.001$) (Ranasinghe et al., 2017; Rathnayake & Ekanayaka, 2016).

Academic workload has emerged as a major source of perceived stress among students (Damayanthi, 2014; Herath, 2019). In nursing students, inadequate support during clinical practice was linked to higher stress levels (Ilankoon & Warnakulasooriya, 2014), while clinical appointments, including interactions with consultants, were identified as major stressors for medical students (Liyanage, 2017). Additionally, nursing students reported that competition with peers was a significant source of stress (Damayanthi, 2014; Ilankoon & Warnakulasooriya, 2014). Healthcare-related students also cited excessive assignments as a stressor (Ilankoon & Warnakulasooriya, 2014; Liyanage, 2017).

Non-medical students frequently mentioned transport issues, meal quality, and the high cost of living as primary sources of stress (Liyanage, 2017). A study of healthcare students at Ruhuna University found that exams and exam timetables were significant contributors to high stress levels (Peris et al., 2021).

3.3 Physical Health and stress

Physical health is closely connected to mental health; thus, individuals experiencing poor physical health may also exhibit compromised mental well-being, potentially leading to reduced performance and productivity. This relationship was demonstrated in a study by (Rathnayake & Ekanayaka, 2016), which found a statistically significant association between self-perceived physical health and stress levels among nursing students ($p = 0.026$).

3.4 Self-efficacy and stress

Albert Bandura established the self-efficacy theory in 1986. According to Bandura, self-efficacy refers to an individual's cognitive assessment of their own competence. It represents how well a person believes they can plan and manage their daily activities. Stress arises when an individual perceives a particular situation or stimulus as a threat. Thus, an individual's level of self-efficacy can influence their stress levels (Sebastian, 2013) . This concept is supported by a study that found a weak negative correlation between perceived stress and general self-efficacy among students ($p < 0.001$, $r = -0.293$) (Walpola et al., 2020).

4. Outcomes of stress among university students

Stress can impact an individual's well-being by either increasing or decreasing productivity. Decreasing productivity leads to diminished performance and lower achievement levels among students (Walpola et al., 2020). However, moderate levels of stress can be beneficial, as they can motivate and encourage individuals to achieve their goals (Noordeen et al., 2018).

Stress can impact various aspects of an individual's life, including physiological, behavioral, and psychological dimensions. Physiological problems may involve hormonal imbalances and medical issues, while psychological problems can include anxiety, depression, and a lack of life satisfaction. Additionally, behavioral issues such as alcohol and substance abuse, as well as poor performance, can also result from stress (Sebastian, 2013). Research has indicated that stress can negatively impact the learning process and memory, although moderate levels of stress can enhance learning and cognitive functions (Herath, 2019; Rathnayake & Ekanayaka, 2016).

A study conducted among students at Uva Wellasa University found that academic stress was significantly associated with Grade Point Average (GPA), indicating that stress influences academic success (Herath, 2019) . Similarly, a study of 3rd year Management undergraduates revealed a negative correlation between academic performance and stress levels ($p < 0.05$, $r = -0.536$), suggesting that higher stress levels are associated with lower academic performance (Praveeni & Herath, 2020) . In contrast, stress levels were not significantly associated with examination results among medical students (Ranasinghe et al., 2017). This might be possibly due to a high baseline of academic motivation that buffers the effects of stress in this group. Additionally, (Hewage & Ponnamperuma, 2023) reported that academic procrastination was negatively associated with stress among university students in the Western Province of Sri Lanka. his is counterintuitive, as procrastination is typically viewed as a cause of stress. This finding might suggest that some students use procrastination as a temporary coping strategy, avoiding stress in the short term, even though it may lead to long-term negative consequences.

It is well-established that anxiety and depression are associated with stress, with various studies demonstrating a significant positive correlation between stress and both depression and anxiety (Kumari & Jian, 2014; Tiwari et al., 2012). This finding is consistent with a study conducted among nursing students at the University of Peradeniya, which reported a significant positive relationship between stress and

depression ($r = 0.785$, $p < 0.001$) as well as between stress and anxiety ($r = 0.763$, $p < 0.001$) (Rathnayake & Ekanayaka, 2016). Additionally, a study from the same setting in 2014 found that students experienced anxiety because of stress (Damayanthi, 2014).

Commonly reported mental symptoms of stress among students include increased nervousness (Damayanthi, 2014; Ilankoon & Warnakulasooriya, 2014), frequent feelings of tiredness (Ilankoon & Warnakulasooriya, 2014), and difficulties with concentration (Damayanthi, 2014; Herath, 2019). Physically, nursing students at Sri Jayewardenepura University reported chest tightness as a stress-related issue (Ilankoon & Warnakulasooriya, 2014). Additionally, (Damayanthi, 2014) noted that stress among nursing students was associated with neck or back pain, migraines, and breathing difficulties.

Quality and quantity of sleep are crucial indicators of an individual's overall health, affecting both mental and physical well-being. Stress levels are a significant predictor of sleep quality among students. Academic workloads and irregular sleeping patterns can adversely impact sleep quality. This is supported by a study that found a positive correlation between sleep quality and perceived stress ($r = 0.199$, $p < 0.05$, $N = 120$) among students at a non-state higher educational institution (Jayasena & Abeysinghe, 2023). Additionally, 32.2% of nursing students reported experiencing poor sleep due to stress (Ilankoon & Warnakulasooriya, 2014).

A study conducted among female students at the University of Peradeniya explored the association between stress and obesity prevalence. The study revealed a significant association between waist circumference and obesity ($p < 0.05$), providing evidence that stress influences body fat distribution, likely due to hormonal imbalances (Ekanayake & Mudiyanse, 2020). While the association is statistically significant, further longitudinal research is needed to confirm causality and explore mediating variables such as diet, coping mechanisms, and sleep patterns. The key finding is summarized in the table 01.

Domain	Effect of stress	Studies
Productivity	Decreased productivity and cause lower academic achievement	(Walpola et al., 2020)
	Moderate level of perceived stress motivates goal achievement	(Noordeen et al., 2018)
Cognitive functions	High stress impairs memory and learning; Moderate stress enhances cognitive performance	(Herath, 2019; Rathnayake & Ekanayaka, 2016)
Academic performance	Associated with the academic performance of the students	(Herath, 2019; Praveeni & Herath, 2020)
	Shows no effect in some medical students	(Ranasinghe et al., 2017)
Behavior	Procrastination unexpectedly linked to reduced stress	(Hewage & Ponnamperuma, 2023)
Psychological health	High correlation with anxiety and depression	(Damayanthi, 2014; Kumari & Jian, 2014; Rathnayake & Ekanayaka, 2016; Tiwari et al., 2012)
Mental symptoms	Nervousness, fatigue, poor concentration	(Damayanthi, 2014; Herath, 2019; Ilankoon &

		Warnakulasooriya, 2014)
Physical symptoms	Tiredness, chest tightness, migraines, neck/back pain, breathing difficulties	(Damayanthi, 2014; Ilankoon & Warnakulasooriya, 2014)
Sleep quality	Poor sleep due to stress And academic workload and irregular routines negatively affect sleep	(Ilankoon & Warnakulasooriya, 2014; Jayasena & Abeysinghe, 2023)
Obesity	Stress associated with waist circumference and fat distribution (via hormonal mechanisms)	(Ekanayake & Mudiyanse, 2020)

Table 1: Summary of the outcome of stress reported in included literatures

5. Coping mechanisms employed by the students

Coping strategies are specialized behavioral and psychological techniques that individuals use to manage, accept, reduce, or minimize stressful situations in their lives (Dubai et al., 2011) . Over the years, researchers have developed various perspectives on stress and the coping mechanisms employed by individuals. While coping capabilities and methods can vary among students from different backgrounds and disciplines, students who exhibit resilience tend to handle stressful situations more effectively (S. Senarath, 2020).

Individuals typically use two main strategies to cope with stress: active and avoidance coping. Active coping mechanisms involve taking steps to address and change the stressor itself, while avoidance mechanisms lead individuals to engage in activities that distract them from the stressful situation and escape from the situation. Active coping is generally considered a more productive approach to managing stress

effectively, whereas avoidance can result in additional psychological and physiological consequences which may affect physical and psychological well-being (Dubai et al., 2011). During university life, students encounter various stressors; therefore, employing appropriate individualized coping mechanisms is crucial for managing stress effectively and enhancing their productivity (Peris et al., 2021).

A study conducted among students at Uva Wellasa University found that time management was the most commonly used strategy for coping with stress (Herath, 2019). While this sounds effective, it raises several critical questions about the depth and effectiveness of such a coping approach. Time management is often promoted as a primary solution to academic stress; however, its successful application requires a set of cognitive and behavioral skills such as goal setting, prioritization, self-discipline, and the ability to delay procrastination that many students may not have been formally trained. Therefore, it finally provides only temporary relief because what they practice may be inefficient or inconsistent.

According to (Noordeen et al., 2018), medical students commonly used the following strategies: watching movies (81.8%), planning (86.8%), talking with friends or parents (88.3%), listening to music (90.6%), and sleeping (92.2%). Conversely, smoking (6.8%) and drug abuse (6.5%) were the least utilized strategies. Among the reported strategies, engaging in religious activities (95.21%) and seeking advice from lecturers and seniors (94.31%) were considered the most effective. In contrast, showing anger towards others (53.79%) and engaging in video and computer games (78.13%) were deemed less effective coping methods.

