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Laporan Kes / *Case Report*

Pivotal Response Treatment as an Intervention Procedure for Autism Spectrum Disorder: A Case Study

Intervensi Tindak Balas Pivotal sebagai Prosedur Intervensi untuk Gangguan Autism: Satu Kajian Kes

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ABSTRACT

Pivotal Response Treatment (PRT) is a naturalistic intervention based on the principles of Applied Behaviour Analysis, targeting pivotal areas of development such as self-initiation and motivation. This case report presents a case that aims to evaluate the effectiveness of PRT in enhancing communication, play skills, affect, and reducing maladaptive behaviours in child disorder (ASD). This case reports a patient AKM, a 3-year 11-month old Malay boy referred for psychological evaluation and management of autistic traits. Assessment tools used were the Childhood Autism Rating Scale (CARS), Gilliam Autism Rating Scale-3 (GARS-3), and Parenting Stress Index (PSI). Assessment results indicated mild to moderate autism spectrum disorder, with pronounced deficits in verbal communication, social initiation, and emotional regulation. Parental stress levels were also elevated, particularly in the mother. PRT was chosen as the primary intervention strategy, focusing on enhancing self-initiated communication, increasing motivation, and reducing dysfunctional behaviours. The intervention involved six planned sessions combining child-directed strategies and parent training. The PRT techniques include providing choice of materials, modelling appropriate verbalizations, varying tasks, using natural reinforcers, and rewarding attempts at communication. Initial clinic-based sessions revealed low response rates; however, progress was noted with the emergence of new verbalisations ("four" and "tak nak") and improved functional communication attempts. Parental reports indicated improved confidence and more effective application of reinforcement strategies at home. Tantrum behaviours showed a reduction in frequency and duration with consistent behaviour management.

Keywords: Autism Spectrum Disorder, Intervention, Pivotal Response Treatment, Behaviour Management

ABSTRAK

Intervensi Tindakbalas Pivotal (PRT) ialah intervensi naturalistik berdasarkan prinsip Analisis Tingkah Laku Gunaan, menyasarkan bidang pembangunan penting seperti permulaan kendiri dan motivasi. Laporan kes ini membentangkan kes yang bertujuan untuk menilai keberkesanan Latihan Tindak Balas Pivotal (PRT), dalam meningkatkan komunikasi, kemahiran bermain, dan mengurangkan tingkah laku maladaptif untuk seorang kanak-kanak yang mengalami gangguan spektrum autisme (ASD). Kes ini melaporkan seorang pesakit AKM, seorang kanak-kanak Melayu berumur 3 tahun 11 bulan yang dirujuk untuk penilaian dan intervensi psikologi. Alat penilaian yang digunakan termasuk Childhood Autism Rating Scale (CARS), Gilliam Autism Rating Scale-3 (GARS-3), dan Parenting Stress Indeks (PSI). Hasil penilaian AKM menunjukkan gangguan spektrum autisme ringan hingga sederhana, dengan defisit yang ketara dalam komunikasi lisan, kemahiran bersosial dan pengawalan emosi. Tahap tekanan ibu bapa juga tinggi, terutamanya pada ibu. PRT dipilih sebagai strategi intervensi utama, memfokuskan pada meningkatkan komunikasi dan mengurangkan tingkah laku tidak berfungsi. Intervensi melibatkan enam sesi yang dijadualkan dengan menggabungkan strategi terarah kanak-kanak dan latihan intervensi untuk ibu bapa. Teknik termasuk menyediakan pilihan bahan, memodelkan verbalisasi yang sesuai, variasi tugas, menggunakan motivasi semula jadi, dan percubaan yang memberi ganjaran dalam komunikasi. Sesi awal berasaskan klinik mendedahkan kadar tindak balas yang rendah, walau bagaimanapun, kemajuan telah

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dicatatkan dengan adanya verbalisasi baharu ("empat" dan "tak nak") dan percubaan komunikasi berfungsi yang lebih baik. Laporan ibu bapa menunjukkan keyakinan yang lebih baik dan penggunaan strategi peneguhan yang lebih berkesan di rumah. Tingkah laku tantrum menunjukkan pengurangan kekerapan dan tempoh dengan pengurusan tingkah laku yang konsisten.

Kata kunci: Autisme, Intervensi, Intervensi Tindak Balas Pivotal, Pengurusan Tingkah Laku

INTRODUCTION

Pivotal Response Treatment (PRT) is described as a method of intervention based on the principles of Applied Behaviour Analysis, which emphasizes teaching skills in a natural setting or an environment that is built on a natural setting (Koegel et al. 1999). Pivotal areas are defined as "those that, when changed, generally produce large collateral improvements in other areas." (Koegel et al. 1999).

Koegel et al. (1999) developed PRT in response to the increasing prevalence of autism spectrum disorder (ASD). ASD is characterised by social communication difficulties and restricted, repetitive patterns of behaviours, interests, or activities (American Psychiatric Association 2022). Children with ASD have been found to exhibit higher levels of challenging behaviours compared to typically developing children (Matson, Wilkins, & Macken, 2008; Hastings et al. 2021). Predictors of increased problem behaviours include greater symptom severity (Matson et al. 2008) and lower levels of language development (Maskey et al. 2013).

Koegel et al. (1999) described self-initiation as one of the pivotal responses, which, when being intervened, is going to increase several desirable behaviours in the following areas, namely, speech, communication, learning, and motivation. Additionally, PRT involves learning in a natural setting (Koegel et al. 1999), making it suitable to be generalised to the patient's real-life setting. Some of the goals in PRT, as described in Koegel et al. (1999), include having an inclusive intervention, having a limited contact hours with a skilled specialist, diversifying the interventionists (to include not only therapists, but also parents), and having target behaviours that are tailored and manageable in the child's settings.

While the concept of PRT is derived from the principles of Applied Behaviour Analysis (ABA) and developmental psychology (Koegel et al. 1999), it was then realised that ABA shows limitations in motivation to learn (Koegel & Koegel 2006). A study found that higher gains in motivation were noted in a randomized control trial of PRT versus ABA by Mohammadzaheri et al. (2015), at the same time showing a reduction of disruptive behaviours. The use of preferred stimulus, variability of task, and interspersing maintenance tasks were believed to be the reasons for the improvements that were seen in children assigned to the PRT group in the study. Additionally, another research found the clinical effectiveness of PRT on improving self-initiations, play skills, language skills, affect, and reduction in dysfunctional behaviour among children (Cadogan & McCrimmon 2015).

PRT intervention is its emphasis on motivation as a central component of intervention (Koegel & Koegel 2006). Incorporating preferred stimuli could enhance learning and motivation in autistic children (Williams et al. 1981), which subsequently informed the development of the PRT intervention. Earlier, the effects on communication and language were also seen when motivation is the key component in the intervention (Koegel et al. 1987). More recent randomized controlled trials (RCTs) further support the effectiveness of PRT in language functioning, including untargeted cognitive and social domains (Wang et al. 2024), and communication skills (Gengoux et al. 2019; Mohammadzaheri et al. 2022).

Pivotal Response Treatment (PRT) emphasizes intervention in naturalistic settings and is therefore feasible for home implementation. In one randomized controlled trial, parents were able to learn and implement PRT within three months, with observed improvements in their children's adaptive communication skills (Hardan et al. 2015). A similar study conducted over a longer intervention period, combined with clinician-led sessions, reported comparable outcomes, specifically improvements in functional utterances, vocabulary, and social communication skills (Gengoux et al. 2019).

Therefore, in this case study report, PRT was the choice of intervention used for the case of AKM, a 3-year-11-month-old Malay boy. The intervention focuses on generalizing the intervention to be applied at home. The report will describe the reason for referral, a brief summary of assessments and findings, clinical impression, case conceptualisation, and a summary of the PRT intervention used. The main objectives of the intervention include (1) increasing self-initiation and functional communication skills, and (2) reducing dysfunctional behaviour.

CASE PRESENTATION

AKM was referred to the Klinik Psikologi Klinikal dan Kaunseling, Fakulti Sains Kesihatan (FSK), Universiti Kebangsaan Malaysia (UKM) by a speech therapist due to several autistic features that warranted diagnostic evaluation. AKM completed 10 speech therapy sessions at Klinik Audiologi dan Sains Pertuturan (KASP), FSK, UKM, and, upon speech and language assessment, AKM was found

to have delayed receptive and expressive language ability (Age Level of 1:0-1:5 years old).

AKM's parents described concerns with poor speech, limited eye contact, and motor difficulties. Another notable issue was his behavioural difficulty, including tantrums, especially when his needs were unmet, or when he sought parental attention, especially during moments when his parents spoke to each other in his presence. To further elaborate, he would often cry whenever they spoke to each other, especially in the car. At home, AKM mainly used physical gesturing to request his needs and has a good understanding of non-verbal gestures. No issues were reported with feeding or sleeping, but tantrums often increase with inadequate sleep (sleeps 9 PM–4 AM).

AKM's mother was unaware of her pregnancy until she was five months pregnant, which resulted in additional stress as she had not been able to prepare herself mentally and financially for the pregnancy, including taking in supplements she believed were important. Other than the gestational diabetes experienced during pregnancy, there were no complications experienced during birth. AKM showed signs of socioemotional delay (poor eye contact) by 10 months, with motor and speech delay by the age of 2. During a routine check-up with a pediatrician, AKM was suspected to have autism spectrum disorder, and intervention of Speech Therapy (ST) and Occupational Therapy (OT) were suggested. There were history of speech and motor delay experienced by AKM's father, which subsequently resolved, and this led the father to believe AKM would later overcome this issue.

AKM is an only child. His mother worked as a teacher and was the breadwinner at that time. His father had been retrenched from a corporate job and worked as a Grab driver while seeking another job The family follows a permissive parenting style. AKM stays with his maternal grandmother during work hours, who also uses a permissive parenting style. At present, AKM goes to a playgroup with his parents, and there was noticeable difficulty with social communication, where AKM prefers to be with his parents instead of following his friends in the group. He exhibited poor speech ability and mostly used gestures to express his needs.

DIAGNOSTIC PROCEDURE

A clinical interview was conducted over one session with AKM's parents, along with behavioural observation with AKM. Gilliam Autism Rating Scale, Third Edition (GARS-3), Childhood Autism Rating Scale (CARS), and Parenting Stress Index (PSI) were the formal psychological assessments used in the evaluation of the autism spectrum disorder and the measurement of parental stress.

AKM showed an active demeanour and was generally curious with the surroundings. He showed neutral affect, and he responded well to overly interactive praise. He clung more to his parents compared to the therapist. He was slow to warm up during the sessions and often cried continuously when the mother left the room. He did not respond well to verbal instructions, but he was able to direct his attention to sounds made through objects. He showed delayed latency in responding to his name being called, despite several verbal and physical prompts. Attention was observed to be brief, and he preferred engaging in solitary play without disruption. During the initial sessions where rapport was not fully established, AKM showed signs of distress when therapists tried to engage with him during play sessions. However, as the therapeutic relationship continued to develop, AKM became more receptive to therapist-led interactions.

AKM's autistic traits were assessed through clinical interview and behavioural observation. Childhood Autism Rating Scale (CARS) and Gilliam Autism Rating Scale, Third Edition (GARS-3) were used as objective measures in determining the presence and the severity of AKM's autistic traits. The Parental Stress Index (PSI) was given to both parents to evaluate their parental stress.

On the CARS, AKM obtained a score of 35.5, classifying him under the Mildly-Moderately Autistic range. AKM obtained a high raw score in the following domains: Verbal Communication (4), Level and Consistency of Intellectual Responses (3), and Imitation (3.5). He showed moderate severity in the following domains, namely, Relating to People (2.5), Emotional Response (2), Body Use (2), Object Use (2), Listening Response (2), Adaptation to Change (2), Taste, Smell and Touch Response and Use (1), Visual Response (2.5), Fear of Nervousness (1), and Activity Level (2.5).

On the GARS-3, AKM obtained an Autism Index Score of 90 (Percentile Rank=25), consistent with DSM-5 Level 2 Severity (requiring substantial support). He often displays repetitive behaviors and strong object interests, difficulties initiating social interactions, and limited nonverbal communication, especially in unfamiliar settings. He also shows heightened emotional distress during routine changes, often needing significant reassurance.

The PSI measures four main areas: the Child Domain, Parent Domain, Total Stress, and Life Stress, with higher scores indicating higher levels of stress. Based on the mother's responses, elevations were observed across all domains. In particular, the Child Domain showed elevated scores in the areas of adaptability, reinforces parent, mood, and acceptability. In the Parent Domain, elevations were noted in isolation, attachment, health, and depression. AKM's father also demonstrated elevated stress levels, specifically in the isolation and health subdomains of the Parent Domain.

The CARS and GARS-3 assessment tools suggested the presence and severity of ASD in

AKM, which correlates with behaviour observation and clinical interview. AKM's adaptive behaviour also correlates with his poor adaptive functioning. AKM's main deficits were in the communication and socialization area, which were also reported in the presenting problem. AKM's poor ability to express his wants and needs led to behavioural issues, which caused extra stress for his parents. His poor independence also requires the parents to provide extra assistance, therefore causing greater stress. The stressors were objectively measured, and elevated stress was seen especially in AKM's mother. The mother reported being the breadwinner, high work demand, and poor relationship with her own mother adds to the current stress that she is experiencing.

According to the Diagnostic and Statistical Manual of Mental Disorders, Text Revision (5th ed.; DSM-5-TR, Psychiatric Association 2022), AKM met all the diagnostic criteria for autism spectrum disorder (ASD).

INTERVENTION PROCEDURE

Koegel (1999) outlined five steps that were used in AKM's intervention, as explained below. The following steps (not in order) were the main methods used to guide the intervention.

1. Provide a choice of instructional materials

AKM's intervention session began in the clinic to assess the suitability before it was then generalized at a naturalistic setting. Therefore, the session set up mimicked naturalistic settings with instructional materials placed on the floor. AKM was encouraged to approach and engage with his preferred task and object, and the motivational level of each task or object was observed.

2. Model the label of the item

Once rapport was built, AKM was approached while playing. Then, the therapist modelled the label of the item that he was playing. He was encouraged to label the item clearly to encourage the production of speech. AKM was given 5-10 seconds to respond, and prompts were given when he did not succeed. It was advisable not to repeatedly request AKM to attempt labelling objects during the initial sessions.

3. Vary task

Task variation was done after each opportunity. It was encouraged for AKM to be exposed to several objects and items, in a minimal amount, and to teach AKM that each item has its own label. The therapist provided enough trials for AKM's favourite item to elicit a word. Varying tasks reduces repetitiveness and increases AKM's motivation.

4. Use natural and direct rewards

AKM was rewarded directly using his choice of preferred item. Hammer toy was identified as AKM's preferred item. This helped AKM to associate getting immediate reward after producing attempting to label items to increase his motivation to produce speech.

5. Reward attempts

AKM was rewarded for any verbal attempt he produced, especially in the beginning. Although AKM's pronunciation may not be clear, it was advisable to reward the initial attempt before providing a clear speech.

A naturalistic environment was created by placing cause-and-effect toys (toys that encourage joint attention), combined with several other toys, to discover AKM's interest. When he had a particular toy that he was interested in (e.g., hammer toy), the hammer was kept as a motivator for him to initiate manding for the toy (E.g., points to the hammer, tries saying hammer). The reinforcer (hammer toy) was delayed until he produced a desirable response. Once he produced the desirable response, he was then reinforced using the specific toy that he manded (hammer).

BASELINE MEASURE

Prior to starting the intervention procedure, AKM's progress was measured according to the objectives. Table 1 provides the explanation of baseline measures taken before starting the intervention. Prior to the intervention, AKM only uttered five words at home: mama, papa, susu, air, and ucu. The primary intervention goal was to increase AKM's motivation for functional speech, specifically through labelling items during intervention sessions, using immediate reward to increase motivation. The frequency of AKM's attempts to label items was recorded as a percentage of opportunities during each session. The pivotal areas targeted in the intervention included expanding expressive vocabulary (number of words uttered) and reducing challenging behaviours. Meanwhile, dysfunctional behaviour was provides the outline of planned sessions.

RESULTS

Six planned weekly sessions, including the assessments conducted for AKM and the implementation of PRT were carried out The first three sessions were focused on the psychological assessments and baseline measures, at the same time building rapport with AKM. The therapist aligned goals with AKM's parents, including getting their consent, cooperation, and engagement in the therapeutic process. Another three sessions in the clinic were focused on the implementation of PRT.

During the first two PRT sessions (sessions 4 and 5) in the clinic, AKM had difficulty reaching his targeted skill, which was to label an item or activity upon request. In session 6, AKM produced the

TABLE 1 Objective and intervention baseline measure

Objective	Measurement	Description
Increase self-initiations and functional communication skills	Response rate	Response rate refers to the percentage of items being labelled when opportunities were presented (number of attempts/opportunities provided X 100%)
	Number of words uttered	Prior to the intervention, AKM only uttered five words (mama, papa, susu, air, ucu). The increase in the number of new words was recorded during the session
Reduce dysfunctional behaviour	Frequency of behaviour and antecedent, behaviour, and consequence (ABC) chart	The information on the frequency of behaviour was gathered through an interview, and the ABC chart was filled. The frequency of behaviour was rated weekly using the ABC chart.

ABC = Antecedent, behaviour and consequences chart

TABLE 2 Objective and intervention baseline measure

Sessions	With AKM	With parents
1-2	Behaviour observation and rating Rapport building	Clinical interview Goal setting
3	Baseline data Identify readiness for intervention	Psychological assessment
4-5	Implementation of PRT	Psychoeducation (Reward and punishment strategies)
6	Implementation of PRT	Demonstration of PRT with parents
7	Implementation of PRT at home	Updates on the implementation of PRT at home

PRT = Pivotal Response Treatment

sound to imitate labelling four in request for a block puzzle of number four. Therefore, his response rate increases from 0% in sessions 4 and 5 to 12.5% in session 6

After the sixth session, the intervention was then continued to be generalized at home. Progress review was done with the parents during the seventh session, which was approximately two weeks after the sixth session, with sufficient time given for parents to implement similar techniques at home. AKM's parents reported a new word that was uttered by AKM at his grandmother's house, twice in the past week, which was 'tak nak'. However, AKM's mother was unsure what led to AKM mentioning the word 'tak nak'. This can be concluded that there was a strong motivational factor that led him to mention the word that has a resisting meaning to it.

An antecedent, behaviour, consequence (ABC) chart was used to collect data on AKM's dysfunctional behaviour. AKM's mother reported an improvement in her reward and punishment usage, in which she observed a positive consequence displayed by AKM. There was once when AKM was playing at a playground and refused to go home despite being told to, resulting in a tantrum that lasted around 15 minutes. The crying prolonged and intensified when AKM's attempts to gain his mother's attention for reassurance were unsuccessful. His mother implemented the behaviour management strategy learned by ignoring the prolonged crying and screaming, rather than attending to the behaviour. She began walking further away, but within the close vicinity, after which AKM gradually calmed down and followed his mother's lead. AKM's mother reported slightly better confidence in strengthening the reward and punishment system at home. She also understood the function of his behaviour better and was more skilled at applying necessary reward and punishment.

Looking at AKM's slight progress implied a good prognosis in the future. AKM's parents played a tremendous role in this intervention. Corrective feedback was provided to ensure the intervention method was being implemented in a correct manner. AKM's parents showed openness towards the intervention process, which eased the process of this intervention. AKM was also responsive to his parents and showed improved social awareness, therefore, contributed to the positive prognosis.

LIMITATIONS AND FUTURE RECOMMENDATIONS

PRT is typically conducted through naturalistic settings, therefore, one limitation of the intervention was the accuracy of data collection regarding AKM's intervention outcome. However, given his

age, learning through naturalistic settings was considered the most appropriate intervention approach in order to reduce the developmental gap. It is believed that once AKM is able to grasp the basic attending skills, receptive and expressive language skills, further intensive intervention that applies Applied Behaviour Analysis (ABA) treatment may be useful.

Time constraints and difficulty in attending regular sessions were also limitations in this intervention. Therefore, a collaborative agreement on designing a feasible intervention was done. This intervention was planned as such that parents can continue to generalise the intervention at home, without the need to attend sessions with the therapist. At the same time, parents was also helped to equip themselves with necessary skillset, but due to time constraints, this component was not implemented as thoroughly as intended.

Therefore, future intervention plans include having parents participate in session to observe both their interactions with AKM and the therapist's implementation of intervention strategies. A longitudinal monitoring would also be beneficial to ensure that parents remain on track with the intervention.

CONCLUSION

This case study reports the use of Pivotal Response Treatment (PRT) on a 3-year-11-month-old Malay boy with ASD. PRT is an intervention that targets pivotal areas of development, leading to improvements in several other domains. It is also a naturalistic intervention, which made it appropriate for AKM's parents to generalize the same techniques at home. The intervention focused on enhancing self-initiated communication and reducing dysfunctional behaviours. Due to the limitation of time, only three PRT sessions were conducted in the clinic setting, and parents were coached to apply the techniques consistently at home. While minimal progress was observed in speech output during the clinic sessions, more notable improvements were reported at home, including increased spontaneous word use and reduced behavioral issues. Considering that this is an intervention that emphasizes motivation, child choice, and natural reinforcement, PRT appears to be a feasible and parent-friendly approach for early intervention in young children with ASD, particularly within the Malaysian cultural context, where family involvement plays a central role in child development.

REFERENCE

American Psychiatric Association. 2022. *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.; DSM-5-TR). American Psychiatric Publishing.

Cadogan, S. & McCrimmon, A. W. 2015. Pivotal response treatment for children with autism spectrum disorder: A systematic review of research quality. *Developmental Neurorehabilitation 18*(2): 137–144. https://doi.org/10.3109/17518423.2013.845615

Gengoux, G. W., Abrams, D. A., Schuck, R., Millan, M. E., Libove, R. A., Ardel, C. M., Phillips, J. M., Fox, M., Frazier, T. W. & Hardan, A. Y. 2019. A pivotal response treatment package for children with autism spectrum disorder: A randomized clinical trial. *Pediatrics,* 144(3), e20190178. https://doi.org/10.1542/peds.2019-0178

Hardan, A. Y., Gengoux, G. W., Berquist, K. L., Libove, R. A., Ardel, C. M., Phillips, J., Frazier, T. W. & Minjarez, M. B. 2015. A randomized controlled trial of pivotal response treatment group for parents of children with autism. *Journal of Child Psychology and Psychiatry* 56(8): 884–892. https://doi.org/10.1111/jcpp.12354

Hastings, S. E., Hastings, R. P., Swales, M. A. & Hughes, J. C. 2022. Emotional and behavioural problems of children with autism spectrum disorder attending mainstream schools. *International Journal of Developmental Disabilities, 68*(5): 633–640. https://doi.org/10.1080/20473869.2020.1869414

Koegel, L. K., Koegel, R. L., Harrower, J. K. & Carter, C. M. 1999. Pivotal response intervention I: Overview of approach. *Journal of the Association for Persons with Severe Handicaps,* 24(3): 174–185. https://doi.org/10.2511/rpsd.24.3.174

Koegel, R. L. & Koegel, L. K. 2006. *Pivotal response treatments for autism: Communication, social, and academic development*. Paul H. Brookes Publishing.

Koegel, R. L., O'Dell, M. C. & Koegel, L. K. 1987. A natural language teaching paradigm for nonverbal autistic children. *Journal of Autism and Developmental Disorders 17*(2), 187–200. https://doi.org/10.1007/BF01495055

Maskey, M., Warnell, F., Parr, J. R., Le Couteur, A., & McConachie, H. (2013). Emotional and behavioural problems in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders 43*(4): 851–859. https://doi.org/10.1007/s10803-012-1622-9

Matson, J. L., Wilkins, J. & Macken, J. 2008. The relationship of challenging behaviors to severity and symptoms of autism spectrum disorders. *Journal of Mental Health Research in Intellectual Disabilities 2*(1):

29–44. https://doi.org/10.1080/19315860802611415

Mohammadzaheri, F., Koegel, L. K., Rezaei, M. & Bakhshi, E. 2015. A randomized clinical trial comparison between pivotal response treatment and adult-driven applied behavior analysis intervention on disruptive behaviors in public school children with autism. *Journal of Autism and Developmental Disorders 45*(9): 2899–2907. https://doi.org/10.1007/s10803-015-2451-4.

Mohammadzaheri, F., Koegel, L. K., Bakhshi, E. & Rezaei, M. 2022. The effect of teaching initiations on the communication of children with autism spectrum disorder: A randomized clinical trial. *Journal of Autism and Developmental Disorders 52*(6): 2598–2609. https://doi.org/10.1007/s10803-021-05153-y

Wang, L., Li, S. & Wang, C. 2024. Using pivotal response treatment to improve language functions of autistic children in special schools: A randomized controlled trial. *Journal of Autism and Developmental Disorders*. Advance online publication. https://doi.org/10.1007/s10803-023-05988-7

Williams, J. A., Koegel, R. L., & Egel, A. L. 1981. Response-reinforcer relationships and improved learning in autistic children. *Journal of applied behavior analysis* 14(1), 53–60. https://doi.org/10.1901/jaba.1981.14-53

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Laporan Kes / *Case Report*

Nutritional Management In Palliative Care For Refractory Diffuse Large B-Cell Lymphoma With Mediastinal Mass Complications

Pengurusan Nutrisi dalam Penjagaan Paliatif bagi Pesakit Limfoma Sel B Besar Difus Refraktori dengan Komplikasi Jisim Mediastinum

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ABSTRACT

Refractory diffuse large B-cell lymphoma (DLBCL) is a highly aggressive malignancy that poses significant challenges, particularly when complicated by comorbidities. This case report examines the nutritional management of a 70-year-old Malay male with DLBCL, who is receiving palliative care. His clinical course is further complicated by tracheal stenosis, hospital-acquired pneumonia (HAP), ischemic heart disease, hypertension, and a history of tuberculosis, all of which influence his nutritional requirements. On admission, his weight was 50 kg and height 132 cm, with a BMI of 28.7 kg/m², classified as overweight. Initially, he required NG feeding in the Intensive Care Unit (ICU) and was prescribed Jevity, an enteral nutrition formula. Upon transfer to the hematology ward, his feeding regimen was adjusted to Nutren Optimum, resulting in improvements in sodium levels and fluid balance. He was then transitioned to oral feeding, successfully tolerating a soft diet supplemented with Nutren Optimum, reaching 966 kcal (64.4% of total energy requirement) and 47 g protein (78.3% of total protein requirement) daily. This case underscores the importance of personalized nutritional interventions in optimizing patient outcomes in palliative care.

Keywords: Refractory diffuse large B-cell lymphoma, palliative care, nutritional management

ABSTRAK

Limfoma sel B besar difus refraktori (DLBCL) ialah kanser yang sangat agresif dan memberi cabaran besar dalam rawatan, terutamanya apabila disertai dengan penyakit lain. Laporan kes ini membincangkan pengurusan nutrisi seorang lelaki Melayu berumur 70 tahun yang menghidap DLBCL dan sedang menerima rawatan paliatif. Keadaan klinikal pesakit menjadi lebih kompleks akibat stenosis trakea, pneumonia yang diperoleh di hospital, penyakit jantung iskemia, hipertensi, serta sejarah tuberkulosis, yang kesemuanya mempengaruhi keperluan nutrisi beliau. Semasa kemasukan, berat badan pesakit ialah 50 kg dan tinggi 132 cm, dengan indeks jisim badan 28.7 kg/m² yang dikategorikan sebagai berat badan berlebihan. Pada peringkat awal, pesakit memerlukan pemakanan melalui tiub nasogastrik di Unit Rawatan Rapi dan diberikan formula enteral Jevity. Selepas dipindahkan ke wad hematologi, rejimen pemakanan beliau disesuaikan kepada Nutren Optimum dan menunjukkan penambahbaikan pada paras natrium serta keseimbangan cecair. Pesakit kemudiannya beralih kepada pemakanan oral dan dapat menelan diet lembut yang diperkaya dengan Nutren Optimum, dengan pengambilan harian sebanyak 966 kcal yang memenuhi 64.4% daripada keperluan tenaga dan 47 g protein yang memenuhi 78.3% daripada keperluan protein harian. Kes ini menekankan kepentingan intervensi nutrisi yang disesuaikan mengikut individu bagi mengoptimumkan hasil penjagaan pesakit dalam rawatan paliatif.

Kata kunci: Limfoma sel B besar difus refraktori, penjagaan paliatif, pengurusan nutrisi

INTRODUCTION

Diffuse large B-cell lymphoma (DLBCL) is the most common subtype of non-Hodgkin lymphoma

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and is characterized by rapid progression and aggressive behavior. A subset of patients develops refractory disease, where the lymphoma does not respond to standard therapies. This presents significant clinical challenges and is associated with poor prognosis and increased risk of complications (Siegel et al. 2020). Refractory DLBCL may result in the development of bulky tumors, such as mediastinal masses, which can compress the trachea and lungs. These complications can impair respiratory function and increase susceptibility to secondary infections, including HAP (Younes et al. 2017). Patients with this condition are often immunocompromised due to both the disease itself and its treatment, further increasing the complexity of care.

The presence of multiple comorbidities can complicate the management of refractory DLBCL. In this case, Mr. O, a 70-year-old male, presented with a mediastinal mass, tracheal stenosis, right middle lobe collapse, and HAP. His medical history includes ischemic heart disease, hypertension, and smear-negative pulmonary tuberculosis. These underlying conditions necessitate a cautious approach to nutrition care, particularly regarding sodium and fluid balance. In palliative care, the primary goal is to optimize patient comfort and quality of life. Malnutrition is common in this population due to reduced oral intake, increased metabolic demands, and treatment-related side effects. Adequate nutritional support is essential to maintain functional status, prevent further deterioration, and support symptom management (Singer et al. 2019). This case highlights the importance of individualized nutrition care in the management of refractory DLBCL, especially in the palliative setting, where nutritional goals must be aligned with overall medical and functional priorities.

PATIENT'S HISTORY

Mr. O is a 70-year-old Malay gentleman admitted to the ICU on 18 December 2024, where he stayed until 30 December before being transferred to the Hematology ward. He presented with sudden-onset shortness of breath for one day, accompanied by a productive cough with whitish sputum for one week, without hemoptysis or chest pain. He is currently being treated for refractory diffuse large B-cell lymphoma (DLBCL) with a worsening mediastinal mass, leading to complications such as right middle lobe collapse, tracheal stenosis, HAP, and resolving pulmonary hemorrhage. His medical history includes refractory DLBCL, previous Hepatitis B infection, smear-negative culture-positive pulmonary tuberculosis (PTB), benign prostatic hyperplasia (BPH), hypertension, and ischemic heart disease with aortic regurgitation treated with stenting 10 years ago. He is currently receiving palliative treatment to optimize comfort and manage his symptoms, as curative options are no longer feasible.

In addition to DLBCL, Mr. O's history of pulmonary tuberculosis (TB) likely contributed to chronic lung changes such as fibrosis and reduced respiratory reserve, making him more vulnerable to severe secondary infections like pneumonia. His ongoing immunosuppression from lymphoma treatment further compromises his ability to recover from HAP. Furthermore, his underlying ischemic heart disease (IHD) and hypertension complicate his management; impaired cardiac function due to IHD increases the risk of fluid overload, while hypertension exacerbates cardiovascular strain, necessitating careful monitoring of sodium and fluid balance to prevent heart failure and stroke (Pocock et al. 2019).

ANTHROPOMETRY

The patient's weight was 50 kg, measured on the day of admission (18 December 2024). Height was recorded as 132 cm based on the hospital outpatient medical record and was not re-measured during the current admission due to the patient's critical condition and limitations within the ICU setting. Based on these measurements, the calculated body mass index (BMI) was 28.7 kg/m², classifying the patient as overweight according to Lipschitz's criteria (1994) for older adults. The ideal body weight, calculated using a BMI of 25 kg/m², was 43.6 kg. According to the patient's guardian, the patient's weight three months prior to admission was 59 kg, representing a 15.3% weight loss over three months, which is indicative of severe weight loss.

BIOCHEMICAL DATA

The patient's most recent biochemical data was from a blood test conducted on 30 December 2024, one day prior to the referral to the dietitian. The renal profile showed hypernatremia with a sodium level of 148 mmol/L and hypokalemia with a potassium level of 3.4 mmol/L. Urea and creatinine were within the normal range at 7.6 mmol/L and 68 mmol/L, respectively. His calculated eGFR was >90 mL/min/1.73m3 indicates normal renal function. The liver function test showed hypoalbuminemia (20 g/L) and low total protein (52 g/L), likely due to malnutrition or hepatic involvement. Elevated alkaline phosphatase (256 U/L), alanine transaminase (86 U/L), and aspartate transaminase (29 U/L) may suggest lymphoma-related or drug-induced liver injury. Calcium (2.31 mmol/L) and magnesium (0.83 mmol/L) were within normal ranges, while phosphate was low at 0.65 mmol/L. The C-reactive protein (CRP) was significantly elevated at 110.41 mg/L, indicating inflammation.

CLINICAL ASSESSMENT

A nutrition-focused physical examination could not be performed as the patient was managed in an isolation room due to active infection, limiting direct bedside assessment by the dietitian. Clinical observations were therefore obtained indirectly through discussion with the nurse in charge, review of medical and nursing records, and visual observation from outside the isolation room, in line with infection control protocols.

The patient was reported to be alert, conscious, and fully responsive, with a Glasgow Coma Scale (GCS) score of 15. Vital signs were stable, with a temperature of 36.6°C, blood pressure of 118/54 mmHg, heart rate of 89 beats per minute, respiratory rate of 18 breaths per minute, and oxygen saturation (SpO_2) of 100% on 5 L/min nasal prong oxygen. The patient had an indwelling urinary catheter, with urine output ranging from 50–120 mL/hour. Bowel movements were documented twice on the previous day, with normal stool consistency. Nasogastric (NG) aspirate was 195 mL. Daily fluid balance showed an intake of 1331 mL and output of 1888 mL, resulting in a negative balance of 686 mL.

The patient had been receiving NG tube feeding since admission. The medication history, reviewed from medical records, included bisoprolol 1.25 mg once daily and amlodipine 5 mg once daily for hypertension and ischemic heart disease, potassium chloride solution 3 g three times daily for correction of hypokalemia, allopurinol 200 mg once daily, lenalidomide 10 mg once daily for refractory diffuse large B-cell lymphoma, tenofovir disoproxil fumarate 300 mg once daily for a previous hepatitis B infection, and ezetimibe 10 mg once daily.

DIETARY ASSESSMENT

He was started on NG feeding with Jevity on 23 December 2024 while he was in the ICU. Jevity was prescribed by the previous dietitian in the ICU ward, as the patient had recently started NG feeding. This standard formula, known for its high fiber content, is a ready-to-use product commonly administered in ICU settings. The prescribed feeding regimen began with continuous feeding at an initial rate of 10 mL/hour for the first 24 hours, gradually advancing to a maximum rate of 50 mL/hour. Additionally, the regimen included a flushing protocol of 50 mL of water every six hours, along with gastric residual volume (GRV) checks every six hours. By 28 December 2024, the patient was at the maximum feeding rate, receiving 1272 kcal/day (25.4 kcal/kg body weight) and 52.4 g of protein (1.05 g/kg body weight). The total fluid intake from the feeding regimen was 1200 mL, with an additional 200 mL from water flushes. The patient tolerated the feeding well, with no signs of aspiration reported. This feeding regimen met 84.8% of the patient's estimated energy requirement.

NUTRITION DIAGNOSIS

Inadequate oral intake related to dysphagia and disease burden secondary to refractory diffuse large B-cell lymphoma as evidenced by dependence on NG tube feeding and inability to meet nutritional requirements orally.