Another study among healthcare-related university students found that common coping strategies included sleeping (93.6%), meeting or talking to friends or loved ones (89.8%), eating (86.3%), and taking a walk (84%). The least used strategies were accessing university Career Guidance Services (69.4%) and meeting with a psychologist (70%). While these findings reflect a dependent on informal and readily accessible coping mechanisms, they also highlight a concerning lower level of

utilization of professional support systems available in the university settings. Students tend to use immediate and familiar activities such as sleeping or social interaction which might give them short-term emotional relief, but they do not take the necessary steps to identify and address the root causes of their stress. This suggests a possible lack of awareness, problems in accessibility, or low level towards formal institutional resources such as counseling or career guidance services. The social stigma associated with seeking psychological help, particularly in South Asian cultural contexts, may discourage students from utilizing the profession support systems. Notably, this study also revealed that nearly half of the participants used alcohol (51.9%) and smoking (50.4%) as stress management strategies (Peris et al., 2021). Thus, sleeping and talking to friends emerged as the most frequently used coping strategies among health-related undergraduates, consistent with findings from previous studies (Noordeen et al., 2018; Peris et al., 2021).

6. Conclusion

Research studies conducted in Sri Lanka among university students to assess the perceived stress levels reveal a complex interplay of factors, including academic demands, personal issues, and coping strategies. These studies consistently show varying stress levels across different disciplines within Sri Lankan universities.

Demographic factors such as age, gender, family income, and parental education showed inconsistent associations with stress, suggesting that while these factors may influence stress perception in specific contexts, they are not universally predictive. Nonetheless, self-efficacy emerged as a crucial determinant, with students possessing higher self-efficacy experiencing lower stress levels. This supports the theoretical view that internal coping resources play a significant role in stress management.

Importantly, stress has been shown to impact students' academic performance and overall productivity. While some level of academic stress may enhance learning, elevated stress levels are more commonly associated with decreased GPA, procrastination, and impaired memory and concentration. Physiological and

behavioral outcomes such as insomnia, anxiety, depression, and substance use also illustrate the broader implications of unmanaged stress.

Despite these challenges, students use a range of coping strategies, from time management to social support networks, which are crucial for managing stress and achieving academic success. Understanding these dynamics is essential for developing effective interventions that promote student well-being and improve educational outcomes across Sri Lanka's diverse university settings.

7. Recommendations

This literature review emphasizes the urgent need for universities in Sri Lanka to implement evidence-based strategies to identify, mitigate, and manage student stress irrespective of discipline and university settings. Institutional support systems, curriculum reforms, and psychological support services must be strengthened and promoted among university students to foster a healthy academic environment. Students must be informed that the utilization of the short-term methods to relieve stress will not help to identify the root cause of the stress. Although the research is conducted among the students to identify the level of stress, there must be a proper tracking system to identify the students who have higher stress and refer them to the support system.

Understanding the sources and outcomes of stress can inform targeted interventions to not only improve student well-being but also enhance academic performance, reduce dropout rates and productivity of the institution. As students are the future workforce and leaders of the country, their mental health is very important for national development. Without adequate support, the prolonged stress experienced during their university life may have long-term consequences for both the individual and society at large.

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THE IMPACT OF BAD DEBT LEVELS ON THE FINANCIAL PERFORMANCE INDICATORS: EVIDENCE FROM SRI LANKA'S NON-FINANCIAL PRIVATE SECTOR

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Abstract

This study investigates the impact of bad debt levels on the financial performance of non-financial private sector companies in Sri Lanka. Amidst the country's recent economic instability characterized by inflation, currency depreciation, and credit market disruptions bad debts have emerged as a critical challenge affecting corporate sustainability. The research aims to empirically examine how variations in bad debt levels influence key financial performance indicators such as profitability (ROA, ROE, NPM), liquidity (current ratio, quick ratio), solvency (debt-to-equity ratio, interest coverage ratio), and efficiency (accounts receivable turnover ratio). A quantitative research design was adopted using secondary data from audited annual reports of 20 non- financial private sector companies listed on the Colombo Stock Exchange for the period of 2020–2024. Data were analyzed using EViews software through descriptive statistics, correlation analysis, and panel regression techniques (Fixed Effects and Random Effects models). The Hausman specification test determined the most appropriate model for each financial dimension. The findings reveal a statistically significant negative relationship between bad debt levels and all key financial performance indicators. Specifically, higher bad debt ratios were associated with declines in profitability, liquidity, solvency, and efficiency. The results indicate that rising uncollectible receivables weaken firms' ability to generate earnings, meet short-term obligations, and sustain operational efficiency. The Random Effects model was validated for most indicators, confirming the robustness of the results. The study concludes that effective credit risk management and receivable control mechanisms are essential for safeguarding financial performance in Sri Lanka's private sector. It recommends strengthening internal credit policies, implementing SLFRS 9- based expected credit loss models, and enhancing debt recovery frameworks. The findings contribute to the limited body of empirical literature on bad debts in Sri Lanka's non-financial sector and offer practical implications for managers, investors, and policymakers aiming to improve corporate financial resilience.

Keywords: Bad Debt, Financial Performance, Profitability, Liquidity, Solvency, Efficiency, SLFRS 9, Private Sector, Sri Lanka

1. Introduction

1.1 Background

In Sri Lanka's dynamic and often volatile economic landscape, the private sector plays a vital role in driving economic growth, employment and innovation (world bank 2020). However, the widespread use of credit sales as a competitive strategy while supporting sales growth has simultaneously elevated the risk of customer defaults, leading to rising levels of bad debts (Nyawa, P. M., Wekesa, M. W., & Kising'u, T. M. 2025, Pike & Cheng 2001). Bad debts defined as receivables unlikely to be collected (Al Zaidanin, J. S., & Al Zaidanin, O. J. 2021) adversely influence financial performance by reducing cash inflows, straining liquidity and increasing dependency on external financing (Yazdanfar & Ohman,2015, Abubakar B A & Sulaiman A.A 2021). Sri Lanka's recent macroeconomic challenges including currency depreciation, inflation and the sovereign debt crisis have further worsened credit risk, making bad debt management a critical issue for non-financial private sector firms (IMF 2023).

1.2 Research Gap

Despite growing relevance, minimal empirical research has explored the specific impact of bad debt levels on the financial performance of non-financial private sector companies in Sri Lanka. Existing studies predominantly examine financial institutions (Al Zaidanin, J. S., & Al Zaidanin, O. J. 2021), leaving a gap in understanding how bad debt affects performance indicators like profitability, liquidity, solvency, and efficiency in other industries. Furthermore, theoretical frameworks such as Credit Risk Theory and Liquidity Preference Theory remain under applied in Sri Lankan corporate contexts. This study addresses both empirical and theoretical gaps, offering timely insights within an under-researched but high-risk sector.

1.2.1 Research Problem

What is the extent to which bad debt levels influence the financial performance of non-financial private sector companies in Sri Lanka?

1.3 Research Questions

1. What is the relationship between bad debt levels and the profitability of non- financial private sector firms in Sri Lanka?
2. How do bad debt levels influence the liquidity position of these firms?
3. To what extent do bad debt levels affect solvency and efficiency indicators?
4. What strategies can firms adopt to mitigate the adverse financial impacts of bad debts?

1.4 Objectives of the study

- To investigate the impact of bad debt levels on key financial performance indicators of private sector firms in Sri Lanka.
- To assess the relationship between bad debts and profitability, liquidity, solvency and efficiency.
- To provide practical recommendations for managing bad debt to improve financial stability.

1.5 Significance of the study

This study makes significant contributions to financial decision making, policy development, and academic inquiry. For practitioners, it offers evidence-based insights to strengthen credit risk management and enhance financial resilience. For investors and creditors, the findings serve as a diagnostic tool to evaluate corporate risk. Policymakers may utilize the outcomes to strengthen regulatory standards around receivable management. Academically, the study enriches the limited literature on bad debt and financial performance within a developing economy context, especially under recent economic shocks.

2. Literature Review

2.1 Introduction

This section reviews scholarly literature on the nexus between bad debt levels and corporate financial performance, focusing on non-financial private sector firms. Bad debt defined as irrecoverable receivables (Douglas & Raudla 2020) has been widely acknowledged as a critical factor affecting firm sustainability due to its direct impact on cash flows, profitability, and financial health. While substantial research has been conducted in developed economies and within the financial sector, limited studies investigate this relationship in emerging economies like Sri Lanka. This review synthesizes theoretical foundations, financial performance metrics, and empirical findings to identify relevant knowledge gaps and justify the present study.

2.2 Theoretical Foundation

2.2.1 Credit Risk Theory

Credit Risk Theory posits that firms incur default risk when extending credit to customers. Increasing bad debts elevate credit risk exposure, leading to higher operational costs, reduced earnings, and weakened capital adequacy (Nyawa, P. M., Wekesa, M. W., & Kising'u, T. M. 2025). As organizations expand credit sales to fuel revenue growth, managing the associated risk becomes vital to prevent erosion of profitability and liquidity.

2.2.2 Liquidity Preference Theory

According to Keynes Liquidity Preference Theory, firms maintain liquidity to manage uncertainty and preserve flexibility (Ghani, U. (2023). Bad debts compromise this position by reducing cash inflows, which undermines operational stability and potentially increases reliance on external debt. Firms in emerging markets face heightened liquidity pressure due to limited access to financing instruments.

2.2.3 Agency Theory

Agency Theory highlights potential conflicts between managers and owners concerning resource allocation and risk management priorities (Jensen & Meckling 1976). High levels of bad debt may result from lax credit policies or inefficient receivables monitoring, often reflecting managerial inefficiencies or misaligned incentives. Addressing bad debts thus becomes central to improving firm level stewardship and financial governance (Zogning, F. 2017).