NUTRITION INTERVENTION

The short-term nutritional goal is to optimize the patient's nutritional status by ensuring adequate protein and energy intake and to achieve normal sodium levels. The long-term goal is to prevent further weight and muscle loss, particularly in view of the patient's prolonged hospital stay and reduced appetite since admission, which necessitated the initiation of enteral feeding. Although the patient's body mass index falls within the overweight range, actual body weight was used to estimate nutritional requirements due to the presence of severe unintentional weight loss, with the primary aim of preventing further weight loss and maintaining adequate nutritional intake. Using the quick method, the patient's energy requirement is estimated at 30 kcal/kg body weight (1500 kcal/day). Protein requirements are calculated at 1.2 g/kg body weight, in accordance with the Dietitians Association of Australia (DAA) 2008 guidelines for oncology patients undergoing radiotherapy, providing a total of 60 g protein per day. The previous maximum NG feeding regimen met only 84.8% of the estimated energy requirements. Therefore, enteral feeding was initiated and advanced as tolerated according to institutional protocol. To meet these requirements, the nutritional intervention includes transitioning from Jevity to Nutren Optimum, a standard complete formula suitable for the patient's condition. The proposed regimen involves bolus feeding with 7 scoops of Nutren Optimum mixed with 210 mL of water, supplemented with 50 mL of water flushes. The detailed feeding plan is outlined in Table 1.

Nutren Optimum was selected in preference to Jevity based on its lower sodium content when standardised to a comparable reconstituted volume, in addition to its suitability for bolus feeding and patient tolerance. To ensure clarity and avoid confusion related to differences in product formulation, sodium content is presented using consistent units per 100 mL of prepared formula. When compared on this basis, Nutren Optimum provides a lower sodium content than Jevity, making it a more appropriate option for this patient in view of elevated sodium levels.

NUTRITION MONITORING AND EVALUATION

For nutrition monitoring and evaluation, feeding tolerance, fluid balance, and relevant biochemical parameters were closely monitored throughout the case. Given the patient's history of reduced intake and baseline hypophosphatemia (0.64–0.7 mmol/L), he was considered at risk of refeeding syndrome. Enteral feeding was therefore initiated cautiously with gradual advancement, accompanied by close biochemical monitoring. Electrolytes, including phosphate, potassium, and magnesium, were monitored regularly as part of routine ICU care, and potassium supplementation was administered as prescribed to correct hypokalaemia. Phosphate levels were closely observed during the initiation of feeding, with replacement administered as clinically indicated according to ICU protocol, and no clinical features suggestive of refeeding syndrome were documented during the monitoring period. Between 2 January and 7 January 2025, a total of three dietetic follow-up sessions were conducted to evaluate Mr. O's progress, with particular attention to his tolerance of the newly initiated enteral feeding product. Table 2 presents the biochemical parameters obtained during the follow-up period to monitor the patient's condition.

These follow-up sessions emphasized monitoring NG feeding tolerance and assessing his overall nutritional status. Overall, Mr. O's condition is showing signs of improvement. A comprehensive summary of his nutrition-focused physical findings is outlined in the Table 3 for further reference. During the follow-up period, Mr. O's dietary intake was monitored. On 2 January 2025, he started Step 3 of the feeding regimen, but the 12:00 p.m. feeding was poorly tolerated, with 240 mL of undigested formula aspirated via the NG tube. The 3:00 p.m. feeding was omitted, and intravenous Maxolon (10 mg, three times daily) was introduced to improve feeding tolerance. By the second follow-up on 5 January 2025, Mr. O tolerated the full regimen, achieving 1512 kcal and 63 g of protein, meeting his energy and protein needs. Total fluid intake was 1560 mL, including water flushes. By the third follow-up on 7 January, Mr. O transitioned to a soft diet, with approval from the Speech and Language Therapy (SALT) team on 6 January. He successfully consumed one cup of milk, one cup of water, and completed a full soft meal by dinner. His appetite gradually improved, and by 7 January, he managed half a bowl of porridge. He continued taking 6 scoops of Nutren Optimum with 180 mL water once per day as an oral nutritional supplement, providing 216 kcal and 9 g of protein. His total intake of 966 kcal and 47 g of protein met 64.4% of energy and 78.3% of protein requirement

TABLE 1 Feeding Plan for Mr. O

Step	Scoops	Water (mL)	Flush (mL)	Energy (kcal)	Protein (g)	Notes
1	3	90	50	648	27	Start feeding; flush every 3 hours. Check GRV every 6 hours.
2	5	150	50	1080	45	Step up after 2 feedings at previous step
3	7	210	50	1512	63	Step up after 2 feedings at previous step
Full regime	7	210	50	1512	63	Provides 1512 kcal (30.24 kcal/kg BW), 63 g protein (1.26 g/kg BW), fluid 1560 mL; omit midnight (12:00 AM and 3:00 AM feeds.

Note: Flushing with 50 mL water every 3 hours and GRV checked every 6 hours.

TABLE 2 Laboratory findings of Mr. O during hospitalisation

Parameter	30/12/2024	02/01/2025	06/01/2025	Reference Range
Renal Function				
Sodium (mmol/L)	148 (High)	144	133 (Low)	136–145
Potassium (mmol/L)	3.4 (Low)	2.7 (Low)	3.7	3.6–5.2
Urea (mmol/L)	7.6	8.1	9.1 (High)	3.2–8.2
Creatinine (μmol/L)	68	70	78	54–97
Liver Function				
Total protein (g/L)	52 (Low)	51 (Low)	55 (Low)	64–82
Albumin (g/L)	20 (Low)	21 (Low)	24 (Low)	32–48

Parameter	30/12/2024	02/01/2025	06/01/2025	Reference Range
Alkaline phosphatase (U/L)	256 (High)	209 (High)	206 (High)	45–129
ALT (U/L)	86 (High)	44	42	10–49
AST (U/L)	29	20	22	<34
Electrolytes				
Calcium (mmol/L)	2.31	2.23	2.34	2.2–2.6
Phosphate (mmol/L)	0.65 (Low)	0.64 (Low)	0.70 (Low)	0.78–1.65
Magnesium (mmol/L)	0.83	0.60	0.66	0.53–1.11
Inflammatory Marker				
CRP (mg/L)	110.41 (High)	38.86 (High)	Not assessed	<5.0
Complete Blood Count				
Hb (g/L)	N/A	48 (Low)	78 (Low)	130–170

Note: Reference normal ranges are based on values from the University Malaya Medical Centre

TABLE 3 Summary of Mr. O's nutrition-focused physical findings during hospitalisation.

Date	Cognitive Status	Vital Signs (BP)	Respiratory Status	Gastrointestinal	IV Drip
2 January 2025	Alert and conscious, full GCS	134/65 mmHg	On oxygen 2 L/min via nasal prong, SpO_2 100%	Bowel open (small amount, soft stool), good urine output	Not supported
5 January 2025	Alert and conscious, full GCS	109/62 mmHg	Room air, SpO_2 99%	Bowel open twice (normal stool), good urine output	Not supported
7 January 2025	Alert and conscious, full GCS	115/69 mmHg	Room air, SpO_2 99%	Bowel open twice (normal stool), good urine output	Not supported

DISCUSSION

Patients with refractory diffuse large B-cell lymphoma (DLBCL) receiving palliative care often face complex nutritional challenges due to disease burden, systemic inflammation, and treatment-related complications. Nutrition care in these patients aims to maintain functional status, reduce symptoms, and prevent further nutritional deterioration rather than achieve weight gain. Cancer-related inflammation and tumour metabolism can increase energy expenditure and accelerate muscle breakdown, contributing to weight loss and impaired immunity (Arends et al. 2017; Arends et al. 2021). Current ASPEN and ESPEN guidelines recommend early, individualised nutrition support when oral intake is insufficient, with adequate energy and protein to reduce the risk of malnutrition and cachexia (Singer et al. 2019; Compher et al. 2021). In this case, enteral nutrition was indicated due to dysphagia and respiratory compromise from tracheal stenosis, which increased aspiration risk. Feeding intolerance is common in critically ill and oncology patients and may be worsened by altered gut motility, medications, and immobility (McClave et al. 2016).

Patients with airway compromise or high aspiration risk are often managed with cautious feeding strategies, such as controlled bolus or continuous enteral feeding, depending on tolerance and stability (ESPEN 2019). Bolus NG feeding was used here with close monitoring, alongside prokinetic therapy (metoclopramide) to improve gastric emptying and tolerance (McClave et al. 2016). Electrolyte management is an important part of nutrition support in these patients. The formula was switched from Jevity to Nutren Optimum to improve electrolyte balance and tolerance. After the change and ongoing monitoring, sodium levels improved, highlighting the need to individualise formula choice based on clinical and biochemical parameters. Monitoring focused on biochemical results, fluid balance, and feeding tolerance. Repeated weight and functional assessments were limited by ICU admission and isolation precautions, which reflects real-world challenges in managing nutrition for critically ill palliative patients.

CONCLUSION

In palliative care, nutrition management prioritises comfort, symptom relief, and quality of life rather than curative outcomes. For this patient with refractory DLBCL and multiple comorbidities, individualized nutrition support helped stabilise metabolism, manage feeding difficulties, and prevent further nutritional decline. Careful formula selection, close monitoring of electrolytes, use of

prokinetic agents, and a gradual transition from enteral to oral intake were implemented in line with ASPEN and ESPEN recommendations (Singer et al. 2019; Compher et al. 2021), ensuring the patient's needs were met while respecting palliative care goals. This case highlights the importance of flexible, patient-centred nutrition care in complex oncology and palliative settings.

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REFERENCE

Compher, C., Bingham, A.L., McCall, M., Patel, J., Rice, T.W., Braunschweig, C. & McKeever, L. 2021. Guidelines for the provision of nutrition support therapy in the adult critically ill patient: American Society for Parenteral and Enteral Nutrition. *Journal of Parenteral and Enteral Nutrition* 46(1):15–34. https://doi.org/10.1002/jpen.2267

Lipschitz, D.A. 1994. Screening for nutritional status in the elderly. *Primary Care* 21(1):55–67.

Pocock, S.J., Ariti, C.A., McMurray, J.J.V. & Maggioni A. 2013. Predicting survival in heart failure: A risk score based on 39,372 patients from 30 studies. *European Heart Journal* 34(19):1404–1413. https://doi.org/10.1093/eurheartj/ehs337

Siegel, R.L., Miller, K.D. & Jemal, A. 2020. Cancer statistics, 2020. *CA: A Cancer Journal for Clinicians.* 70(1):7–30. https://doi.org/10.3322/caac.21590

Singer, P., Blaser, A.R., Berger, M.M., Alhazzani, W., Calder, P.C., Casaer, M.P., Hiesmayr, M., Mayer, K., Montejo, J.C., Pichard, C., Preiser, J.C., van Zanten, A.R.H., Oczkowski, S., Szczeklik, W. & Bischoff, S.C. 2019. ESPEN guideline on clinical nutrition in the intensive care unit. *Clinical Nutrition.* 38(1):48–79. https://doi.org/10.1016/j.clnu.2018.08.037

Younes, A., Sehn, L.H., Johnson, P., Zinzani, P.L., Hong, X., Zhu, J., Patti, C., Belada, D., Samoilova, O., Villa, D., et al. 2017. Randomized phase III trial of ibrutinib and rituximab plus chemotherapy in untreated non-germinal center B-cell diffuse large B-cell lymphoma. *Journal of Clinical Oncology* 35(5):510–518. https://doi.org/10.1200/JCO.2016.69.9845

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Artikel Asli / *Original Article*

Status Kesihatan Respiratori Dalam Kalangan Pelajar Di Sebuah Sekolah Berhampiran Bekas Tapak Pelupusan Sisa

Respiratory Health Status Among Students at a School Near a Former Waste Disposal Site

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ABSTRACT

Abandoned solid waste disposal sites have the potential to release various harmful gases that can adversely affect the respiratory health of local communities, especially school students who experience continuous environmental exposure. This study aims to assess respiratory health among students of Sekolah Menengah Kebangsaan Taman Dato' Harun (SMKTDH), located near a former disposal site. A questionnaire was conducted alongside lung function measurements using a Peak Flow Meter and Spirometer, with comparisons between Form One and Form Five students. A total of 95 Form One students and 100 Form Five students participated. The results showed significant differences ($p < 0.001$) for FEV1, FVC, and PEFR, where Form Five students had higher mean values: FEV1 (2.20 L), FVC (2.59 L), PEFR (392.45 L/min) compared to Form One: FEV1 (1.70 L), FVC (2.13 L), PEFR (319.0 L/min). The FEV1/FVC ratio also differed significantly ($p=0.012$) between the two groups. However, there was no significant difference in the classification of respiratory health categories between the two groups, indicating that although there are differences in lung function based on age and physiological maturity, the overall respiratory health levels of both groups are comparable. These findings emphasize the importance of regular monitoring of respiratory health among students in schools near environmentally hazardous areas such as former waste disposal sites.

Keywords: Landfill, Respiratory health, Lung Function, School students.

ABSTRAK

Tapak pelupusan sisa pepejal terbiar berpotensi melepaskan pelbagai gas berbahaya yang boleh memberi kesan buruk terhadap kesihatan respiratori komuniti setempat, terutamanya murid sekolah yang mengalami pendedahan persekitaran secara berterusan. Kajian ini bertujuan menilai kesihatan respiratori dalam kalangan pelajar Sekolah Menengah Kebangsaan Taman Dato' Harun (SMKTDH), yang terletak berhampiran dengan bekas tapak pelupusan. Soal selidik dijalankan bersama pengukuran fungsi paru-paru menggunakan Peak Flow Meter dan Spirometer, dengan perbandingan antara pelajar Tingkatan Satu dan Tingkatan Lima. Seramai 95 pelajar Tingkatan Satu dan 100 pelajar Tingkatan Lima terlibat. Keputusan menunjukkan perbezaan ketara ($p < 0.001$) bagi FEV1, FVC, dan PEFR, di mana pelajar Tingkatan Lima mempunyai nilai min lebih tinggi: FEV1 (2.20 L), FVC (2.59 L), PEFR (392.45 L/min) berbanding Tingkatan Satu: FEV1 (1.70 L), FVC (2.13 L), PEFR (319.0 L/min). Nilai FEV1/FVC juga berbeza secara signifikan ($p=0.012$) antara kedua kumpulan. Namun, tiada perbezaan signifikan dalam pengelasan kategori kesihatan respiratori antara kedua-dua kumpulan, menunjukkan bahawa walaupun terdapat perbezaan fungsi paru-paru berasaskan umur dan kematangan fisiologi, tahap kesihatan respiratori keseluruhan kedua-dua kumpulan adalah setanding. Dapatan ini menekankan kepentingan pemantauan berkala kesihatan respiratori dalam kalangan pelajar di sekolah berhampiran kawasan berisiko alam sekitar seperti bekas tapak pelupusan sisa.

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Kata kunci: Tapak pelupusan, Kesihatan respiratori, Fungsi paru-paru, Pelajar sekolah

PENDAHULUAN

Malaysia sedang berdepan cabaran dalam pengurusan sisa pepejal, dan implikasinya terhadap kesihatan awam, khususnya berkaitan sisa perubatan dari fasiliti kesihatan, menjadi semakin kritikal. Bekas tapak pelupusan sisa pepejal yang telah ditutup masih boleh melepaskan gas berbahaya seperti metana dan hidrogen sulfida yang berpotensi menjejaskan kesihatan respiratori komuniti berhampiran, khususnya kanak-kanak sekolah yang terdedah kepada pendedahan persekitaran secara berterusan. Peningkatan populasi telah meningkatkan jumlah sisa yang dilupuskan ke tapak pelupusan, yang kini semakin tepu akibat pembangunan infrastruktur berterusan. Hal ini membimbangkan kerana fasiliti perubatan termasuk pengimejan perubatan dan radioterapi menghasilkan sisa berbahaya yang perlu diurus dengan betul bagi mengelakkan pencemaran alam sekitar (Khan et al. 2019).

Dalam bidang perubatan, terutamanya di jabatan perubatan nuklear, penghasilan sisa radioaktif merupakan isu penting. Prosedur menggunakan radiofarmaseutikal boleh menghasilkan sisa tercemar yang berisiko jika tidak diurus dengan betul. Contohnya, pesakit menerima rawatan metastatik prostat mungkin mengalami inkontinens urin, menghasilkan sisa tercemar yang memerlukan kaedah pelupusan khusus bagi melindungi pesakit dan persekitaran (Graves 2023; Macedo & de Oliveira 2020). Pelupusan sisa radioaktif dikawal ketat bagi memastikan pendedahan radiasi berada dalam had selamat (Sančanin & Penjišević, 2023), termasuk proses decay di mana sisa disimpan sehingga tahap radioaktiviti merosot (Sabour & Amron 2024).

Selain itu, kewujudan tapak pelupusan berhampiran fasiliti dan kawasan perumahan menimbulkan kebimbangan tambahan. Gas dan sebatian toksik dari tapak pelupusan boleh meresap ke bangunan berhampiran, termasuk sekolah. Pendedahan udara tercemar secara berpanjangan boleh menyebabkan masalah respiratori kronik seperti asma, COPD, dan kanser paru-paru (Ithnin et al. 2013; Udayanga et al. 2021). Simptom lain seperti sakit kepala dan masalah psikologi juga boleh berlaku bergantung kepekatan gas (Ashtari et al. 2020; Khan et al. 2019).

Walaupun kajian terdahulu telah mengenal pasti kesan pencemaran udara terhadap kesihatan respiratori, terdapat jurang pengetahuan berkaitan impak khusus bekas tapak pelupusan terhadap kanak-kanak sekolah di Malaysia. Kajian ini menumpukan kepada kesihatan respiratori pelajar SMK Taman Dato Harun yang terletak berhampiran tapak pelupusan. Penilaian ini penting dalam konteks kesihatan awam dan persekitaran di Malaysia, khususnya bagi memaklumkan dasar perancangan guna tanah dan penempatan sekolah, serta keperluan pemantauan kesihatan berkala bagi populasi berisiko. Dapatan ini memberi gambaran mengenai keperluan intervensi dan penambahbaikan polisi pengurusan sisa serta penilaian kesihatan komuniti di Malaysia.

BAHAN DAN KAEDAH

Kajian keratan rentas ini dijalankan di sebuah sekolah menengah berhampiran dengan tapak pelupusan sisa pepejal yang telah menjalani proses pemulihan lebih daripada dua dekad yang lalu. Secara khususnya, sekolah tersebut berada pada jarak kira-kira 240 meter daripada tapak pelupusan lama tersebut. Kaedah persampelan mudah telah digunakan untuk pemilihan responden. Responden kajian terdiri daripada dua kumpulan umur, iaitu pelajar Tingkatan 1 yang berumur sekitar 13 tahun dan pelajar Tingkatan 5 yang berumur sekitar 17 tahun. Sebanyak 258 orang pelajar telah terlibat, dengan pembahagian seimbang iaitu 129 pelajar Tingkatan 1 dan 129 pelajar Tingkatan 5. Saiz sampel telah ditentukan berdasarkan formula Krejcie dan Morgan (1970) untuk populasi sekolah, dengan tahap keyakinan 95% dan margin ralat 5%. Pembahagian seimbang ini membolehkan perbandingan yang lebih jelas dibuat antara remaja awal dan remaja lewat, serta memberikan gambaran mengenai potensi pengaruh faktor umur terhadap tahap kesihatan respiratori.

Kajian ini tidak melibatkan pengukuran langsung kualiti udara persekitaran. Penilaian risiko pendedahan adalah berdasarkan jarak kedekatan sekolah (240 meter) daripada bekas tapak pelupusan. Maklumat tambahan mengenai tempat tinggal responden dan faktor persekitaran lain dikumpul melalui soal selidik untuk memberikan konteks pendedahan yang lebih komprehensif.

Bagi mendapatkan data yang komprehensif, satu borang soal selidik berstruktur telah digunakan, disertai ujian fungsi paru-paru. Soal selidik berstruktur yang digunakan telah diadaptasi daripada kajian Ithnin et al. (2013) mengenai kesihatan respiratori pelajar berhampiran tapak pelupusan, dengan kebolehpercayaan (Cronbach's alpha) 0.78. Soal selidik tersebut dibahagikan kepada tiga bahagian utama. Bahagian A menumpukan kepada maklumat sosiodemografi, seperti umur, jantina, dan latar belakang sosioekonomi. Bahagian B meneliti persekitaran tempat tinggal dan faktor yang mungkin mempengaruhi gaya hidup serta keadaan kesihatan responden. Bahagian C pula menilai simptom-simptom kesihatan yang dialami oleh pelajar ketika

mengikuti sesi persekolahan, bagi mengenal pasti potensi hubungan antara persekitaran sekolah dan kesihatan respiratori mereka.

Selepas melengkapkan soal selidik, semua responden menjalani ujian fungsi paru-paru menggunakan dua peralatan, iaitu Peak Flow Meter dan Spirometer. Peak Flow Meter (TruZone, Precision Medical Ltd) ditentukur sebelum setiap sesi pengukuran menggunakan piawai pengeluar. Spirometer (MicroLab, CareFusion) ditentukur setiap pagi menggunakan picagari penentukuran 3-liter. Peak Flow Meter digunakan untuk mengukur Kadar Aliran Hembusan Puncak (Peak Expiratory Flow Rate, PEFR), yang merupakan indikator penting bagi menilai keupayaan pernafasan semasa menghembus nafas. Manakala Spirometer digunakan untuk mengukur dua parameter utama, iaitu Isipadu Udara Hembusan Paksa dalam Satu Saat (Forced Expiratory Volume in One Second, FEV1) dan Kapasiti Vital Paksa (Forced Vital Capacity, FVC). Setiap responden melakukan tiga percubaan, dan bacaan terbaik direkodkan mengikut garis panduan American Thoracic Society (ATS). Bacaan ini penting bagi menilai keupayaan paru-paru dan mengenal pasti kemungkinan berlakunya gangguan atau masalah respiratori.

Kajian ini telah mendapat kelulusan daripada Jawatankuasa Etika Penyelidikan Universiti Kebangsaan Malaysia. Persetujuan bertulis telah diperoleh daripada ibu bapa atau penjaga setiap responden. Selain itu, persetujuan lisan turut diperoleh daripada para pelajar sebelum penyertaan. Semua data dikendalikan secara sulit dan dianalisis secara agregat tanpa pendedahan identiti individu.
Data dianalisis menggunakan Statistical Package for the Social Sciences (SPSS) versi 26.0. Statistik deskriptif (min, sisihan piawai (SD), frekuensi, peratusan) digunakan untuk menghuraikan ciri-ciri responden dan tahap kesihatan respiratori. Normaliti data dinilai menggunakan ujian Shapiro-Wilk. Ujian-t sampel bebas digunakan untuk membandingkan min fungsi paru-paru antara kedua kumpulan umur, manakala ujian khi-kuasa dua (χ^2) digunakan untuk membandingkan kategori kesihatan respiratori. Tahap signifikansi ditetapkan pada nilai $p < 0.05$. Data yang hilang (< 2%) dikendalikan menggunakan kaedah pairwise deletion. Melalui analisis ini, kajian bertujuan untuk mengenal pasti hubungan yang berpotensi antara simptom kesihatan respiratori pelajar dengan persekitaran sekolah, khususnya memandangkan kedudukan sekolah yang berhampiran bekas tapak pelupusan sisa tersebut.

KEPUTUSAN

SOSIODEOMGRAFI RESPONDEN

Sebanyak 195 orang pelajar daripada sebuah sekolah menengah di Petaling Jaya, Selangor telah mengambil bahagian dalam kajian ini. Seperti ditunjukkan dalam JADUAL 1, seramai 95 orang responden merupakan pelajar Tingkatan 1, manakala 100 orang lagi terdiri daripada pelajar Tingkatan 5. Dari segi jantina, bilangan responden perempuan adalah sedikit lebih tinggi (101 orang) berbanding lelaki (94 orang).

Komposisi etnik pula menunjukkan majoriti responden adalah daripada bangsa Melayu. Bagi pelajar Tingkatan 1, 97.9% adalah Melayu, manakala bagi Tingkatan 5, peratusan tersebut ialah 81%. Perincian ini memberikan gambaran jelas tentang profil sosiodeomgrafi populasi kajian.

SIMPTOM RESPIRATORI RESPONDEN

Jadual 2 memaparkan maklumat deskriptif berkaitan simptom respiratori yang dilaporkan oleh responden. Analisis menunjukkan majoriti besar responden menyatakan tiada simptom respiratori bagi kesemua item soal selidik. Dapatan ini menunjukkan bahawa kadar kehadiran simptom respiratori dalam kalangan pelajar adalah rendah, sekaligus mencerminkan keadaan kesihatan respiratori yang relatif baik dalam populasi kajian.

PERBANDINGAN PARAMETER FUNGSI PARU-PARU

Jadual 3 menunjukkan nilai min dan sisihan piawai bagi Peak Expiratory Flow Rate (PEFR), Forced Expiratory Volume in one second (FEV1), Forced Vital Capacity (FVC), dan nisbah FEV1/FVC berdasarkan bacaan Peak Flow Meter dan Spirometer.

Ujian-t tidak berpasangan mendapati terdapat perbezaan yang signifikan secara statistik antara pelajar Tingkatan 1 dan Tingkatan 5 bagi keempat-empat parameter fungsi paru-paru ($p < 0.05$). Dapatan ini menunjukkan bahawa pelajar Tingkatan 5 mempunyai tahap fungsi paru-paru yang lebih tinggi, berkemungkinan disumbangkan oleh faktor perkembangan fisiologi dan kematangan sistem respiratori mengikut umur.

TAHAP KESIHATAN RESPIRATORI RESPONDEN

Jadual 4 menunjukkan perbandingan tahap kesihatan respiratori berdasarkan kategori “Normal” dan “Tidak Normal”. Seramai 65 orang (68.4%) pelajar Tingkatan 1 dan 75 orang (75.0%) pelajar Tingkatan 5 dikategorikan sebagai mempunyai tahap kesihatan respiratori “Tidak Normal”. Walau bagaimanapun, ujian Chi-square menunjukkan nilai $\chi^2 = 1.041$ ($p = 0.308$), yang menandakan bahawa perbezaan antara kedua-dua kumpulan tidak signifikan secara statistik. Perbandingan bagi kategori “Normal” juga konsisten dengan dapatan

JADUAL 1 Sosiodemografi Responden

Sosiodemografi	Responden	
	Tingkatan 1 n (%)	**Tingkatan 5 n (%)**
Jantina		
Lelaki	48(50.5)	46(46)
Perempuan	47(49.5)	54(54)
Bangsa		
Melayu	93(97.9)	81(81)
Bukan Melayu	2(2.1)	19(19)

JADUAL 2 Simptom Respiratori

Simptom Respiratori	Responden	
	Tingkatan 1 n(%)	**Tingkatan 5 n(%)**
Simptom (berdengkur)		
Ya	4 (4.2)	5 (5.1)
Tidak	80 (84.2)	70 (70.7)
Kadang-kadang	11 (11.6)	24 (24.2)
Simptom (bersin)		
Ya	7 (7.4)	12 (12.0)
Tidak	65 (68.4)	61 (61.0)
Kadang-kadang	23 (24.2)	27 (27.0)
Simptom (kahak)		
Ya	20 (21.1)	14 (14.1)
Tidak	51 (53.7)	55 (55.6)
Kadang-kadang	24 (25.3)	30 (30.3)
Simptom (menahan nafas)		
Ya	11 (11.6)	4 (4.0)
Tidak	68 (71.6)	78 (78.8)
Kadang-kadang	16 (16.8)	17 (17.2)
Simptom (keradangan)		
Ya	1 (1.1)	2 (2.0)
Tidak	83 (89.2)	86 (86.9)
Kadang-kadang	9 (9.7)	11 (11.1)
Simptom (batuk berpanjangan)		
Ya	4 (4.2)	2 (2.0)
Tidak	71 (74.7)	85 (85.0)
Kadang-kadang	20 (21.1)	13 (13.0)
Simptom (ketidakcukupan nafas)		
Ya	2 (2.1)	4 (4.0)
Tidak	75 (79.8)	79 (79.0)
Kadang-kadang	17 (18.1)	17 (17.0)
Simptom (nafas bersiul)		
Ya	7 (7.4)	4 (4.0)
Tidak	74 (77.9)	83 (83.0)
Kadang-kadang	14 (14.7)	13 (13.0)

JADUAL 3 Bacaan Ujian Fungsi Paru-Paru (Liter dan L/min)

Ujian Fungsi Paru-Paru	Responden					
	Tingkatan 1		Tingkatan 5			
	n	Min±SD	n	Min±SD	t	Nilai p
FEV	95	1.70±0.445	100	2.20±0.604	-6.567	< 0.001
FVC	95	2.13±0.612	100	2.59±0.688	-4.905	< 0.001
PEFR	95	319.00±56.581	100	392.45±91.405	-6.783	< 0.001
FEV_1/FVC	95	0.81±0.147	100	0.86±0.120	-2.535	0.012

Nota kaki: FEV1 = Forced Expiratory Volume in 1 second (Isipadu Udara Hembusan Paksa dalam Satu Saat); FVC = Forced Vital Capacity (Kapasiti Vital Paksa); PEFR = Peak Expiratory Flow Rate (Kadar Aliran Hembusan Puncak); t = Independent t-test (Ujian-t sampel bebas); p = p-value (Nilai signifikansi); Unit: FEV1 dan FVC dalam liter (L); PEFR dalam liter per minit (L/min)"

JADUAL 4 Perbandingan tahap kesihatan respiratori responden.

Tahap kesihatan respiratori	Responden		Nilai χ^2	Nilai p
	Tingkatan 1 n (%)	Tingkatan 5 n (%)		
Tidak normal	65(68.4)	75(75.0)	1.041	0.308
Normal	30(31.6)	25(25.0)		

Nota kaki: χ^2 = Chi-square test (Ujian khi-kuasa dua); p = p-value (Nilai signifikansi)

tersebut, iaitu masing-masing 31.6% untuk Tingkatan 1 dan 25.0% untuk Tingkatan 5.

PERBINCANGAN

Walaupun pelajar Tingkatan 5 menunjukkan nilai fungsi paru-paru yang lebih tinggi berbanding Tingkatan 1, majoriti responden dalam kedua-dua kumpulan masih dikategorikan sebagai Tidak Normal berdasarkan nilai piawai fungsi paru-paru mengikut umur dan ketinggian. Fenomena ini menunjukkan bahawa walaupun terdapat peningkatan fungsi paru-paru seiring dengan pertumbuhan fisiologi, nilai mutlak masih berada di bawah paras normal yang dijangka untuk kumpulan umur masing-masing. Keadaan ini mungkin mencadangkan kesan kumulatif pendedahan persekitaran jangka panjang terhadap kedua-dua kumpulan umur, yang menghalang pencapaian fungsi paru-paru optimum walaupun dengan perkembangan fisiologi normal.

Meskipun kematangan fisiologi memainkan peranan penting dalam perbezaan fungsi paru-paru antara kumpulan umur, peranan faktor persekitaran tidak boleh diabaikan. Pendedahan jangka panjang kepada pencemar udara daripada bekas tapak pelupusan, termasuk zarah terampai halus ($PM_{2.5}$, PM_{10}), sebatian organik meruap, dan gas seperti metana dan hidrogen sulfida, berpotensi menjejaskan perkembangan dan fungsi paru-paru kedua-dua kumpulan responden. Kajian terdahulu oleh Yu et al. (2018) melaporkan kesan buruk pencemaran udara daripada tapak pelupusan terhadap kesihatan respiratori kanak-kanak dalam radius 500 meter. Memandangkan sekolah dalam kajian ini terletak hanya 240-meter dari bekas tapak pelupusan, kemungkinan pendedahan kronik kepada pencemar udara adalah tinggi dan mungkin menyumbang kepada tahap kesihatan respiratori "Tidak Normal" yang diperhatikan dalam majoriti.

Penutupan tapak pelupusan selama bertahun-tahun tidak menghapuskan risiko kesihatan kepada komuniti berhampiran kerana pendedahan kepada bahan pencemar udara masih berterusan. (Vinti et al. 2021). Proses pereputan sisa oleh bakteria boleh berterusan selama antara dua puluh hingga seratus tahun, bergantung pada cara pengurusan tapak pelupusan tersebut. Pereputan sisa organik berlaku dalam empat peringkat, dan setiap peringkat mempengaruhi komposisi gas yang dihasilkan. Semasa proses pereputan berlaku, gas pelupusan akan terhasil secara semula jadi sebagai bahan sampingan. Secara umumnya, gas pelupusan terdiri daripada kira-kira 45% hingga 60% metana dan 40% hingga 60% karbon dioksida, yang kedua-duanya merupakan gas rumah hijau yang boleh menyumbang kepada pemanasan global (Gautam & Agrawal 2021).

Selain metana dan karbon dioksida, gas pelupusan juga mengandungi pelbagai pencemar lain yang berbahaya termasuk non-methane organic compounds (NMOCs) seperti trikloroetilena, benzena dan vinil klorida. Sebatian-sebatian ini boleh memberi kesan buruk terhadap kesihatan, khususnya kepada populasi yang tinggal berhampiran tapak pelupusan (Siddiqua, Hahladakis & Al-Attiya 2022). Kehadiran bahan pencemar udara ini boleh menjejaskan kualiti udara dan membawa kesan kesihatan yang serius, terutamanya kepada golongan sensitif seperti kanak-kanak dan individu yang mempunyai masalah respiratori sedia ada (Kumar et al. 2023; Yu et al. 2018).

Pencemar udara boleh wujud di ruang dalaman dan luaran, dan berpotensi mengakibatkan kesan kesihatan yang serius. Pencemaran udara ditakrifkan sebagai pencemaran persekitaran dalaman atau luaran oleh unsur kimia, fizikal, atau biologi yang mengubah sifat semula jadi atmosfera (Nnaji, Chibueze & Afangideh 2023). Antara kesan kesihatan yang serius termasuk gangguan respiratori seperti asma, penyakit pulmonari obstruktif kronik (COPD), kanser paru-paru dan kecacatan kelahiran, selain isu kardiovaskular (Kumar et al. 2023; Manisalidis et al. 2020). Gejala lain seperti sakit kepala, pening, gangguan psikologi dan alahan juga boleh berlaku bergantung kepada jenis dan kepekatan gas pelupusan di udara (Vinti et al. 2021).

Tambahan pula, fasiliti perubatan yang menggunakan pengimejan perubatan dan radioterapi turut menyumbang kepada kerumitan pengurusan sisa di kawasan ini. Pelupusan tidak terkawal sisa radioaktif daripada fasiliti tersebut boleh menambahkan lagi risiko yang berkaitan dengan pelepasan dari tapak pelupusan. Sisa radioaktif yang tidak diurus dengan baik boleh menyebabkan pencemaran alam sekitar dan membawa risiko kesihatan kepada komuniti sekeliling (Meshram et al. 2022). Sebagai contoh, pesakit yang menjalani radioterapi boleh menghasilkan bahan tercemar yang memerlukan prosedur pelupusan yang berwaspada bagi mengelakkan pendedahan radiasi.

Risiko kesihatan yang berkaitan dengan lokasi berhampiran tapak pelupusan adalah lebih membimbangkan dalam konteks institusi pendidikan. Sekiranya sekolah dibina berhampiran tapak pelupusan lama, kualiti udara di dalam kawasan sekolah boleh terjejas sekali gus mempengaruhi kesihatan warga sekolah, terutamanya kanak-kanak. Kanak-kanak lebih mudah terdedah kepada kesan pencemaran udara kerana sistem respiratori mereka masih berkembang serta kadar aktiviti luar yang lebih tinggi. Kajian menunjukkan bahawa kanak-kanak yang terdedah kepada kualiti udara yang rendah mempunyai risiko lebih tinggi untuk mengalami penyakit respiratori serta masalah kesihatan lain (Aithal, Sachdeva & Kurmi 2023; Njoku, Edokpayi & Odiyo 2019).

Pendedahan kepada pencemaran udara termasuk zarah terampai daripada pelepasan industri dan asap kenderaan boleh menjejaskan fungsi paru-paru (Manisalidis et al. 2020). Kehadiran alergen seperti debunga, kulat, hama dan bulu haiwan juga boleh memburukkan lagi masalah respiratori seperti asma (Brożek et al. 2017). Selain itu, kualiti udara dalaman juga perlu diberi keutamaan. Pengudaraan yang tidak mencukupi, asap rokok dan penggunaan produk domestik tertentu boleh menyumbang kepada penurunan kesihatan respiratori (Holden et al. 2023). Tahap aktiviti fizikal turut memainkan peranan penting dalam mengekalkan fungsi paru-paru. Gaya hidup sedentari boleh melemahkan sistem respiratori, menjadikan pelajar lebih mudah terdedah kepada masalah pernafasan (Marijančić et al. 2023). Justeru, galakan terhadap aktiviti fizikal yang konsisten adalah penting.

Dalam konteks Malaysia, dapatan kajian ini mempunyai beberapa implikasi praktikal yang penting terhadap dasar awam dan pengurusan kesihatan persekitaran. Pertama, berkaitan dasar kesihatan sekolah, Kementerian Kesihatan Malaysia dan Kementerian Pendidikan Malaysia perlu mempertimbangkan pelaksanaan program pemantauan fungsi paru-paru tahunan dan saringan kesihatan respiratori sistematik bagi pelajar di sekolah yang terletak berhampiran kawasan berisiko alam sekitar (Annesi-Maesano et al. 2013; Norbäck et al. 2017; Syazwan et al. 2019). Program sedemikian memerlukan kolaborasi erat antara pihak berkuasa kesihatan, pendidikan, dan sekolah untuk mengesan masalah kesihatan respiratori pada peringkat awal (Ellwood et al. 2017). Kedua, dari aspek perancangan guna tanah, pihak berkuasa tempatan perlu mengkaji semula dan memperkukuhkan garis panduan penempatan sekolah berhampiran tapak pelupusan, sama ada aktif atau telah ditutup, dengan mempertimbangkan zon penampan minimum (*buffer zone*) serta menjalankan penilaian impak kesihatan (*Health Impact Assessment*) sebelum meluluskan pembinaan sekolah baru berhampiran kawasan berisiko (Rushton 2003; Vrijheid et al. 2011). Ketiga, pengurusan bekas tapak pelupusan sisa perlu diperkukuhkan melalui pemantauan kualiti udara berkala dan langkah-langkah mitigasi yang berkesan bagi melindungi komuniti setempat, khususnya populasi berisiko seperti kanak-kanak sekolah (Giusti 2009; Mataloni et al. 2016). Keempat, pelaksanaan program pendidikan kesihatan respiratori untuk pelajar, guru, dan ibu bapa bagi meningkatkan kesedaran mengenai risiko pencemaran udara dan langkah-langkah perlindungan diri adalah amat penting (Xie et al. 2019).

Beberapa cadangan untuk kajian lanjutan dicadangkan bagi memperkukuhkan pemahaman mengenai isu ini. Pertama, kajian masa depan perlu merangkumi pengukuran langsung kualiti udara

persekitaran ($PM_{2.5}$, PM_{10}, VOC, gas metana, hidrogen sulfida) di sekolah dan kawasan sekitar bekas tapak pelupusan untuk menentukan tahap pendedahan sebenar (Giusti, 2009; Mataloni et al. 2016). Kedua, pelaksanaan kajian susulan longitudinal untuk mengesan perubahan fungsi paru-paru dalam kalangan pelajar yang sama sepanjang tempoh beberapa tahun bagi memahami kesan jangka panjang pendedahan persekitaran adalah perlu (Gauderman et al. 2015). Ketiga, kajian perbandingan antara sekolah berhampiran bekas tapak pelupusan dengan sekolah kawalan yang terletak jauh daripada sumber pencemaran untuk mengenal pasti hubungan kausal yang lebih jelas perlu dijalankan (Porta et al. 2009). Keempat, kajian yang lebih komprehensif merangkumi penilaian faktor risiko tambahan seperti pendedahan asap rokok di rumah, tahap aktiviti fizikal, status pemakanan, dan sejarah penyakit respiratori keluarga dicadangkan (Raaschou-Nielsen et al. 2016). Kelima, penilaian keberkesanan intervensi seperti pemasangan penapis udara di bilik darjah atau program promosi kesihatan terhadap penambahbaikan fungsi paru-paru dan kesihatan respiratori pelajar perlu dilaksanakan (Barn et al. 2016; Huang et al. 2020).

KESIMPULAN

Dapatan kajian ini menunjukkan bahawa majoriti pelajar tidak melaporkan simptom respiratori yang ketara, namun penilaian fungsi paru-paru dan tahap kesihatan respiratori mendapati sebahagian besar responden tergolong dalam kategori "Tidak Normal". Perbandingan antara kumpulan umur menunjukkan pelajar Tingkatan 5 mempunyai nilai fungsi paru-paru yang lebih tinggi berbanding Tingkatan 1, selaras dengan perkembangan fisiologi yang berlaku mengikut peningkatan umur. Walau bagaimanapun, perbezaan tahap kesihatan respiratori keseluruhan antara kedua-dua kumpulan tidak signifikan secara statistik.

Secara keseluruhannya, kajian ini menekankan kepentingan pemantauan berkala terhadap kesihatan respiratori dalam kalangan pelajar, terutamanya dalam konteks sekolah yang terletak berhampiran kawasan berisiko alam sekitar seperti bekas tapak pelupusan sisa pepejal. Pemerhatian berterusan, intervensi pencegahan, dan strategi pendidikan kesihatan perlu dipertingkatkan bagi memastikan kesihatan respiratori pelajar kekal berada pada tahap yang optimum, khususnya bagi populasi yang terdedah kepada pendedahan persekitaran jangka panjang.

RUJUKAN

Aithal, S.S., Sachdeva, I. & Kurmi, O.P. 2023. Air quality and respiratory health in children. *Breathe* 19(2): 230040. https://doi.org/10.1183/20734735.0040-2023.

Ashtari, A., Sadegh Tabrizi, J., Rezapour, R., Rashidian Maleki, M., Azami-Aghdash, S. 2020. Health Care Waste Management Improvement Interventions Specifications and Results: A Systematic Review and Meta-Analysis. *Iranian Journal of Public Health* 49(9):1611-1621. doi:10.18502/ijph.v49i9.4074.

Brożek, J.L., Bousquet, J., Agache, I., Agarwal, A., Bachert, C., Bosnic-Anticevich, S. et.al. 2017. Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines-2016 revision. *The Journal of Allergy and Clinical Immunology* 140(4): 950–958. https://doi.org/10.1016/j.jaci.2017.03.050.

Gautam, M. & Agrawal, M. 2021. Greenhouse Gas Emissions from Municipal Solid Waste Management: A Review of Global Scenario. In: Muthu, S.S. (eds) Carbon Footprint Case Studies. *Environmental Footprints and Eco-design of Products and Processes*, pp 123-160, Springer, Singapore. https://doi.org/10.1007/978-981-15-9577-6_5

Graves, S.A. 2023. Radiation Safety Considerations of Household Waste Disposal After Release of Patients Who Have Received (177Lu) Lu-PSMA-617. *Journal of Nuclear Medicine*, 64(10):1567-1569. doi: 10.2967/jnumed.123.265750

Holden, K.A., Lee, A.R., Hawcutt, D.B. & Sinha, I.P. 2023. The impact of poor housing and indoor air quality on respiratory health in children. *Breathe*, 19 (2): 230058. https://doi.org/10.1183/20734735.0058-2023

Ithnin, A., Rahman, M.S., Awang, N., Yusuf, N.M., Abdullah, R. & Ariffin, F.D. 2013. Study on air quality in school located near the former landfill site and its influences on student's respiratory health. *Middle-East Journal of Scientific Research*, 14, 371-374. 10.5829/idosi.mejsr.2013.14.3.71237.

Khan, B.A., Cheng, L., Khan, A.A. & Ahmed, H. 2019. Healthcare waste management in Asian developing countries: A mini review. *Waste Management Research* 37(9): 863–875. doi:10.1177/0734242X19857470

Kumar, P., Singh, A.B., Arora, T., Singh, S. & Singh, R. 2023. Critical review on emerging health effects associated with the indoor air quality and its sustainable management. *The Science of The Total Environment* 872: 162163. https://doi.org/10.1016/j.scitotenv.2023.162163

Macedo, J.C. & de Oliveira, E.H.C. 2020. Waste from health services: Situation and actions in a public hospital from Manaus (Amazonas, Brazil). *International Journal of Advanced Engineering Research and Science* 7(4): 237–244. doi:10.22161/ijaers.74.30

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. 2020. Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health 8*: 14. https://doi.org/10.3389/fpubh.2020.0001416

Marijančić, V., Grubić Kezele, T., Peharec, S., Dragaš-Zubalj, N., Pavičić Žeželj, S. & Starčević-Klasan, G. 2023. Relationship between Physical Activity and Sedentary Behavior, Spinal Curvatures, Endurance and Balance of the Trunk Muscles-Extended Physical Health Analysis in Young Adults. *International Journal of Environmental Research and Public Health* 20(20): 6938. https://doi.org/10.3390/ijerph20206938

Meshram, S., Mohatkar, M., Bokde, S., Shahu, P.A., Rathi, S. & Chopkar, S. 2022. Review paper on Radioactive Wastes and its Management. *NeuroQuantology* 20(9):2038-2044. 10.14704/nq.2022.20.9.NQ44235

Njoku, P.O., Edokpayi, J.N. & Odiyo, J.O. 2019. Health and Environmental Risks of Residents Living Close to a Landfill: A Case Study of Thohoyandou Landfill, Limpopo Province, South Africa. *International Journal of Environmental Research and Public Health*, 16(12): 2125. https://doi.org/10.3390/ijerph16122125

Nnaji, C.C., Chibueze, C.V. & Afangideh, C.B. 2023. The menace and mitigation of air pollution in the built environment: A review. *Nigerian Journal of Technology* 42: 12-29. 10.4314/njt.v42i1.3.

Sabour, M.R. & Amron, R. 2024. A systematic analysis of research trends on healthcare waste management during 1995–2022. *International Journal of Environmental Science and Technology.* https://doi.org/10.1007/s13762-024-05770-x

Sančanin, B. & Penjišević, A. 2023. Safe Management of Medical Radiological Waste. MEDIS– *International Journal of Medical Sciences and Research*. DOI:10.35120/medisij020207s

Siddiqua, A., Hahladakis, J.N. & Al-Attiya, W.A.K.A. 2022. An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. *Environmental Science and Pollution Research* 29(39): 58514-58536. doi: 10.1007/s11356-022-21578-z.

Udayanga, L., Sahana, L., Perera, A., Ranasinghe, K. & Ranathunge, T. 2021. Knowledge, perceptions and practices on healthcare waste management and associated occupational health hazards among healthcare professionals in the Colombo District, Sri Lanka: A cross-sectional study. *Biosystems Engineering* 1-12. doi:10.1016/j.biosystemseng.2021.09.001

Vinti, G., Bauza, V., Clasen, T., Medlicott, K., Tudor, T., Zurbrügg, C., & Vaccari, M. (2021). Municipal Solid Waste Management and Adverse Health Outcomes: A Systematic Review. *International Journal of Environmental Research and Public Health* 18(8): 4331. https://doi.org/10.3390/ijerph18084331

Yu, Y., Yu, Z., Sun, P., Lin, B., Li, L., Wang, Z., Ma, R., Xiang, M., Li, H. & Guo, S. 2018. Effects of ambient air pollution from municipal solid waste landfill on children's non-specific immunity and respiratory health. *Environmental pollution* 236: 382–390.https://doi.org/10.1016/j.envpol.2017.12.094

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Ulasan Artikel/*Review Article*

Advancing Forensic Proteomics in a Developing Forensic System: A Scoping Review of Malaysian Studies in a Global Context

Proteomik Forensik dalam Sistem Forensik yang Sedang Membangun: Satu Tinjauan Skop Kajian Malaysia dalam Konteks Global

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ABSTRACT

Proteomics is increasingly recognised as a complementary tool to DNA analysis in forensic science, particularly for degraded or limited biological evidence. This scoping review aimed to systematically map proteomic studies conducted in Malaysia involving forensically relevant biological samples and to evaluate their alignment with forensic applications. A comprehensive search of PubMed, Scopus, ScienceDirect, and EBSCO Academic databases identified studies published between 2010 and February 2024. Following PRISMA-ScR screening and eligibility assessment, 12 original research articles met the inclusion criteria. These studies primarily investigated hair (n = 5), bodily fluids and tissues (n = 7), with no Malaysian studies identified on bone or fingerprint proteomics for forensic purposes. Most included studies were biomedical in focus; however, they employed mass spectrometry-based methodologies directly transferable to forensic investigations. The review demonstrates that explicitly forensic proteomic research in Malaysia remains limited, despite clear evidence of local technical capacity and expertise. This gap highlights significant opportunities for translational research, population-specific protein databases, and interdisciplinary collaboration to integrate proteomics into routine forensic practice.

Keywords: biological evidence, forensic proteomics, Malaysia, mass-spectrometry, protein biomarkers.

ABSTRAK

Proteomik semakin diiktiraf sebagai alat pelengkap kepada analisis DNA dalam sains forensik, khususnya bagi bukti biologi yang terdegradasi atau terhad. Tinjauan skop ini bertujuan untuk memetakan secara sistematik kajian proteomik yang dijalankan di Malaysia melibatkan sampel biologi yang relevan secara forensik serta menilai kesesuaiannya dengan aplikasi forensik. Pencarian menyeluruh dalam pangkalan data PubMed, Scopus, ScienceDirect dan EBSCO Academic mengenal pasti kajian yang diterbitkan antara tahun 2010 hingga Februari 2024. Selepas proses saringan PRISMA-ScR dan penilaian kelayakan, sebanyak 12 artikel penyelidikan asal memenuhi kriteria kemasukan. Kajian-kajian ini terutamanya meneliti rambut (n = 5), serta cecair dan tisu badan (n = 7), manakala tiada kajian dari Malaysia dikenal pasti berkaitan proteomik tulang atau cap jari untuk tujuan forensik. Kebanyakan kajian yang dimasukkan berfokuskan bioperubatan; namun demikian, kajian-kajian tersebut menggunakan metodologi berasaskan spektrometri jisim yang boleh dipindahkan secara langsung kepada penyiasatan forensik. Tinjauan ini menunjukkan bahawa penyelidikan proteomik yang secara khusus bersifat forensik di Malaysia masih terhad, walaupun terdapat bukti jelas mengenai keupayaan teknikal dan kepakaran tempatan. Jurang ini menonjolkan peluang yang signifikan untuk penyelidikan translasi, pembangunan pangkalan data protein khusus populasi, serta kerjasama antara disiplin bagi mengintegrasikan proteomik ke dalam amalan forensik rutin.

Kata Kunci: bukti biologi, Malaysia, protein biopenanda, proteomik forensik, spektrometri jisim

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INTRODUCTION

Globally, forensic proteomics has progressed rapidly, with validated applications in human identification, post-mortem interval estimation, and toxicological screening. However, the adoption of these advances remains uneven across regions. Examining country-specific research landscapes provides insight into structural, technical, and translational challenges faced by developing forensic systems. Within this context, Malaysia serves as a representative case study of an emerging forensic proteomics environment with established analytical capacity but limited forensic implementation.

The handling and analysis of biological evidence recovered from crime scenes constitute a fundamental component of forensic science. Traditionally, forensic identification has been dominated by DNA analysis; however, recent advances in proteomics have introduced new opportunities to complement and, in certain contexts, extend beyond DNA-based approaches (Sacco & Aquila 2023). Proteomics, broadly defined as the large-scale study of proteins, is conceptualised differently across disciplines. Within the forensic context, proteomics may be understood as the application of protein analysis for human identification and investigative reconstruction, particularly when conventional DNA evidence is degraded, limited, or absent.

Forensic proteomic research generally follows two main analytical approaches. The first focuses on identifying and quantifying specific proteins or protein markers within biological materials, such as hair shafts, that may be characteristic of an individual or tissue type. The second approach applies population-based statistical frameworks, whereby the probability of observing particular protein markers is calculated using reference datasets. These probabilities can then be used to assess the likelihood that a questioned sample originates from a specific individual, for example by comparing relative protein abundances in a recovered hair strand against population-level expectations (Tisdale 2016).

Proteins possess several intrinsic properties that make them particularly valuable for forensic investigations. Compared with DNA, proteins are generally more abundant, chemically stable, and structurally complex, and they retain biologically informative signatures linked to their tissue of origin (Aebersold & Mann 2016; Wadsworth et al. 2017). While DNA remains the gold standard for forensic identification, proteins are composed of twenty amino acids, as opposed to the four nucleotides found in DNA, allowing for a greater diversity of molecular variation and potentially richer contextual information (Tisdale 2016). These characteristics render proteomics especially advantageous when analysing compromised biological evidence.

The forensic applications of proteomics are diverse, ranging from individual identification using hair and blood (Parker et al. 2016; Patel et al. 2016) to studying post-mortem processes. Beyond identification, proteomic techniques have contributed to the study of cadaver decomposition processes. Quantitative approaches, including isobaric tags for relative and absolute quantification (iTRAQ) coupled with liquid chromatography–tandem mass spectrometry (LC–MS/MS), have been employed to characterise microbial proteomes involved in decomposition, providing insights into post-mortem changes (Baldrian & López-Mondéjar 2014). Furthermore, predictable patterns of post-mortem protein degradation have been shown to support estimations of the time since death (Kocsmár et al. 2023). Bone proteomics, in particular, has demonstrated value in distinguishing between microbially driven and environmentally induced diagenetic processes, thereby improving models for post-mortem interval (PMI) estimation (Procopio et al. 2021). Such information is crucial for reconstructing sequences of events in forensic investigations. Proteomic analysis has also been extended to fingermark evidence; despite challenges associated with low protein abundance, sensitive sampling strategies and ageing biomarkers have been successfully developed (Oonk et al. 2018).

The relatively late emergence of proteomics compared with other omics disciplines can largely be attributed to technological constraints, including the complexity of protein structures, data analysis challenges, and the lack of standardised analytical protocols (Al-Amrani et al. 2021). Nevertheless, significant technological advancements particularly in mass spectrometry have driven a rapid evolution in proteomic research capabilities (Aebersold & Mann 2016; Amir et al. 2021; Darrelyn et al. 2021; Tan et al. 2024a; Tan et al. 2024b). These developments have improved analytical sensitivity, increased the volume of recoverable information, and reduced processing times, thereby addressing many early methodological limitations. Continued research remains necessary to fully evaluate the long-term impact of proteomics on human identification and forensic practice.

Despite substantial global progress, forensic-focused proteomic research in Malaysia remains limited. Existing Malaysian studies predominantly concentrate on medical and biomedical applications, even though they involve biological samples frequently encountered in forensic contexts. This disparity highlights a significant research gap between international advances in forensic proteomics and local implementation within Malaysia. Accordingly, this scoping review aims to examine proteomic studies conducted in Malaysia that involve forensically relevant biological

materials and to identify opportunities for expanding forensic applications. By highlighting both existing capabilities and unmet research needs, this study underscores the importance of strategic, localised research efforts and interdisciplinary collaboration to translate existing proteomic capacity into actionable forensic tools within Malaysia.

MATERIALS AND METHODS

STUDY DESIGN

This scoping review was conducted in accordance with the five-stage methodological framework proposed by (Arksey & O'malley 2005), which is widely used to map the extent, nature, and characteristics of research activity within an emerging field. The framework comprises the following stages: (1) defining the research question; (2) identifying relevant studies through clearly defined inclusion and exclusion criteria; (3) systematically searching for and collecting relevant literature; (4) charting the extracted evidence; and (5) collating, summarising, and reporting the findings. The review process was further guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), in accordance with the recommendations of (Tricco et al. 2018), to enhance transparency and methodological rigour.

STEP 1: DEFINING THE RESEARCH QUESTION

The primary research question guiding this review was: *What does the current proteomic literature in Malaysia reveal about local research interest and engagement in forensic proteomics?* To ensure conceptual clarity and consistency during study selection, a formalised definition of *forensic proteomics* was adopted. In this review, forensic proteomics is defined as the application of protein analysis techniques for forensic investigation purposes (Sacco & Aquila 2023). The aim of the review was to map proteomic studies conducted in Malaysia that involve biological samples relevant to forensic contexts, while also drawing on selected global forensic proteomic literature to contextualise local research gaps and highlight areas requiring further investigation within the Malaysian setting.

STEP 2: SOURCES OF DATA AND SEARCH STRATEGY

The literature search strategy was developed in accordance with the review objectives and predefined eligibility criteria. Electronic database searches were conducted in PubMed, Scopus, ScienceDirect, and EBSCO Academic for studies published between January 2010 and February 2024. The following Boolean search string was adapted for each database syntax:
(“forensic proteomics” OR “mass spectrometry-based proteomics” OR “protein biomarker*” OR “protein analysis”) AND (“forensic science” OR “body fluid identification”) AND (“Malaysia”).

In PubMed, Medical Subject Headings (MeSH) and Title/Abstract fields were applied where appropriate. Searches in other databases were restricted to title, abstract, and keyword fields.
The initial search yielded 835 records. After removal of duplicates, 470 unique records remained for title and abstract screening. Seventy-three studies were deemed potentially eligible and retrieved for full-text assessment. Following full-text evaluation against predefined inclusion and exclusion criteria, 12 studies met the eligibility requirements and were included in the qualitative synthesis. To minimise publication bias and identify potentially missed local studies, a supplementary manual search was conducted via Google Scholar using the same keyword combinations. No additional eligible studies were identified beyond those captured in the database search.

STEP 3: STUDY SELECTION AND DATA EXTRACTION

Eligibility for inclusion was independently assessed by the authors against the pre-defined criteria. The study selection was conducted in two distinct phases. In the initial phase, titles and abstracts were screened for relevance, and any records that clearly failed to meet the inclusion criteria were excluded. In the second phase, the full text of the remaining articles was retrieved and examined in detail, with the inclusion and exclusion criteria rigorously re-applied to ensure consistency.

Mendeley Reference Manager was employed to organise the retrieved literature and to identify and remove duplicate records. Any disagreements regarding the eligibility of specific studies were resolved through discussion with the second author (N.H.H.) to reach a consensus on the final selection. For each study that progressed to the full-text review, relevant data were systematically extracted into a charting form to facilitate analysis. The following information was captured:

- **Bibliographic details:** Author(s) and year of publication.
- **Sample characteristics:** The type of forensically relevant biological sample analysed (e.g., hair, blood, saliva, tissue).
- **Methodological approach:** The primary proteomic technique employed (liquid chromatography–tandem mass spectrometry (LC-MS/MS), two-dimensional gel electrophoresis).

- **Study focus and key findings:** The principal aim of the research and its main outcomes.
- **Forensic relevance:** An assessment of the study's direct applicability or methodological contribution to forensic science, based on the adopted definition of forensic proteomics.

Following duplicate removal, 470 records remained for title and abstract screening. Seventy-three studies met the preliminary eligibility criteria and were retrieved for full-text assessment. After detailed evaluation against predefined inclusion and exclusion criteria, 12 studies were deemed suitable for inclusion in the qualitative synthesis. Reasons for exclusion at full-text stage included non-forensic application, absence of proteomic methodology, review-only articles, and insufficient validation data. This extracted data provided the basis for the narrative synthesis and was later summarised in Table 1 to present an overview of the included studies categorised by biological sample type, year, and research focus.

STEP 4: INCLUSION AND EXCLUSION CRITERIA

Studies were eligible for inclusion if they met all of the following criteria:
(i) original research articles published between January 2010 and February 2024;
(ii) conducted wholly or partially in Malaysia, or involving Malaysian institutional affiliation;
(iii) employed proteomic techniques, including mass spectrometry-based or gel-based protein analysis;
(iv) analysed biological samples with established forensic relevance (e.g., hair, bodily fluids, tissues, bone, fingerprints); and
(v) provided sufficient methodological detail to assess proteomic workflows.
Studies were excluded if they:
(i) were review articles, conference abstracts, editorials, or opinion papers;
(ii) did not involve proteomic analysis;
(iii) focused exclusively on non-biological or non-forensic materials;
(iv) lacked full-text availability; or
(v) contained insufficient methodological information to permit evaluation.

RESULTS

SEARCH OUTCOME

The systematic database search identified a total of 835 records across PubMed, Scopus, ScienceDirect, and EBSCO Academic. Following the removal of duplicate records, titles and abstracts of the remaining studies were screened for relevance. This process resulted in 59 articles undergoing full-text assessment. After applying the predefined inclusion and exclusion criteria, 12 studies were deemed eligible for inclusion in this scoping review. The study selection process and reasons for exclusion at each stage are summarised in the PRISMA-ScR flow diagram (FIGURE 1).

CHARACTERISTICS OF INCLUDED STUDIES

The 12 included studies reflect proteomic research conducted in Malaysia between 2010 and 2024 involving biological materials of potential forensic relevance. These studies were categorised according to biological sample type, research focus, and analytical methodology, as summarised in TABLE 1.

Hair samples constituted the most frequently investigated biological material within a forensic-oriented framework. Several studies focused on methodological optimisation for protein extraction and profiling from human hair shafts, alongside the identification of keratin-derived peptide signatures with potential relevance for individual differentiation. In contrast, no Malaysian studies applying proteomic analysis to bone or fingerprint samples for forensic purposes were identified during the review period.

Studies involving bodily fluids and tissues such as blood, plasma, saliva, urine, and soft tissues were more numerous but were predominantly situated within medical or biomedical research contexts. These investigations primarily aimed at biomarker discovery, disease characterisation, or optimisation of proteomic workflows rather than forensic application. Nevertheless, the biological matrices examined are routinely encountered in forensic casework, and the analytical approaches employed are directly transferable to forensic investigations.

TRENDS IN METHODOLOGICAL APPROACHES

Across all included studies, mass spectrometry-based proteomic techniques dominated the analytical landscape. Liquid chromatography–tandem mass spectrometry (LC–MS/MS) was the most commonly employed platform, often complemented by gel-based separation methods such as two-dimensional gel electrophoresis. The consistent use of these high-resolution analytical techniques indicates a well-established technical capacity for advanced proteomic analysis within Malaysian research institutions.

TABLE 1 Proteomic analysis on biological samples in Malaysia by year and type of study

No	Biological Sample	Author (s)	Year	Study Type	Study Title
1	Hair	(Mohamed Nasir et al. 2020)	2020	Proteomic Analysis	Potential use of human hair shaft keratin peptide signatures to distinguish gender and ethnicity
2		(Wong et al. 2019)	2019	Analysis method development	Development of high-performance two-dimensional gel electrophoresis for human hair
3		(Wong et al. 2016)	2016	Analysis method development	A high-yield two-hour protocol for extraction of human hair shaft proteins
4	Bodily Fluid & Tissues	(Rehiman et al. 2022)	2022	Blood proteomes	Fibrinogen isoforms as potential blood-based biomarkers of Alzheimer's disease using a proteomics approach
5		Oothuman et al. (2021)	2021	Urine proteomes	Optimised Preparation of Urine Samples from Acute Meliodosis Patients for In-Solution Proteomic Studies
6		(Al-Wajeeh et al. 2020)	2020	Tissues Proteomes	Comparative proteomic analysis of different stages of breast cancer tissues using ultra high performance liquid chromatography tandem mass spectrometer
7		(Mohamed Bakrim et al. 2019)	2019	Plasma proteomes	Proteomic profiling of Young Adults with Acute Myocardial Infarction
8		(Ibrahim 2017)	2017	Blood proteomes	Serum proteomic analysis of patients with bone tumours using gel-, Lectin- and mass spectrometry based strategies
9		(Rahim et al. 2015)	2015	Saliva proteomes	Can saliva proteins be used to predict the onset of acute myocardial infarction among high-risk patients?
10		(Wan-Ibrahim et al. 2015)	2015	Tissue proteomes	Biomarkers for bone tumours: discovery from genomics and proteomics studies and their challenges
11		(Ab-Rahim et al. 2016)	2016	Blood proteomes	Proteome Comparisons between Pre-Chemotherapy and Post-Chemotherapy Serum of Metastatic Osteosarcoma Patients Reveals Potential Novel Biomarker
		(Ellias et al. 2012)	2012	Saliva proteomes	Proteomic analysis of saliva identifies potential biomarker for orthodontic tooth movement
12		(Ellias et al. 2012)	2012	Saliva proteomes	Proteomic analysis of saliva identifies potential biomarker for orthodontic tooth movement

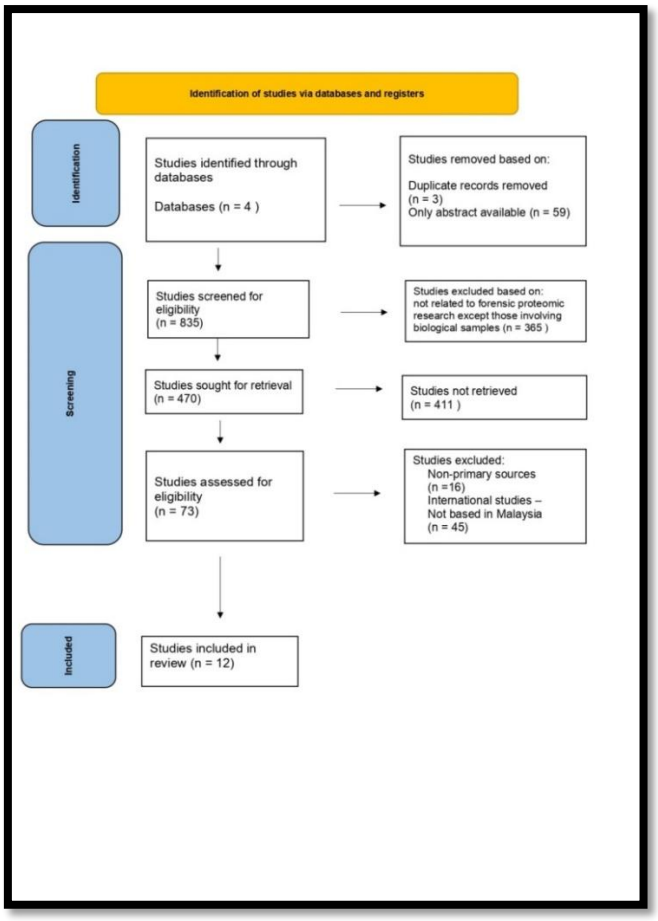


FIGURE 1 PRISMA-ScR flowchart and reasons of studies exclusion

TABLE 2 Comparison of GVP analysis and traditional DNA analysis

GVP Analysis	Comparison	Traditional DNA Analysis
GVPs are present in any part of biological sample regardless of condition (Parker et al. 2016)	Presence	DNA can be absent in degraded and compromised biological samples (Parker et al. 2016)
Proteins have higher chemical stability (Porto et al. 2011)	Resistance	DNA have limited chemical stability (Porto et al. 2011)
Around 60 000 possible GVP alleles in an individual cell (Plott et al. 2020)	Abundance	Trace DNA are typically found in minute biological samples which is less than 100 pg (Van Oorschot et al. 2010)

Temporal analysis of the included studies suggests a gradual increase in proteomic research activity over the past decade, with a more pronounced growth observed in recent years. This trend reflects broader global developments in proteomic technologies, including improvements in instrumental sensitivity, data acquisition, and bioinformatics support.

FORENSIC RELEVANCE AND RESEARCH GAPS

Despite the increasing volume of proteomic research, explicit forensic applications remain limited. Only a small subset of studies directly addressed forensic questions, while the majority were aligned with biomedical or translational research objectives. This reveals a clear disparity between methodological capability and forensic implementation.

Notably, several biological sample types of high forensic importance particularly bone and fingerprints were entirely absent from Malaysian proteomic research within the scope of this review. This contrasts with international forensic proteomics literature, where these matrices are increasingly explored for human identification, post-mortem interval estimation, and activity-level reconstruction.

Overall, the results indicate that while forensic proteomics in Malaysia is still in an early developmental stage, the foundational infrastructure, expertise, and methodological competence required for forensic translation are

already in place. The principal limitation lies not in technical capacity but in the lack of targeted forensic validation studies and application-driven research.

DISCUSSION

Here is a glimpse into the growing interest of forensic proteomics in Malaysia by various researches on common biological samples in crime scenes.

HAIR

Hair is a commonly encountered biological sample in forensic investigations and is formed through the keratinisation of epidermal keratinocytes (Bragulla & Homberger 2009). Structurally, hair exhibits considerable physical flexibility and resilience, enabling it to withstand harsh environmental conditions more effectively than many other biological materials. This durability is largely attributed to its biochemical composition, which consists predominantly of coiled-coil keratin proteins stabilised by extensive intermolecular disulfide bonds (Bengtsson et al. 2012). These characteristics make hair a valuable source of forensic information, as it can persist at crime scenes long after other biological evidence has degraded.

In forensic practice, hair has traditionally been utilised for human identification and for establishing potential associations between individuals and crime scenes. In addition to genetic information, hair can retain exogenous and endogenous chemical signatures over extended periods. For example, (Aziz et al. 2022) demonstrated that heavy metal exposure can be detected in hair many years after exposure, owing to the long biological half-life of such elements within the hair shaft. These persistent chemical profiles may therefore provide supplementary individualising or contextual information in forensic investigations.

DNA analysis remains the most widely used approach for hair-based identification, particularly when hair roots are present, as mitochondrial DNA can be recovered from the follicular tissue. However, DNA extraction from hair samples is technically challenging and often yields limited results, especially when the hair is fragmented, lacks a root, or has undergone environmental degradation (Landron 2019). In hair samples, several studies reported successful detection of keratin-derived and other structural protein markers despite limited or compromised DNA recovery. The relative resistance of hair shaft proteins to environmental degradation enabled informative proteomic profiling in cases where nucleic acid analysis was incomplete or unsuccessful. These findings suggest that protein-based approaches may provide supplementary evidential value in the examination of degraded hair specimens.

Proteomic studies of hair have also demonstrated the potential to extract information beyond that obtainable from DNA analysis alone. Protein expression patterns and post-translational modifications can reflect biological attributes such as age, sex, and ethnic background, which are not directly encoded at the DNA sequence level. Within the Malaysian context, several studies have contributed to the development of hair proteomics. Notably, a collaborative study between the University of Malaya and a Japanese institution established a high-performance two-dimensional gel electrophoresis protocol to improve protein separation and identification in human hair (Wong et al. 2019). Additional research has demonstrated the feasibility of using hair shaft keratin peptide signatures to distinguish between individuals based on sex and ethnicity (Mohamed Nasir et al. 2020). Earlier methodological work also reported a rapid alkaline-based protein extraction protocol that enhanced protein yield from hair samples (Wong et al. 2016). These studies collectively confirm the technical feasibility of hair proteomics in Malaysia and provide preliminary data on peptide signatures for gender and ethnicity. The logical next step for local forensic research is to expand these pilot studies into larger, population-specific databases to assess the statistical power of such signatures for individual discrimination.

BONES

Bones constitute a highly valuable form of biological evidence in forensic investigations. Owing to their rigid structure and the presence of mineral salts within the osteoid matrix, bones are considerably more resistant to physical, chemical, and biological degradation than most soft tissues (Freckelton 2021). As a result, skeletal remains often persist long after death and are frequently used to establish biological profiles, including age, sex, ancestry, and stature, thereby contributing to the identification of unknown individuals. Bone samples recovered from crime scenes may also provide information about the demographic characteristics of individuals involved in criminal events (Freckelton 2021).