2.3 Financial Performance Indicators

Firm level financial performance is commonly evaluated through profitability, liquidity, solvency and efficiency measures (Fajri, O. M. 2024)

Profitability

Metrics such as Return on Assets (ROA), Return on Equity (ROE), and Net Profit Margin (NPM) assess a firm's capacity to generate earnings from assets or equity. Bad debts reduce profitability by raising operating expenses and diminishing revenue (Erina & Lace 2013, Demel & Buddhika 2025)

Liquidity

Current and Quick Ratios measure a firm's ability to meet short-term obligations. High levels of bad debt disrupt cash flows, weakening liquidity and potentially prompting costly external financing (Baker & Stein 2004, Shahimi et al. 2021, Ahmad S M,Omar 2019).

Solvency

Indicators like debt to Equity and Interest Coverage Ratios evaluate long term financial stability. Rising bad debts impair retained earnings and increase leverage, compromising solvency (Vlad 2014, Phan Thi Hang, N. 2023).

Efficiency

Accounts Receivable Turnover reflects how effectively firms manage credit collections. Poor receivables management associated with higher bad debts reduces turnover and operational efficiency (Cihak et al 2012, Sirisumani et al 2024).

2.4 Empirical Evidence

2.4.1 Bad debt and Profitability

Kipkoech and Kenyatta (2015) and Swamy (2017) report a robust negative relationship between bad debts and profitability across sectors. Recent findings from industrial firms in emerging economies reaffirm this inverse association. (Sirisumani et al 2024) However, research covering Sri Lanka's non-financial private sector is limited, especially in the post pandemic context.

2.4.2 Bad Debt and Liquidity

Onwong'a et al. (2023) found that increasing uncollectible accounts reduce liquidity in Kenyan manufacturing firms. Similar findings from Nigerian industrial companies demonstrate consistent liquidity deterioration with rising debts ratios (Ismail Alhassan 2021). These results are yet to be validated in Sri Lanka's private sector landscape.

2.4.3 Bad Debt and Solvency

Persistent bad debts elevate leverage and threaten long-term solvency (Haabazoka et al. 2021). In Romania, firms facing rising bad debt levels exhibited growing debt-to-equity ratios due to external financing used to mask receivable losses (Vlad 2014). The lack of analogous evidence for Sri Lankan private firms presents a significant knowledge gap.

2.4.4 Bad Debt and Efficiency

Inefficient receivable management contributes directly to rising bad debt risks, with negative consequences on cash conversion cycles and asset turnover (Sirisumani

2024). Firms with poor credit determination mechanisms face reduced operating efficiency and greater exposure to financial fragility.

2.5 Research Gap

Despite extensive documentation of the detrimental effects of bad debts globally, empirical research specific to Sri Lanka's private sector remains sparse, fragmented, and outdated (De Mel & Buddhika 2025). Most local studies have centered on banking institutions while neglecting non-financial firms. Additionally, existing research has not fully accounted for the economic disruptions of 2020-2024 triggered by the Covid-19 pandemic and the sovereign debt crisis. This study fills this empirical gap by analyzing recent panel data from listed non-financial firms in Sri Lanka, offering a timely perspective on how bad debt impacts profitability, liquidity, solvency and efficiency.

3. Methodology

3.1 Research Design

This study employs a quantitative, explanatory research design to investigate the relationship between bad debt levels and financial performance among non- financial private sector companies in Sri Lanka. A panel dataset covering the period 2020-2024 was compiled using audited financial statements allowing for robust statistical analysis of firm-level financial indicators. The design aligns with the study's deductive approach, enabling hypothesis testing through inferential statistics.

3.2 Conceptual Definition and Hypotheses Development.

3.2.1 Key Concept Definitions

Bad Debt levels, refers to the proportion of accounts receivable deemed uncollectible, typically expressed as a percentage of total credit sales or receivables (Douglas & Raudla 2020). Financial performance indicators measured through four dimensions, of profitability (ROA, ROE, NPM), Liquidity (Current and Quick ratios), Solvency

(Debt-to- Equity ratio, Interest Coverage ratio) Efficiency (Accounts receivable turnover ratio). Financial performance uses quantifiable metrics to evaluate a company's financial strength for profitability and efficiency against its strategic goals or industry benchmarks (Agyapong D 2011).

3.2.2 Hypotheses Development

Based on the literature on bad debt and financial performance (e.g., Swamy 2017, Ismail 2021, Sirisumani 2024) the following hypotheses were developed.

Hypothesis code	Null Hypothesis (H0)	Alternative Hypothesis
H1	There is no significant impact between bad debt levels and profitability of non-financial private sector companies in Sri Lanka.	There is a significant impact between bad debt levels and profitability of non-financial private sector companies in Sri Lanka.
H2	There is no significant impact between bad debt levels and liquidity of non-financial private sector companies in Sri Lanka.	There is a significant impact between bad debt levels and liquidity of non-financial private sector companies in Sri Lanka.
H3	There is no significant impact between bad debt levels and solvency of non-financial private sector companies in Sri Lanka.	There is a significant impact between bad debt levels and solvency of non-financial private sector companies in Sri Lanka.
H4	There is no significant impact between bad debt levels and efficiency of non-financial private sector companies in Sri Lanka.	There is a significant impact between bad debt levels and efficiency of non-financial private sector companies in Sri Lanka.

Source: Author

3.3 Conceptual Framework

The conceptual model illustrates the hypothesized relationship between bad debt levels (independent variable) and financial performance (dependent variables) with a multi -dimensional performance perspective.

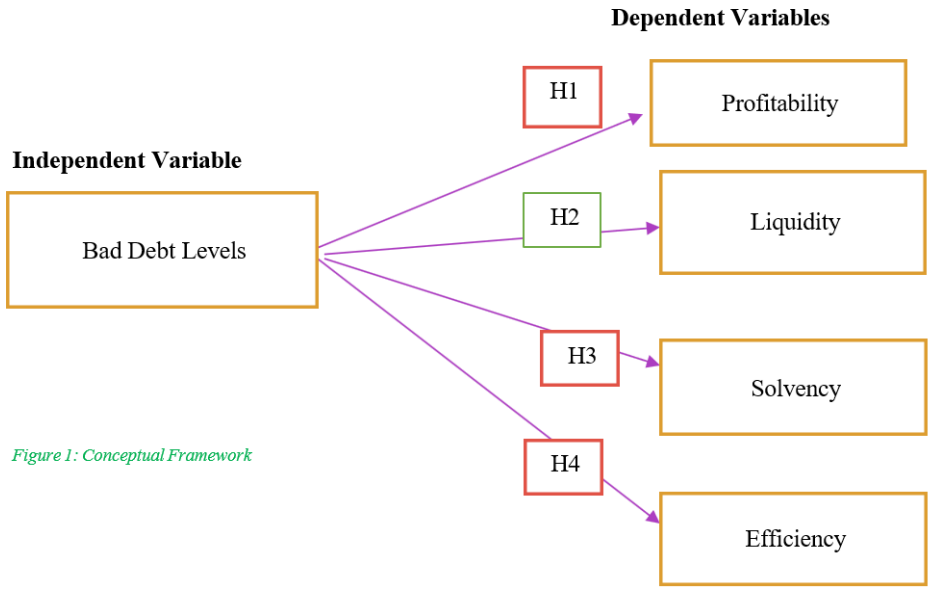

Figure 1: Conceptual Framework

3.4 Measurement of Variables

Table 1: Variable measurement summary

Construct	Indicators	Measurement	Source
Bad debt levels	Bad debt expenses as % of revenue or receivables.	Ratio	SLFRS 9 Douglas Raudla,2020
Profitability	ROA, ROE, NPM	Ratio	De Mel & Buddhika, 2025

Liquidity	Current ratio, Quick ratio	Ratio	Shahimi, 2021
Solvency	Debt to equity ratio, Interest coverage ratio	Ratio	Phan Thi Hang, N. 2023
Efficiency	Accounts receivables turnover ratio	Ratio	Sirisumani ,2024

The study utilizes financial ratios derived from audited financial statements.

3.5 Data Sources and Sampling

3.5.1 Population and sampling technique

The population comprises all non-financial private sector firms listed on the Colombo Stock Exchange (CSE). A purposive sampling technique was adopted to select 20 companies from sectors with significant credit exposure and adequate disclosure of bad debt and performance data. Firms were included based on, availability of audited financial statements for 2020-2024, clear disclosure of accounts receivable and bad debt expenses, compliance with SLFRS/IFRS reporting standards (Sri Lanka Financial reporting Standard, International Financial Reporting Standards).

3.5.2 Unit of Analysis

The unit of analysis is the individual firm, enabling firm-level assessment of credit risk and performance dynamics.

3.6 Data collection and analysis

Secondary data was extracted from audited annual reports, accessible via the Colombo Stock Exchange website and company disclosures. The analytical approach includes, descriptive statistics for summary trends, correlation analysis to assess inter-variable relationships, panel regression (fixed and random effects models) to test

hypotheses, Hausman test to determine the appropriate model, conducted in EViews software for econometric rigor.

This methodology systematically operationalizes concepts, aligns variables with theory, and specifies procedures for a rigorous empirical test of how bad debt levels affect financial performance. The use of firm-level panel data and multiple financial dimensions enhance the robustness and applicability of findings for managers, investors, and regulators in Sri Lanka and similar emerging markets.