Burnt skeletal remains present particular forensic significance, as arson is commonly employed in attempts to destroy biological evidence. However, exposure to high temperatures causes substantial physical and chemical alterations in bone tissue, which can severely compromise DNA integrity and complicate genetic profiling (Imaizumi 2015). Additional challenges arise from the dense mineralised structure of bone, which necessitates complex extraction procedures and may co-extract inhibitory substances that further hinder DNA analysis (Iyavoo & Goodwin 2022). These limitations highlight the need for alternative or

complementary analytical approaches when dealing with skeletal evidence.

Within skeletal samples, studies highlighted the persistence of collagen and other structural bone matrix proteins across extended post-mortem intervals. The mineralised matrix and cross-linked architecture of bone appear to facilitate long-term preservation of selected protein biomarkers, enabling proteomic characterisation even in environmentally challenged remains. This capacity was particularly evident in samples where conventional DNA profiling yielded limited results. (Choi et al. 2018). Previous studies have demonstrated the utility of bone proteomes in estimating biological age and post-mortem interval (PMI), as well as in differentiating between intrinsic biological changes and environmentally driven diagenetic processes (Procopio et al. 2017; Sawafuji et al. 2017).

To date, no studies have been reported that specifically apply proteomic analysis to skeletal remains within the Malaysian forensic context. Nevertheless, a growing body of local forensic and forensic anthropology research underscores the recognised value of bone as a source of biological information. For instance, age regression models for Malaysian males have been developed using cortical bone histomorphometry (Khan et al. 2018), while population-specific stature estimation studies have employed radiographic measurements of upper limb bones (Ismail et al. 2018). Morphological and morphometric analyses of skeletal features, such as the mental foramen of the mandible, have also been conducted to support forensic identification within local populations (Alias et al. 2017). This existing research ecosystem, focused on skeletal morphology, presents a prime opportunity for interdisciplinary collaboration to integrate proteomic analyses, thereby adding a molecular dimension to traditional osteological methods for identification and PMI estimation.

BODILY FLUID AND TISSUE

Bodily fluids such as blood, semen, and saliva are critical sources of evidence in forensic investigations. Identification of these fluids can establish the origin of the sample, aiding in the identification of victims, suspects, and potential third parties. Beyond source attribution, bodily fluids can provide information on individual characteristics including sex, age, and ethnicity (Bhuptani et al. 2018; Shao et al. 2021). Analysis of these fluids may also reveal the presence of drugs, toxins, or other substances of forensic interest, and contribute to the estimation of post-mortem interval (PMI) (Nolan et al. 2020; Wilke 2021).

Proteomic analysis offers several advantages over conventional DNA-based approaches when examining bodily fluids. Across degraded and low-template samples, included studies consistently demonstrated the detectability of fluid-specific protein biomarkers under conditions associated with reduced nucleic acid quality (Parker et al. 2016). These observations indicate that proteomic assays may retain analytical utility in compromised specimens, particularly in mixed or environmentally exposed samples (Liu et al. 2019). Additionally, proteomic analysis can detect drugs and toxins within biological samples, providing further context to cause-of-death investigations or substance exposure at the crime scene.

In Malaysia, numerous proteomic studies have been conducted on bodily fluids and tissues, although most focus on medical research rather than forensic applications. For example, (Ibrahim 2017) analysed serum proteomes in patients with bone tumours using gel-, lectin-, and mass spectrometry-based strategies. High-performance instrumentation is commonly employed to improve analytical sensitivity and reproducibility, as demonstrated in studies examining breast cancer tissues using ultra-high-performance liquid chromatography coupled with tandem mass spectrometry (Al-Wajeeh et al. 2020). Sample preparation optimisation has also been a focus, as in the study by (Pakeer et al. 2021), which developed enhanced protocols for urine samples from patients with acute melioidosis. Proteomic profiling has additionally been applied in the context of acute myocardial infarction (Mohamed Bakrim et al. 2019), Alzheimer's disease, and other conditions (Rahim et al. 2015; Rehiman et al. 2022; Wan-Ibrahim et al. 2015).

Saliva proteomics has been explored primarily in relation to oral and systemic health. For instance, Rahim et al. (2015) investigated salivary proteomes to predict the onset of acute myocardial infarction, while (Ellias et al. 2012) identified potential biomarkers associated with orthodontic tooth movement. Although these studies are predominantly biomedical, they demonstrate methodological approaches directly applicable to forensic research, indicating that proteomic workflows are already established and feasible within the Malaysian context.

Overall, while local studies of bodily fluids and tissues are currently medical in focus, they provide a foundational platform for future forensic proteomic research. Existing expertise, instrumentation, and analytical methodologies position Malaysian researchers well to translate these techniques to forensic investigations, supporting the development of more targeted studies on fluids and tissues relevant to crime scene analysis. Therefore, while a direct forensic proteomic literature is sparse, the required technical infrastructure, methodological expertise, and experience with relevant sample types are demonstrably present within the Malaysian biomedical research community. Bridging this gap

requires fostering collaborations between forensic practitioners and proteomics laboratories to re-purpose these techniques for forensic question-solving

FINGERPRINT

Fingerprints represent a challenging but forensically crucial sample where proteomics may offer supplemental data. Proteins within fingerprint residue have the potential to carry genetic information via single amino acid polymorphisms (SAPs) (Parker et al. 2016). Fingerprints are a valuable but limited source of information due to how unique they are to each individual in terms of DNA identification (Borja et al. 2019) .They have been an important source of suspect identification for years and will continue to be in future. The physical amount of material which is transferred from the skin to solid surface is highly sample limited and contains genetic information (Hefetz et al. 2019). Proteomics analysis serves as a wonderful opportunity to gain more information about this biological sample as protein has the potential to carry genetic information in the form of single amino acid polymorphisms (SAP) (Parker et al. 2016).

A study by (Deininger et al. 2016) developed an in-situ proteomic method to enable multiple blood signatures on blood fingerprints. The blood mapping on fingerprints was predicted to be useful in reconstructing events of bloodshed. A study in China has developed artificial fingerprints samples using advancements in protein sequence identification so that these samples contain an adequate amount of protein (Lesassier et al. 2019). The development of these artificial fingerprints is to further understand proteomic and genomic analysis for forensic purposes.

There is no proteomic analysis conducted on fingerprints in Malaysia till date. However, fingerprints are commonly studied locally in forensic cases. Fingerprint distributions are commonly studied among different demographics such as age, ethnic group and gender to determine significant differences (Darrelyn et al. 2021; Nayak et al. 2010; Seif et al. 2022). With the growing interest of research in other proteomic analysis on other biological samples, there are many interesting potential insights to discover with the proteomic research on fingerprints in Malaysia.

GLOBAL ADVANCES AND THEIR IMPLICATIONS FOR MALAYSIA

GENETICALLY VARIED PEPTIDES (GVPS) CONCEPT

Proteomics can provide more detailed individual identification are due to the amount of the genetic information in proteins. In fact, some pioneering work in population genetics relied on protein markers (Woerner et al. 2022). GVPs are crucial in enabling more detailed proteomic analysis as a promising biomolecular profiling technique in forensic science (Dahal et al. 2023). Genetically varied peptides (GVPs) refer to peptides that contain single amino acid polymorphism (SAPs). Like all peptides, GVPs are produced by the proteases in the human body but the codes of these proteins are single nucleotide polymorphisms (SNPs) (Chu et al. 2019). A typical genome contains 3.5-4.3 million SNPs at an individual level (Auton et al. 2015). SNPs are caused by DNA mutation, the most common type of genetic variation where nucleotide substitution occurs in the DNA sequence.

These SNPs then form single amino acid polymorphisms (SAPs) where the amino acid in the protein sequence undergoes substitution as how nucleotide substitution occurred in the SNPs formation throughout a person's DNA (Rizzato et al. 2017). The correlation of SNPs and SAPs ensures high accuracy of individual identification. The presence of a particular SNP is associated with the presence of a particular SAP as SNPs can sometimes alter the amino acid sequence of a protein (Wu & Zeng 2012) (Table 2).

Table 2

In forensics, GVPs are not only an alternative for human identification but can also be used to determine ancestry and distinguish monozygotic twins (Wu et al. 2017). The correlation of SNPs and SAPs enables GVPs to generate detailed individual profiling from various biological samples such as hair, blood and human saliva (Chu et al. 2019). GVPs contain genetic variations unique to every individual as the probability of two people have the exact same genetic variations are low. GVPs are also useful as it can conduct human identification even when DNA is compromised or absent as proteins are more resilient. Cleaved DNA which are often found in incomplete biological samples at crime scenes are also not suitable for DNA profiling thus making GVPs more effective.

MAIN APPROACH TO GVP USE IN FORENSIC SCIENCE

STANDARD GVP IDENTIFICATION

A group of GVPs are selected if they contain information for human identification. These groups consist of GVPs that correspond with SNPs with population frequencies within 10% to 70% (Zhang et al. 2020). The wide range ensures that these groups of GVPs are highly informative and can be applied to any crime evidence containing protein without much suspect initial information in the case.

TARGETED GVP ANALYSIS

Specific GVPs are targeted which are known to be potentially associated with the individuals involved in a certain crime case. This is conducted in instances where a suspect is known to obtain a certain specific genetic disorder or any likelihood of the data given some hypothesis (Woerner et al. 2022). This can also be used if a suspect's ethnicity is potentially known so that the GVP of the ethnic group is targeted (Huang et al. 2015) as shown in TABLE 2.

CASE EXAMPLES OF BREAKTHROUGH IN FORENSIC PROTEOMICS

The potential of proteomics application in enhancing forensic identification in several cases globally are highlighted as below. A brief review of these breakthrough helps highlight the urgent need to explore forensic proteomic studies in Malaysia to bring impact to the forensic field locally.

DISTINGUISH MONOZYGOTIC TWINS

In forensics generally, physical information provided by biological samples is highly dependant on the quantity and quality. Monozygotic twins are produced from single fertilization as they arise from the same zygote causing perfectly identical genomes and little known about their genomic differences (Jonsson et al. 2021). This is the reason why twins cannot be distinguished by DNA analysis till date, despite the presence of new developments in the recent DNA sequencing technology may potentially distinguish these twins (Rolf & Krawczak 2021).

From the proteomics perspective, it is observed that proteins can be used in distinguish the twins with the presence of genetically varied proteins (GVPs). Current research validates more recent proteomic approaches to extract quantitative genetic information especially using hair samples of monozygotic twins. A study by (Wu et al. 2017) applied protein profiling using protein tryptic digests where results revealed samples from identical twins have fewer protein expression differences than unrelated individuals.

ANALYSIS OF BULLET HOLES ON ORGANS

Usually, bullets examination is conducted with a mechanical or ballistic reconstruction of the crime according to standard procedures. This is conducted to identify the projectile using DNA analysis of the biological sample on the surface. The issue lies in the difficulty to identify the projectile. With proteomic approach, (Dammeier et al. 2016) develops a method to determine biological material on the projectile surface by analysing the tissues involved. Various major bovine organs were penetrated with projectiles experimentally and validated organ classification accuracy of >99% was achieved.

PEPTIDE TOXICOLOGICAL DETECTION

Proteomics application assists in toxicological detection of biological material inserted into a sample. Current DNA-based methods in forensic are unhelpful in detecting purified protein such as protein toxin. Proteomics methods are used in protein and peptide analyses. Conventional proteomic detection methods include merging proteomic methods with in vitro bioassays such as immunoassays and mass spectrometry-based techniques (Duracova et al. 2018). For instance, ricin is from a family of protein toxins that is crucially detected for food production and security purposes such as doping control (Guan & Robinson 2017; Rasetti-Escargueil & Avril 2023). A study have detected dermorphin which originates from the skin of the South American Phyllomedusa frog (Mizoguchi et al. 2011). There is also several research on the detection of synthetic insulins with suspected usage for homicides.

POTENTIAL BIOMARKERS

This study used mass spectrometry-based techniques to identify differentially expressed proteins as potential biomarkers in the post-mortem diagnosis of drowning. A study at Spain performed a pilot proteomic experiment which identified apolipoprotein A1 (ApoA1) and α-1 antitrypsin as the differentially expressed proteins (Hernández-Romero et al. 2020). Results of the study showed higher ApoA1 levels and lower α-1 antitrypsin among drowned individuals and vice versa. This is a pilot approach and future studies are necessary to affirm the preliminary data.

There are several studies on biomarker identification in the determination of the post-mortem interval (PMI). There is also a study that also utilises mass spectrometry for protein markers for the estimation of post-mortem interval. Initially, degradation of skeletal muscle during post-mortem is used to estimate the time since death in the early post-mortem phase. This study utilises an unbiased protein analysis to gain information on systemic post-mortem protein alterations. The differentially expressed proteins selected, eEF1A2 and GAPDH potrays intra- and interspecies degradation behaviour and are potentially used as biomarkers for PMI estimation (Choi et al. 2019). A sim,ilar study was also conducted highlighting different proteins such as PDLIM7, TPM1 and ATP2A2 as useful proteins for potential PMI estimation (Battistini et al. 2023).

STRENGTHS, LIMITATION AND RECOMMENDATION

This scoping review provides a structured and comprehensive mapping of the current landscape of proteomic research in Malaysia with relevance to forensic science. By employing a systematic methodology guided by the PRISMA-ScR framework, the review offers a clear and reproducible account of existing local research activity and identifies a critical nexus between advanced technical capacity and untapped forensic application.

Several limitations should be acknowledged. The primary constraint is the scarcity of studies with an explicit forensic focus, which necessarily limits the breadth of application-specific findings that can be discussed. While a thorough literature search was conducted, it remains possible that some relevant studies, particularly older publications not fully digitised or in lesser-known local journals, were not captured. Furthermore, by concentrating the analysis on biological sample types, the review may not encompass all proteomic research with potential forensic relevance, such as studies on microbial communities associated with decomposition.

To address these gaps and capitalise on the identified opportunities, a set of targeted recommendations is proposed. These are derived directly from the review's findings, which highlight a strong foundational proteomics infrastructure awaiting forensic translation.

First, strategic funding initiatives should encourage and facilitate collaborative projects between forensic science institutions and established biomedical proteomics laboratories. Such partnerships are essential to pivot existing expertise towards forensic problem-solving. Second, research efforts should prioritise the development and validation of standardised protein extraction and analysis protocols optimised for forensically challenging samples prevalent in the local context, such as environmentally degraded hair, burnt bone, or aged fingermarks. Finally, exploratory work should begin to establish population-specific databases of protein markers, including genetically variant peptides (GVPs), using the high-resolution mass spectrometry platforms already available within the country. This would provide the statistical framework necessary to move proof-of-concept studies towards validated forensic tools. By implementing these recommendations, future research can build directly upon the foundation outlined in this review, thereby accelerating the integration of proteomics into the Malaysian forensic science toolkit and enhancing investigative capabilities.

Despite the demonstrated analytical robustness of proteomic approaches, their routine implementation within Malaysian forensic laboratories remains limited. Several factors may contribute to this translational gap. First, mass spectrometry–based platforms require substantial capital investment, specialised instrumentation, and highly trained personnel, which may exceed the operational capacity of standard forensic laboratories. Secondly, forensic casework prioritises validated, court-tested methodologies such as Short Tandem Repeat (STR) profiling, which benefit from established accreditation frameworks and judicial acceptance. Proteomic workflows, although analytically promising, have yet to achieve equivalent standardisation and admissibility benchmarks within the Malaysian legal context. Additionally, forensic laboratories often operate under resource constraints and heavy case backlogs, limiting opportunities for the integration of novel research-based methodologies. Finally, the absence of nationally endorsed validation guidelines specific to forensic proteomics may contribute to institutional reluctance towards implementation. Addressing these structural and regulatory barriers will be essential for bridging the gap between academic proteomic research and operational forensic practice in Malaysia.

CONCLUSION

This scoping review reveals that while forensic proteomics is an emerging global field with demonstrated utility, focused research within Malaysia remains nascent. The analysis highlights a distinct dichotomy: a scarcity of studies with explicit forensic aims, yet a strong and growing local capacity in advanced proteomic techniques, largely situated within biomedical research. This existing expertise, applied to forensically relevant sample types like blood and hair, forms a robust foundation for translation. Proteins offer significant advantages for forensic science, particularly their stability and abundance in degraded evidence. The ongoing evolution of proteomic technology, including more sensitive mass spectrometers and improved bioinformatics tools, continues to expand its potential. For the Malaysian context, these advancements present a clear opportunity. Future innovations, alongside strategic collaborations between forensic practitioners and proteomics laboratories, are essential to bridge the identified research gap. Such efforts would enable the development of localised, reproducible workflows, transforming proteomic analysis from a promising complementary tool into a practical asset within the Malaysian forensic landscape, ultimately enhancing investigative capabilities.

ABBREVIATIONS

ApoA1	Apolipoprotein A1
ATP2A2	ATPase sarcoplasmic/endoplasmic

	reticulum Ca2+ transporting 2
DNA	Deoxyribonucleic Acid
eEF1A2	Eukaryotic Translation Elongation Factor 1 Alpha 2
GAPDH	Glyceraldehyde-3-Phosphate Dehydrogenase
GVP	Genetically Varied Peptides
PDLIM7	PDZ and LIM domain 7
PMI	Post-mortem Interval
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and the Meta-Analysis extension for Scoping Reviews
SAP	Single Amino Acid Polymorphisms
SNP	Single Nucleotide Polymorphisms
TPM1	Tropomyosin 1

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REFERENCE

Ab-Rahim, S., Mansor, A. & Roslan, Z. 2016. Proteome Comparisons between PreChemotherapy and Post-Chemotherapy Serum of Metastatic Osteosarcoma Patients Reveals Potential Novel Biomarker. *Biochemistry & Molecular Biology Journal* 1(19): 1-10.

Aebersold, R. & Mann, M. 2016. Mass-spectrometric exploration of proteome structure and function. *Nature* 537(7620): 347-355.

Al-Amrani, S., Al-Jabri, Z., Al-Zaabi, A., Alshekaili, J. & Al-Khabori, M. 2021. Proteomics: Concepts and applications in human medicine. *World Journal of Biological Chemistry* 12(5): 57-69.

Al-Wajeeh, A.S., Salhimi, S.M., Al-Mansoub, M.A., Khalid, I.A., Harvey, T.M., Latiff, A. & Ismail, M.N. 2020. Comparative proteomic analysis of different stages of breast cancer tissues using ultra high performance liquid chromatography tandem mass spectrometer. *PLoS One* 15(1): e0227404.

Alias, A., Ibrahim, A., Abu Bakar, S.N., Shafie, M.S., Das, S. & Mohd Nor, F. 2017. Morphometric and Morphological Study of Mental Foramen in the Malaysian Population: Anatomy and Forensic Implications. *IIUM Medical Journal Malaysia* 16(2).

Amir, S.H., Yuswan, M.H., Aizat, W.M., Mansor, M.K., Desa, M.N.M., Yusof, Y.A., Song, L.K. & Mustafa, S. 2021. Comparative database search engine analysis on massive tandem mass spectra of pork-based food products for halal proteomics. *Journal of Proteomics* 241: 104240. https://doi.org/10.1016/j.jprot.2021.104240

Arksey, H. & O'Malley, L. 2005. Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology* 8(1): 19-32.

Auton, A., Abecasis, G.R., Brooks, L.D., Durbin, R.M., Garrison, E.P., Kang, H.M., Korbel, J.O., Marchini, J.L., McCarthy, S. & McVean, G.A. 2015. A global reference for human genetic variation. *Nature* 526(7571): 68-74.

Aziz, M.Y., Hussain, S.H., Ishak, A.R., Abdullah, M.A., Mohamed, R., Ruzi, I.I., Yahaya, N., Samad, N.A. & Edinur, H.A. 2022. Heavy Metal Concentrations in Malaysian Adults' Hair and Associated Variables in Bukit Mertajam, Penang, Malaysia. *Biological Trace Element Research* 200(8): 3475-3481.

Baldrian, P. & López-Mondéjar, R. 2014. Microbial genomics, transcriptomics and proteomics: new discoveries in decomposition research using complementary methods. *Applied Microbiology and Biotechnology* 98(4): 1531-1537.

Battistini, A., Capitanio, D., Bailo, P., Moriggi, M., Tambuzzi, S., Gelfi, C. & Piccinini, A. 2023. Proteomic analysis by mass spectrometry of postmortem muscle protein degradation for PMI estimation: A pilot study. *Forensic Science International* 349: 111774. https://doi.org/10.1016/j.forsciint.2023.111774

Bengtsson, C.F., Olsen, M.E., Brandt, L.Ø., Bertelsen, M.F., Willerslev, E., Tobin, D.J., Wilson, A.S. & Gilbert, M.T.P. 2012. DNA from keratinous tissue. Part I: Hair and nail. *Annals of Anatomy - Anatomischer Anzeiger* 194(1): 17-25. https://doi.org/10.1016/j.aanat.2011.03.013

Bhuptani, D., Kumar, S., Vats, M. & Sagav, R. 2018. Age and gender related changes of salivary total protein levels for forensic application. *J Forensic Odontostomatol* 36(1): 26-33.

Borja, T., Karim, N., Goecker, Z., Salemi, M., Phinney, B., Naeem, M., Rice, R. & Parker, G. 2019. Proteomic genotyping of fingermark donors with genetically variant peptides. *Forensic Science International: Genetics* 42: 21-30. https://doi.org/10.1016/j.fsigen.2019.05.005

Bragulla, H.H. & Homberger, D.G. 2009. Structure and functions of keratin proteins in simple, stratified, keratinized and cornified epithelia. *Journal of Anatomy* 214(4): 516-559.

Choi, K.-M., Zissler, A., Kim, E., Ehrenfellner, B., Cho, E., Lee, S.-i., Steinbacher, P., Yun,

K.N., Shin, J.H., Kim, J.Y., Stoiber, W., Chung, H., Monticelli, F.C., Kim, J.-Y. & Pittner, S. 2019. Postmortem proteomics to discover biomarkers for forensic PMI estimation. *International Journal of Legal Medicine* 133(3): 899-908.

Choi, N.-R., Sándor, G.K. & Kim, Y.-D. 2018. Efficacy of Collagen-Based Membranes in Alveolar Bone Augmentation. *Applied Sciences* 8(11): 2048.

Chu, F., Mason, K.E., Anex, D.S., Paul, P.H. & Hart, B.R. 2019. *Human Identification Using Genetically Variant Peptides in Biological Forensic Evidence Applications in Forensic Proteomics: Protein Identification and Profiling* (Vol. 1339, pp. 107-123): American Chemical Society.

Dahal, A., McNevin, D., Chikhani, M. & Ward, J. 2023. An interdisciplinary forensic approach for human remains identification and missing persons investigations. *WIREs Forensic Science* 5(4): e1484. https://doi.org/10.1002/wfs2.1484.

Dammeier, S., Nahnsen, S., Veit, J., Wehner, F., Ueffing, M. & Kohlbacher, O. 2016. Mass-Spectrometry-Based Proteomics Reveals Organ-Specific Expression Patterns To Be Used as Forensic Evidence. *Journal of Proteome Research* 15(1): 182-192.

Darrelyn, C.N., Nurul Syafiqah, A. & Lee, L.C. 2021. A Forensic Study of Ethnicity and Sex Differences in Fingerprint Patterns in a Malaysian Subpopulation. *Medicine & Health* 16(1): 92-107.

Deininger, L., Patel, E., Clench, M.R., Sears, V., Sammon, C. & Francese, S. 2016. Proteomics goes forensic: Detection and mapping of blood signatures in fingermarks. *PROTEOMICS* 16(11-12): 1707-1717. https://doi.org/10.1002/pmic.201500544

Duracova, M., Klimentova, J., Fucikova, A. & Dresler, J. 2018. Proteomic Methods of Detection and Quantification of Protein Toxins. *Toxins* 10(3): 99.

Ellias, M.F., Zainal Ariffin, S.H., Karsani, S.A., Abdul Rahman, M., Senafi, S. & Megat Abdul Wahab, R. 2012. Proteomic Analysis of Saliva Identifies Potential Biomarkers for Orthodontic Tooth Movement. *The Scientific World Journal* 2012(1): 647240. https://doi.org/10.1100/2012/647240

Freckelton, I.E. 2021. Forensic Analysis - Scientific and Medical Techniques and Evidence under the Microscope. London: IntechOpen.

Guan, F. & Robinson, M.A. 2017. Comprehensive solid-phase extraction of multitudinous bioactive peptides from equine plasma and urine for doping detection. *Analytica Chimica Acta* 985: 79-90. https://doi.org/10.1016/j.aca.2017.07.005

Hefetz, I., Einot, N., Faerman, M., Horowitz, M. & Almog, J. 2019. Touch DNA: The effect of the deposition pressure on the quality of latent fingermarks and STR profiles. *Forensic Science International: Genetics* 38: 105-112. https://doi.org/10.1016/j.fsigen.2018.10.016

Hernández-Romero, D., Sánchez-Rodríguez, E., Osuna, E., Sibón, A., Martínez-Villanueva, M., Noguera-Velasco, J.A. & Pérez-Cárceles, M.D. 2020. Proteomics in Deaths by Drowning: Diagnostic Efficacy of Apolipoprotein A1 and α-1 Antitrypsin, Pilot Study. *Diagnostics* 10(10): 747.

Huang, T., Shu, Y. & Cai, Y.-D. 2015. Genetic differences among ethnic groups. *BMC Genomics* 16(1): 1093.

Ibrahim, W.I.W. (2017). *Serum Proteomic Analyses of Patients with Bone Tumours Using Gel-, Lectin-and Mass Spectrometry-Based Strategies.* (Doctoral), University of Malaya (Malaysia).

Imaizumi, K. 2015. Forensic investigation of burnt human remains. *Research and Reports in Forensic Medical Science* 5(null): 67-74.

Ismail, N.A., Abd Khupur, N.H., Osman, K., Mansar, A.H., Shafie, M.S. & Mohd Nor, F. 2018. Stature estimation in Malaysian population from radiographic measurements of upper limbs. *Egyptian Journal of Forensic Sciences* 8(1): 22.

Iyavoo, S. & Goodwin, W.H. 2022. Recovery of DNA from bone without demineralization. *Forensic Science International: Genetics Supplement Series* 8: 85-87.

Jonsson, H., Magnusdottir, E., Eggertsson, H.P., Stefansson, O.A., Arnadottir, G.A., Eiriksson, O., Zink, F., Helgason, E.A., Jonsdottir, I., Gylfason, A., Jonasdottir, A., Jonasdottir, A., Beyter, D., Steingrimsdottir, T., Norddahl, G.L., Magnusson, O.T., Masson, G., Halldorsson, B.V., Thorsteinsdottir, U., Helgason, A., Sulem, P., Gudbjartsson, D.F. & Stefansson, K. 2021. Differences between germline genomes of monozygotic twins. *Nature Genetics* 53(1): 27-34.

Khan, I., Abdul Jamil, M.M.B. & Nor, F.M. 2018. Age regression for Malaysian males using cortical bone Histomorphometry. *Journal of Physics: Conference Series* 1019(1): 012011.

Kocsmár, É., Schmid, M., Cosenza-Contreras, M., Kocsmár, I., Föll, M., Krey, L., Barta, B.A., Rácz, G., Kiss, A., Werner, M., Schilling, O., Lotz, G. & Bronsert, P. 2023. Proteome alterations in human autopsy tissues in relation to time after death. *Cellular and Molecular Life Sciences* 80(5): 117.

Landron, A. 2019. Trichology: A Study of Hair and its Uses as Trace Evidence. *Ursidae: The Undergraduate Research Journal at the University of Northern Colorado* 5: 5.

LeSassier, D.S., Schulte, K.Q., Manley, T.E., Smith, A.R., Powals, M.L., Albright, N.C., Ludolph, B.C., Weber, K.L., Woerner, A.E., Gardner, M.W. & Hewitt, F.C. 2019. Artificial fingerprints for cross-comparison of forensic DNA and protein recovery methods. *PLoS One* 14(10): e0223170.

Liu, W., Butler, E., Yang, H., Fenyö, D. & Siegel, D. 2019. *Informatics Approaches to Forensic Body Fluid Identification by Proteomic Mass Spectrometry Applications in Forensic Proteomics: Protein Identification and Profiling* (Vol. 1339, pp. 81-90): American Chemical Society.

Mizoguchi, H., Bagetta, G., Sakurada, T. & Sakurada, S. 2011. Dermorphin tetrapeptide analogs as potent and long-lasting analgesics with pharmacological profiles distinct from morphine. *Peptides* 32(2): 421-427. https://doi.org/10.1016/j.peptides.2010.11.013

Mohamed Bakrim, N., Mohd Shah, A., Mohd Shah, A., A. Talib, N., A. Rahman, J., Muhamad Bunnori, N. & Mohd Yusri, I. 2019. Proteomic Profiles of Young Adults with Acute Myocardial Infarction. *IIUM Medical Journal Malaysia* 18(3).

Mohamed Nasir, N., Hiji, J., Jayapalan, J.J. & Hashim, O.H. 2020. Potential use of human hair shaft keratin peptide signatures to distinguish gender and ethnicity. *PeerJ* 8: e8248.

Nayak, V.C., Rastogi, P., Kanchan, T., Yoganarasimha, K., Kumar, G.P. & Menezes, R.G. 2010. Sex differences from fingerprint ridge density in Chinese and Malaysian population. *Forensic Science International* 197(1): 67-69. https://doi.org/10.1016/j.forsciint.2009.12.055

Nolan, A.-N.D., Maker, G., Mead, R.J., Bringans, S. & Speers, S.J. 2020. Peptide analysis of mammalian decomposition fluid in relation to the post-mortem interval. *Forensic Science International* 311: 110269. https://doi.org/10.1016/j.forsciint.2020.110269

Oonk, S., Schuurmans, T., Pabst, M., de Smet, L.C.P.M. & de Puit, M. 2018. Proteomics as a new tool to study fingermark ageing in forensics. *Scientific reports* 8(1): 16425.

Pakeer, A., Mustafa Mahmud, M.I.A., Ismail, N. & Mariappan, V. 2021. Optimized Preparation of Urine Samples from Acute Melioidosis Patients for In-Solution Proteomic Studies using LCMS QTOF or MALDI TOF MS. *IIUM Medical Journal Malaysia* 20(3).

Parker, G.J., Leppert, T., Anex, D.S., Hilmer, J.K., Matsunami, N., Baird, L., Stevens, J., Parsawar, K., Durbin-Johnson, B.P., Rocke, D.M., Nelson, C., Fairbanks, D.J., Wilson, A.S., Rice, R.H., Woodward, S.R., Bothner, B., Hart, B.R. & Leppert, M. 2016. Demonstration of Protein-Based Human Identification Using the Hair Shaft Proteome. *PLoS One* 11(9): e0160653.

Patel, E., Cicatiello, P., Deininger, L., Clench, M.R., Marino, G., Giardina, P., Langenburg, G., West, A., Marshall, P., Sears, V. & Francese, S. 2016. A proteomic approach for the rapid, multi-informative and reliable identification of blood. *Analyst* 141(1): 191-198.

Plott, T.J., Karim, N., Durbin-Johnson, B.P., Swift, D.P., Scott Youngquist, R., Salemi, M., Phinney, B.S., Rocke, D.M., Davis, M.G., Parker, G.J. & Rice, R.H. 2020. Age-Related Changes in Hair Shaft Protein Profiling and Genetically Variant Peptides. *Forensic Science International: Genetics* 47: 102309. https://doi.org/10.1016/j.fsigen.2020.102309

Porto, I.M., Laure, H.J., de Sousa, F.B., Rosa, J.C. & Gerlach, R.F. 2011. New techniques for the recovery of small amounts of mature enamel proteins. *Journal of Archaeological Science* 38(12): 3596-3604. https://doi.org/10.1016/j.jas.2011.08.030

Procopio, N., Chamberlain, A.T. & Buckley, M. 2017. Intra- and Interskeletal Proteome Variations in Fresh and Buried Bones. *Journal of Proteome Research* 16(5): 2016-2029.

Procopio, N., Mein, C.A., Starace, S., Bonicelli, A. & Williams, A. 2021. Bone Diagenesis in Short Timescales: Insights from an Exploratory Proteomic Analysis. *Biology* 10(6): 460.

Rahim, M.A., Rahim, Z.H., Ahmad, W.A. & Hashim, O.H. 2015. Can Saliva Proteins Be Used to Predict the Onset of Acute Myocardial Infarction among High-Risk Patients? *Int J Med Sci* 12(4): 329-335.

Rasetti-Escargueil, C. & Avril, A. 2023. Medical Countermeasures against Ricin Intoxication. *Toxins* 15(2): 100.

Rehiman, S.H., Lim, S.M., Lim, F.T., Chin, A.-V., Tan, M.P., Kamaruzzaman, S.B., Ramasamy, K. & Abdul Majeed, A.B. 2022. Fibrinogen isoforms as potential blood-based biomarkers of Alzheimer's disease using a proteomics approach. *International Journal of Neuroscience* 132(10): 1014-1025.

Rizzato, F., Rodriguez, A., Biarnés, X. & Laio, A. 2017. Predicting Amino Acid Substitution Probabilities Using Single Nucleotide Polymorphisms. *Genetics* 207(2): 643-652.

Rolf, B. & Krawczak, M. 2021. The germlines of male monozygotic (MZ) twins: Very similar, but not identical. *Forensic Science International: Genetics* 50: 102408.

Sacco, M.A. & Aquila, I. 2023. Proteomics: A New Research Frontier in Forensic Pathology. *Int J Mol Sci* 24(13): 10735. https://doi.org/10.1016/j.fsigen.2020.102408

Sawafuji, R., Cappellini, E., Nagaoka, T., Fotakis, A.K., Jersie-Christensen, R.R., Olsen, J.V., Hirata, K. & Ueda, S. 2017. Proteomic profiling of archaeological human bone. *Royal Society Open Science* 4(6).

Seif, E.A., Elsehly, W.M., Henaidy, M.F. & Mabrouk Soffar, M.H. 2022. Sex Identification Using Fingerprint White Line Counts in a Sample of Adult Egyptians and Malaysians. *Journal of Forensic Science and Medicine* 8(3): 88-96.

Shao, D., Huang, L., Wang, Y., Cui, X., Li, Y., Wang, Y., Ma, Q., Du, W. & Cui, J. 2021. HBFP: a new repository for human body fluid proteome. *Database* 2021.

Tan, Y.C., Low, T.Y., Lee, P.Y. & Lim, L.C. 2024a. Single-cell proteomics by mass spectrometry: Advances and implications in cancer research. *PROTEOMICS* 24(12-13): 2300210. https://doi.org/10.1002/pmic.202300210

Tan, Y.C., Mustangin, M., Rosli, N., Wan Ahmad Kammal, W.S.E., Md Isa, N., Low, T.Y., Lee, P.Y., Chellappan, D.K., Jarmin, R., Zuhdi, Z., Azman, A., Ian, C., Yusof, N.M. & Lim, L.C. 2024b. EtOH-LN cryoembedding workflow to minimize freezing artifact in frozen tissues: A pilot study in preparing tissues compatible with mass spectrometry-based spatial proteomics application. *Cryobiology* 114: 104843.https://doi.org/10.1016/j.cryobiol.2023.104843

Tisdale, G. 2016. Protein Found at the Scene of the Crime: The Potential for Using Proteomics for Identification https://ssrn.com/abstract=2907742. http://dx.doi.org/10.2139/ssrn.2907742

Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., Hempel, S., Akl, E.A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M.G. & Garritty, C. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med* 169(7): 467-473.

van Oorschot, R.A.H., Ballantyne, K.N. & Mitchell, R.J. 2010. Forensic trace DNA: a review. *Investigative Genetics* 1(1): 14.

Wadsworth, C., Procopio, N., Anderung, C., Carretero, J.-M., Iriarte, E., Valdiosera, C., Elburg, R., Penkman, K. & Buckley, M. 2017. Comparing ancient DNA survival and proteome content in 69 archaeological cattle tooth and bone samples from multiple European sites. *Journal of Proteomics* 158: 1-8. https://doi.org/10.1016/j.jprot.2017.01.004

Wan-Ibrahim, W.I., Singh, V.A., Hashim, O.H. & Abdul-Rahman, P.S. 2015. Biomarkers for Bone Tumors: Discovery from Genomics and Proteomics Studies and Their Challenges. *Molecular Medicine* 21(1): 861-872.