3.7 Justification for methodological choice.

The adoption of a quantitative research design with secondary financial data analysis is appropriate for answering the research question namely, how bad debt levels influence the financial performance of non-financial private sector companies in Sri Lanka. This approach allows for objective and systematic measurement of the relationships among variables using audited, numerical data that are standardized across firms and over time. Such a design ensures high levels of reliability and comparability (Hair et al. 2020). Furthermore, the use of panel data econometrics enables control over unobserved firm-specific effects and enhances the statistical power of the analysis, making it suitable for studying financial phenomena across multiple power of the analysis, making it suitable for studying financial phenomena across multiple entities and years (Baltagi 2008). By employing robust techniques such as fixed and random effects models, the study accurately captures the causal impact of bad debt levels on key random effects models, the study accurately captures the causal impact of bad debt levels on key financial performance indicators, while mitigating issues of endogeneity and multicollinearity (Gujarati & Porter 2009). Therefore, this method provides a rigorous empirical foundation to support informed conclusions and practical recommendations on credit risk management in the corporate sector.

4. Data Analysis and results

4.1 Overview

This section presents the empirical results assessing the impact of bad debt levels on the financial performance of non-financial private sector companies in Sri Lanka. Using a balanced panel of 20 firms covering the period 2020–2024, panel regression techniques were applied to estimate the effects of bad debt on profitability, liquidity, solvency, and efficiency. Descriptive statistics, correlation analysis, and regression models (Fixed Effects and Random Effects) were used, followed by model selection via the Hausman test.

4.2 Descriptive Statistics

Table 4 1: Descriptive Statistics of variables

	ART	BD	CURRENT	DE	IC	NPM	QUICK	ROA	ROE
Mean	5.007500	4.149300	1.810000	1.507200	2.579200	7.932000	1.378300	7.104100	13.80540
Median	4.160000	3.195000	1.270000	0.865000	1.835000	5.105000	0.990000	4.680000	10.04500
Maximum	21.19000	16.44000	8.200000	6.650000	13.25000	44.34000	7.100000	53.50000	84.20000
Minimum	0.050000	0.000000	0.250000	0.190000	-1.130000	-17.25000	0.060000	-11.77000	-7.880000
Std. Dev.	4.213285	3.536567	1.534201	1.512192	2.461800	10.57283	1.415635	10.21021	16.45013
Skewness	1.354894	1.088019	1.833642	1.639336	1.674912	1.081983	2.057397	2.577307	1.850499
Kurtosis	5.347164	3.880740	6.514761	5.219934	7.074105	5.284179	7.081945	10.84976	7.116522
Jarque-Bera	53.55054	22.96183	107.5105	65.32415	115.9152	41.25093	139.9742	367.4532	127.6797
Probability	0.000000	0.000010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	500.7500	414.9300	181.0000	150.7200	257.9200	793.2000	137.8300	710.4100	1380.540
Sum Sq. Dev.	1757.425	1238.223	233.0236	226.3858	599.9855	11066.68	198.3982	10320.59	26790.07
Observations	100	100	100	100	100	100	100	100	100

Source: Author's calculated from EViews 2025

4.2.1. Measures of Central Tendency (Mean and Median)

Table 4.2: Measures of Central Tendency

Interpretation

Variable	*Mean Interpretation*
Bad Debt (BD = 4.15)	On average, firms have a bad debt ratio of 4.15%, indicating a moderate level of uncollectible receivables relative to total credit sales.
ROA (7.10) & ROE (13.80)	Firms generate an average return of 7.10% on assets and 13.80% on equity, showing profitability.
NPM (7.93)	Average net profit margin of 7.93% suggests firms retain around 8% of their revenue as profit.
Current Ratio (1.81) & Quick Ratio (1.37)	Both ratios are above 1, indicating firms can meet short-term liabilities, but the quick ratio is slightly lower due to inventory exclusion.
Debt-to-Equity (DE = 1.50)	On average, firms use LKR 1.50 of debt for every LKR 1 of equity, indicating moderate leverage.
Interest Coverage (IC = 2.58)	Firms can cover interest expenses 2.58 times using earnings, reflecting relatively safe solvency.
Accounts Receivable Turnover (ART = 5.0)	Firms collect receivables around 5 times per year, indicating moderate collection efficiency.

Source: Author

Table 4.1 presents descriptive statistics for 100 panel observations across key variables, revealing significant variability in financial performance among non-financial companies in Sri Lanka. Bad debt levels averaged 4.14% of receivables (SD = 3.53), indicating moderate yet diverse credit risk exposure.

Profitability indicators ROA (mean = 7.10), ROE (13.80), and NPM (7.93) show positive averages but high dispersion, reflecting uneven earnings generation and cost control. Liquidity metrics such as the current ratio (mean = 1.81) and quick ratio (1.37) suggest acceptable short-term solvency, though skewness and extreme values reveal that some firms are either highly liquid or under financial strain. Solvency measures display moderate leverage with a mean debt-to-equity ratio of 1.50 and interest coverage of 2.57, though negative minimum values indicate periods of operating loss. The accounts receivable turnover ratio (mean = 5.00) highlights variations in collection efficiency across the sample. Non-normality in all variables (Jerque-Bera $p < 0.05$) supports the use of robust panel regression techniques to assess the impact of bad debt on firm performance.

4.2.2. Measures of Dispersion (Standard Deviation)

The notable standard deviations in profitability ratios ROA (10.21), ROE (16.45), and NPM (10.57) highlight substantial variability in firms' earnings performance. Similarly, the bad debt ratio (SD = 3.53) reflects diverse levels of credit risk and collection effectiveness among firms. Liquidity measures such as the current and quick ratios also show moderate dispersion, indicating varying capacities to meet short-term liabilities. This variation underscores the heterogeneous financial health and risk exposure across the sampled non- financial private sector companies.

4.2.3. Skewness and Kurtosis (Distribution Shape)

Table 4.3: Skewness and kurtosis

		Interpretation
All variables show positive skewness	Values > 0	Indicates long right tail a few firms have extremely high-performance values (e.g., very high ROE or profitability).
High kurtosis (>3)	Most variables	Indicates leptokurtic distributions, meaning data is peaked with heavy tails. This suggests outliers are present.

4.2.4 Normality (Jerque-Bera Test)

Jerque-Bera Probability = 0.0000 for All Variables

The Jerque-Bera test results (p = 0.0000) confirm that all variables deviate from normality at the 5% significance level. Despite positive mean values of ROA, ROE, and NPM indicating overall financial health, the high standard deviations highlight notable performance disparities among firms. The average bad debt ratio of 4.15% reflects manageable yet impactful credit risk. Skewness and kurtosis values further support the presence of non-normality, validating the application of robust panel regression techniques. Overall, the findings suggest substantial variability in bad debt levels and financial performance across firms, underscoring their potential interdependence.

4.4 Regression Results

Panel regression analysis was performed using both Fixed Effects (FE) and Random Effects (RE) models, depending on the results of the Hausman specification test. Table presents the coefficient estimates and their significance levels.

Summary of Regression Results and Hypothesis Decisions

Table 4.4: Summary of Regression Results and Hypothesis Decisions

Dependent Variable (Financial Indicator)	**Model Selected (Based on Hausman Test)**	**Coefficient of Bad Debt**	**p-value**	**Relationship Direction**	**Significance**	**Hypothesis Decision**
ROA (Return on Assets) – Profitability	Random Effects	-1.492970	0.0000	Negative	Significant	Accepted
ROE (Return on Equity) – Profitability	Random Effects	-2.856369	0.0000	Negative	Significant	Accepted

NPM (Net Profit Margin)– Profitability	Fixed Effects	- 3.395437	0.0000	Negative	Significant	Accepted
Current Ratio – Liquidity	Random Effects	- 0.124300	0.0001	Negative	Significant	Accepted
Quick Ratio – Liquidity	Random Effects	- 0.145229	0.0000	Negative	Significant	Accepted
Debt-to-Equity Ratio – Solvency	Random Effects	- 0.038969	0.2868	Negative	Not Significant	Rejected
Interest Coverage Ratio – Solvency	Fixed Effects	- 0.524234	0.0000	Negative	Significant	Accepted
Accounts Receivable Turnover (ART) – Efficiency	Random Effects	- 0.346461	0.0008	Negative	Significant	Accepted

Source: Author

The regression results reveal that bad debt exerts a significant and adverse influence on multiple dimensions of financial performance. Profitability is consistently reduced across all measures ROA, ROE, and NPM indicating a clear negative relationship between rising bad debt levels and firm earnings. Liquidity also deteriorates as both the current ratio and quick ratio significantly decline with higher bad debt, highlighting weakened short-term financial resilience. In terms of solvency, bad debt significantly lowers the interest coverage ratio, suggesting increased difficulty in fulfilling debt obligations, although the debt-to-equity ratio remains unaffected, implying stable leverage practices despite credit risk. Finally, efficiency declines as higher bad debt levels lead to a significant drop in accounts receivable turnover, indicating slower receivables recovery and ineffective credit collection.

4.5 Correlation Analysis

Table 4.5: Summary of Regression Results and Hypothesis Decisions

Variable	Correlation with BD	Interpretation
ROA	-0.467	**Moderately strong negative relationship as bad debt increases, return on assets decreases.**
ROE	-0.466	**Moderately strong negative, bad debt reduces shareholder returns.**
NPM	-0.379	**Bad debt negatively affects operating profitability.**
Current Ratio	-0.205	**Weak negative, high bad debt reduces liquidity.**
Quick Ratio	-0.142	**Weak negative relationship similar effect on immediate liquidity.**
DE (Debt-to- Equity Ratio)	+0.018	**Very weak positive bad debt has almost no impact on capital structure.**

IC (Interest Coverage)	**-0.176**	**Weak-to-moderate negative bad debt reduces ability to meet interest expenses.**

Source: Author

The correlation analysis confirms that bad debt (BD) has a consistently negative relationship with most financial performance indicators moderately affecting profitability (ROA, ROE, NPM) and weakly impacting liquidity (current and quick ratios), efficiency (accounts receivable turnover), and interest coverage, thereby indicating deteriorating financial stability as bad debt rises. However, the insignificant correlation with the debt-to-equity ratio suggests that capital structure decisions remain unaffected by fluctuations in bad debt. These results align with the regression findings, reinforcing that higher bad debt weakens profitability, liquidity, and efficiency, while having limited influence on firms' leverage positions.

5. Discussion of Findings

5.1 Overview

This section interprets the empirical findings in relation to the research objectives, research questions, and theoretical foundations of this study. The objective was to evaluate the extent to which bad debt levels affect the financial performance of non-financial private sector companies in Sri Lanka, particularly in terms of profitability, liquidity, solvency, and efficiency. Findings are contextualized within the Sri Lankan economic landscape and existing scholarly literature.

5.2 Findings in Relation to Research Objectives and Questions

Table 5.1: Linkage of Findings, Research Questions, and Research Objectives

Research Objective	**Research Question**	**Hypothesis Tested**	**Empirical Finding**	**Decision**	**Conclusion**
To assess the impact of bad debt levels on profitability indicators (ROA, ROE, NPM).	What is the relationship between bad debt levels and profitability of private sector companies in Sri Lanka?	H1: Bad debt significantly affects profitability.	ROA, ROE, and NPM models show negative and statistically significant coefficients ($p < 0.01$).	Accepted	Bad debt levels have a strong negative impact on profitability.
To evaluate the effect of bad debt levels on liquidity indicators (Current Ratio, Quick Ratio).	How do bad debt levels influence the liquidity position of companies?	H2: Bad debt significantly affects liquidity.	Current Ratio model shows a negative and significant effect ($p < 0.01$).	Accepted	Increased bad debt reduces firms' short-term liquidity.

To analyze the influence of bad debt levels on solvency indicators	To what extent do bad debt levels affect solvency?	H3: Bad debt significantly affects solvency.	Bad debt has a negative impact on interest coverage, but an insignificant impact	Partially Accepted	Bad debt impairs solvency through interest coverage but does not significant

Source: Autho

The results demonstrate clear and consistent evidence that bad debt adversely affects financial performance. The effect is most pronounced on profitability, liquidity, and efficiency, while mixed for solvency, where only interest coverage is negatively impacted.

5.3 Financial Performance Dimension

5.3.1 Profitability

The study confirms a statistically significant negative relationship between bad debt and all three profitability indicators (ROA, ROE, NPM). Increasing bad debt reduces net earnings and return on investment, highlighting the earnings erosion effect of uncollectible receivables. These findings align with Credit Risk Theory (Saunders & Allen, 2002) and prior empirical results (Swamy, 2017; Sirisumani, 2024). This relationship is especially crucial in economically distressed environments like Sri Lanka, where cash inflows are sensitive to market shocks. Effective receivables policies and stricter credit screening are essential to preserve earnings and shareholder value.

5.3.2 Liquidity

Both Current and Quick Ratios were significantly reduced by rising bad debt, indicating immediate pressures on working capital. As unpaid receivables accumulate, liquidity constraints intensify, in alignment with Liquidity Preference Theory (Keynes, 1936). Firms must adopt dynamic credit control and short-term cash flow forecasting to manage liquidity risks arising from bad debt.

5.3.3 Solvency

The findings offer a nuanced view: while bad debt reduces the Interest Coverage Ratio significantly, it has no detectable effect on the Debt-to-Equity Ratio. This discrepancy suggests firms continue borrowing even amid rising defaults perhaps due to limited equity financing options, consistent with studies in emerging economies (Haabazoka et al., 2021). Solvency assessments in Sri Lanka must consider differences between short-term debt servicing ability and long-term capital structure decisions.

5.3.4 Efficiency

Higher bad debt significantly reduces Accounts Receivables Turnover, pointing to weakened operational efficiency. This supports Efficiency Theory and demonstrates that rising uncollectible receivables slow down the conversion of revenue into cash flow (Nguyen, 2022). Credit monitoring and recovery efforts must be strengthened to avoid decline in asset productivity.

5.3.5 Theoretical Contribution and Resolution of the Theoretical Gap

This study addressed the theoretical gap identified in Chapter One by empirically testing the applicability of established financial and credit-risk theories within the context of Sri Lankan non-financial private sector firms an area previously underexplored. The findings provide strong support for the propositions of Credit Risk Theory (Saunders & Allen, 2002) and the Expected Credit Loss (ECL) model under IFRS 9 (IASB, 2014), as the results confirm that higher levels of bad debt

significantly reduce profitability (ROA, ROE, NPM) and weaken liquidity positions (Current and Quick ratios). These outcomes are also consistent with Liquidity Preference Theory (Keynes, 1936), (Ogiriki, Tonye & Andabai, PW. 2014) which asserts that firms require sufficient cash inflows to sustain short-term financial stability, and with Efficiency Theory, as increased bad debt was shown to significantly decrease accounts receivable turnover (Nguyen, 2022). Thus, the study empirically validates the theoretical link between impaired receivables and deteriorating financial performance, confirming the relevance of these models in an emerging market environment.

However, the findings also offer a context-specific theoretical extension. While bad debt significantly reduced the interest coverage ratio, it did not have a statistically significant effect on the debt-to-equity ratio. This outcome diverges from classical Financial Distress Theory (Altman, 1968), (Altman, E. I., & Hotchkiss, E. 1993), which predicts simultaneous declines in both solvency indicators. The persistence of leverage levels despite rising credit risk suggests a structural pattern in the Sri Lankan private sector, where firms continue to rely on debt financing due to limited access to equity capital and underdeveloped capital markets (Haabazoka et al., 2024). Therefore, the study contributes new empirical evidence demonstrating that solvency responses to bad debt in developing economies may not align fully with traditional Western-based theoretical expectations. This reinforces the need for theory contextualization and highlights that credit risk behavior in emerging markets may require modified theoretical interpretation.

The study underscores important practical implications across key stakeholder groups. Managers must prioritize robust credit policies, incorporating early warning systems and customer risk scoring to mitigate rising bad debt. Policymakers should strengthen regulatory oversight and enforce stricter credit monitoring standards in alignment with SLFRS 9 to safeguard financial stability and Investors and lenders are encouraged to integrate bad debt ratios into valuation and risk assessment models due to their significant influence on firm performance. Overall, the findings affirm that

bad debt is a critical determinant of financial health in Sri Lanka's non-financial private firms, negatively affecting profitability, liquidity, efficiency, and debt-servicing capacity. This highlights the necessity for enhanced credit management systems and proactive policy measures to support sustainable financial performance in emerging markets.

6. Conclusion and Recommendations

This study examined the extent to which bad debt levels affect the financial performance of non-financial private sector firms in Sri Lanka using panel data from 2020 to 2024 across 20 companies. Employing panel regression techniques guided by the Hausman test, the results show that bad debt exerts a significantly negative impact on key performance dimensions profitability (ROA, ROE, NPM), liquidity (current and quick ratios), efficiency (accounts receivable turnover), and solvency (interest coverage), while the debt-to-equity ratio remains statistically unaffected. These findings suggest that bad debt compresses earnings, weakens working capital, slows cash conversion, and strains debt- servicing capacity, although firms' leverage structures tend to remain stable in the short term. The study validates core financial theories such as Credit Risk Theory, Liquidity Preference Theory, and the Expected Credit Loss (ECL)

model under IFRS 9 in the context of emerging markets, while offering a novel insight: interest servicing capacity declines even when leverage ratios do not adjust, highlighting financing stickiness in economies with constrained capital markets. From a managerial perspective, this research underscores the strategic need for data-driven credit risk frameworks, including customer risk scoring, forward-looking provisioning under SLFRS 9, active receivable aging control, stress-tested debt service plans, and integration of performance KPIs such as day sales outstanding and write-off rates. Boards are encouraged to formalize credit risk appetite and enhance oversight through regular exposure reviews. Policymakers should strengthen compliance standards, expand credit bureau coverage to non-financial firms, and

expedite dispute resolution mechanisms to support receivable recovery and financial transparency. Socially and economically, improved credit governance has broader implications by enhancing financial resilience, safeguarding employment, and building investor confidence in the private sector. While this study is limited by its reliance on secondary data, omission of qualitative drivers, and focus on a specific period marked by economic crises, it offers robust empirical evidence for the strategic centrality of credit risk management and highlights several areas for further research, including sector-specific analysis, dynamic modeling, and cross- country comparisons. Ultimately, this study concludes that proactive, digitally- enabled, and policy-aligned credit governance is imperative to sustaining financial health and fostering long-term economic stability in Sri Lanka's private enterprise landscape.