Wilke, C. 2021. Proteomics Offers New Clues for Forensic Investigations. *ACS Central Science* 7(10): 1595-1598.

Woerner, A.E., Crysup, B., Hewitt, F.C., Gardner, M.W., Freitas, M.A. & Budowle, B. 2022. Techniques for estimating genetically variable peptides and semi-continuous likelihoods from massively parallel sequencing data. *Forensic Science International: Genetics* 59: 102719. https://doi.org/10.1016/j.fsigen.2022.102719

Wong, S.Y., Hashim, O.H. & Hayashi, N. 2019. Development of high-performance two-dimensional gel electrophoresis for human hair shaft proteome. *PLoS One* 14(3): e0213947.

Wong, S.Y., Lee, C.C., Ashrafzadeh, A., Junit, S.M., Abrahim, N. & Hashim, O.H. 2016. A High-Yield Two-Hour Protocol for Extraction of Human Hair Shaft Proteins. *PLoS One* 11(10): e0164993.

Wu, J.R. & Zeng, R. 2012. Molecular basis for population variation: From SNPs to SAPs. *FEBS Letters* 586(18): 2841-2845. https://doi.org/10.1016/j.febslet.2012.07.036

Wu, P.W., Mason, K.E., Durbin-Johnson, B.P., Salemi, M., Phinney, B.S., Rocke, D.M., Parker, G.J. & Rice, R.H. 2017. Proteomic analysis of hair shafts from monozygotic twins: Expression profiles and genetically variant peptides. *PROTEOMICS* 17(13-14): 1600462. https://doi.org/10.1002/pmic.201600462

Zhang, Z., Burke, M.C., Wallace, W.E., Liang, Y., Sheetlin, S.L., Mirokhin, Y.A., Tchekhovskoi, D.V. & Stein, S.E. 2020. Sensitive Method for the Confident Identification of Genetically Variant Peptides in Human Hair Keratin. *Journal of Forensic Sciences* 65(2): 406-420. https://doi.org/10.1111/1556-4029.14229

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Laporan Kes / *Case Report*

Nutritional and Lifestyle Management for Bariatric Surgery Preparation: A Case Report

Pengurusan Pemakanan dan Gaya Hidup bagi Persediaan Pembedahan Bariatrik: Laporan Kes

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ABSTRACT

Obesity is a complex, multifactorial condition associated with numerous comorbidities. Bariatric surgery has emerged as the ultimate surgical solution when non-surgical weight loss methods fail. This case report discusses a 34-year-old Malay male with morbid obesity, referred to a dietitian for weight management before bariatric surgery. The patient weighs at 120.8 kg, with a BMI of 41.8 kg/m², excess body fat of 35.6%, and visceral fat of 30. His latest blood lipid profile showed elevated triglycerides at 3.0 mmol/L, normal LDL-cholesterol level at 2.9 mmol/L, and decreased HDL-cholesterol level at 0.8 mmol/L. Despite prior attempts, the patient was unsuccessful in losing weight and reported exacerbation of the symptoms of gastroesophageal reflux disease (GERD) during the process. He exhibited excessive volume eating, irregular mealtimes, and unhealthy food choices. The nutritional goal was to achieve 10% weight loss prior to bariatric surgery and reduction of GERD symptoms. The patient was prescribed with a 2500kcal/day weight reducing diet and received education on weight-reducing strategies, including portion control, healthier cooking methods, food choices, meal timing, and physical activity. A reduction of 1.8kg was observed over three weeks. Subsequently the follow-up interventions were tailored to the patient's progress.

Keywords: Bariatric surgery, morbid obesity, meal timing, pre- operative weight management

ABSTRAK

Obesiti merupakan satu keadaan kompleks dan multifaktorial yang dikaitkan dengan pelbagai komorbiditi. Pembedahan bariatrik telah muncul sebagai solusi secara pembedahan apabila pelbagai kaedah penurunan berat badan gagal. Laporan kes ini membincangkan tentang seorang lelaki Melayu berusia 34 tahun yang mengalami obesiti morbid dan dirujuk kepada pakar dietetik bagi pengurusan berat badan sebelum menjalani pembedahan bariatrik. Pesakit mempunyai berat badan 120.8kg, dengan BMI 41.8kg/m², peratus lemak badan yang berlebihan sebanyak 35.6%, dan lemak viseral sebanyak 30. Profil lipid darah terkini menunjukkan paras trigliserida yang tinggi iaitu 3.0mmol/L, paras LDL-kolesterol normal pada 2.9mmol/L, dan paras HDL-kolesterol yang rendah pada 0.8mmol/L. Walaupun telah mencuba sebelum ini, pesakit tidak berjaya menurunkan berat badan dan melaporkan simptom penyakit refluks gastroesofagus (GERD) semakin teruk semasa proses tersebut. Beliau menunjukkan corak pengambilan makanan dalam jumlah berlebihan, waktu makan yang tidak teratur, serta pilihan makanan yang tidak sihat. Matlamat pemakanan adalah untuk mencapai penurunan berat badan sebanyak 10% sebelum pembedahan bariatrik dan mengurangkan simptom GERD. Pesakit telah diberikan diet pengurangan berat badan sebanyak 2500 kcal/hari dan menerima pendidikan mengenai strategi penurunan berat badan, termasuk kawalan saiz hidangan, kaedah memasak dan pemilihan makanan yang lebih sihat, penetapan waktu makan, dan aktiviti fizikal. Penurunan berat badan sebanyak 1.8kg telah diperhatikan dalam tempoh tiga minggu. Seterusnya, intervensi susulan disesuaikan berdasarkan kemajuan pesakit

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Kata Kunci: Pembedahan bariatrik, obesiti morbid, waktu makan, pengurusan berat badan pra-pembedahan

INTRODUCTION

Obesity is widely recognized as a significant public health issue, affecting populations on both national and global levels. It is a chronic and complex disease characterized by excessive fat deposition that negatively impacts overall health. As stated by the Ministry of Health Malaysia (2023b), obesity is associated with numerous comorbidities, including gastrointestinal conditions (e.g., Metabolic Associated Fatty Liver Disease, Gastroesophageal Reflux Disease, and hernias), metabolic disorders (e.g., Type 2 Diabetes Mellitus and gout), cardiovascular diseases (e.g., hypertension, atherosclerosis, dyslipidemia, and heart failure), neurological complications (e.g., stroke), pulmonary conditions (e.g., obstructive sleep apnea), and even certain cancers. When obesity reaches more severe levels, it is referred to as morbid obesity, a condition that significantly increases the risk of developing additional serious health problems. In Malaysia, the prevalence of overweight and obesity has steadily risen over the years. According to the National Health and Morbidity Survey (NHMS) (2024), the proportion of overweight and obese adults increased from 44.5% in 2011 to 54.4% in 2023. Similarly, abdominal obesity rose from 45.4% in 2011 to 54.5% in 2023, highlighting the escalating nature of the issue.

The latest Clinical Practice Guidelines Management of Obesity provides diagnostic criteria tailored to the Asian population, as the World Health Organization (WHO) body mass index (BMI) cut-off points do not accurately reflect Asian-specific risks. Asians generally have higher body fat percentages at similar BMI cut-off points compared to Caucasians, with comorbidity risks beginning at lower BMI. Overweight is defined as a BMI of 23 kg/m² or higher, while obesity is further classified as follows: Obese I (27.5–32.4 kg/m²), Obese II (32.5–37.4 kg/m²), and Obese III (≥37.5 kg/m²) (Ministry of Health Malaysia, 2023b). Obesity is a multifactorial disease influenced by genetic, behavioral and environmental factors (WHO 2021). One significant factor is the obesogenic environment, characterized by the availability of calorie-dense, unhealthy foods, social norms promoting large portion sizes, and limited access to affordable, healthy food options. Structural factors, such as busy work schedules, hinder regular exercise and healthy eating. Besides, chrono-nutrition disruptions, including irregular meal timing and late-night eating, along with genetic predispositions, also plays a role in appetite and energy regulation. (Spiegel et al. 2004; Stenvers et al. 2018).

Management of obesity includes lifestyle modifications (dietary and exercise), pharmacologic therapy and bariatric surgery. Bariatric surgery has emerged as one of the most effective therapies for severe obesity, particularly in cases where conventional weight loss methods have failed. It helps reduce obesity-related comorbidities and mortality (Sjöström, 2013). The indications for bariatric surgery are shown in Table 1. Bariatric procedures have been considered to function as restrictive, malabsorptive and a combination of both. Restrictive procedures in which the stomach capacity is reduced, promoting early satiety and limiting calorie intake. Examples include Gastric banding and sleeve gastrectomy. Malabsorptive procedures focus on reducing nutrient absorption by shortening the absorptive surface of the small intestine. Combination procedures such as Biliopancreatic diversion/duodenal switch (BPD/DS), Roux-en-Y gastric bypass and Mini gastric bypass (MBG) or one anastomosis gastric bypass (ABG), incorporate both restrictive and malabsorptive components. Additionally, a non-operative restrictive procedure, the intragastric balloon (IGB), involves placing a temporary balloon in the stomach to reduce its volume, promoting satiety and limiting food intake. Pre-operative weight loss, targeting a 10% weight loss prior to surgery, is recommended to improve the operative and postoperative outcomes as it helps to decrease liver size, reduce visceral fat, and lower the risk of surgical complications (Ministry of Health Malaysia, 2023b).

CASE PRESENTATION

This is a new case involving a 34-year-old Malay male patient, diagnosed with morbid obesity and underlying comorbidities, including hypertension (HTN), and gastroesophageal reflux disease (GERD). However, he is currently not on any medications. Based on the STOP-Bang questionnaire, the patient scored a 6, indicating High risk (moderate to severe) for Obstructive Sleep Apnea (OSA). The STOP-BANG questionnaire is the gold-standard clinical screening tool for Obstructive Sleep Apnea (OSA) (Chung et al. 2008). The patient is a candidate for gastric bypass surgery, with the procedure scheduled for confirmation in February 2025. His social history is notable for his employment as a Navy maritime crew member, which involves three days of duty-related travel per week. He resides with his wife, an office worker, and their three children. Regarding health behaviors, the patient denies alcohol consumption but is an active smoker with a significant tobacco history, consuming 10 cigarettes daily since age 13. He has no prior surgical or hospitalization history. Significant family history includes maternal type 2 diabetes and paternal chronic kidney disease.

Upon visiting to the diet clinic, he weighed at 120.8 kg, with a height of 170 cm, and a BMI of 41.8 kg/m², which is classified as obesity class III. The patient's body fat percentage was measured at 35.6%, which significantly exceeds the obesity threshold for males (≥25%) as defined by the Jackson & Pollock (1985) standards. Additionally, the patient's visceral fat was measured at 30 using Bioelectrical Impedance Analysis (BIA). According to the thresholds established by the Japan Society for the Study of Obesity (JASSO) (2002), this level significantly exceeds the established healthy reference range of 0.5–10, classifying the patient in the 'Very High' risk category for metabolic disease. Which also indicates a high volume of intra-abdominal adiposity, which is a known predictor of surgical complexity in bariatric procedures due to potential hepatomegaly.

His ideal body weight (IBW) based on BMI at 18.5 to 24.9 kg/m² was 53.5 to 72kg. According to the patient's weight history, his lowest weight was 55kg when he was at the age of 21. He reported consuming protein powder without exercising to gain weight, finishing two cans in total. Following this, his appetite increased, and his weight progressively rose to a peak of 137 kg last year. The patient, who was eager to reduce weight, started a strict ketogenic diet on his own after reading about it online. He consumed only two eggs, butter and black coffee for 2 main meals daily while incorporating 40 minutes of brisk walking. After one month, he experienced a total weight loss of 10 kg. However, he discontinued the diet after developing symptoms of GERD, including heartburn and belching.

His latest fasting serum lipid profile (FSL) results are shown in Table 2. The total cholesterol was at 5.1 mmol/L, triglycerides at 3.0 mmol/L, LDL-cholesterol at 2.9 mmol/L, and HDL-cholesterol at 0.8 mmol/L. The elevated triglyceride levels may be attributed to excessive calorie intake from carbohydrates and fat, while the low HDL-cholesterol levels could be associated with low physical activity and smoking habits.

In terms of clinical findings, the patient reported experiencing GERD symptoms, including stomach bloating, especially when he did not adhere to regular mealtimes, as he often ate beyond mealtimes during outstations. However, the patient was not on any medication to treat this condition. Moreover, he noted occasional heartburn during walking, which ultimately led to him to discontinue brisk walking as part of his routine, which results in low physical activity, especially when he is off duty from work.

The patient mostly bought food from outside. He claimed that his appetite increased over the past month. He reported that his usual dietary intake differed from his intake during outstation assignments (three times per week), where he consumed less food and had irregular mealtimes due to a busy schedule. During outstation, the patient claimed to primarily consume biscuits, bread, and noodles. A dietary assessment of his usual intake on non-outstation days was conducted for a better understanding of his usual dietary patterns. The complete usual dietary intake is detailed in Table 3.

The estimated intake was approximately 3335kcal with macronutrient distribution consisting of 47% carbohydrates, 11% protein, and 42% fat. This eating pattern indicated a regular intake of calorie-rich foods that are high in fat, mainly saturated fat, while being low in fiber from fruits and vegetables. The patient also reported regularly requesting extra portions of rice, leading to meal sizes of 4 to 7.5 exchanges of carbohydrates. He preferred chicken and eggs as his primary protein sources, typically opting for chicken breast with skin and two scoops of coconut milk-based gravy. Additionally, he regularly ordered sugary drinks such as teh tarik or iced tea in every meal. Regarding dietary habits, the patient tended to have late dinners and heavy suppers, often claiming the inability to control his appetite and a tendency to snack after main meals. Patient also reported he usually stays up late and only sleeps around 2-3 am.

Hence, the first nutrition diagnosis for this case was, excessive energy intake related to frequent consumption of large portion sizes, high-fat foods, and sugary beverages as evidenced by BMI of 41.8 kg/m² (Class III obesity), body fat 35.6%, visceral fat 30, diet history of large meals, frequent snacking on calorie-dense foods, and minimal intake of fiber-rich foods. The second nutrition diagnosis was physical inactivity related to a sedentary lifestyle and limited engagement in structured physical activity as evidenced by patient's self-report of minimal movement, late sleep patterns (2–3 a.m.), and excessive screen time contributing to weight gain and metabolic risk.

NUTRITIONAL INTERVENTIONS

NUTRITION PRESCRIPTION

The main management goal for this patient is to achieve at least 10% weight loss before bariatric surgery and to alleviate GERD symptoms. The estimated energy requirement (EER) was calculated using the Mifflin St. Jeor Equation (1990). An activity factor of 1.2 was applied, considering the patient's sedentary lifestyle, resulting in 2526 kcal. To achieve a weight reduction of 0.5–1 kg per week, a gradual energy reduction of 500 kcal was deducted from the estimated energy intake (EEI). Consider that the patient's current energy intake was 3335kcal/day, the gradual reduction in energy intake was also emphasized, starting from 2800 kcal to 2500kcal within 2 weeks. A 2000kcal, will be prescribed during the next follow-up.

TABLE 1 Indications for bariatric surgery

Morbid obesity without any comorbidities	Bariatric surgery should be considered for the treatment of obesity in suitable patients with BMI ≥37.5 kg/m^2 who fulfil the selection criteria
Morbid obesity with metabolic syndrome	The surgical approach may be considered as a non-primary alternative to treat obesity in suitable patients with BMI ≥32.5 kg/m^2 with metabolic syndrome or CV risk following inadequate weight loss by virtue of medical therapy and lifestyle modifications
Low BMI with or without comorbidities	Any surgery for metabolic syndrome or obesity related comorbidity in patients with a BMI <32.5kg/m2 should not be a routine clinical practice and should be strictly performed only under clinical study protocol with informed consent from the patient and prior approval from an ethics committee
Age restriction	Bariatric surgery is recommended for patients between the ages of 18 and 65 years
Special circumstances	Upon consultation with a physician, paediatrician, orthopaedic surgeon, clinical psychologist, or a surgeon, bariatric surgery may be performed in morbidly obese adolescent patients provided they have attained the physiological bone maturity consistent with Tanner stage 4

Source: Clinical Practice Guidelines Management of Obesity (2nd Edition) 2023.

TABLE 2 Fasting serum lipid profile (FSL)

Parameter	Result	Reference range
Total cholesterol	5.0	< 5.2 mmol/L
LDL- cholesterol	4.5	< 3.0 mmol/L
HDL- cholesterol	0.8	> 1.2 mmol/L
Triglyceride	3.8	< 1.7 mmol/L

Source: Clinical Practice Guidelines Management of Dyslipidemia (6th Edition) 202

TABLE 3 Dietary intake

Meal Occasion	**Food & Beverage Item**	**Estimated Portion / Exchange**	**Frequency**
Breakfast (9:30am)	Nasi Lemak	2 cups	3–4 times/week
	Fried Chicken (with skin)	1 piece (approx. ½ breast)	3–4 times/week
	Fried Egg	1 piece	3–4 times/week
	Teh Tarik (Sweetened)	1 cup (250ml)	3–4 times/week
	Sweet Kuih-Muih	3 pieces	Once/week
Lunch (2:00pm)	White Rice	2 ½ medium bowls	Daily
	Chicken (assorted)	1 piece (2 exchanges)	Daily
	Coconut Milk Gravy (Santan)	2 scoops	Daily
	Fried Egg	1 piece	Daily
	Iced Tea (Sweetened)	1 cup (250ml)	3–4 times/week

Afternoon Tea (5:00–6:00pm)	Fish Crackers (Keropok)	4–5 pieces	Daily*
Dinner (9:00–11:00pm)	Fried Rice	2 ½ bowls	Daily
	Fried Chicken (with skin)	1 piece (approx. ½ breast)	Daily
	Fried Egg	1 piece	Daily
	Teh Tarik (Sweetened)	1 cup (250ml)	Daily
Supper (after 11:00pm)	Roti Canai Curry	2 pieces ½ small bowl	2–3 times/week
	Teh Tarik (Sweetened)	1 cup (250ml)	2–3 times/week

The calorie intake will be further reduced to 1500kcal, followed by 1200 kcal, and finally reaching around 800 kcal, in line with a very low-calorie diet (VLCD) for at least 2 weeks before the bariatric surgery.

The macronutrient distribution was as follows: 55% carbohydrates, 15% protein, and 30% fat, with 7-10% of the total fat from saturated fat, less than 1% from trans fats, and a daily intake of less than 300 mg of cholesterol and less than 2000 mg of sodium. These recommendations align with the latest Clinical Practice Guidelines for Dyslipidemia (Ministry of Health Malaysia, 2023a).

DIETARY ADVICE

The weight-reducing diet and a healthy balanced diet were prescribed for this patient. The importance of pre-operative weight loss was thoroughly explained. The main reasons for pre-operative weight loss were to reduce the risk of surgical complications and promote better post-operative weight maintenance.

To address the issue of large portion sizes, the patient was encouraged to reduce the portion size of rice to one medium bowl or three scoops per meal. Additionally, he was advised not to request extra portions and to limit gravy intake to one scoop per meal. To help the patient manage portion sizes effectively, the use of the healthy plate model was recommended as a visual guide to prevent overeating. Besides, healthier cooking methods, such as grilling, boiling, steaming, and preparing soup-based dishes, were emphasized to reduce calorie intake. The patient was suggested to switch from roti canai to one piece of thosai or chapati, as these options contain less oil. The patient was also encouraged to replace sugary drinks, like teh tarik, with healthier alternatives, such as plain water or plain tea. Healthier snack options were recommended, such as one serving of fruit or three pieces of plain biscuits, which would satisfy hunger without contributing to excess calories. It is crucial to remind the patient not to indulge in unquantified snacks or eat directly from containers, as this can lead to overeating and loss of portion control.

BEHAVIORAL STRATEGIES

Given that the patient finds it challenging to control his appetite, the importance of a proper eating sequence was emphasized, starting with protein, followed by fibre, and then carbohydrates. This sequence helps control hunger. Furthermore, the patient was encouraged to reduce his carbohydrate intake, as excessive carbohydrates will cause an insulin surge, which may contribute to increased hunger and overeating. Increasing fiber intake to three servings of vegetables per day was also suggested to help enhance satiety and support weight management. The patient was encouraged to start with preferred vegetables, such as spinach, to make the transition less hard. To assist with appetite control and reduce the likelihood of overeating, the patient was advised to drink some water before meals. Moreover, the patient was advised on the importance of not consuming main meals after 8 pm, as eating late can interfere with the body's circadian rhythm and digestion.

MANAGING GERD SYMPTOMS

Nutritional interventions for the management of GERD symptoms focused on the elimination of dietary triggers, specifically high-fat and spicy foods. The patient was instructed to adopt a small, frequent meal pattern to prevent excessive gastric distension. Additionally, the importance of meal consistency was emphasized, with specific advice to avoid skipping meals and to refrain from late-night consumption to prevent nocturnal reflux.

PHYSICAL ACTIVITY PLAN

The patient was encouraged to increase physical activity starting with low to moderate intensity physical activity. Patient was advised to start with low impact aerobic exercise such as static cycling or home workouts for 10 minutes per session, five days a week. Over time, the goal would gradually increase to at least 30 minutes per session, five days a week, if tolerated, to achieve 150 minutes of moderate intensity physical activity per week.

MONITORING AND EVALUATION

Monitoring focused on anthropometric trends (weight change) and behavioural adherence, specifically regarding meal timing, portion regulation, and the transition toward low-fat/low-sugar cooking modalities. Furthermore, the patient's symptomatic response to dietary modifications was assessed, with particular attention to the frequency of gastroesophageal reflux (GERD) symptoms, including pyrosis (heartburn) and belching, and evaluation of physical activity levels. A follow-up assessment was conducted three weeks post-initial consultation via telecommunication (WhatsApp) to evaluate clinical progress.

The patient reported a weight reduction to 119kg, showing a loss of 1.8kg (1.5%) within the three weeks, which indicates a significant weight reduction. However, the BMI remained in the Obese Class III range at 41.2kg/m². The patient made several positive changes, including reducing the rice portion to four scoops and stopping from requesting extra portions. He also made efforts to reduce his consumption of coconut milk-based dishes to four times per week, although he mentioned that finding alternative, healthier gravies was challenging. In addition, the patient started including one scoop of vegetables, such as spinach, brinjal, or ulam (raw vegetable) during lunch and dinner. However, he reported inconsistent vegetable intake during the morning meal, citing limited accessibility. The patient also mentioned that while he had tried to reduce the frequency of supper, sometimes his children insisted on going out to eat when they were hungry. However, the patient mentioned that he just started static cycling 1 week ago and was only able to cycle for 15 minutes per session, three times per week, without experiencing any exacerbation of his GERD symptoms.

As part of the nutrition intervention, individualized recommendations were provided based on the patient's expressed concerns. The patient was advised to continue reducing rice portion sizes and, when healthier meal options were unavailable, to substitute with vermicelli soup added with vegetables. To improve fiber intake, the patient was encouraged to prepare salads, cherry tomatoes, or fruits at home as convenient, ready-to-eat options. He was also counseled to select vegetables prepared with minimal oil to avoid excess caloric intake. Regarding the late-night eating habit, the patient was advised to refrain from ordering food when accompanying his children to reduce exposure to temptation. Positive reinforcement was provided for the patient's current efforts, and he was encouraged to further increase physical activity, with emphasis that regular exercise contributes to improved stamina and overall health. Given these positive lifestyle modifications and the patient's demonstrated motivation, continued improvement is anticipated at the subsequent clinic follow-up.

DISCUSSION

According to CPG Obesity (2023), obesity is a complex condition influenced by various factors, including genetic, environmental, behavioral, and physiological aspects. It can be explained through the concept of energy balance: when there is a long-term positive energy balance, meaning that energy intake exceeds energy expenditure, the excess energy is stored as fat in the adipose tissue, leading to weight gain over time. Chronic obesity triggers inflammation throughout the body, affecting multiple physiological systems and contributing to serious comorbidities, a condition known as morbid obesity. The additional abdominal fat, increase intro-abdominal pressure, leading to weakened lower esophageal sphincter (LES) function and increased risk of GERD symptoms which are also illustrated in this case (Chang, et al. 2014). In this patient, dietary factors such as large portion sizes, unhealthy food choices, and cooking methods are direct contributors to obesity. However, certain behavioral and lifestyle factors, such as uncontrolled appetite, late-night eating, and late sleep patterns, also play a vital role in driving overeating, which ultimately contributes to excessive weight gain and obesity.

Irregular sleep patterns, particularly staying up late at night, can disrupt the body's circadian rhythm, the internal 24-hour clock that regulates physiological processes. The suprachiasmatic nucleus (SCN), located in the anterior hypothalamus above the optic chiasm, serves as the central pacemaker, coordinating sleep–wake cycles, hormone secretion, appetite, digestion, and body temperature in response to light–dark cues. Peripheral organs also possess local circadian clocks that align with the SCN to optimize metabolic and behavioral functions. Disruption of these rhythms has been linked to adverse health outcomes, including metabolic dysregulation and impaired glucose tolerance (Hastings et al. 2018; Partinen, 2019).

Late-night sleep disrupts the circadian rhythm, affecting metabolic processes. Study by Spiegel et al. (2004) indicates that such disruptions disturb the balance between ghrelin, which stimulates hunger, and leptin, which signals satiety. This imbalance can lead to increased appetite and overeating. In addition, individuals who stay up late often make unhealthy food choices and consume larger portions, which can further perpetuate the cycle of excessive calorie intake and weight gain. Studies proves that circadian rhythm regulates metabolic efficiency, which functions less effectively at night compared to daytime (Stenvers et al. 2018). Studies also suggest that the circadian system coordinates glucose metabolism by managing glucose absorption,

insulin sensitivity in tissues such as muscles, fat, and the liver, and insulin secretion by the pancreas is optimized during the daytime, suggesting that nighttime metabolic functioning is less effective for food intake (Poggiogalle et al. 2018; Zhang et al. 2025). Disruptions or misalignments between the body's internal rhythms and daily behaviors, such as late-night eating or late sleeping schedules, can lead to insulin resistance. During the night, this resistance encourages the storage of calories as fat rather than their use for immediate energy (Stenvers et al. 2018). Overall, disruptions to the circadian rhythm caused by irregular sleep patterns and late-night eating result in dysregulated appetite, reduced calorie expenditure, and increased fat storage, which are major contributors to the development of obesity.

Although bariatric surgery is being offered to this patient, it is essential to provide both pre-operative and post-operative dietary and lifestyle guidance to ensure sustainable weight loss outcomes. Recommendations alone may not be sufficient; it is crucial to emphasize the importance of pre-operative weight loss and explain the rationale behind a gradual calorie reduction approach. Gradual calorie reduction helps prevent overwhelming the patient and provides time for mental preparation for the transition to a very low-calorie diet (VLCD). Sudden restrictions, such as an immediate shift to an 800kcal diet, could cause undue stress if the patient has not been informed of the gradual reduction in food intake. Post-operative dietary patterns should also be thoroughly explained to the patient, allowing them to understand the changes they need to make. A practical strategy during consultations involved comparing the patient's current dietary habits (large portions, high fat, and high sugar) with the post-operative recommendations (small, frequent meals with reduced fat intake and limited refined carbohydrates). Additionally, potential post-operative nutritional complications, such as abdominal distension, vomiting, diarrhea, or dumping syndrome, were addressed if the current eating pattern was maintained. This comparison helps the patient gain a clearer understanding of the necessary improvements while addressing potential complications. By explaining the rationale behind these changes, the patient can better comprehend their importance and feel more motivated to adhere to the recommended adjustments. To sum up, besides dietary adjustments, it is crucial to address mindful eating practices and lifestyle modifications, as these play a significant role in controlling appetite and preventing overeating. This is particularly important since the patient struggles with regulating their appetite and has a habit of late-night eating. Late-night meals are not ideal, as they disrupt the circadian rhythm, as previously mentioned. Furthermore, the choices for these meals are concerning, as they are typically calorie-dense and nutritionally unbalanced.

A critical area for clinical optimization in this case should involve the assessment of the patient's importance, confidence, and readiness regarding weight loss. Given the patient's interest in bariatric surgery, evaluating these psychosocial markers is essential for identifying potential barriers such as emotional instability, surgical misconceptions, or potential non-adherence to perioperative lifestyle protocols. Early intervention based on this assessment ensures the patient is psychologically and behaviorally prepared to achieve optimal long-term outcomes.

CONCLUSION

Dietitian plays a crucial role in assessing a patient's weight history, previous dieting approaches, and current dietary intake to provide practical interventions that support preoperative weight loss in bariatric surgery patients. Addressing lifestyle and behavioral modifications, such as late-night eating and irregular sleep patterns, is essential for tackling other factors contributing to weight gain. Additionally, assessing a patient's readiness, confidence, and motivation for weight loss is vital in identifying barriers and ensuring they are both mentally and physically prepared for surgery. Effective interventions should be engaging and supported by clear explanations to help patients understand and implement dietary changes. Continuous follow-up is essential for monitoring progress, addressing patient concerns, and ensuring steady progression toward weight loss goals, ultimately improving surgical outcomes and long-term weight management.

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REFERENCES

Chang, P. & Friedenberg, F. 2014. Obesity and GERD. *Gastroenterology clinics of North America* 43(1): 161–173. https://doi.org/10.1016/j.gtc.2013.11.009

Chung, F., Yegneswaran, B., Liao, P., Chung, S. A., Vairavanathan, S., Islam, S., Khajehdehi, A. & Shapiro, C. M. 2008. STOP questionnaire: a tool to screen patients for obstructive sleep apnea. *Anesthesiology* 108(5): 812–821.

https://doi.org/10.1097/ALN.0b013e31816d83e4

Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity (JASSO). 2002. New Criteria for 'Obesity Disease' in Japan. *Circulation Journal* 66(11): 987–992.

Hastings, M. H., Maywood, E. S. & Brancaccio, M. 2018. The mammalian circadian timing system and the suprachiasmatic nucleus as its pacemaker. *Biological Reviews* 93(2): 747–795. https://doi.org/10.1111/brv.12313

Institute for Public Health. 2024. National Health and Morbidity Survey (NHMS) 2023: Non-Communicable Diseases and Healthcare Demand - Technical Report. Shah Alam: Ministry of Health Malaysia.

Jackson, A. S. & Pollock, M. L. 1985. Practical Assessment of Body Composition. The Physician and Sportsmedicine, 13(5): 76–90.

Ministry of Health Malaysia. 2023a. Clinical Practice Guidelines: Management of Dyslipidaemia (6th Edition). Putrajaya: Ministry of Health Malaysia.

Ministry of Health Malaysia. 2023b. Clinical Practice Guidelines: Management of Obesity (Second Edition). Putrajaya: Ministry of Health Malaysia

Partinen, M. 2019. Biological clocks and circadian rhythms. *Journal of Internal Medicine* 285(1): 1–16. https://doi.org/10.1111/joim.12815

Poggiogalle, E., Jamshed, H. & Peterson, C. M. 2018. Circadian regulation of glucose, lipid, and energy metabolism in humans. *Metabolism* 84: 11–27. https://doi.org/10.1016/j.metabol.2017.11.017

Sjöström L. 2013. Review of the key results from the Swedish Obese Subjects (SOS) trial - a prospective controlled intervention study of bariatric surgery. *Journal of internal medicine* 273(3): 219–234. https://doi.org/10.1111/joim.12012

Spiegel, K., Tasali, E., Penev, P. & Van Cauter, E. 2004. Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Annals of internal medicine* 141(11): 846–850. https://doi.org/10.7326/0003-4819-141-11-200412070-00008

Stenvers, D. J., Scheer, F. A. J. L., Schrauwen, P., la Fleur, S. E. & Kalsbeek, A. 2018. Circadian clocks and insulin resistance. *Nature Reviews Endocrinology* 15(2): 75–89. https://doi.org/10.1038/s41574-018-0122-1

World Health Organization. 2021. Obesity and Overweight. https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight

Zhang, Z., Wang, S. & Gao, L. 2025. Circadian rhythm, glucose metabolism and diabetic complications: the role of glucokinase and the enlightenment on future treatment. *Frontiers in Physiology* 16. https://doi.org/10.3389/fphys.2025.1537231

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Artikel Asli /*Original Article*

Academic Stress and Financial Stress as Predictors of Anxiety Level Among Radiologic Technology Students

Tekanan Akademik dan Tekanan Kewangan sebagai Peramal Tahap Kebimbangan dalam Kalangan Pelajar Teknologi Radiologi

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ABSTRACT

This study examined whether academic stress and financial stress significantly predict anxiety levels among Radiologic Technology students. A quantitative descriptive-predictive design was employed. A stratified random sample of 187 Radiologic Technology students from all year levels in selected higher education institution in Davao City, Philippines participated during the second semester of Academic Year 2024–2025. Data were collected using adapted versions of validated instruments measuring Academic Stress Inventory, Financial Stress Scale, and Axiety Scale, all demonstrating acceptable reliability (Cronbach's α = .765–.943). Descriptive statistics, Pearson correlation, and multiple linear regression analysis were utilized. Students reported a high level of academic stress (overall mean = 3.64), particularly in test- and subject-related domains (mean = 3.94). Financial stress was rated at a moderate level (overall mean = 2.62), while anxiety levels were also moderate (overall mean = 2.62). Correlation analysis showed significant positive relationships between anxiety and academic stress (r = .633, $p < .001$) and financial stress (r = .358, $p < .001$). Multiple linear regression analysis revealed that academic stress significantly predicted anxiety levels (β = .605, $p < .001$), whereas financial stress was not a significant predictor (β = .057, p = .390). These findings highlight that academic-related pressures are the primary drivers of anxiety among Radiologic Technology students, emphasizing the need for targeted academic and psychosocial interventions.

Keywords: Academic stress, anxiety level, financial stress, radiologic technology students, predictive study

ABSTRAK

Kajian ini bertujuan untuk menentukan sama ada tekanan akademik dan tekanan kewangan merupakan peramal signifikan kepada tahap kebimbangan dalam kalangan pelajar Teknologi Radiologi. Reka bentuk kajian kuantitatif deskriptif-ramalan telah digunakan. Seramai 187 orang pelajar Teknologi Radiologi daripada semua peringkat pengajian di institusi pengajian tinggi terpilih di Davao City, Filipina telah dipilih melalui kaedah pensampelan rawak berstrata dan terlibat dalam kajian ini semasa semester kedua Tahun Akademik 2024–2025. Data dikumpulkan menggunakan versi adaptasi daripada instrumen yang telah disahkan, iaitu Inventori Stres Akademik, Skala Stres Kewangan, dan Skala Kebimbangan, yang semuanya menunjukkan kebolehpercayaan yang memuaskan (Cronbach's α = .765–.943). Analisis statistik yang digunakan merangkumi statistik deskriptif, korelasi Pearson, dan analisis regresi linear berganda. Dapatan kajian menunjukkan bahawa pelajar mengalami tahap tekanan akademik yang tinggi (min keseluruhan = 3.64), khususnya dalam domain berkaitan ujian dan subjek (min = 3.94). Tekanan kewangan pula berada pada tahap sederhana (min keseluruhan = 2.62), manakala tahap kebimbangan juga berada pada tahap sederhana (min keseluruhan = 2.62). Analisis korelasi menunjukkan hubungan positif yang signifikan antara kebimbangan dengan tekanan akademik (r = .633, $p < .001$) serta tekanan kewangan (r = .358, $p < .001$). Analisis regresi linear berganda pula menunjukkan bahawa tekanan akademik merupakan peramal signifikan kepada tahap kebimbangan (β = .605, $p < .001$), manakala tekanan kewangan tidak menunjukkan kesan ramalan yang signifikan (β = .057, p = .390). Secara keseluruhannya, dapatan kajian ini

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menunjukkan bahawa tekanan berkaitan akademik merupakan faktor utama yang mempengaruhi tahap kebimbangan dalam kalangan pelajar Teknologi Radiologi, sekali gus menekankan keperluan intervensi akademik dan psikososial yang bersasar bagi menyokong kesejahteraan pelajar.

Kata Kunci: Kebimbangan, pelajar teknologi radiologi, tekanan akademik, tekanan kewangan

INTRODUCTION

Radiologic Technology education is characterized by a unique combination of rigorous academic instruction, technical skill development, and high-stakes clinical responsibilities. Students are required to master radiation safety protocols, precise imaging techniques, patient positioning, and the operation of advanced diagnostic equipment, all while ensuring patient safety. These demands create a highly pressurized learning environment that may contribute to elevated levels of academic stress (Trigueros et al. 2020). Academic stress arises when educational demands exceed a student's perceived ability to cope and is commonly associated with examinations, subject complexity, classroom performance, and fear of failure (Pascoe, Hetrick & Parker 2020). In Radiologic Technology programs, stress is intensified by competency-based assessments and clinical exposure, where errors may have direct implications for patient outcomes (Ho et al. 2022).

In addition to academic demands, financial stress is an important factor influencing student well-being, particularly in low- and middle-income settings such as the Philippines. Many students rely on family support, scholarships, or limited financial resources to sustain their education. Financial strain has been associated with emotional distress, reduced academic engagement, and increased anxiety, especially among students facing uncertainty regarding tuition and daily expenses (Bernardo et al. 2019; Heo, Cho & Lee 2020; Mcloud & Bann 2019). Despite the growing body of literature on stress and anxiety among healthcare students, there remains a paucity of research focusing specifically on Radiologic Technology students. Furthermore, limited studies have examined the predictive contribution of academic stress and financial stress in explaining anxiety within this population. Guided by the Conservation of Resources Theory, which posits that stress occurs when individuals perceive a threat to valued resources such as time, energy, and financial security (Hobfoll et al. 2018).

This study aims to determine whether academic stress and financial stress significantly predict anxiety levels among Radiologic Technology students. Its findings provide valuable insights for students, educators, academic institutions, and mental health practitioners, guiding the development of targeted interventions and support systems to improve student well-being and academic performance.

MATERIALS AND METHODS

This section describes the research design, participants, instruments, data collection procedures, and statistical analyses employed in the study.

STUDY DESIGN AND PARTICIPANTS

This study employed a quantitative descriptive-predictive research design conducted in selected higher education institution Davao City, Philippines. A total of 187 Radiologic Technology students were selected using stratified random sampling technique. The distribution of participants was based on identified strata, which included first year (n = 76), second year (n = 53), third year (n = 40) and fourth year (n = 18) yielding a total sample size of 187 respondents out of 360 population using raosoft.com calculator. Participants were included if they were officially enrolled Radiologic Technology students, aged 18 years and above, present during the data collection period, and willing to provide informed consent. Students who submitted incomplete responses or declined participation were excluded from the study. The respondents were generally within the age range of 18 to 22 years and included both male and female students across all year levels, providing a comprehensive representation of the student population.

RESEARCH INSTRUMENTS

The study utilized three adapted and validated instruments, namely the Academic Stress Inventory developed by Pizze and Kraemer (2019) to reflect the specific context of Radiologic Technology education, particularly in relation to classroom demands, personal stress, and examination pressures, the APR Financial Stress Scale developed by Heo, Cho, and Lee (2020) assessed affective, relational, and physiological responses to financial strain, while the Anxiety Scale captured common anxiety experiences encountered in academic and performance-based situations, and Anxiety Scale developed by Raykov and Martinelli (2019) to measure academic-related anxiety domains such as test anxiety, writing anxiety, public speaking anxiety, and group work anxiety. All instruments utilized a five-point Likert scale ranging from strongly disagree to strongly agree. The instruments demonstrated acceptable internal consistency with Cronbach's alpha values academic stress (15 items, $\alpha = .765$), financial stress (24 items, $\alpha = .943$), and

anxiety level (12 items, α = .962).

DATA GATHERING PROCEDURES

Data were collected through a self-administered survey conducted during the second semester of Academic Year 2024–2025. The questionnaire was administered either in paper-based and via google form depending on accessibility and availability of respondents. Prior to data collection, participants were informed about the purpose of the study, and informed consent was obtained.

DATA ANALYSIS

Descriptive statistics measures academic stress, financial stress, and anxiety levels. Pearson correlation examined relationships among variables, while multiple linear regression assessed the predictive effects of academic and financial stress on anxiety at a 0.05 significance level. Assumptions of normality, linearity, and absence of multicollinearity were checked prior to analysis.

ETHICAL CONSIDERATIONS

Ethical approval was obtained from the San Pedro College Research Ethics Committee with Certificate Approval No. 2025-0073. Participation was voluntary with informed consent secured from all respondents.

RESULTS AND DISCUSSION

This section presents the results and discussion on the levels of academic stress, financial stress, and anxiety among the respondents. It also includes correlation and predictive analyses examining the relationships among these variables and the influence of stress on anxiety, interpreted in relation to the study objectives and relevant literature.

The Table 1 presents the distribution of respondents according to year level. The majority were first-year students (41%), followed by second-year (28%), third-year (21%), and fourth-year students (10%). This indicates that lower-year students comprised a larger proportion of the sample, which may influence the overall stress and anxiety levels reported. Early-year students often experience adjustment challenges related to academic workload, learning environment, and expectations, which may heighten their stress levels. In contrast, senior students, although fewer in number, may experience different stressors such as clinical responsibilities and career preparation.

The Table 2 indicate that respondents experienced a high level of academic stress (M = 3.64, SD = 0.65). Among the domains, test- and subject-related stress recorded the highest mean (M = 3.94), followed by personal (M = 3.66), while classroom-related stress was moderate (M = 3.33). This suggests that evaluation-driven demands, such as examinations, complex subject content, and fear of inadequate preparation, are the primary contributors to academic stress. These findings are consistent with prior studies (Pascoe et al., 2020; Ho et al., 2022), which emphasize that academic workload and performance expectations are major sources of psychological strain among healthcare students. From a theoretical perspective, the Conservation of Resources Theory explains that continuous academic demands may deplete students' cognitive and emotional resources. Frequent assessments and high expectations require sustained effort, leaving students vulnerable to stress when resources such as time, energy, and coping mechanisms are insufficient.

The Table 3 shows the financial stress among respondents was found to be moderate, based on the overall mean of 2.62 (SD = 0.79). It is important to clarify that the previously stated value of 3.06 refers only to the affective reaction domain, not the overall level—this discrepancy has now been corrected. Among the indicators, affective reactions (M = 3.06) were moderate, suggesting that students experience emotional concerns related to finances. However, relational/interpersonal (M = 2.40) and physiological responses (M = 2.41) were low, indicating that financial stress may not strongly manifest in social behavior or physical symptoms. This pattern suggests that while students are aware and concerned about financial challenges, these concerns may be partially mitigated by external support systems such as family assistance, scholarships, or institutional resources. This supports the idea that financial stress may operate as a secondary or interacting stressor, rather than a primary driver of anxiety in this population. Similar findings were reported by Bernardo et al. (2019), who observed that financial stress negatively affects well-being but often interacts with academic pressures rather than acting independently.

The Table 4 shows level of anxiety among respondents was high (M = 3.48, SD = 1.00). Moreover, domain-specific analysis shows that public speaking anxiety (M = 3.93) and test/exam anxiety (M = 3.77) were high, while writing (M = 3.30) and group work anxiety (M = 2.95) were moderate. This suggests that performance-based academic situations are among the primary sources of anxiety for students. These findings align with previous research (Krispenz et al., 2019), which highlights that evaluative and public performance contexts commonly associate anxiety in university settings. In Radiologic Technology, students are frequently exposed to oral presentations, practical exams, and clinical evaluations. These high-stakes situations may intensify anxiety due to fear of failure, negative evaluation, or inadequate preparation. This aligns

with global evidence indicating that evaluative and performance-based academic situations commonly trigger anxiety among university students (Krispenz, Gort & Schultze 2019).

The Table 5 shows the correlation analysis revealed significant positive relationships between anxiety and both academic stress ($r = .633$, $p < 0.001$) and financial stress ($r = .358$, $p < 0.001$). All subdomains of academic and financial stress also showed significant correlations with anxiety. This indicates that as levels of stress increase, anxiety levels also tend to increase. Notably, test- and subject-related stress ($r = .634$) showed the strongest association with anxiety, further reinforcing the role of academic demands as a key factor influencing students' psychological well-being. This finding supports earlier research indicating that academic-related demands exert a stronger and more immediate influence on student anxiety than financial concerns (Trigueros et al. 2020; Pascoe et al. 2020).

The Table 6 shows the multiple regression analysis revealed that academic stress is a significant predictor of anxiety ($\beta = .605$, $p < 0.001$), while financial stress is not a significant predictor ($\beta = .057$, $p = 0.390$). The model explained approximately 40.3% of the variance in anxiety ($R^2 = .403$), indicating a substantial effect. This finding suggests that although financial stress is related to anxiety, it does not independently influence anxiety when academic stress is taken into account. One possible explanation is that academic stress is more immediate, constant, and embedded in students' daily experiences, whereas financial stress may fluctuate and be buffered by external support systems. From the Conservation of Resources Theory perspective, academic demands may result in continuous resource depletion, making them a stronger predictor of anxiety compared to financial concerns, which may not exert the same persistent pressure (Hobfoll et al. 2018). Additionally, contextual factors such as enrollment in a private institution may imply that some students have access to financial resources or support, reducing the direct impact of financial stress on anxiety.

TABLE 1. Demographic Profile of the Respondents

Year Level	**Frequency**	**Percentage**
First-Year Students	76	41%
Second-Year Students	53	28%
Third-Year Students	40	21%
Fourth-Year Students	18	10%
Total	**187**	**100%**

TABLE 2. Level of Academic Stress among Radiologic Technology Students

Indicators	**Mean**	**Std. Dev.**	**Interpretation**
Personal	3.66	0.70	High
Classroom	3.33	0.80	Moderate
Test and Subject	3.94	0.85	High
Overall Mean	**3.64**	**0.65**	**High**

Legend: *4.21–5.00 = 5 (Very High), 3.41–4.20 = 4 (High), 2.61–3.40 = 3 (Moderate), 1.81–2.60 = 2 (Low), 1.00–1.80 = 1 (Very Low)* adapted from Vagias (2006)

TABLE 3. Level of Financial Stress among Radiologic Technology Students

Indicators	**Mean**	**Std. Dev.**	**Interpretation**
Affective Reaction	3.06	0.18	Moderate
Relational/Interpersonal Behavior	2.40	1.02	Low
Physiological Responses	2.41	1.18	Low
Overall Mean	**2.62**	**0.79**	**Moderate**

Legend: *4.21–5.00 = 5 (Very High), 3.41–4.20 = 4 (High), 2.61–3.40 = 3 (Moderate), 1.81–2.60 = 2 (Low), 1.00–1.80 = 1 (Very Low)* adapted from Vagias (2006)

TABLE 4. Level of Anxiety Level among Radiologic Technology Students

Indicators	Mean	Std. Dev.	Interpretation
Test/Exam Anxiety	3.77	0.98	High
Writing Anxiety	3.30	1.12	Moderate
Public Speaking Anxiety	3.93	1.02	High
Group Work Anxiety	2.95	0.91	Moderate
Overall Mean	**3.48**	**1.00**	**High**

Legend: *4.21–5.00 = 5 (Very High), 3.41–4.20 = 4 (High), 2.61–3.40 = 3 (Moderate), 1.81–2.60 = 2 (Low), 1.00–1.80 = 1 (Very Low)* adapted from Vagias (2006)

TABLE 5. Correlation Analysis of Academic Stress, Financial Stress and Anxiety Levels of Radiologic Technology Students

Anxiety Levels	Correlation Coefficient	p-value	Interpretation
Academic Stress	.633**	p <0.000	Significant
Personal	.382**	p<0.000	Significant
Classroom	.530**	p<0.000	Significant
Test and Subject	.634**	p<0.000	Significant
Financial Stress	.358**	p<0.000	Significant
Affected Reaction	.274**	p<0.000	Significant
Relation/Interpersonal Behavior	.311**	p<0.000	Significant
Physiologic Responses	.403**	p<0.000	Significant

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

TABLE 6. The Variables that Best Predict the Anxiety Level Among Radiologic Technology Students

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.758	.251		3.018	.003
	Academic Stress	.719	.078	.605	9.210	.000
	Financial Stress	.042	.049	.057	.861	.390

R=.635; R^2=.403; R^2 Adjusted =.397; f value=62.190; p=0.000

CONCLUSION

This study highlights the central role of academic stress in shaping anxiety among Radiologic Technology students, emphasizing that pressures related to examinations, subject difficulty, and performance expectations are the most influential contributors to students' psychological well-being. While financial stress remains a relevant concern, its influence appears to be secondary and context-dependent, suggesting that academic demands are more immediate and pervasive in students' daily experiences. These findings underscore the importance of fostering supportive academic environments within healthcare education. Institutions should move beyond general mental health initiatives and implement targeted strategies such as balanced assessment practices, structured academic support, mentoring programs, and stress management interventions tailored to the academic context. Strengthening these areas can help mitigate anxiety and promote both student well-being and academic success. Future research may explore longitudinal designs to better understand causal relationships between stress and anxiety, as well as

include participants from multiple institutions to enhance generalizability. Additionally, examining moderating factors such as socioeconomic status, coping mechanisms, and institutional support systems may provide deeper insight into how different forms of stress interact and influence student outcomes.

LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. First, the data were collected from a single institution, which may limit the generalizability of the findings to other populations. Second, reliance on self-reported measures may introduce response bias. Future research may consider longitudinal designs, multi-institutional samples, and mixed-method approaches to provide a more comprehensive understanding of student stress and anxiety.

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REFERENCES

Bernardo, A. B. I., Resurreccion, K. F., Vinluan, A. A. & Hinaus, B. M. 2019. Financial stress and well-being of Filipino college students: The moderating role of parental support. *Journal of Happiness Studies* 20(6): 1815–1831. https://doi.org/10.31710/pjp/0051.01.03

Heo, W., Cho, S. H. & Lee, P. 2020. APR financial stress scale: Development and validation of a multidimensional measurement. *Journal of Financial Counseling and Planning* 31(2): 217–231.https://doi.org/10.4148/1944-9771.1216

Hobfoll, S. E., Halbesleben, J., Neveu, J. P. & Westman, M. 2018. Conservation of resources in the organizational context: The reality of resources and their consequences. *Annual Review of Organizational Psychology and Organizational Behavior* 5: 103–128.https://doi.org/10.1146/annurev-orgpsych-032117-104640

Ho, M.C, Lee, C.Y., Pang, K.Y. & Ooi, P.B. 2022. Academic stress and anxiety among undergraduate students in Malaysia. International Journal of Education, Psychology and Counseling, 7(46), 98–109. https://doi.org/10.35631/IJEPC.746009

Krispenz, A., Gort, C., Schültke, L. & Dickhäuser, O. 2019. How to reduce test anxiety and academic procrastination through inquiry of cognitive appraisals: A pilot study investigating the role of academic self-efficacy. Frontiers in Psychology, 10, 1917. https://doi.org/10.3389/fpsyg.2019.01917

McCloud, T. & Bann, D. 2019. Financial stress and mental health among higher education students in the UK up to 2018: Rapid review of evidence. Journal of Epidemiology and Community Health, 73(10), 977–984. doi.10.1136/jech-2019-212154

Pizzie, R. G. & Kraemer, D. J. M. 2019. The academic anxiety inventory: Evidence for dissociable patterns of anxiety related to math and other sources of academic stress. *Frontiers in Psychology* 9, 2684. https://doi.org/10.3389/fpsyg.2018.02684

Pascoe, M. C., Hetrick, S. E. & Parker, A. G. 2020. The impact of stress on students in secondary and tertiary education. *International Journal of Adolescence and Youth* 25(1): 104–112. https://doi.org/10.1080/02673843.2019.1596823

Raykov, T., & Martinelli, C. 2019. Evaluation of a classroom anxiety scale for secondary-school students. *Forum Oświatowe* 31(2), 43–60. https://doi.org/10.34862/fo.2019.2.3

Trigueros, R., Padilla, A., Aguilar-Parra, J., Lirola, M., García-Luengo, A., Rocamora-Pérez, P., & López-Liria, R. 2020. The influence of teachers on motivation and academic stress and their effect on the learning strategies of university students. International Journal of Environmental Research and Public Health, 17(23), 9089. https://doi.org/10.3390/ijerph17239089

Vagias, W. M. 2006. Likert-type scale response anchors. Clemson International Institute for Tourism & Research Development, Department of Parks, Recreation and Tourism Management, Clemson University.

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Artikel Asli /*Original Article*

Academic Stress as Predictor of Academic Performance among First-Year Radiologic Technology Students

Tekanan Akademik sebagai Peramal Prestasi Akademik dalam Kalangan Pelajar Tahun Pertama Teknologi Radiologi

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ABSTRACT

Academic stress is a common challenge among students enrolled in health-related academic programs due to demanding coursework and high performance expectations. This study examined the relationship between academic stress and academic performance among first-year Radiologic Technology students in a selected private higher education institution in Davao City, Philippines. A descriptive–correlational research design was employed involving 107 first-year Radiologic Technology students during the Academic Year 2024–2025. Participants were selected using Simple Random Sampling technique. Academic stress was measured using an adapted Academic Stress Inventory developed by Lin and Chen (2009), while academic performance was determined using the students' Weighted Percentage Average (WPA) obtained from institutional records with administrative approval. Descriptive statistics were used to determine the level of academic stress and academic performance, while Pearson correlation and linear regression analyses were employed to examine the relationship between the variables at a 0.05 level of significance. Results showed that students experienced a moderate level of academic stress (M = 3.37, SD = 0.549) and a high level of academic performance (M = 3.90, SD = 0.285). However, Pearson correlation analysis revealed no significant relationship between academic stress and academic performance (r = –0.039, p = 0.686). Similarly, regression analysis indicated that academic stress did not significantly predict academic performance (β = –0.039, p = 0.686). These findings suggest that although students experience moderate academic stress, it does not significantly influence their academic performance. The results highlight the importance of institutional support systems that promote students' resilience and effective coping strategies in demanding academic environments.

Keywords: academic stress, academic performance, radiologic technology students, higher education

ABSTRAK

Tekanan akademik merupakan cabaran yang lazim dihadapi oleh pelajar yang mengikuti program akademik berkaitan kesihatan disebabkan oleh tuntutan pembelajaran yang tinggi serta jangkaan prestasi yang ketat. Kajian ini bertujuan untuk meneliti hubungan antara tekanan akademik dan prestasi akademik dalam kalangan pelajar tahun pertama Teknologi Radiologi di sebuah institusi pengajian tinggi swasta terpilih di Davao City, Filipina. Reka bentuk kajian deskriptif-korelasi digunakan dengan melibatkan seramai 107 orang pelajar tahun pertama Teknologi Radiologi bagi Tahun Akademik 2024–2025. Responden dipilih menggunakan teknik persampelan rawak mudah (Simple Random Sampling). Tekanan akademik diukur menggunakan Academic Stress Inventory yang diadaptasi daripada Lin dan Chen (2009), manakala prestasi akademik ditentukan berdasarkan Purata Wajaran Peratusan (Weighted Percentage Average, WPA) pelajar yang diperoleh daripada rekod institusi dengan kebenaran pentadbiran. Statistik deskriptif digunakan untuk menentukan tahap tekanan akademik dan prestasi akademik, manakala analisis korelasi Pearson dan regresi linear digunakan untuk menilai hubungan antara pemboleh ubah pada aras signifikan 0.05. Hasil kajian menunjukkan bahawa pelajar mengalami tahap tekanan akademik yang sederhana (M = 3.37, SD = 0.549) dan tahap prestasi akademik yang tinggi (M = 3.90, S D =

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0.285). Walau bagaimanapun, analisis korelasi Pearson menunjukkan bahawa tiada hubungan yang signifikan antara tekanan akademik dan prestasi akademik ($r = –0.039$, $p = 0.686$). Begitu juga, analisis regresi menunjukkan bahawa tekanan akademik tidak meramalkan prestasi akademik secara signifikan ($\beta = –0.039$, $p = 0.686$). Dapatan ini menunjukkan bahawa walaupun pelajar mengalami tekanan akademik pada tahap sederhana, tekanan tersebut tidak memberi pengaruh yang signifikan terhadap prestasi akademik mereka. Hasil kajian ini menekankan kepentingan sistem sokongan institusi yang dapat menggalakkan daya tahan pelajar serta strategi daya tindak yang berkesan dalam menghadapi persekitaran akademik yang mencabar.

Kata Kunci: tekanan akademik, prestasi akademik, pelajar teknologi radiologi, pengajian tinggi

INTRODUCTION

Academic stress is a significant concern among students in health-related programs, particularly those enrolled in Radiologic Technology, where rigorous academic and clinical demands are expected. First-year students are especially vulnerable as they transition into higher education, encountering new academic environments, increased workload, and heightened expectations that may contribute to anxiety and psychological pressure (Maymon & Hall 2021). Radiologic Technology students often experience substantial academic pressure due to the complexity of subjects, frequent assessments, and the need to master clinical and laboratory skills. These program-specific demands distinguish them from general student populations and necessitate focused investigation. Studies have shown that academic stress can negatively influence students' academic performance, mental health, and overall well-being (Bedewy & Gabriel 2015; Deng et al. 2022). For first-year students, this stress may be more pronounced due to limited coping experience and adjustment challenges, potentially leading to anxiety and reduced academic efficiency (Maymon & Hall 2021).

Recent literature emphasizes that academic stress is multifactorial, shaped by personal, academic, and institutional factors. For instance, Deng et al. (2022) found that academic stress significantly contributes to depressive symptoms, which in turn affect academic outcomes. Similarly, Bedewy and Gabriel (2015) identified key stressors such as academic workload, fear of failure, and classroom-related pressures, all of which are highly relevant in structured programs like Radiologic Technology. However, emerging evidence suggests that the relationship between academic stress and academic performance is not always linear, as coping strategies and institutional support may moderate this association. In international contexts, studies have demonstrated varying relationships between academic stress and performance. For example, Joseph & Sudhesh (2023) reported that students' adjustment and social support significantly influenced how stress affected academic outcomes. These findings highlight the importance of contextual and environmental factors in understanding student performance. However, such studies are often conducted in general or diverse student populations, with limited focus on highly specialized programs such as Radiologic Technology.In the Philippine context, recent studies have begun to examine academic stress among Radiologic Technology students, particularly in private higher education institutions. Research conducted among students reported that Radiologic Technology students experience considerable stress due to academic workload, teacher-related pressures, and financial concerns (Arguel et al. 2016). Furthermore, Alipio (2019) found that Filipino college students in allied health programs experience academic stress influenced by psychological factors such as locus of control and motivation, which may affect both performance and well-being. Notably, these studies suggest that high academic performance does not necessarily equate to low stress levels, indicating a complex relationship between these variables.Moreover, recent works such as those by Huffstetler (2021) and Rosenbaum (2024) explore student stress and persistence in Radiologic Technology education but do not directly establish the predictive relationship between academic stress and academic performance. Similarly, Tucker (2018) focused on instructional strategies without addressing the psychological demands experienced by students. Despite these emerging findings, a critical gap remains in the literature. Existing studies in the Philippines largely focus on general stress levels or associated factors but do not explicitly examine whether academic stress predicts academic performance among first- year Radiologic Technology students. Additionally, while international research provides valuable insights, its applicability to the local context remains limited due to differences in educational systems, cultural factors, and institutional support structures. With this scenario, this study aims to address this gap by examining the relationship between academic stress and academic performance among first-year Radiologic Technology students in a selected private higher education institution in the Philippines. By focusing on this specific population, the study seeks to provide evidence that can inform the development of targeted interventions, enhance student support systems, and ultimately improve both academic outcomes and student well-being.

MATERIALS AND METHODS

This section describes the research design, participants, instruments, data collection procedures, and statistical analyses employed in the study.

RESEARCH DESIGN

This study utilized a descriptive–predictive research design to examine the relationship between academic stress and academic performance and to determine whether academic stress significantly predicts the academic performance of first-year Radiologic Technology students.

PARTICIPANTS

The respondents of the study consisted of 107 first-year Radiologic Technology students enrolled during the Academic Year 2024–2025 in a selected private higher education institution in Davao City, Philippines. Participants were selected using a simple random sampling technique to ensure better representation of the target population by providing each eligible student an equal chance of being included in the study. The required sample size was determined using the Raosoft Sample Size Calculator, a widely used online statistical tool for calculating appropriate sample sizes in survey research. From a total population of 153 first-year Radiologic Technology students, a minimum sample size of 107 respondents was computed based on a 95% confidence level, 5% margin of error, and 50% response distribution.

Participants included in the study were students who were officially enrolled as first-year Radiologic Technology students, 18 years old and above, and willing to participate by providing informed consent. Students who declined participation or submitted incomplete survey responses were excluded from the final data analysis to maintain the accuracy and completeness of the dataset.

RESEARCH INSTRUMENTS

Academic stress was measured using the Academic Stress Inventory developed by Lin and Chen (2009). The instrument assesses four dimensions of academic stress: personal inadequacy, fear of failure, interpersonal difficulties with teachers, and inadequate learning resources. The questionnaire utilized a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument demonstrated high internal consistency reliability in this study with a Cronbach's alpha coefficient of 0.90, indicating excellent reliability (DeVellis 2017). Academic performance was measured using the students' Weighted Percentage Average (WPA) obtained from official institutional academic records with administrative approval.

DATA COLLECTION PROCEDURE

Data were collected using an online survey administered through Google Forms. Prior to data collection, permission to conduct the study and access academic records was obtained from the institution's academic administration. Students were provided with an informed consent form explaining the purpose of the study, voluntary participation, confidentiality, and anonymity. Academic performance data (WPA) were retrieved from institutional records after approval from the registrar's office and were matched with survey responses using coded identifiers.

DATA ANALYSIS

Descriptive statistics were employed to analyze the data and determine the levels of academic stress and academic performance among the respondents. Specifically, the mean and standard deviation were used to summarize and describe the central tendency and variability of the variables under study. To examine the relationship between academic stress and academic performance, Pearson Product– Moment Correlation was utilized to measure the strength and direction of the association between the two variables. Furthermore, simple linear regression analysis was conducted to determine whether academic stress significantly predicts the academic performance of the students and were tested at a 0.05 level of significance.

ETHICAL CONSIDERATIONS

Ethical approval for the study was obtained from the San Pedro College Research Ethics Committee 2025-0127 prior to data collection. The study adhered to ethical principles including voluntary participation, informed consent, confidentiality, and anonymity in accordance with the Philippine Data Privacy Act of 2012 (RA 10173)

RESULTS AND DISCUSSION

This section presents the results and discussion on the levels of academic stress and academic performance among the respondents. It also examines the relationship between these variables through correlation and predictive analyses. The findings are interpreted in relation to the objectives of the study and supported by relevant literature.

Table 1 presents the demographic profile of the respondents in terms of sex. Out of the total 107 first-year Radiologic Technology students, 71 respondents (66%) were female, while 36 respondents (34%) were male. This indicates that the majority of the participants in the study were female students. The higher proportion of female respondents suggests that female students comprise a larger segment of the first-year Radiologic Technology population in the selected institution.

The demographic distribution indicates that the study sample reflects the existing gender composition of the program, thereby supporting the reliability of the data gathered for the analysis of academic stress and academic performance among first-year Radiologic Technology students.

Table 2 presents the level of academic stress experienced by first-year Radiologic Technology students across four domains: personal inadequacy, fear of failure, interpersonal difficulties with teachers, and inadequate learning resources. The results indicate that the respondents experienced an overall moderate level of academic stress with a mean score of 3.37 (SD = 0.549). This suggests that while students encounter noticeable academic pressures, these stress levels remain within a manageable range. Among the indicators, fear of failure (M = 3.67, SD = 0.792) and personal inadequacy (M = 3.49, SD = 0.653) were interpreted as high levels of stress, indicating that many students feel pressured to meet academic expectations and may experience self-doubt regarding their academic abilities. These findings reflect the challenges faced by students during their transition to higher education, particularly in demanding health-related programs such as Radiologic Technology, where students are required to master complex theoretical knowledge and develop professional competencies. On the other hand, interpersonal difficulties with teachers (M = 3.06, SD = 0.751) and inadequate learning resources (M = 3.25, SD = 0.633) were interpreted as moderate sources of stress. These results suggest that while interactions with instructors and access to learning resources contribute to students' stress experiences, they may not be the most dominant stressors affecting the respondents. Nevertheless, these factors remain important aspects of the academic environment that can influence students' overall learning experience. The findings imply that psychological and performance-related concerns, particularly fear of academic failure and feelings of inadequacy, may play a more prominent role in shaping students' academic stress compared to environmental factors. This highlights the need for institutions to provide academic guidance, mentoring, and psychological support programs that can help students build confidence and develop effective coping strategies. These results are consistent with previous studies showing that academic demands, fear of failure, and self-perceived academic competence are major contributors to stress among university students (Bedewy & Gabriel 2015). Similarly, recent research among Radiologic Technology students reported that academic workload and performance expectations significantly contribute to students' stress levels (Alipio et al. 2024). Addressing these stressors through supportive learning environments and student support services may help improve students' academic adjustment and overall well-being. Table 3 presents the level of academic performance among first-year Radiologic Technology students. The results indicate that the respondents demonstrated a high level of academic performance, as reflected by an overall mean score of 3.90 (SD = 0.285). This finding suggests that the students were generally able to meet the academic requirements of their program and perform well in their coursework during their first year of study. The high academic performance observed among the respondents may indicate that students possess the necessary academic preparation, motivation, and learning strategies needed to succeed in a rigorous health-related program such as Radiologic Technology. Despite experiencing moderate levels of academic stress, the respondents were still able to maintain strong academic outcomes. This suggests that the level of stress experienced by the students may not be severe enough to negatively affect their academic functioning. In some cases, moderate levels of stress may even serve as a motivating factor that encourages students to remain focused and engaged with their academic responsibilities.

Furthermore, the findings may reflect the presence of supportive academic structures within the institution, such as effective instructional practices, accessible learning resources, and guidance from faculty members, which can contribute to students' academic success. The relatively low standard deviation also indicates that the respondents' academic performance scores were closely clustered around the mean, suggesting a relatively consistent level of performance among the students. The implication of this finding is that while academic stress exists among students, it does not necessarily translate into poor academic outcomes. Instead, students may develop adaptive coping strategies and resilience that allow them to manage academic pressures while maintaining satisfactory academic performance (Islam & Rabbi 2024; Bibi et al. 2022). Nevertheless, academic institutions should continue to strengthen academic support services, mentoring programs, and student wellness initiatives to ensure that students can effectively balance academic demands with their overall well-being. Table 4 presents the correlation analysis between academic stress and academic performance among first-year Radiologic Technology students. The results indicate that there is no significant relationship between academic stress and academic performance, as reflected by the correlation coefficient (r = –0.039) and p-value (p = 0.686), which is greater than the 0.05 level of significance. This finding suggests that variations in students' academic stress levels are not statistically associated with changes in their academic performance. Similarly, the analysis of the specific dimensions of academic stress—including personal inadequacy (r= –0.017, p = 0.859), fear of failure (r = –0.033, p = 0.736), interpersonal difficulties with teachers (r = –0.051, p = 0.602),

0.051, p = 0.602), and inadequate learning resources (r = –0.139, p = 0.152)—also revealed no significant correlations with academic performance. These results imply that although students experience moderate levels of academic stress, such stress does not appear to significantly influence their academic performance within the context of this study. One possible explanation is that students may have developed effective coping strategies or adaptive behaviors that allow them to manage academic pressures without negatively affecting their academic achievement. Additionally, institutional support systems, structured learning environments, and academic guidance may help students maintain consistent academic performance despite experiencing stress. The absence of a significant relationship also suggests that academic performance among Radiologic Technology students may be influenced more strongly by other factors not examined in the present study, such as study habits, time management skills, motivation, prior academic preparation, or access to academic support services. These factors may play a more substantial role in determining students' academic outcomes than academic stress alone. The findings highlight that while academic stress is present among students, it does not necessarily translate into measurable changes in academic performance. This underscores the importance of further research exploring other academic, psychological, and environmental factors that may contribute to students' academic success in health-related education programs. The findings are also consistent with the stress-performance framework, which suggests that while moderate stress may motivate students, excessive stress adversely affects learning efficiency and academic achievement (Hanafi et al. 2024; Cruz et al. 2024; Michelotto et al. 2022). For Radiologic Technology students, the combination of academic rigor and early professional expectations may heighten vulnerability to stress, emphasizing the need for structured academic support and stress management programs. The results in Table 5 indicate that academic stress does not significantly predict academic performance among Radiologic Technology students. The regression analysis shows that the unstandardized coefficient for academic stress is –0.021 (p = 0.686), which is not statistically significant at the 0.05 level. Similarly, the standardized coefficient (β = –0.039) suggests a very weak and negligible relationship between academic stress and academic performance. The overall model statistics further support this finding. The R value of 0.039 indicates a very weak association between the variables, while the R^2 value of 0.002 shows that academic stress explains only 0.2% of the variance in academic performance. The adjusted R^2 value of –0.008 further indicates that the model has no practical explanatory power. Moreover, the F value of 0.164 with a corresponding p-value of 0.686 confirms that the regression model is not statistically significant. The absence of a significant predictive relationship suggests that academic stress alone is insufficient to explain variations in academic performance among first-year Radiologic Technology students. Several plausible explanations may account for this finding. First, students may possess effective coping mechanisms—such as time management, peer collaboration, and adaptive learning strategies—that buffer the negative effects of stress. These coping strategies can enable students to maintain stable academic performance despite experiencing moderate to high stress levels (Cruz et al. 2024; Michelotto et al. 2022).

TABLE 1. Demographic Profile of the Respondents

Respondents	**Frequency**	**Percentage**
Male	36	34%
Female	71	66%
Total	**107**	**100%**

TABLE 2. Level of Academic Stress among First Year Radiologic Technology Students

Indicators	**Mean**	**Std. Dev.**	**Interpretation**
Personal Inadequacy	3.49	0.653	High
Fear of Failure	3.67	0.792	High
Interpersonal Difficulties with Teachers	3.06	0.751	Moderate
Inadequate Learning Resources	3.25	0.633	Moderate
Overall Mean	**3.37**	**0.549**	**Moderate**

Legend: *4.21–5.00 = 5 (Very High), 3.41–4.20 = 4 (High), 2.61–3.40 = 3 (Moderate), 1.81–2.60 = 2 (Low), 1.00–1.80 = 1 (Very Low).*

TABLE 3. Level of Academic Performance among First-Year Radiologic Technology Students

Indicators	Mean	Std. Dev.	Interpretation
Overall Mean	**3.90**	**0.285**	**High**

Legend: *4.21–5.00 = 5 (Very High), 3.41–4.20 = 4 (High), 2.61–3.40 = 3 (Moderate), 1.81–2.60 = 2 (Low), 1.00–1.80 = 1 (Very Low).*

TABLE 4. Correlation Analysis of Academic Stress and Academic Performance of Radiologic Technology Students

Academic Performance	Correlation Coefficient	p-value	Interpretation
Academic Stress	-.039	.686	Not Significant
Personal Inadequacy	-.017	.859	Not Significant
Fear of Failure	-.033	.736	Not Significant
Interpersonal Difficulties with Teachers	-.051	.602	Not Significant
Inadequate Learning Resources	-.139	.152	Not Significant

**. Significant level at 0.05

TABLE 5. The Variable that Best Predict the Academic Performance Among Radiologic Technology Students

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.975	.173		23.028	.000
	Academic Stress	-.021	.051	-.039	-.405	.686

R=0.039; R^2=0.002; R^2 Adjusted =-0.008; f value=0.164; p=0.686

Second, institutional support systems may play a critical role. Structured curricula, accessible faculty support, and organized learning environments in Radiologic Technology programs may help students manage academic demands more effectively. Such support mechanisms can mitigate the potential negative impact of stress on academic outcomes. Third, the findings may reflect the multidimensional nature of academic performance. Academic achievement is influenced by various factors beyond stress, including motivation, study habits, prior academic preparation, and psychological resilience. As such, academic stress, when examined in isolation, may not emerge as a strong predictor of performance.