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ASSESSMENT OF NUTRITIONAL STATUS AND ANTHROPOMETRIC PROFILES OF UNDERGRADUATES AT NSBM GREEN UNIVERSITY, SRI LANKA

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Abstract

University students often experience lifestyle changes, academic pressures, and greater independence, which can lead to unhealthy dietary practices and altered nutritional status. This study assesses the dietary patterns and anthropometric profiles of undergraduates at NSBM Green University, Sri Lanka. This was a cross-sectional descriptive study which was conducted from March to May 2025 among 102 undergraduates. Purposive sampling technique was used to recruit the participants. Data was collected using a structured, self-administered online questionnaire, which included sociodemographic and basic characteristics and food consumption patterns. Anthropometric measurements, including weight, height, and waist circumference were measured to compute Body Mass Index (BMI) and assess the abdominal obesity. The mean age of participants was 21.92 ± 1.65 years, with a majority being female (83.3%). Most students consumed both plant and animal products (87.3%), but irregular meal patterns were common, with 46.1% skipping breakfast sometimes and 74.5% consuming snacks between meals. Anthropometric assessments revealed that 15.7% were underweight (BMI < 18.5kg/m^2), 40.2% had normal weight (BMI = 18.5 - 2.9 kg/m^2), 14.7% were overweight (BMI = 23 - 24.9kg/m^2), and 29.4% were classified as obese (BMI > 25kg/m^2). Among all the participants, 41.2% had abdominal obesity, while 58.8% did not. When stratified by sex, 17.6% of males (waist circumference >= 90cm) and 45.9% of females (waist circumference >= 80cm) were as having abdominal obesity. A statistically significant association was observed between BMI and abdominal obesity ($p < 0.001$), although 17.1% of participants with normal BMI still had abdominal obesity. The study highlights a dual burden of malnutrition and unhealthy dietary practices among university students. BMI alone may underestimate central obesity risk, emphasizing the importance of waist circumference measurement. Limited sample size and inclusion of only one setting may limit the generalizability of the study. University based nutrition education and interventions targeting balanced diets, regular meal patterns, and lifestyle modifications are crucial to promote health and reduce long term disease risks in this population.

Keywords: *Anthropometric measure, Nutritional status, Sri Lanka, Undergraduates*

1. Introduction

Nutritional status refers to the overall health condition of an individual which is influenced by the nutrient intake, absorption, and utilization by the body. It could be assessed using physical and biochemical techniques. Eating habits of an individual describe the reasons and way people eat, the types of foods they choose, the company they share meals with, and the processes involved in obtaining, storing, preparing, and disposing of food (Bede et al., 2020). As well as several factors such as the quality and quantity of food consumed and an individual's overall physical health, determine nutritional status (Omage & Omuemu, 2018).

Nutritional status plays a crucial role in adolescent health as it affects growth, development, and the risk of long-term diseases (Omage & Omuemu, 2018). The nutritional status of an individual is commonly evaluated using various assessment methods, including anthropometric measurements, dietary assessment tools, and body composition indicators. Anthropometric measurements such as weight, height, and waist circumference provide valuable understanding about an individual's growth, development, and overall health. Body Mass Index (BMI) is one of the important and commonly used tools for assessing nutritional status. It measures body fatness and helps to identify problems like undernutrition and obesity (Mushonga et al., 2013).

It is calculated by dividing an individual's weight in kilograms by the square of their height in meters. The formula was developed in the 1830s by Belgian mathematician Adolphe Quetelet to allow comparison of White middle-aged European men of different heights using a standard parameter. In 1972, Ancel Keys named this measurement the "body mass index" (Eknoyan, 2008). According to the Asian cut-off of BMI, less than 18.5 kg/m^2 is considered underweight, 18.5 to 22.9 kg/m^2 is considered normal weight, 23 to 27.9 kg/m^2 is considered overweight, and the obesity range is 27.5 kg/m^2 or higher (Somasundaram et al., 2014). BMI has several limitations. First, it does not reflect how body fat is distributed. Second, BMI correlates only moderately with actual body fat. Third, BMI offers no insight into

the genetic, metabolic, physiological, or psychological factors contributing to obesity, limiting its usefulness in understanding the underlying causes of excess weight (Bray, 2023).

Abdominal obesity, also called central or visceral obesity, refers to the accumulation of fat in the abdominal region. This type of fat can vary even among individuals with similar total body fat or BMI. In 1997, the World Health Organization (WHO) Expert Consultation on Obesity Committee recognized abdominal obesity as a useful proxy measure to complement BMI, particularly in populations prone to central fat accumulation(El-Atat et al., 2003). Waist circumference is a clinical measure of abdominal obesity and is associated with an increased risk of coronary heart disease, diabetes, hypertension, and dyslipidaemia. According to the WHO guidelines for Sri Lanka, abdominal obesity is defined as a waist circumference of ≥90 cm in males and ≥80 cm in females (Somasundaram et al., 2014).

University students are a very important group in society because they can influence healthy lifestyles and eating habits in their families and communities (Al-Naabi et al., 2020). The transition from adolescence to young adulthood, along with greater expectations of independence, often makes it challenging for young adults to make healthy food choices. This period is frequently associated with unhealthy eating habits, including higher consumption of energy-dense and ultra-processed foods like fast food, which can increase the risk of weight gain (Saha et al., 2022).

Understanding the nutritional status of university students is very important for both public health and education. Addressing these challenges at the university level can help young adults have better long-term health and lower their risk of diet related diseases. Considering all this information, dietary patterns and the nutritional status of university students are very important topics today. There were so many studies about the nutritional assessments to observe the nutritional status and dietary patterns of undergraduate students around the world. Researchers show how affect the university life of undergraduate students to their nutritional status and dietary patterns. Sri Lanka also conducted a few studies to show the relationship between university life and the nutritional status and dietary practices among university

students. This research aims to assess the dietary patterns and nutritional status of undergraduate students in a Sri Lankan university setting.

2. Literature Review

Research across different regions consistently demonstrates that undergraduate students are vulnerable to poor dietary habits and related nutritional issues, influenced by academic, social, and economic factors.

A study done in a private Nigerian university highlighted the irregular food intake patterns, frequent prevalence of fast-food consumption, and meal skipping particularly breakfast resulting in inadequate nutrient intake among the students. The study also exhibited a double burden of malnutrition, with undernutrition coexisting alongside overweight and obesity, emphasizing the health risks associated with poor dietary practices (Omage & Omuemu, 2018). Similarly, in South America, a study done among same population identified distinct dietary patterns, many of which were unhealthy and linked to academic stress, low fibre and vitamin intake. The findings reinforced that university life and stress significantly shape students' eating behaviours, underscoring the need for university-based nutritional interventions (Pereira-Santos et al., 2016).

Parallel evidence from Asia further supports these concerns. In Iran, a study found widespread imbalanced diets among university students, with both undernutrition and overweight, as well as micronutrient deficiencies fibre, phosphorous, calcium, iron, vitamins A, B6, and B12), influenced by lifestyle factors such as physical activity and socioeconomic status (Delvarianzadeh et al., 2016). In Macao, identified three major dietary patterns among students, revealing widespread deficiencies in essential nutrients like vitamin A, thiamine, calcium, and iodine. It is also observed that high sugar and high intakes of grains and animals' foods habits among the participants (Tao et al., 2022).

Similarly, a study done in Pakistan reported that a significant proportion of students were overweight or obese, while many others were underweighted, with the majority

consuming fewer calories than recommended and exhibiting nutrient deficiencies such as anaemia (Rana et al., 2020).

A study was conducted among University Students in Selected Universities in Southern Province, Sri Lanka aimed to assess the nutritional status and dietary behaviours of university students. The findings revealed that most students had normal BMI (73.8%), though 15.4% were underweight and 10.8% were overweight. Additionally, while most students skipped meals and consumed fast food and sugary drinks frequently, a large portion reported not engaging in regular physical activity. The study concluded that although most students had a normal BMI, their dietary habits were generally poor, indicating the need for nutritional education and awareness programs to promote healthier lifestyles among university students(Karthijekan & Angela, 2020).

Collectively, these studies demonstrate that university students worldwide face challenges in maintaining balanced diets due to factors like stress, financial constraints, lifestyle changes, and academic demands. Despite regional differences, common patterns emerge high consumption of processed and energy dense foods, irregular meal patterns, and widespread nutrient deficiencies. These findings highlight the urgent need for targeted nutritional education programs and interventions within universities to promote healthier eating behaviours, improve nutrient intake, and prevent both short- and long-term health risks.

With this evidence in the world, there are only a few studies on this topic in Sri Lanka. The effects of Sri Lankan university life on students' nutrition and health are still not entirely understood. There is not enough research available to inform national health policy or initiatives. This research aims to bridge this critical knowledge gap by comprehensively assessing the dietary patterns and nutritional status of undergraduate students in a Sri Lankan university setting. The findings will provide valuable insights into current health risks faced by this population and offer evidence-based recommendations for university-level nutrition education.

3. Methodology

3.1 Study design and population

This is a cross-sectional descriptive study conducted among the undergraduates at the NSBM Green University. The study population included undergraduates who were enrolled at NSBM Green University, while undergraduates who were receiving any form of medication, and those who were acutely ill or had chronic diseases, were excluded from the study. The data collection period was between March to May 2025, and 102 participants were recruited during this period.

3.2 Data collection tools

Data were collected using a structured and self-administered online questionnaire. The questionnaire was divided into three sections: socio-demographic and basic characteristics, basic food consumption patterns, and anthropometric measurements.

a. Socio-demographic details and basic characteristics

Information regarding age, sex, marital status, number of siblings, ethnicity, residency, degree program, academic batch, father's education level, mother's education level, and monthly family income was collected.

b. Basic food consumption patterns

Information was gathered on dietary preferences, main source of daily food, number of main meals consumed in a day, usual source of daily food, breakfast skipping, eating between-meal snacking habits, alcohol consumption, and tobacco smoking.

c. Anthropometric measurements

Anthropometric measurements were taken with participants wearing light clothing and no shoes.

i. Weight measurement - A mechanical scale was zeroed before each measurement. Participants were asked to remove heavy items from their pockets and bulky clothing. They were instructed to remain still and face forward. Weight was recorded to the nearest 0.5 kg after the reading was stabilized.

ii. Height measurements - Height was measured using a stadiometer. Participants were positioned with their back touching the wall (heels, calves, buttocks, upper back, and head). Height was recorded to the nearest 0.5 cm.

iii. Waist circumference -Waist circumference was measured at the midpoint between the lower edge of the last palpable rib and the top of the iliac crest using a non-stretchable measuring tape, to the nearest 1 cm at the end of normal exhalation.