Additionally, it is possible that moderate levels of stress do not necessarily impair performance and may, in some cases, serve as a motivating factor that encourages students to meet academic demands. This aligns with the concept that stress does not uniformly produce negative outcomes and may vary depending on individual differences and contextual factors. Thus, these findings reinforce the earlier correlation results, highlighting that although students experience moderate to high levels of academic stress, they are still able to sustain high academic performance. This underscores the importance of considering mediating and moderating.

CONCLUSION

This study examined the relationship between academic stress and academic performance among first-year Radiologic Technology students in a selected private higher education institution. The findings revealed that students experienced a moderate level of academic stress while maintaining a high level of academic performance. However, statistical analyses demonstrated that academic stress was neither significantly related to nor a significant predictor of academic performance. These results indicate that, although students experience varying levels of academic stress, such stress does not necessarily translate into diminished academic achievement. The findings further suggest that other factors may play a more critical role in sustaining academic performance, including students' resilience, effective coping strategies, and the presence of supportive institutional structures. These elements may buffer the potential negative effects of stress, enabling students to meet academic demands successfully. Given the limited predictive value of academic stress observed in this study, future research should consider examining additional variables that may influence academic performance among Radiologic Technology students. These may include study habits, learning environment, motivation, and psychological well- being, as well as potential mediating or moderating

factors that shape the relationship between stress and academic outcomes.

LIMITATIONS OF THE STUDY

This study has several limitations. The use of a descriptive-predictive design limits causal interpretation. The sample was drawn from a single private higher education institution, which may restrict the generalizability of the findings. The focus on first-year Radiologic Technology students further limits applicability to other year levels. Academic stress was measured using a self-reported instrument, which may be subject to response bias. Additionally, the study examined academic stress as a single predictor, without accounting for other factors such as motivation, study habits, resilience, and mental health, which may influence academic performance.

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REFERENCES

Alipio, M. 2019. Adjustment to college and academic performance: Insights from Filipino college freshmen in an allied health science course. https://www.researchgate.net/publication/340624014

Alipio, M. M., Campomanes, E. S. A., Belleno, E. E. L., & Alipio, M. M. 2024. Academic stress measurement and management of Radiologic Technology students. *Asian Journal of Education and Social Studies* 50(4): 38–53. 10.9734/ajess/2024/v50i41309

Arguel, M. J., De Guzman, A. C., Lo, M. Y., Mercado, K. E., Sincosa, P. M., & Soriano, M. V. 2016. Level of academic stress of first to third year radiologic technology students of De La Salle Health Sciences Institute. https://greenprints.dlshsi.edu.ph/bsrt/104/

Bedewy, D., & Gabriel, A. 2015. Examining perceptions of academic stress and its sources among university students. *Health Psychology Open* 2(2). https://doi.org/10.1177/2055102915596714

Bibi, Z., Alvi, S. M. & Noor, Z. 2022. Relationship of stress with academic performance among university students. *Journal of Management Practices, Humanities and Social Sciences* 6(6): 29–34.10.33152/jmphss-6.6.4

Cruz, D. A., Campomanes, E. S., Belleno, E. E. & Alipio, M. (2024). Academic stress measurement and management of radiologic technology students. *Asian Journal of Education and Social Studies* 50(4): 38–53. https://journalajess.com/index.php/AJESS/article/view/1309/2547

Deng, Y., Cherian, J., Khan, N. U., Kumari, K., Sial, M. S., Comite, U., Gavurova, B., & Popp, J. 2022. Family and academic stress and their impact on students' depression level and academic performance. *Frontiers in Psychiatry* 13: 869337.

https://doi.org/10.3389/fpsyt.2022.869337 Eysenck, M. W., Derakshan, N., Santos, R., &

Calvo, M. G. 2007. Anxiety and cognitive performance: *Attentional control theory. Emotion* 7(2): 336–353. https://doi.org/10.1037/1528-3542.7.2.336

Hanafi, M., Hassuona, A., El Tarhouny, S. & Mansour, T. 2024. Effect of stress on academic performance among undergraduate medical students: A follow-up study. Journal of *HealthProfessions Education and Innovation* 1(3): 27–34. https://journals.ekb.eg/article_388818_89b119c633c61bd305f5228f28921553.pdf

Huffstetler, B. J. 2021. Students' perceptions of persistence in two-year radiologic technology programs (Doctoral dissertation). https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=11019&context=dissertations.

Islam, M. S. & Rabbi, M. F. 2024. Exploring the sources of academic stress and adopted coping mechanisms among university students. *International Journal on Studies in Education* 6(2).

https://www.ijonse.net/index.php/ijonse/article/download/203/pdf

Lin, Y. & Chen, F. 2009. Academic stress inventory of students at universities and colleges of technology. World Transactions on Engineering and Technology Education, 7(2), 157–162

Maymon, R. & Hall, N. C. 2021. A review of first-year student stress and social support. *Social Sciences* 10(12): 472.

https://doi.org/10.3390/socsci10120472 Pascoe, M. C., Hetrick, S. E. & Parker, A. G. 2019.

The impact of stress on students in secondary school and higher education. International *Journal of Adolescence and Youth* 25(1):

104–112. https://doi.org/10.1080/02673843.2019.1596823

Rafidah, K., Azizah, A. R., Norzaidi, M. D. & Chong, S. C. 2009. Stress and academic performance: Empirical evidence from university students. *Academy of Educational Leadership Journal* 13(1): 37-51.

Rosenbaum, K. A. 2024. Factors contributing to stress and methods of coping among students (Master's thesis). https://dc.etsu.edu/cgi/viewcontent.cgi?article=4536&context=etd

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Laporan Kes/*Case Report*

Optimising Growth Through Early Dietary Intervention in a Prepubertal Boy with Constitutional Delay of Growth and Puberty

Pengoptimuman Pertumbuhan melalui Intervensi Pemakanan Awal dalam kalangan Kanak-kanak Lelaki Pra-Akil Baligh dengan Kelewatan Konstitusi Pertumbuhan dan Akil Baligh

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ABSTRACT

Growth failure in children may result from delayed maturation and long-term inadequate dietary intake. Early nutiritional assessment and appropriate dietary intervention are important to support normal growth and optimise growth potential. A 12-year-9-month-old boy with stunting (< -2 SD) and severe thinness (BMI < -3 SD) was referred to a dietitian for dietary evaluation due to poor growth in weight and height and low body mass index (BMI). He remained prepubertal (Tanner Stage 1) with a bone age of approximately 6 years, consistent with constitutional delay of growth and puberty (CDGP). Dietary assessment revealed chronic undernutrition, with daily energy and calcium intakes meeting only 62% and 36% of requirements, respectively, low calorie density, limited protein variety, and minimal fruit intake. Biochemical investigations were normal for growth hormone and micronutrients. The nutrition diagnosis was inadequate energy intake related to limited food and nutrition-related knowledge regarding appropriate energy intake to support catch-up growth, likely due to lack of prior nutrition education and limited exposure to dietary guidance, leading to inappropriate eating behaviors as evidenced by total energy intake meeting only ~63% of estimated requirements, persistent BMI-for-age < -3 SD (severe thinness), and height-for-age < -2 SD, stunting). A structured intervention was implemented, focusing on calorie-dense meal modification, increased protein variety, calcium-rich foods, and age-appropriate oral nutrition supplementation with family-centred education tailored to vegetarian dietary practices. At two-week follow-up, dietary intake improved, with energy intake reaching 84% of requirements, calcium intake 95%, and protein intake 2.5 g/kg/day. Modest short-term gains in weight (1.24%) and height (0.5 cm) were observed, suggesting a positive early nutritional response. However, the follow-up duration was insufficient to confirm sustained catch-up growth or long-term growth outcomes. Ongoing monitoring every 3 months is required to evaluate growth velocity over time and to determine whether nutritional optimisation can support the child in achieving his genetic height potential.

Keywords: Catch-up Growth, Calcium Intake, Calorie-Dense Diet, Constitutional Delay of Growth and Puberty (CDGP), Oral Nutritional Supplement (ONS)

ABSTRAK

Kegagalan pertumbuhan dalam kalangan kanak-kanak boleh berpunca daripada kelewatan kematangan dan pengambilan diet yang tidak mencukupi dalam tempoh jangka panjang. Penilaian pemakanan awal dan intervensi diet yang sesuai adalah penting untuk menyokong pertumbuhan normal dan mengoptimumkan potensi

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pertumbuhan. Seorang kanak-kanak lelaki berumur 12 tahun 9 bulan dengan pertumbuhan terbantut (< -2 SD) dan kurus teruk (BMI < -3 SD) dirujuk kepada ahli dietetik untuk penilaian diet kerana pertumbuhan berat badan dan tinggi yang tidak memuaskan serta indeks jisim tubuh (BMI) yang rendah. Pesakit masih pra-baligh (Tanner Tahap 1) dengan umur tulang sekitar 6 tahun, sejajar dengan kelewatan pertumbuhan dan akil baligh berunsur konstitusional (CDGP). Penilaian diet menunjukkan malpemakanan kronik, dengan pengambilan tenaga dan kalsium harian hanya 62% dan 36% daripada keperluan, kepadatan kalori rendah, variasi protein terhad dan pengambilan buah yang minima. Keputusan ujian biokimia adalah normal untuk hormon pertumbuhan dan mikronutrien. Diagnosis pemakanan ialah pengambilan tenaga tidak mencukupi berkaitan dengan pengetahuan terhad berkaitan pemakanan dan pengambilan tenaga yang sesuai untuk menyokong pertumbuhan pemulihan, berkemungkinan disebabkan oleh kekurangan pendedahan kepada pendidikan pemakanan dan panduan diet, yang membawa kepada corak pemakanan yang tidak sesuai, dibuktikan dengan jumlah pengambilan tenaga hanya memenuhi ~63% daripada keperluan, BMI mengikut umur < -3 SD (kurus teruk) yang berterusan, serta tinggi mengikut umur < -2 SD (pertumbuhan terbantut). Intervensi menumpukan pada pengubahsuaian makanan berkalori tinggi, peningkatan variasi protein, makanan kaya kalsium dan suplemen pemakanan oral sesuai, berserta pendidikan memfokuskan keluarga yang disesuaikan dengan corak diet vegetarian. Temujanji susulan selepas dua minggu menunjukkan pengambilan tenaga meningkat kepada 84%, kalsium 95%, dan protein 2.5 g/kg/hari. Peningkatan sederhana dalam jangka pendek bagi berat badan (1.24%) dan ketinggian (0.5 cm) telah diperhatikan, ini menunjukkan respons pemakanan awal yang positif. Walau bagaimanapun, tempoh temujanji susulan adalah tidak mencukupi untuk mengesahkan berlakunya pertumbuhan pemulihan yang berterusan atau hasil pertumbuhan jangka panjang. Pemantauan berterusan tiga bulan diperlukan untuk menilai kadar pertumbuhan dari masa ke semasa dan menentukan sama ada pengoptimuman pemakanan dapat membantu kanak-kanak tersebut mencapai potensi ketinggian genetiknya.

Kata Kunci: Diet Kalori Tinggi, Pengambilan Kalsium, Pertumbuhan Mengejar, Kelewatan Pertumbuhan dan Akil Baligh Berunsur Konstitusional (CDGP), Suplemen Pemakanan Oral (ONS)

INTRODUCTION

Constitutional Delay of Growth and Puberty (CDGP) is the most common cause of delayed puberty in boys, characterized by short stature relative to age, delayed bone maturation, and slower progression through pubertal stages, while typically resulting in a normal adult height (European Society for Paediatric Endocrinology [ESPE] 2019). Boys with CDGP usually present with delayed testicular enlargement (≥ 4 mL) or absence of Tanner stage G2 characteristics by 13.5-14 years of age (Huynh et al. 2015; Soliman et al. 2022).

Stunting reflects chronic undernutrition, defined as height-for-age < -2 SD (severe < -3 SD), while wasting or thinness reflects acute undernutrition, defined as weight-for-height or BMI-for-age < -2 SD (severe < -3 SD) (Institute for Public Health [IPH], 2019). CDGP patients are typically healthy, with no history of prenatal or perinatal morbidities, chronic illnesses, and eating disorders (Luciano et al., 2025). Although CDGP is generally physiological, when coexists with chronic undernutrition and inadequate dietary intake may exacerbate growth faltering and reduce the likelihood of achieving genetic height potential.

Adequate energy, protein, calcium, and micronutrient intake (particularly vitamin D, iron and zinc) intake during the prepubertal years are critical for supporting linear growth, bone mineralization, and the initiation of pubertal development (National Coordinating Committee on Food and Nutrition [NCCFN] 2017; Soliman et al. 2022). Early identification of nutritional deficiencies in paediatric outpatient settings allows for timely dietetic intervention, supporting catch-up growth and long-term health outcomes (Soliman et al. 2022).

Despite CDGP being a common physiological variant of delayed maturation, evidence specifically guiding nutritional management in this population remains limited. Most clinical literature focuses on endocrine evaluation, growth monitoring, and reassurance rather than structured dietary intervention (Gaudino et al. 2022; Abacı & Besci 2024). Evidence from nutritionally at-risk paediatric populations suggests that oral nutritional supplementation and energy-dense dietary modification can improve weight gain and growth velocity (Alarcón et al. 2003; Huynh et al. 2015). However, these findings are not specific to CDGP, and there is a lack of clinically detailed reports describing individualized dietetic management in this group. This gap limits practical guidance for dietitians managing children who present with both delayed maturation and inadequate dietary intake. Therefore, this case report contributes to the literature by describing structured nutrition care and early growth outcomes in a prepubertal boy with CDGP and faltering growth.

CASE PRESENTATION

A 12-year-9-month-old Chinese boy was referred to the Paediatrics Outpatient Dietetics Clinic due to short stature, poor weight gain, and low BMI. He was diagnosed with constitutional delay of growth

and puberty (CDGP), a temporary condition commonly seen in boys, characterised by delayed bone age (~6 years), delayed sexual maturation (prepubertal, Tanner Stage 1, testicular volume below 4 mL), but with eventual attainment of normal adult height.

He was born full-term via normal vaginal delivery, weighing 3.2 kg (15th-50th percentile), with no feeding difficulties, chronic illness, or developmental delay. Growth had consistently lagged behind peers since age two, but no medical attention was sought until concerns increased upon entering secondary school, prompting referral for nutritional optimisation. Family history supports CDGP which his father experienced a late pubertal growth spurt at 14 years, his mother attained menarche at 14 years, and mid-parental height was 174.6 cm (15th-50th percentile). He attends afternoon school sessions and lives with both parents and one older sister, who had normal growth and menarche.

NUTRITION ASSESSMENT

At the initial assessment, the patient's weight was 24.2 kg and height was 137.5 cm (< -2 SD), indicating stunting, with a BMI of 12.8 kg/m² (< -3 SD), consistent with severe thinness. Over 16 months, height increased from 131.6 to 137.5 cm (~5.9 cm/year), which falls within the lower normal range for a prepubertal boy (5-6.5 cm/year) (Ministry of Health Malaysia, 2019). However, weight gain was only 2.1 kg (~0.13 kg/month), which was below the expected target for catch-up growth (~1.5 kg/month). Achieving this rate would correspond to an approximate 4.7 kg increase to reach a BMI of 15.3 kg/m² at the next three-month follow-up, based on the WHO BMI-for-age growth chart for boys aged 5-19 years. Previous literature indicates that in boys, peak weight velocity occurs at approximately the same time as peak height velocity and averages about 9 kg/year. During catch-up growth, weight gain of approximately two to three times the normal rate has been suggested, although excessive gain should be avoided due to the potential risk of later obesity. Based on this principle, a projected range of 18-27 kg/year (approximately 1.5-2.25 kg/month) was considered (Rogol et al. 2000; American Academy of Pediatrics, 2014). As no specific reference values are available for children with CDGP in this age group, a conservative target of 1.5 kg/month was selected and monitored based on clinical judgement and available growth evidence. Although both height and BMI remain below the median, the upward trends suggest intact growth potential. The patient falls below the mid-parental height target (15th-50th percentile), indicating that his current growth trajectory does not yet reflect his genetic height potential.

Biochemical evaluation demonstrated normal thyroid function with Triiodothyronine (T3: 5.9 pmol/L) and Thyroxine (T4: 17 pmol/L), an adequate cortisol response (831 nmol/L), and an Insulin-like Growth Factor-1 level of 90 ng/mL, which falls within the age-appropriate reference range, indicating preserved growth hormone activity. Serum vitamin D concentration was 64 nmol/L, consistent with sufficiency. No additional micronutrient parameters were assessed, as laboratory investigations were conducted by the attending medical officer as part of the routine medical evaluation. Overall, the available biochemical findings did not indicate endocrine dysfunction or vitamin D deficiency contributing to the patient's growth faltering.

Clinically, the patient appeared alert and cheerful, with normal appetite, adequate sleep (10:30 pm-8:00 am), and regular daily bowel habits (Bristol Stool Form Scale type 3-4). He was independent in activities of daily living, with no oral pain, swallowing difficulties, or gastrointestinal symptoms. Nutrition-focused physical examination (NFPE) revealed no visible loss of subcutaneous fat in the orbital, triceps, or thoracic regions, and no evidence of muscle wasting in the temples, clavicular, shoulder, or interosseous muscle areas. No oedema or other clinical signs of malnutrition were observed. A brief psychosocial screening indicated that the patient was an active participant in school activities and demonstrated age-appropriate social engagement. He did not express concerns regarding body image or self-esteem, and no psychosocial barriers to dietary adherence were identified based on caregiver report and clinical interaction.

Dietary assessment, a 24-hour dietary recall was obtained through self-report to assess the participant's food and nutrient intake. The participant consumed three main meals and two snacks throughout the day, with most meals being home-cooked except for afternoon tea, which was purchased from the school canteen. Breakfast at 8.00 am consisted of two hard-boiled eggs and 200 ml of full-cream packaged milk, providing approximately 260 kcal with 8.6 g carbohydrate, 20 g protein, 15 g fat, and 296 mg calcium. Lunch, consumed between 10.45-11.15 am, included white rice, steamed fish prepared without oil, and stir-fried green leafy vegetables, contributing about 305 kcal, 45 g carbohydrate, 13 g protein, 10 g fat, and 12 mg calcium. Afternoon tea at 3.20-3.40 pm comprised packaged nasi lemak with either half a piece of fried chicken breast or a fried egg, sambal with anchovies, and Teh O with less sugar, supplying approximately 312 kcal, 30 g carbohydrate, 9 g protein, 17 g fat, and 5 mg calcium. Dinner at 7.45 pm consisted of white rice and vegetable soup containing bitter gourd and lentils, contributing around 241 kcal with 45 g carbohydrate, 7 g protein, 2 g fat, and 37 mg

calcium. Supper before bedtime included a fried egg with oil, one slice of wholemeal bread, and one slice of cheese, providing approximately 237 kcal, 19 g carbohydrate, 12 g protein, 13 g fat, and 114 mg calcium. Overall, the total daily energy intake was approximately 1,356 kcal/day (~62% of requirements) and protein 63 g/day (1.8 g/kg, adequate but limited in variety, mainly from eggs). Although protein intake met the requirement, calcium intake remained inadequate at 464 mg/day (~36% of requirements), and fibre intake was low (mainly three servings of leafy green vegetables and only two servings of fruit per month). The patient's father is vegetarian for dinner and weekend meals; however, the patient consumes animal-based protein at other meals. The patient does not have lactose intolerance. The patient is not on any long-term medications and is not taking or prescribed any nutritional supplements.

Physical activity was moderate (~30 minutes/day, including at least 100 jumps, with occasional cycling or badminton on weekends). Both the patient and caregiver demonstrated high readiness to change, and the supportive home environment during family meals and weekends allowed for practical dietary intervention.

Both the patient and patient's mother demonstrated limited understanding of energy requirements and expressed concerns regarding appropriate dietary choices, particularly in selecting foods that support catch-up growth, such as energy-dense meals, protein-rich sources, and calcium-rich foods. This reflects a prior lack of nutrition education and highlights the need for structured guidance. They also have limited knowledge of appropriate portion sizes, feeding frequency, and practical meal planning strategies required to support optimal growth and development.

NUTRITION DIAGNOSIS

Inadequate energy intake related to limited food and nutrition-related knowledge regarding appropriate energy intake to support catch-up growth, likely due to lack of prior nutrition education and limited exposure to dietary guidance, leading to inappropriate eating behaviors [knowledge etiology] as evidenced by total energy intake meeting only ~63% of estimated requirements, persistent BMI-for-age < -3 SD (severe thinness), and height-for-age < -2 SD, stunting).

Malnutrition (undernutrition) related to chronic inadequate energy and protein intake insufficient to support normal growth and development, secondary to constitutional delay of growth and puberty (CDGP) with suboptimal dietary intake [physiologic metabolic etiology], as evidenced by BMI-for-age <−3 SD (severe thinness), height-for-age < −2 SD (stunting), total energy intake meeting only ~63% of estimated requirements, and failure to achieve expected catch-up growth.

NUTRITION GOAL

The short-term goals (1-2 weeks) were to increase the patient's daily energy intake to meet at least 80-90% of requirements, improve calcium intake to approach recommended levels, and introduce greater protein variety to support early catch-up growth.

Long-term goals (3-6 months) focused on achieving consistent weight and height gain towards the expected catch-up trajectory, and establishing lasting family-centered eating habits that support healthy growth, alongside regular physical activity and adequate sleep to enhance overall development.

NUTRITION INTERVENTION

By comparing with several comparative standards, such as the Recommended Nutrient Intake (RNI, 2017), the Failure to Thrive (FTT) formula (Peterson & Washington, 1984), and the Schofield formula for boys aged 10-18 years (Schofield, 1985), with the dosing weight targeted at the 3rd to 50th percentiles (28-34 kg), the patient's nutrition prescription was set at 2,200 kcal/day to support catch-up growth. The protein target was set at 1.8-2.5 g/kg/day, which falls within ranges shown to support muscle and bone accretion. Although higher intakes of up to 2.8 g/kg/day have been reported in specific research settings (Mukhlas Fikri et al. 2024), such levels should be approached with caution. Protein intake above the upper target should only be considered on an individual basis with close monitoring of renal function, hydration status, and overall energy balance, particularly in growing individuals or those with underlying health conditions. Therefore, the recommended intake for this case prioritised a moderate, evidence-based range to optimise benefits while minimising potential risks associated with excessive protein consumption. Calcium intake was prescribed at 1,300 mg/day (RNI 2017), achieved through dietary sources and oral nutrition supplementation.

The nutrition intervention focused on optimising the patient's dietary intake to support catch-up growth and was delivered using a family-centred approach. The patient and caregiver were first educated on the importance of dietary modification and appropriate portion sizes, emphasizing that inadequate energy intake was the main contributor to the patient's persistent thinness and limited growth despite intact genetic potential. The rationale for increasing calorie density was clearly explained, highlighting that a growing prepubertal child requires sufficient energy not only for daily activities but also for tissue building, immune function, and bone development. In addition to

energy, the importance of adequate and varied protein sources was emphasised, as protein is essential for muscle accretion, bone matrix formation, and recovery from chronic undernutrition. Calcium was highlighted as a critical nutrient for bone mineralisation and linear growth, particularly in a child with delayed bone age.

A detailed menu plan was developed for the family, incorporating interchangeable options from each macronutrient group to support flexible meal construction. Simple, practical plant-based recipes aligned with the father's vegetarian pattern were also developed to help the family enrich meals with energy, protein, and micronutrients using affordable, easy-to-prepare ingredients such as tofu, *tempeh*, eggs, legumes, and soymilk alternatives. Education emphasised practical strategies that aligned with household eating practices and planning balanced school meals.

A stepwise dietary plan was introduced to address specific nutrient inadequacies. First, calorie-dense ingredients were incorporated through the use of healthy fats such as olive oil, canola oil, sesame oil, nuts, seeds, avocado, and nut spreads. These options were demonstrated in the context of the family's usual meals, such as adding one to two teaspoons of oil to steamed fish, stir-fried vegetables, and soups, or including peanut butter or avocado on bread to increase caloric intake without excessive food volume. Second, protein variety was expanded to improve overall nutrient quality and support muscle and bone accretion. Both animal-based and plant-based protein sources were discussed, including eggs, poultry, fish, tofu, tempeh, lentils, red beans, and baked beans. Considering the father's vegetarian diet and the family's shared evening meals, cooking methods that blend plant-based proteins into dinner dishes were taught to promote practicality and sustainability, such as adding tofu into soups, incorporating tempeh into stir-fries, or preparing lentil-based dishes.

Third, despite adequate protein intake, calcium intake remained low. Therefore, calcium intake was prioritised due to the patient's markedly low baseline intake and the critical role of calcium in bone mineralisation, particularly in prepubertal children with delayed growth. The caregiver was educated on both dairy and non-dairy calcium sources, including milk, cheese, yoghurt, fortified soy milk, tofu, *tempeh*, sardines, and leafy green vegetables such as *kailan* and *sawi*. Practical strategies for increasing calcium intake included adding cheese to sandwiches, spreading baked beans on bread, and offering yoghurt with almonds as snacks.

To further support nutrient adequacy, the patient was prescribed an age-appropriate oral nutritional supplement (Pediasure 10+®) due to its higher calcium content. Two servings per day (5 scoops + 190 mL lukewarm water) were recommended, providing an additional ~454 kcal, 17 g protein, and 900 mg calcium daily. The supplement was scheduled for the morning and pre-bedtime to prevent any reduction in appetite during main meals. Research indicates that with approximately 2 servings/day of PediaSure (or similar oral nutritional supplements), improvements in weight are typically observed within 4-8 weeks, whereas measurable height/linear growth usually becomes apparent after 4-8 months of continuous use (Alarcon et al. 2003).

Education was also provided on increasing fibre intake through daily consumption of fruits (2 servings) and vegetables (3 servings), recognising their contribution to micronutrient intake, bowel regularity, and vitamin C content, which enhances iron absorption. Lifestyle modifications were reinforced, including maintaining 9-11 hours of sleep per night to support growth hormone secretion and engaging in regular physical activity such as skipping, badminton, or cycling at least 3-5 times per week to stimulate appetite, strengthen muscles, and promote healthy growth. A family-centred behavioural counselling approach underpinned the intervention. This included addressing barriers related to family meal patterns, supporting meal planning within the context of the father's vegetarian practices, encouraging consistent food preparation methods at home, and strengthening caregiver confidence in managing the child's dietary needs. Through collaborative goal-setting and continuous caregiver engagement, the intervention aimed to improve dietary compliance and ensure long-term sustainability of healthy eating habits to optimise the child's growth trajectory.

NUTRITION MONITORING AND EVALUATION

A two-week outpatient follow-up was conducted via phone call to assess anthropometric progress, dietary intake, oral nutrition supplement (ONS) acceptance, and adherence to the prescribed intervention. Early dietary improvements were observed. The patient's body weight increased by 0.3 kg and height by 0.5 cm. Although his BMI improved to 12.9 kg/m², it remained below -3 SD, indicating persistent severe thinness but some early improvement in nutritional status. Weight gain was below the targeted velocity, whereas height increase was consistent with expected interval growth. However, the short follow-up period limits the ability to draw conclusions regarding linear growth. Additionally, reliance on home measurements may reduce the validity of the data due to variations in measurement equipment, location, and personnel.

It is also important to note that anthropometric measurements obtained during home-based follow-

up may vary from hospital-based measurements due to differences in equipment, measurement technique, and potential technical error; therefore, a longer follow-up duration (e.g., 3 months) is recommended to more accurately evaluate true growth trends and intervention effectiveness.
In addition, biochemical parameters will require ongoing monitoring, particularly the renal profile, given the relatively high protein provision; this will be reassessed during the 3-month follow-up at the dietetics clinic to ensure metabolic tolerance and safety.

Dietary evaluation using a three-day food diary showed notable improvements in intake quality and quantity. The patient consumed PediaSure® 10+ twice daily as recommended, contributing approximately 24% of daily energy and 73% of total calcium intake. He tolerated the supplement well, reporting no gastrointestinal discomfort, and both the patient and caregiver demonstrated excellent compliance. Total energy intake increased from 1,356 kcal to 1,855 kcal/day (~84% of estimated requirements). Calcium intake improved markedly from 464 mg to 1,238 mg/day (~95% of requirements). Protein intake reached 2.5 g/kg/day with greater diversity of sources. Fruit consumption increased from twice per month to twice per week, indicating better dietary variety.

Physical activity patterns remained appropriate for his age, consisting of daily jumping activities (~30 minutes) and intermittent participation in badminton or football during weekends. The caregiver reported an enhanced understanding of nutrition goals, reflecting improved family engagement and adherence to recommended practices. Overall, the nutrition diagnosis of inadequate energy intake remains active and in progress. The patient has shown meaningful early improvements across anthropometric, dietary, and behavioural domains. Continued monitoring is required to ensure sustained catch-up growth and achievement of targeted nutritional goals. The next follow-up visit is scheduled in three months in the dietetics clinic.

DISCUSSION

This case highlights the interaction between CDGP and chronic undernutrition, demonstrating how inadequate dietary intake can further compromise growth outcomes in an otherwise physiological growth variant. Although CDGP is typically characterised by delayed skeletal maturation and pubertal onset with eventual attainment of normal adult height, suboptimal nutritional status may exacerbate growth faltering and delay the realisation of genetic height potential (Rogol et al. 2000; Soliman et al. 2022). The patient presented with persistent severe thinness and stunting despite normal endocrine function, a pattern consistent with previous observations that energy insufficiency primarily limits weight gain and may secondarily impair linear growth in prepubertal children (Rogol et al. 2000).

Although CDGP is generally considered a self-limiting condition, short-term low-dose testosterone therapy may be considered in selected boys when delayed puberty is associated with significant psychological distress. However, pharmacological intervention is not routinely required in CDGP, as most boys will enter puberty spontaneously and achieve normal adult height without hormonal treatment (Gaudino et al. 2022). Importantly, testosterone therapy does not replace the need for adequate nutritional support. Nutritional inadequacy may independently limit growth response and compromise the effectiveness of spontaneous or induced pubertal growth. Therefore, optimisation of dietary intake remains a fundamental component of management, particularly in children with co-existing undernutrition, regardless of whether hormonal therapy is considered (Gaudino et al. 2022; Soliman et al. 2022).

Catch-up growth is recognised to be nutritionally demanding, requiring sufficient energy availability alongside increased protein intake to support tissue accretion (American Academy of Pediatrics 2014; Fikri et al. 2024). Recent reviews propose protein intakes ranging from 2.0 to 3.0 g/kg/day for nutritionally compromised children, while cautioning against prolonged excessive intakes due to potential metabolic consequences (Fikri et al. 2024). In this case, the achieved protein intake of approximately 2.5 g/kg/day aligns with these recommendations, providing anabolic support without exceeding suggested upper limits. Notably, the increase in protein intake occurred largely as a consequence of improving calcium adequacy, as several calcium-rich foods and oral nutritional supplements also contributed substantial protein. This highlights the interdependence of nutrient optimisation in clinical practice, where targeting one limiting nutrient may concurrently influence others. Nevertheless, given the relatively high protein provision, ongoing monitoring of renal function is warranted to ensure metabolic tolerance and safety during sustained nutritional rehabilitation.

Calcium inadequacy was another key contributor to growth risk in this patient, given calcium's essential role in bone mineralisation and linear growth, especially in children with delayed bone age (NCCFN 2017; Soliman et al. 2022). The marked improvement in calcium intake following dietary modification and oral nutritional supplementation reflects findings from previous intervention studies showing that supplementation can effectively address micronutrient gaps when dietary sources alone are insufficient (Alarcón et al. 2003; Huynh et al. 2015). However, supplementation was

implemented as an adjunct rather than a replacement for meals, supporting sustained dietary behaviour change and appetite preservation.

The modest increases in weight and height observed after two weeks should be interpreted cautiously. Short-term anthropometric changes may reflect early nutritional responsiveness rather than definitive catch-up growth, which typically requires several months of sustained intervention. Additionally, home-based anthropometric measurements are subject to technical variability, further limiting short-term interpretation.

Nonetheless, the rapid improvement in dietary adequacy, adherence to oral nutritional supplementation, and caregiver engagement are clinically meaningful indicators that the patient is progressing towards a favorable growth trajectory. Family meal patterns significantly influenced dietary intake in this case. The father's vegetarian diet during dinner and weekend limited available animal-protein sources, necessitating a family-centered approach to ensure adequate nutrient provision. Strategies included incorporating a variety of plant-based proteins (tofu, lentils, *tempeh*), emphasizing higher-calorie and animal-protein sources earlier in the day, and ensuring the inclusion of micronutrient-rich foods such as fruits and vegetables. Practical interventions such as adding healthy oils to cooked meals and modifying school meals were also effective in addressing nutritional gaps.

This case reinforces the importance of individualized, structured, evidence-based, and family-centred dietetic intervention in children with CDGP and faltering growth. While nutritional therapy cannot alter the intrinsic timing of pubertal onset, it plays a critical role in ensuring that children enter puberty with sufficient nutritional reserves to support optimal pubertal growth and bone accretion (Rogol et al. 2000; Soliman et al. 2022). Tailoring dietary strategies to household eating patterns, particularly in families practising partial vegetarianism, enhances feasibility, adherence, and long-term sustainability. Overall, this report contributes practical clinical insight into the role of nutrition optimisation as a cornerstone of supportive management in CDGP complicated by chronic undernutrition.

CONCLUSION

In conclusion, this case highlights the importance of early nutritional optimisation in a prepubertal boy with constitutional delay of growth and puberty (CDGP) and chronic undernutrition. Comprehensive dietetic intervention led to improvements in dietary adequacy, including increased energy and calcium intake and greater variety of protein sources, within a short follow-up period. While substantial linear growth cannot be conclusively assessed over two weeks, the initial dietary response suggests improved nutritional support for growth and bone accretion. With continued family involvement, sustained dietary intervention, and regular long-term outpatient monitoring, nutrition support has the potential to facilitate catch-up growth and optimise growth outcomes, enabling children with CDGP to approach their full height potential over time.

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CONFLICT

The authors declare no conflict of interest.

REFERENCES

Abacı, A. & Beşci, Ö. 2024. A current perspective on delayed puberty and its management. *Journal of Clinical Research in Pediatric Endocrinology* 16(4): 379-400. https://doi.org/10.4274/jcrpe.galenos.2024.2024-2-7

Alarcón, P.A., Lin, L.-H., Noche, M., et al. 2003. Effect of oral supplementation on catch-up growth in picky eaters. *Clinical Pediatrics* 42(3): 209-217. https://doi.org/10.1177/000992280304200304

American Academy of Pediatrics. 2014. Failure to thrive. In: *Pediatric nutrition: Policy of the American Academy of Pediatrics*. 7th ed. Elk Grove Village, Illinois: American Academy of Pediatrics. pp. 663-700.

European Society for Paediatric Endocrinology (ESPE). 2019. Constitutional delay of growth and puberty. *Hormone Disorders Series*. European Society for Paediatric Endocrinology.