3.3 Data analysis

Data were analyzed using SPSS version 29 software. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as mean ± standard deviation (SD). Chi-square test was applied to identify associations, with significance set at $p < 0.05$. BMI and abdominal obesity were calculated and derived from primary data such as height, weight and waist circumference.

i. BMI

It was calculated by dividing an individual's weight in kilograms by the square of their height in meters. According to the Asian cut-off, BMI less than 18.5 kg/m^2 is considered underweight, 18.5 to 22.9 kg/m^2 is considered normal weight, 23 to 27.9 kg/m^2 is considered overweight, and the obesity range is 27.5 kg/m^2 or higher(Somasundaram et al., 2014).

ii. Abdominal obesity

According to WHO guidelines for Sri Lanka, waist circumference of ≥ 90 cm in males is considered having abdominal obesity and ≥ 80 cm in females is considered having abdominal obesity (Somasundaram et al., 2014).

3.4 Ethical considerations

Ethical clearance was obtained from the Ethical Review Committee of the Institute of Biology, Sri Lanka (IOBSL). Permission to conduct data collection was obtained from the deans after obtaining the ethical approval. Online informed consent was obtained from each participant before the data collection. Confidentiality and privacy were strictly maintained throughout the study process.

4. Findings

4.1 Socio demographic and basic characteristics of the participants

A total of 102 undergraduates were recruited between the data collection period of March to May 2025. The mean age of the participants was 21.92 (SD ±1.65) years, ranging from 18 to 26 years. Most participants (63.7%) were between 21 and 23 years old. Among the participants, 83.3% were female undergraduates. The majority were unmarried (95.1%), had one sibling (54.1%), were Sinhalese (93.1%), lived at home (51%), and reported a monthly household income of more than 100,000 Sri Lankan Rupees (74.5%). Regarding parental education, most fathers had completed up to the Advanced Level (46.1%), while nearly half of the mothers had attained a diploma or degree (47.1%). Overall, this indicates that many of both parents had educational qualifications up to the Advanced Level. Sociodemographic and basic characteristics of the participants are shown in the Table 01.

Table 2: Socio demographic and Basic characteristics of the participants

Socio demographic and Basic characteristics		Frequency	Percentage (%)
Age	18-20	20	19.6%
	21-23	65	63.7%
	24-26	17	16.7%
Sex	Male	17	16.7%
	Female	85	83.3%
Marital status	No	97	95.1%
	Yes	5	4.9%
Ethnicity	Sinhala	95	93.1%
	Tamils	3	2.9%
	Malay	1	1.0%
	Muslim	3	2.9%
Residency	Home	52	51.0%

	Boarding place and Outside	37	36.3%
	University hostel	13	12.7%
Father's education qualification	O/L	9	8.8%
	A/L	47	46.1%
	Diploma or above	44	43.1%
	Primary	2	2.0%
Mother's education qualification	O/L	7	6.9%
	A/L	47	46.1%
	Diploma or above	48	47.1%
	Primary	0	0.0%
Monthly family income	≤ Rs. 50,000.00	3	2.9%
	Rs. 50,000.00 - Rs.100,000.00	23	22.5%
	≥ Rs.100,000.00	76	74.5%
Number of siblings	No	15	14.7
	1	26	54.9
	2	54	23.5
	3	5	4.9
	>3	2	2.0

4.2 Food consumption patterns of the participants

Majority of the students reported they consume both animal and plant products without any restriction (87.3%). Majority of the participants' main source of food was their home (55.9%), followed by those consuming canteen-prepared food (16.7%), own made food (15.7%), and food from shops (11.8%). When considering the number of main meals consumed per day, most participants (51.0%) reported consuming three main meals. And 73.5% reported that they consume food from both prepared and purchased sources.

About one-third of participants (32.4%) reported never skipping breakfast, while 22.5% skipped breakfast daily. The cumulative percentages indicate that nearly half of the participants skip breakfast at least occasionally. Most participants (74.5%) reported eating snacks between meals. Less than half of the participants (45.1%) reported eating snacks every day. Most participants reported eating between meals, with similar proportions for males (76.5%) and females (74.1%). This indicates that snacking between meals is a common habit across both sexes. Males were less likely to consume snacks daily (35.3%) compared to females (47.1%), while a larger proportion of males (64.7%) reported not eating snacks every day (Table 02).

Table 3: Food consumption patterns of the participants

Food consumption patterns		Frequency	Percentage (%)
Dietary Preference	Omnivores	89	87.3%
	Semi-vegetarian	10	9.8%
	Ovo- lacto vegetarian	2	2.0%
	Pollotarian	1	1.0%
Main sources of daily food	Home	57	55.9%
	own made	16	15.7%
	shop	12	11.8%
	canteen	17	16.7%
Usual source of daily food	prepared only	18	17.6%
	purchased only	9	8.8%
	Both	75	73.5%
Breakfast skipping	Daily	23	22.5%
	>3 times a week	21	20.6%
	≤3times/week	25	24.5%
	Never	33	32.4%
Eats in between meals	No	26	25.5%
	Yes	76	74.5%

Eats snacks every day	No	56	54.9%
	Yes	46	45.1%
Alcohol consumption patterns	Daily	0	0.0%
	>3 times a week	3	2.9%
	≤3times/week	11	10.8%
	Never	88	86.3%
Smoking pattern	Daily	1	1.0%
	>3 times a week	1	1.0%
	≤3times/week	1	1.0%
	Never	99	97.1%
Number of main meals consumed per day	1	4	3.9%
	2	39	38.2%
	3	52	51.0%
	>3	7	6.9%

Among the 102 participants, the frequency of daily meals varied. Breakfast was consumed every day by 44.1% of participants, while 9.8% never ate breakfast. Lunch was the most consistently consumed meal, with 79.4% of participants eating it every day. Dinner was consumed every day by 60.8% of participants and only 1% never ate dinner. Overall, lunch showed the highest daily consumption, whereas breakfast demonstrated the greatest variability among participants (Table 03).

Table 4: Frequency of main meal consumption among participants

Main meal consumption patterns		**Frequency**	**Percentage (%)**
Breakfast	Everyday	45	44.1%
	Sometimes	47	46.1%
	Never	10	9.8%
Lunch	Everyday	81	79.4%
	Sometimes	19	18.6%

	Never	2	2.0%
Dinner	Everyday	62	60.8%
	Sometimes	39	38.2%
	Never	1	1.0%

4.3 Anthropometric characteristics of the participants

4.3.1 Body Mass Index

The BMI of the 102 participants was categorized according to standard classification. Among the participants, 16 (15.7%) were underweight (BMI < 18.5kg/m^2), 41 (40.2%) had normal weight (BMI = 18.5 – 22.9 kg/m^2), 15 (14.7%) were overweight (BMI = 23 – 24.9kg/m^2), and 30 (29.4%) were classified as obese (BMI > 25kg/m^2). Most participants fell within the normal weight category (40.2%) while a substantial proportion (44.1%) were above the normal weight range (overweight or obese), indicating a high prevalence of excess body weight in the study sample.

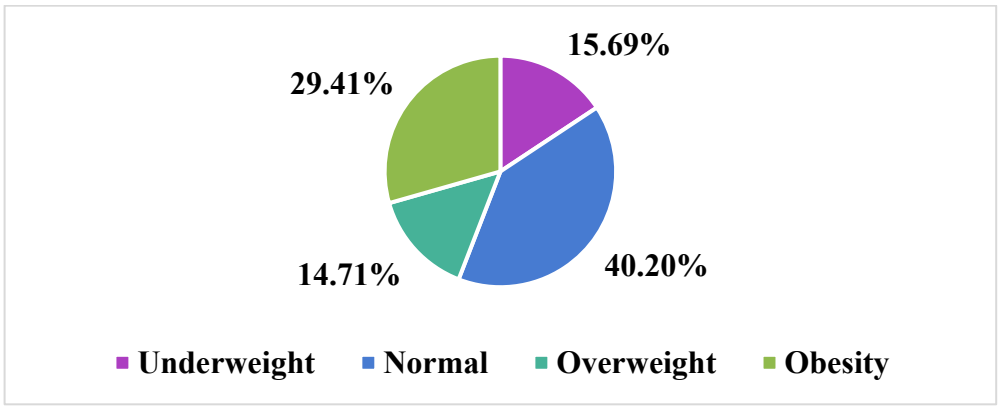

Figure 1: BMI distribution among the participants

Table 5: Stratification of BMI categories among Sex

BMI category	Male	Female
Underweight	0	16 (18.8%)
Normal	9 (52.9%)	32 (37.6%)
Overweight or obesity	8 (47.1%)	37 (43.5%)

4.3.2 Abdominal Obesity

Among all the participants recruited in the study, 41.2% had abdominal obesity, while 58.8% did not. When stratified by sex, 17.6% of males (waist circumference >= 90cm) and 45.9% of females (waist circumference >= 80cm) were as having abdominal obesity. In contrast, 82.4% of males (waist circumference <= 90cm) and 54.1% of females (waist circumference <= 80cm) had no abdominal obesity (Table 05).

Table 6: Stratification of Abdominal Obesity categories among Sex

Abdominal obesity status		Male	Female	Total
Abdominal	No	14 (82.4%)	46 (54.1%)	60
Obesity	Yes	3 (17.6%)	39 (45.9%)	42

It is also highlighted by the results of the study that among those classified as overweight or obese by BMI, the majority (77.8%) had abdominal obesity. However, 22.2% did not. Conversely, although BMI was in the normal range, 17.1% of participants still presented abdominal obesity. None of the underweight participants had abdominal obesity.

4.4 Association between socio demographic and basic characteristics and anthropometric measurements

4.4.1 Association between socio demographic and basic characteristics and BMI

A chi-square test was conducted to examine the association between BMI category and socio demographic and basic characteristics of the participants. This showed there is no statically significant association between sex (x^2 (2, N = 102) = 4.064 , p = 0.131) ; age (x^2 (4, N = 102) = 6.153 , p = 0.188); number of siblings (x^2 (2, N = 102) = 0.441 , p = 0.802) ; ethnicity (x^2 (6, N = 102) = 3.155 , p = 0.789) ; place of residency (x^2 (4, N = 102) = 0.591, p = 0.964) ; father's educational qualification (x^2 (6, N = 102) = 6.330 , p = 0.387) ; mother's educational qualification (x^2 (4, N = 102) = 2.994 , p = 0.559) ; and monthly income of the family (x^2 (4, N = 102) = 6.906, p = 0.141) and BMI category.

4.4.2 Association between socio demographic and basic characteristics and Abdominal Obesity

A chi-square test was conducted to examine the association between presence or absent of abdominal obesity and socio demographic and basic characteristics of the participants. This reveled there is no significant association between age (x^2 (2, N = 102) = 1.951 , p = 0.377); number of siblings in the family (x^2 (1, N = 102) = 1.073 , p = 0.300); ethnicity (x^2 (3, N = 102) = 1.582, p = 0.664); residency (x^2 (2, N = 102) = 0.891, p = 0.641); father' s educational qualification (x^2 (3, N = 102) = 3.240 , p = 0.356); and mother's educational qualification (x^2 (2, N = 102) = 2.924 , p = 0.232) and presence or absent of abdominal obesity.

And also, it was found that there is a statistically significant association between presence or absent of abdominal obesity and sex (x^2 (1, N = 102) = 4.663, p = 0.031) and monthly income (x^2 (2, N = 102) = 6.372, p = 0.041).

4.5 Association between food consumption patterns and anthropometric measurements

4.5.1 Association between food consumption patterns and BMI

Chi-square test was conducted to examine the association.

Table 7: Association between food consumption patterns and BMI

Variable		Chi-square value	df	P value
Breakfast skipping	Daily Sometimes Never	2.596	4	0.628
Number of meals consumed per day	1 2 >= 3	4.591	4	0.332
Main source of food	Home Own made Outside	4.487	4	0.344
Dietary preferences	Eat both animal and plant products without any restrictions Other preferences which omit any type of food	3.823	2	0.148
Breakfast frequency	Everyday Sometimes Never	5.473	4	0.242
	Everyday	4.478	4	0.345

Lunch frequency	Sometimes Never			
Dinner frequency	Everyday Sometimes Never	1.791	4	0.774
Alcohol consumption	Yes No	0.229	2	0.892
Smoking	Yes No	3.915	2	0.141
Eat snacks every day	Yes No	2.002	2	0.367
Eat in between food	Yes No	7.467	2	0.024
Usual source of food	Purchased only Prepared only Both	3.990	4	0.407

The result of the test revealed that the BMI was statistically significantly associated with eating or not eating in between meals ($p = 0.024$).

4.5.2 Association between food consumption patterns and Abdominal Obesity

Chi-square test was conducted to examine the association. The result of the test revealed that the abdominal obesity was statistically significantly associated with eating or not eating in between meals ($p = 0.024$) and dietary preferences ($p = 0.028$).

Table 8: Association between food consumption patterns and Abdominal obesity

Variables		Chi-square value	df	P value
Breakfast skipping	Daily Sometimes Never	0.094	2	0.954
Number of meals consumed per day	1 2 >= 3	2.351	2	0.309
Main source of food	Home Own made Outside	1.089	2	0.580
Dietary preferences	Eat both animal and plant products without any restrictions Other preferences which omit any type of food	4.841	1	0.028
Breakfast frequency	Everyday Sometimes Never	1.147	2	0.564
Lunch frequency	Everyday Sometimes Never	3.601	2	0.165
Dinner frequency	Everyday Sometimes Never	1.678	2	0.432
Alcohol consumption	Yes	0.019	1	0.891

	No			
Smoking	Yes	0.829	1	0.363
	No			
Eat snacks everyday	Yes	0.616	1	0.433
	No			
Eat in between food	Yes	5.973	1	0.015
	No			
Usual source of food	Purchased only			
	Prepared only	0.162	2	0.922
	Both			

4.6 Association between BMI and abdominal obesity

The chi-square test shows there is a statistically significant association between abdominal obesity and the BMI categories (x^2 (2, N = 102) = 45.923, p < 0.000).

5. Discussion

According to the study it was apparent was although majority of the father' (89.2%) and mothers' (93.2%) educational qualifications were up to A/L or above and monthly income was ≥ Rs.100,000.00 (74.5%), unhealthy dietary practices sch as breakfast skipping every day (22.5%) and not consuming breakfast every day (55.9%), underweight (15.7%), overweight and obesity (39.6%) are still prevalent. Several factors may contribute to this pattern. Higher income and education do not necessarily translate into healthy dietary behaviors, as busy work schedules, increased access to fast food, and reliance on convenience meals can encourage habits such as breakfast skipping.

In this study, it was revealed that the majority eat both plant and animal products (87.3%) and this is consistent with another study done in Sri Lanka, that reported the majority were non-vegetarians (88%) (Karthijekan & Angela, 2020). About 51% of

the participants reported consumed 3 main meals per day and that was the majority response which reflects the cultural and traditional way of Sri Lankan eating habits. Another Sri Lankan study done in 2022 also reported that all the surveyed respondents consumed three major meals per day (Swarnamali & Jayawardena, 2022). This is in contrast with a Nigerian study in which majority of the participants consumed only two main meals daily. This same study also reported that skipping breakfast and eating between meals are common in university students. (Omage & Omuemu, 2018). When considering all three main meals (breakfast, lunch and dinner), lunch showed the highest daily consumption, whereas breakfast demonstrated the greatest variability among participants.

Dual burden of the malnutrition exists among the sample. That means 15.7 % of the sample had underweight while, overweight and obesity were prevalent among 39.6% of the undergraduate students. The double burden of malnutrition refers to the simultaneous presence of overnutrition (such as overweight and obesity) and undernutrition (underweight) within the same population (The Lancet, 2020). The result is in consistent with the other studies which revealed a significant proportion of the sample reported underweight and overnutrition (overweight and obesity) (Karthijekan & Angela, 2020; Rana et al., 2020; Taklual et al., 2020).

According to most of the research done in the world, most of the male students are obese than females (Karthijekan & Angela, 2020; Salameh et al., 2014). But, in this study, obesity was more prevalent in females than in males. This result could be related to more female predominant sample. According to research conducted at Eastern University, prevalence of abdominal obesity was high in females (Karthijekan & Angela, 2020). Same as this study as well, abdominal obesity was higher in females (45.88%), compared to males (17.65%). Biological and genetic factors, including the influence of estrogen, brown adipose tissue activity, and sex-specific genetic loci, contribute to these differences(Kim et al., 2025).

The findings revealed that among individuals categorized as overweight or obese based on BMI, most (77.8%) also exhibited abdominal obesity, while 22.2% did not.

In contrast, 17.1% of those with a normal BMI still showed signs of abdominal obesity.

These findings support using waist circumference or waist-to-hip ratio alongside BMI to better identify at-risk individuals, especially in young adult populations like undergraduates. Even among populations that appear healthy by BMI standards, a notable proportion can have abdominal obesity, which may predispose them to metabolic syndrome, diabetes, or cardiovascular issues later.

6. Conclusion

This study provides valuable information and insights into the dietary habits, nutritional status, and anthropometric characteristics of undergraduate students. The findings revealed a dual burden of malnutrition indicating the coexistence of undernutrition and overnutrition within the same population. This pattern underscores the need for targeted nutritional interventions addressing both ends of the malnutrition spectrum.

Anthropometric assessments demonstrated that BMI alone may not fully capture health risks, as some proportion of the students with normal BMI still exhibited abdominal obesity. Conversely, the majority of overweight and obese students also had abdominal obesity, reinforcing the strong association between excess body weight and central fat accumulation. These results emphasize that waist circumference should complement BMI in nutritional assessments, particularly among young adults. Notably, abdominal obesity was more prevalent in females than males, which may reflect both lifestyle patterns and the higher proportion of female participants in the study.

Despite the relatively high socioeconomic status and parental education levels of the participants, unhealthy dietary practices persisted, suggesting that knowledge alone may not translate into healthy eating behaviors, and that factors such as convenience, lifestyle changes, and academic demands play a substantial role.

Overall, this study highlights the urgent need for nutrition education and intervention programs aimed at promoting balanced diets, regular meal consumption, and awareness of central obesity risk at the university level. Interventions should be tailored to address both underweight and overweight students, emphasizing the importance of meal regularity, food choices that are nutrition rich, and monitoring of abdominal obesity. In conclusion, integrating anthropometric monitoring, dietary education, and lifestyle interventions at the university level is essential for mitigating malnutrition and promoting optimal health among young adults in Sri Lanka.

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