Gaudino, R., De Filippo, G., Bozzola, E., Gasparri, M., Bozzola, M., Villani, A. & Radetti, G. 2022. Current clinical management of constitutional delay of growth and puberty. *Italian Journal of Pediatrics* 48(1): 45. https://doi.org/10.1186/s13052-022- 01223-7

Fikri, A.M., Astuti, W., Nurhidayati, V.A., Prameswari, F.S.P. & Ismail, N.H. 2024.

Protein intake recommendation for stunted children: An update review. *Nutrición Clínica y Dietética Hospitalaria* 44(3): 117-123. https://doi.org/10.12873/443mukhlas

Huynh, D.T.T., Estorninos, E., Capeding, R.Z., Oliver, J.S., Low, Y.L. & Rosales, F.J. 2015. Longitudinal growth and health outcomes in nutritionally at-risk children who received long-term nutritional intervention. *Journal of Human Nutrition and Dietetics* 28(6): 623-635. https://doi.org/10.1111/jhn.12306

Institute for Public Health (IPH). 2019. Possible risk factors for malnourished children aged below five years in Putrajaya, 2018. Institute for Public Health, Ministry of Health Malaysia.

Luciano, T.M., Stecchini, M.F. & Antonini, S.R.R. 2025. Boys with constitutional delay of growth and puberty developed spontaneous puberty and reached standard adult height without pharmacological therapy. Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo.

Ministry of Health Malaysia. 2019. Paediatric protocols for Malaysian hospitals. 4th ed. Ministry of Health Malaysia.

Mukhlas Fikri, A., Astuti, W., Nurhidayati, V.A., Prameswari, F.S.P. & Ismail, N.H. 2024. Protein intake recommendation for stunted children: An update review. *Nutrición Clínica y Dietética Hospitalaria* 44(3): 117-123. https://doi.org/10.12873/443mukhlas

National Coordinating Committee on Food and Nutrition (NCCFN). 2017. Recommended nutrient intakes for Malaysia: A report of the Technical Working Group on Nutritional Guidelines. Ministry of Health Malaysia.

Rogol, A.D., Clark, P.A. & Roemmich, J.N. 2000. Growth and pubertal development in children and adolescents: Effects of diet and physical activity. *The American Journal of Clinical Nutrition* 72(2): 521S-528S.https://doi.org/10.1093/ajcn/72.2.521S

Soliman, A.T., Alaaraj, N., Noor Hamed, Alyafei, F., Ahmed, S., Shaat, M., Itani, M., Elalaily, R. & Soliman, N. 2022. Nutritional interventions during adolescence and their possible effects. *Acta Bio-Medica: Atenei Parmensis* 93(1): e2022087. https://doi.org/10.23750/abm.v93i1.12789

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Ulasan Artikel/*Review Article*

Machine Learning in Gamma Knife Radiosurgery: Current Applications, Challenges, and Future Perspectives

Pembelajaran Mesin dalam Bedah Radio Gamma Knife: Aplikasi Semasa, Cabaran, dan Perspektif Masa Hadapan

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ABSTRACT

Gamma Knife radiosurgery (GKRS) is a well-established treatment modality for intracranial lesions, including brain metastases, benign tumours, and vascular malformations. Despite high local control rates, treatment outcomes remain heterogeneous, and predicting tumor response and radiation-induced toxicity remains a significant clinical challenge. Conventional prognostic models rely mainly on clinical and dosimetric parameters, which may not adequately capture tumour heterogeneity and complex biological interactions. Machine learning (ML) has emerged as a promising approach for analysing high-dimensional clinical and imaging data to improve predictive modeling in radiosurgery. This narrative review examines current applications of ML in predicting radiotherapy outcomes following GKRS, including tumour control, survival, and radiation-induced toxicity. Relevant literature was identified through searches of PubMed, Scopus, and Web of Science using keywords related to GKRS, machine learning, artificial intelligence, and radiomics. Existing studies show that ML models integrating radiomic, clinical, and dosimetric features outperform single-modality approaches in predicting key outcomes such as local tumour control, radionecrosis, and overall survival. Radiomics derived from pretreatment MRI demonstrates potential for identifying imaging biomarkers of treatment response, while multimodal models improve risk stratification. However, current evidence is limited by small, predominantly single-centre retrospective datasets, heterogeneity in imaging and feature extraction methods, and lack of robust external validation, which constrain reproducibility and clinical applicability. Addressing these challenges will require standardised radiomics workflows, adherence to quality frameworks, and multicentre prospective validation to support reliable clinical translation.

Keywords: Gamma Knife radiosurgery, Machine learning, Radiomics, Brain metastases Outcome prediction.

ABSTRAK

Radiosurgeri Gamma Knife (GKRS) merupakan satu kaedah rawatan yang telah terbukti berkesan untuk lesi intrakranial, termasuk metastasis otak, tumor jinak, dan malformasi vaskular. Walaupun kadar kawalan setempat adalah tinggi, hasil rawatan masih menunjukkan variasi, dan peramalan tindak balas tumor serta ketoksikan akibat

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radiasi kekal sebagai cabaran klinikal yang signifikan. Model prognostik konvensional kebanyakannya bergantung kepada parameter klinikal dan dosimetri, yang mungkin tidak mencerminkan sepenuhnya heterogeniti tumor dan interaksi biologi yang kompleks. Pembelajaran mesin (ML) telah muncul sebagai pendekatan yang berpotensi dalam menganalisis data klinikal dan pengimejan berdimensi tinggi bagi meningkatkan pemodelan ramalan dalam radiosurgeri. Ulasan naratif ini menilai aplikasi semasa ML dalam meramalkan hasil radioterapi selepas GKRS, termasuk kawalan tumor, kelangsungan hidup, dan ketoksikan akibat radiasi. Literatur yang berkaitan dikenal pasti melalui carian dalam pangkalan data utama seperti PubMed, Scopus, dan Web of Science menggunakan kata kunci berkaitan GKRS, pembelajaran mesin, kecerdasan buatan, dan radiomik. Kajian sedia ada menunjukkan bahawa model ML yang mengintegrasikan ciri radiomik, klinikal, dan dosimetri mengatasi pendekatan satu sumber dalam meramalkan hasil utama seperti kawalan tumor setempat, radionekrosis, dan kelangsungan hidup keseluruhan. Radiomik yang diperoleh daripada MRI pra-rawatan menunjukkan potensi dalam mengenal pasti biomarker pengimejan bagi tindak balas rawatan, manakala model multimodal meningkatkan stratifikasi risiko. Walau bagaimanapun, bukti semasa terhad oleh saiz sampel yang kecil, kebanyakannya daripada kajian retrospektif satu pusat, variasi dalam protokol pengimejan dan kaedah pengekstrakan ciri, serta kekurangan pengesahan luaran yang kukuh. Kekangan ini menjejaskan kebolehulangan dan kebolehgunaan klinikal. Oleh itu, penyeragaman aliran kerja radiomik, pematuhan kepada kerangka kualiti, serta pengesahan prospektif pelbagai pusat diperlukan bagi menyokong pelaksanaan klinikal yang lebih boleh dipercayai.

Kata Kunci: Radiosurgeri Gamma Knife, Pembelajaran mesin, Radiomik, Metastasis otak, Ramalan hasil

INTRODUCTION

Gamma Knife radiosurgery (GKRS) has become an established treatment modality for a wide range of intracranial pathologies, including brain metastases, arteriovenous malformations, vestibular schwannomas, and meningiomas (Alazawy et al. 2024). By delivering highly focused radiation beams with submillimetre precision, GKRS enables effective tumour control while minimizing damage to surrounding normal tissues (Du et al. 2023).

Despite its clinical success, predicting treatment outcomes following radiosurgery remains challenging. Patient outcomes depend on multiple interacting factors, including tumour characteristics, treatment dose, and patient clinical variables (Xia et al. 2025). Conventional statistical models often struggle to capture these complex nonlinear relationships, which has motivated increasing interest in artificial intelligence (AI) and machine learning (ML) approaches (Yahya et al. 2016).

Machine learning techniques have shown promise in analysing large and complex datasets, enabling the identification of patterns that may not be readily detectable using traditional statistical approaches (Kufel et al. 2023). In the context of radiosurgery, ML methods have been applied to predict treatment response, tumour control, survival outcomes, radiation-induced toxicity, tumour recurrence, and treatment planning parameters (Tan et al. 2023). This narrative review summarises current evidence on the application of machine learning techniques in Gamma Knife radiosurgery. It aims to provide a comprehensive overview of current approaches, highlight methodological challenges, and discuss potential clinical applications of machine learning in radiosurgery.

LITERATURE SEARCH AND ARTICLE SELECTION

A structured literature search was conducted using PubMed, Scopus, and Web of Science to identify relevant studies on machine learning applications in Gamma Knife radiosurgery. The search covered articles published up to December 2025. The main search terms included combinations of “Gamma Knife radiosurgery”, “stereotactic radiosurgery”, “machine learning”, “artificial intelligence”, “radiomics”, “deep learning”, “brain metastases”, “radionecrosis”, “treatment response”, “toxicity prediction”, “survival prediction”, and “treatment planning”.

Articles were considered relevant if they discussed the application of machine learning, artificial intelligence, radiomics, or deep learning in Gamma Knife radiosurgery or closely related stereotactic radiosurgery settings. Priority was given to studies addressing outcome prediction, local tumour control, survival, radionecrosis, treatment-related toxicity, treatment planning, model validation, radiomics workflow, and clinical translation. Only articles published in English were considered. Additional relevant publications were identified by manually screening the reference lists of selected articles. Studies not related to radiosurgery, articles with no relevance to machine learning or radiomics, and publications focused solely on conventional radiotherapy without radiosurgical relevance were excluded.

MACHINE LEARNING IN MEDICAL IMAGING AND RADIOTHERAPY

Machine learning has become increasingly integrated into medical imaging and radiotherapy research due to its ability to process high-

dimensional data and extract meaningful patterns. In radiotherapy, ML algorithms have been applied to tasks such as image segmentation, treatment planning optimisation, outcome prediction, and toxicity modelling (Kufel et al. 2023).

Radiomics has emerged as a particularly important application of ML in medical imaging. It involves the extraction of quantitative imaging features from medical images, which can capture tumour shape, texture, and intensity characteristics that may reflect underlying biological processes (Umaru, Abdul Manan, et al. 2025). These features can then be combined with clinical variables to develop predictive models that assist in treatment decision-making.

RADIOMIC FEATURE CATEGORIES AND SOURCES OF VARIABILITY

Radiomic features can generally be grouped into several categories. First-order features describe the distribution of voxel intensity values within the segmented region of interest without considering spatial relationships between voxels. These include measures such as mean intensity, median, standard deviation, skewness, kurtosis, entropy, and energy. Shape-based features describe the three-dimensional geometry of the lesion, including volume, surface area, compactness, sphericity, elongation, and irregularity. Texture features evaluate spatial relationships between neighbouring voxels and are commonly derived from matrices such as the grey-level co-occurrence matrix, grey-level run-length matrix, grey-level size-zone matrix, and neighbouring grey-tone difference matrix. These features may capture intratumour heterogeneity, which is particularly relevant in brain metastases and other intracranial lesions treated with Gamma Knife radiosurgery. Higher-order features are obtained after applying image filters or mathematical transformations, such as wavelet decomposition, Laplacian of Gaussian filtering, or intensity discretisation, to highlight specific spatial patterns that may not be visible on conventional imaging (Larue et al. 2017; Zwanenburg et al. 2016).

Despite their potential value, radiomic features are sensitive to several sources of variability. These include differences in MRI acquisition parameters, scanner manufacturers, magnetic field strength, slice thickness, voxel size, reconstruction settings, image normalisation, segmentation methods, and feature extraction software. Manual segmentation may introduce inter-observer variability, whereas automatic and semi-automatic segmentation approaches may be affected by algorithm performance and image quality. Preprocessing steps such as resampling, grey-level discretisation, filtering, and normalisation can also substantially influence extracted feature values (Traverso et al. 2018; Umaru, Manan, Kumar, Hamsan & Yahya 2025). Therefore, standardised imaging protocols, reproducible segmentation procedures, harmonised preprocessing pipelines, and transparent reporting of feature extraction methods are essential to improve the reliability and reproducibility of radiomics-based machine learning models in radiosurgery.

In radiosurgery, radiomics and ML approaches have been increasingly explored to improve the prediction of treatment response and complications. By integrating imaging features with clinical and dosimetric data, ML models may provide a more comprehensive understanding of tumour behaviour and treatment outcomes (Umaru, Manan, Kumar, Hamsan, Tan, et al. 2025).

MACHINE LEARNING WORKFLOW IN GAMMA KNIFE RADIOSURGERY

The development of machine learning models in radiosurgery typically follows several key steps, including data acquisition, image preprocessing, feature extraction, model training, and validation (Tulum 2023).

First, clinical and imaging data are retrieved from patients undergoing Gamma Knife radiosurgery. Imaging modalities commonly used include magnetic resonance imaging (MRI), computed tomography (CT), and occasionally functional imaging techniques such as positron emission tomography (Nowakowski et al. 2022). Next, is image preprocessing is performed to ensure data consistency. This may include image normalization, resampling to uniform voxel sizes, noise reduction, and correction for imaging artifacts (Meißner et al. 2023; Umaru, Manan, Kumar, Hamsan & Yahya 2025). Tumour segmentation is then carried out to define the region of interest from which features can be extracted.

Following segmentation, radiomic features are extracted from the tumour region and prepared for model development. The reliability of these features depends strongly on image acquisition parameters, segmentation consistency, preprocessing methods, and the software used for feature extraction. (Tulum 2023).

Once features have been extracted, machine learning algorithms are used to develop predictive models. Common algorithms used in radiosurgery studies include logistic regression, LASSO, support vector machines, random forests, gradient boosting methods, and neural networks (Cao et al. 2025; Liao et al. 2023). To provide a clearer comparison of these modelling approaches, Table 1 summarises commonly used machine learning algorithms in radiomics and Gamma Knife radiosurgery research, including their main characteristics, advantages, limitations, and potential applications.

For effective clinical integration, model validation is a critical step in the ML workflow. Internal validation techniques such as cross-

validation are often used during model development, while external validation using independent datasets is necessary to evaluate generalisability (Lambin et al. 2017) Figure 1 showed the radiomics workflow from image acquisition to model validation.

Although machine learning workflows follow these structured steps, the reliability of predictive models in radiotherapy strongly depends on data quality, feature robustness, and rigorous external validation. Failure to address these factors may lead to model overfitting and limited clinical applicability.

FEATURE SELECTION AND MODEL DEVELOPMENT CONSIDERATIONS

Feature selection is an important step in radiomics-based machine learning because the number of extracted imaging features is often much larger than the number of patients included in radiosurgery studies. Without appropriate feature reduction, models may identify unstable or redundant predictors, leading to overfitting and poor performance on independent datasets. Common feature selection methods include least absolute shrinkage and selection operator (LASSO), minimum redundancy maximum relevance (mRMR), and recursive feature elimination (RFE).

LASSO applies regularisation to shrink less informative feature coefficients toward zero, thereby retaining a smaller set of relevant predictors. The mRMR method selects features that are strongly associated with the outcome while reducing redundancy among selected variables. RFE works by repeatedly training a model, ranking features according to their contribution, and removing the least important features until an optimal subset is obtained (Perniciano et al. 2025; Zhang et al. 2023).

TABLE 1 Comparison of commonly used machine learning algorithms in radiomics and Gamma Knife radiosurgery research

Algorithm	**Main characteristics**	**Advantages**	**Limitations**	**Potential application in GKRS**
Logistic regression	A linear classification model that estimates the probability of an outcome based on selected predictors.	Simple, interpretable, computationally efficient, and useful as a baseline model.	Limited ability to model complex non-linear relationships unless interaction terms or transformations are included.	Prediction of binary outcomes such as tumour control, recurrence, radionecrosis, or survival status.
Ridge and elastic net regression	Regularised regression methods that reduce model complexity by penalising large coefficients. Elastic net combines L1 and L2 penalties.	Useful when predictors are correlated; reduces overfitting and improves model stability.	Requires careful tuning of regularisation parameters and may still underperform when relationships are highly non-linear.	Development of stable radiomics-based prediction models using correlated imaging features.
LASSO regression	A regularised regression method that performs coefficient shrinkage and feature selection.	Useful for high-dimensional radiomics data; reduces overfitting by selecting the most relevant features.	May select unstable features when predictors are highly correlated; performance depends on regularisation strength.	Radiomic feature selection and development of interpretable prediction models.
Support vector machine	A supervised learning algorithm that separates classes using an optimal hyperplane; kernel functions allow non-linear classification.	Effective in small- to medium-sized datasets and high-dimensional feature spaces.	Less interpretable than linear models; requires careful tuning of kernel and hyperparameters.	Classification of treatment response, local failure, or radionecrosis risk.

k-nearest neighbours	A distance-based algorithm that classifies a case according to the most similar examples in the training data.	Simple and intuitive; can capture local patterns in data.	Sensitive to feature scaling, noise, irrelevant variables, and class imbalance.	Exploratory classification of treatment response or toxicity risk in small datasets.
Decision tree	A tree-based model that splits data into decision rules based on predictor variables.	Easy to interpret and can model non-linear relationships.	Prone to overfitting if not pruned or validated properly.	Identification of clinical, dosimetric, or radiomic decision rules for outcome prediction.
Random forest	An ensemble method that combines multiple decision trees using bootstrap sampling and feature randomness.	Handles non-linear relationships, reduces variance, and provides feature importance estimates.	Can still overfit noisy data and may be less transparent than simpler models.	Prediction of treatment outcomes using combined clinical, dosimetric, and radiomic features.
Gradient boosting methods/XG Boost	Ensemble models that sequentially build decision trees to correct previous prediction errors.	High predictive performance and ability to capture complex feature interactions.	Sensitive to hyperparameter tuning and prone to overfitting if not carefully validated.	Risk stratification, survival prediction, treatment response prediction, and multimodal outcome modelling.
Naïve Bayes	A probabilistic classifier based on Bayes' theorem and an assumption of feature independence.	Computationally efficient and useful for small datasets.	The independence assumption is often unrealistic in radiomics because many features are correlated.	Preliminary classification tasks or baseline comparison in outcome prediction studies.
Artificial neural networks/deep learning	Models composed of interconnected layers that learn complex non-linear patterns from imaging or tabular data.	Suitable for complex image-based learning and automatic feature representation.	Requires larger datasets, has limited interpretability, and may be difficult to validate externally.	Automated image analysis, segmentation, treatment response prediction, and survival modelling.
Cox regression and survival-based models	Models designed to analyse time-to-event outcomes while accounting for censored data.	Appropriate for survival analysis and time-dependent endpoints.	Conventional Cox models assume proportional hazards and may not capture complex non-linear relationships.	Prediction of overall survival, progression-free survival, and time to local failure after GKRS.
Random survival forest	An ensemble survival model that extends random forest methods to censored time-to-event data.	Captures non-linear survival patterns and interactions without requiring proportional hazards assumptions.	Requires adequate sample size and external validation; interpretation may be more complex than Cox regression.	Survival prediction and risk stratification in patients treated with GKRS.

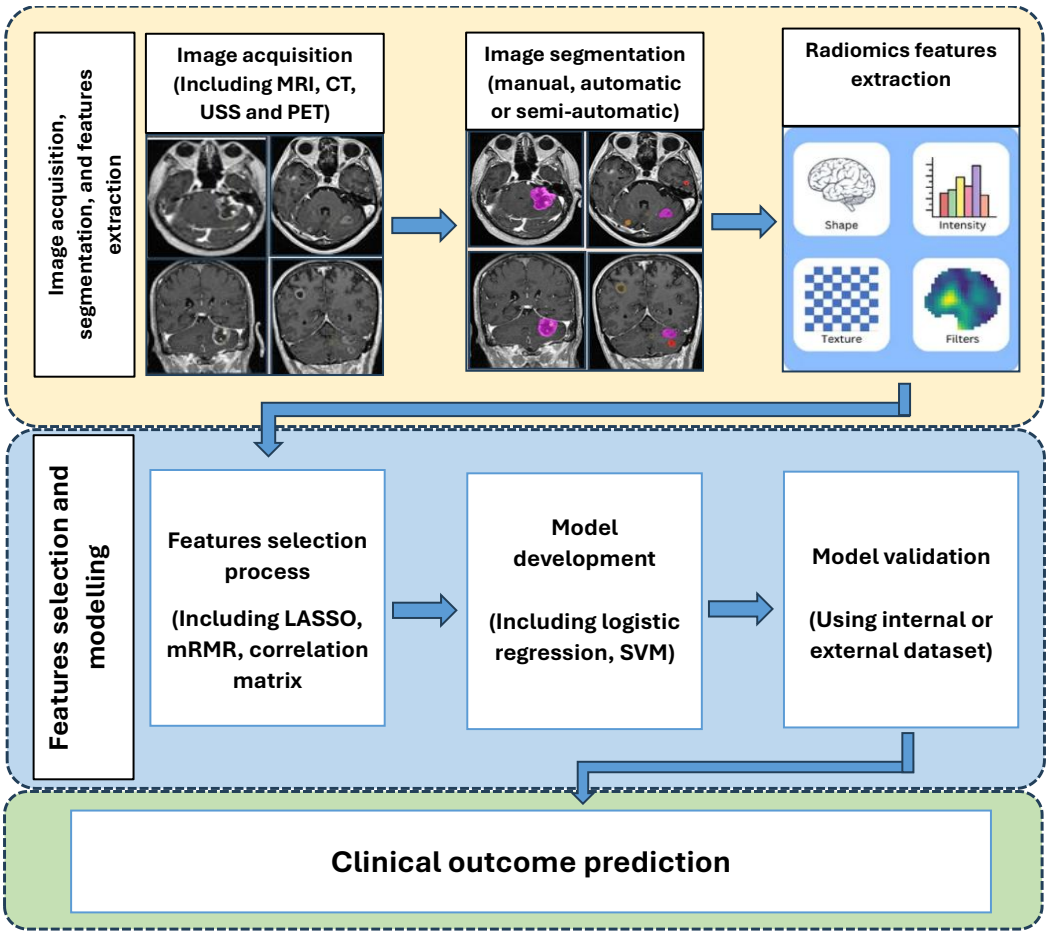


FIGURE 1. Radiomics and machine learning workflow in Gamma Knife radiosurgery, showing image acquisition, image segmentation, radiomic feature extraction, feature selection, machine learning model development, model validation, and clinical outcome prediction. Abbreviations: MRI, magnetic resonance imaging; CT, computed tomography; USS, ultrasonography; PET, positron emission tomography; ROI, region of interest; LASSO, least absolute shrinkage and selection operator; mRMR, minimum redundancy maximum relevance; SVM, support vector machine; NN, neural network.

Several model development challenges must also be considered in Gamma Knife radiosurgery studies. Overfitting is a major concern, particularly when small retrospective datasets are used with high-dimensional radiomic features. To reduce this risk, studies should apply appropriate feature selection, cross-validation, regularisation, and, where possible, independent external validation. Class imbalance is another important issue, especially when the outcome of interest is uncommon, such as radionecrosis or local failure. If not addressed, models may favour the majority class and produce misleadingly high accuracy while performing poorly for clinically important minority outcomes. Approaches such as stratified sampling, class weighting, resampling methods, and reporting sensitivity, specificity, area under the receiver operating characteristic curve, precision-recall metrics, and calibration can provide a more balanced assessment of model performance. Ultimately, model generalisability remains one of the most important requirements for clinical translation, and predictive models should be tested across independent cohorts, different scanners, imaging protocols, and institutional settings before routine clinical use (D'Amico et al. 2019; Staartjes & Schröder 2018).

APPLICATIONS OF MACHINE LEARNING IN GAMMA KNIFE RADIOSURGERY

Machine learning has been applied to several key clinical tasks in Gamma Knife radiosurgery, including outcome prediction, toxicity assessment, and survival modeling.

One of the most widely studied applications is the prediction of local tumour control following radiosurgery. ML models trained on radiomic features extracted from pretreatment MRI scans have demonstrated the ability to identify imaging biomarkers associated with treatment response (Feng et al. 2022; Horvat et al. 2022).

Another important application is the prediction of radiation-induced complications, such as radionecrosis. Early identification of patients at risk of developing radionecrosis may allow clinicians to adjust treatment plans or implement closer follow-up strategies (Hettal et al. 2020; Peng et al. 2018). Machine learning models have also been used to predict overall survival in patients with brain metastases treated with radiosurgery. By integrating imaging features with dosimetric and clinical variables such as age, performance status, and primary tumour type, these models may help stratify patients according to prognosis and guide treatment decisions (D'Amico et al. 2020; Della Seta et al. 2019).

Several studies have demonstrated that combining radiomic features with clinical and dosimetric variables improves predictive performance compared with single-modality models. Multimodal models may capture complementary information, such as tumour morphology, microenvironment heterogeneity, and patient-specific clinical characteristics (Umaru et al. 2026). However, variability in imaging protocols, segmentation strategies, and feature extraction pipelines remains a major source of heterogeneity across studies, which may limit reproducibility and generalisability of radiomics-based prediction models.

MACHINE LEARNING IN TREATMENT PLANNING

Machine learning is also being explored to improve treatment planning in Gamma Knife radiosurgery. Predictive models can assist clinicians in estimating treatment outcomes based on different planning parameters, thereby facilitating more personalised treatment strategies (Munai et al. 2024).

For example, ML models may help identify optimal dose distributions that maximise tumor control while minimising the risk of toxicity. In addition, predictive algorithms can assist in determining appropriate prescription doses based on tumor size, location, and patient-specific factors (Umaru, Manan, Kumar, Hamsan, Tan, et al. 2025). Beyond outcome prediction, machine learning is increasingly being explored for treatment planning optimisation in Gamma Knife radiosurgery. Predictive algorithms can assist clinicians in estimating dose distributions, evaluating plan quality, and identifying optimal treatment parameters before plan delivery. Knowledge-based planning approaches trained on historical treatment data have shown potential for predicting achievable dose volume histograms and improving planning efficiency. In addition, machine learning methods may support automated target segmentation and organ-at-risk delineation, which are critical steps in radiosurgery planning. Although these approaches remain largely investigational, they represent a promising direction for improving planning consistency and workflow efficiency in radiosurgical practice.

CHALLENGES IN MACHINE LEARNING FOR GAMMA KNIFE RADIOSURGERY

Despite the growing interest in machine learning (ML) applications in Gamma Knife radiosurgery, several methodological and practical challenges continue to limit clinical translation.

One of the most frequently reported limitations is the restricted availability of large, high-quality datasets. Many published studies rely on relatively small retrospective cohorts derived from single institutions, which may introduce selection bias and limit the statistical power of predictive models. Small datasets are particularly problematic in radiomics research, where the number of extracted imaging features can substantially exceed the number of patients, increasing the risk of overfitting and reducing model generalisability (Umaru, Abdul Manan, et al. 2025). Multicentre collaborations and data-sharing initiatives are therefore essential to improve the robustness and external validity of ML models. In addition, class imbalance should be explicitly addressed in model development because clinically important outcomes such as radionecrosis, tumour recurrence, or treatment failure may occur less frequently than favourable outcomes, potentially biasing model predictions towards the majority class.

Another major challenge is the lack of standardisation in radiomics workflows. Radiomic feature values can be highly sensitive to variations in imaging acquisition parameters, reconstruction settings, segmentation techniques, and preprocessing pipelines (Umaru, Manan, Kumar, Hamsan & Yahya 2025). Even minor differences in MRI protocols or voxel resolution can significantly alter extracted features, thereby affecting model performance. To address these issues, several initiatives have been proposed to improve methodological consistency. The Image Biomarker Standardisation Initiative (IBSI) provides standardised definitions for radiomic features and feature extraction procedures, while the Radiomics Quality Score (RQS) offers a structured framework for evaluating methodological rigor and reproducibility in radiomics studies (Lambin et al. 2017; Zwanenburg et al. 2016). In addition, reporting guidelines such as TRIPOD-AI have been introduced to promote transparency in the development and validation of predictive models (Collins et al. 2024). However, despite the availability of these frameworks, many published studies still employ heterogeneous methodologies,

highlighting the need for greater adherence to standardised protocols.

Closely related to these issues is the challenge of harmonising imaging and radiomic data across institutions. Differences in scanner manufacturers, acquisition protocols, and image reconstruction algorithms can introduce systematic variability in radiomic features. Harmonisation techniques, such as statistical normalisation methods and approaches like ComBat harmonisation, have been proposed to mitigate these effects and improve the reproducibility of multicentre studies. Nevertheless, consistent implementation of such techniques remains limited.

Finally, model interpretability and transparency represent important barriers to clinical adoption. Many machine learning algorithms particularly deep learning architectures operate as complex "black box" systems, making it difficult to understand how individual features contribute to predictions. This lack of interpretability may reduce clinician trust and hinder integration into clinical workflows. Explainable artificial intelligence approaches, including feature importance analysis, SHAP-based interpretation, and visualisation techniques, are increasingly being explored to address this limitation and improve the transparency of ML decisions (Sim et al. 2023; Yoon et al. 2022).

Collectively, addressing these methodological and translational challenges will be essential for enabling the reliable integration of machine learning models into clinical radiosurgery practice.

LIMITATIONS OF THE STUDY

This narrative review has several limitations. First, the evidence synthesised is largely derived from retrospective, single-centre studies with relatively small sample sizes, which may introduce selection bias and limit generalisability. Second, there is considerable methodological heterogeneity across studies, particularly in imaging protocols, segmentation approaches, and radiomic feature extraction pipelines, making comparison and reproducibility challenging.

Although standardisation initiatives such as the Image Biomarker Standardisation Initiative (IBSI), Radiomics Quality Score (RQS), and reporting guidelines like TRIPOD-AI have been developed to improve consistency, their application remains inconsistent, and many studies continue to adopt varying analytical approaches. In addition, most models lack robust external validation, limiting confidence in their performance across different clinical settings.

Furthermore, as a narrative review, this study does not follow a formal systematic review or meta-analysis framework, which may introduce selection bias in the included literature. Finally, the predominance of complex "black-box" machine learning models with limited interpretability remains a broader limitation within the field, potentially hindering clinical adoption.

FUTURE DIRECTIONS

Future research in machine learning for Gamma Knife radiosurgery should prioritize the development of large, high-quality multicentre datasets. Collaborative data sharing will be essential to improve model generalisability and reduce overfitting, particularly in radiomics-based studies where feature dimensionality often exceeds sample size. In parallel, the adoption of standardised imaging protocols and harmonised radiomics pipelines will be critical to enhance reproducibility across institutions.

The integration of multimodal data, including advanced imaging, genomic information, clinical variables, and treatment parameters, represents another key direction. The emerging field of radiogenomics, which links imaging phenotypes with underlying molecular characteristics, may provide deeper insight into tumour biology and radiosensitivity, thereby improving predictive accuracy and enabling more personalised treatment strategies.

Advances in deep learning may further strengthen predictive modelling by automatically capturing complex spatial patterns from imaging data. When applied to large, well-annotated datasets, these approaches may improve prediction of treatment response, radionecrosis risk, and survival outcomes.

For clinical translation, however, machine learning models must demonstrate not only high predictive performance but also interpretability, robustness, and integration into existing workflows. Explainable AI techniques may enhance clinician trust, while prospective validation studies and real-world clinical trials will be essential to determine their true clinical impact.

CONCLUSION

Machine learning is emerging as a powerful tool for advancing precision radiosurgery by enabling improved prediction of tumour control, treatment toxicity, and survival outcomes.

By integrating imaging, radiomic, clinical, and dosimetric data, these models offer the potential to support more personalised treatment strategies for patients undergoing Gamma Knife radiosurgery.

However, significant challenges remain, including limited dataset sizes, variability in radiomics methodologies, and the need for rigorous external validation. Future research should focus on multicentre collaborations, standardised data pipelines, and prospective validation studies to

ensure that machine learning models can be safely and effectively translated into clinical practice.

REFERENCE

Alazawy, N. M. A., Almusawi, M. S., Alabedi, H. H., Faraj, M. K., Ahmad, R. & Albosaabar, M. H. 2024. Gamma knife versus volumetric arc modulated therapy in a linear accelerator in treatment of multiple brain metastasis: Literature review. *Journal of Pioneering Medical Sciences* 13:93-100. 10.61091/jpms202413213

Cao, P., Jia, X., Wang, X., Fan, L., Chen, Z., Zhao, Y., Zhu, J. & Wen, Q. 2025. Deep learning radiomics for the prediction of epidermal growth factor receptor mutation status based on MRI in brain metastasis from lung adenocarcinoma patients. *BMC cancer* 25(1): 443. 10.1186/s12885-025-13823-8.

Collins, G. S., Moons, K. G., Dhiman, P., Riley, R. D., Beam, A. L., Van Calster, B., Ghassemi, M., Liu, X., Reitsma, J. B. & Van Smeden, M. 2024. TRIPOD+ AI statement: updated guidance for reporting clinical prediction models that use regression or machine learning methods. *bmj* 385. 078378. https://doi.org/10.1136/bmj-2023-078378.

D'amico, N. C., Merone, M., Sicilia, R., Cordelli, E., D'antoni, F., Zanetti, I. B., Valbusa, G., Grossi, E., Beltramo, G. & Fazzini, D. 2019. Tackling imbalance radiomics in acoustic neuroma. *International Journal of Data Mining and Bioinformatics* 22(4): 365-388. https://doi.org/10.1504/ijdmb.2019.101396.

D'amico, N. C., Sicilia, R., Cordelli, E., Tronchin, L., Greco, C., Fiore, M., Carnevale, A., Iannello, G., Ramella, S. & Soda, P. 2020. Radiomics-based prediction of overall survival in lung cancer using different volumes-of-interest. *Applied Sciences (Switzerland)* 10(18): 6425. https://doi.org/10.3390/app10186425.

Della Seta, M., Collettini, F., Chapiro, J., Angelidis, A., Engeling, F., Hamm, B. & Kaul, D. 2019. A 3D quantitative imaging biomarker in pre-treatment MRI predicts overall survival after stereotactic radiation therapy of patients with a singular brain metastasis. *Acta Radiologica* 60(11):1496-1503. 10.1177/0284185119831692

Du, P., Liu, X., Xiang, R., Lv, K., Chen, H. Y., Liu, W. F., Cao, A. H., Chen, L., Wang, X. F., Yu, T. G., Ding, J., Li, W. C., Li, J., Li, Y. X., Yu, Z. K., Zhu, L., Liu, J. & Geng, D. Y. 2023. Development and validation of a radiomics-based prediction pipeline for the response to stereotactic radiosurgery therapy in brain metastases. *European Radiology* 33(12): 8925-8935. 10.1007/s00330-023-09930-4.

Feng, A., Yuan, P., Huang, T., Li, L. & Lyu, J. 2022. Distinguishing Tumor Recurrence From Radiation Necrosis in Treated Glioblastoma Using Multiparametric MRI. *Academic Radiology* 29(9): 1320-1331. 10.1016/j.acra.2021.11.008.

Hettal, L., Stefani, A., Salleron, J., Courrech, F., Behm-Ansmant, I., Constans, J. M., Gauchotte, G. & Vogin, G. 2020. Radiomics Method for the Differential Diagnosis of Radionecrosis Versus Progression after Fractionated Stereotactic Body Radiotherapy for Brain Oligometastasis. *Radiation Research* 193(5): 471-480. 10.1667/RR15517.1.

Horvat, N., Veeraraghavan, H., Nahas, C. S. R., Bates, D. D. B., Ferreira, F. R., Zheng, J., Capanu, M., Fuqua, J. L., Fernandes, M. C., Sosa, R. E., Jayaprakasam, V. S., Cerri, G. G., Nahas, S. C. & Petkovska, I. 2022. Combined artificial intelligence and radiologist model for predicting rectal cancer treatment response from magnetic resonance imaging: an external validation study. *Abdominal Radiology* 47(8): 2770-2782. 10.1007/s00261-022-03572-8.

Kufel, J., Bargieł-Łączek, K., Kocot, S., Koźlik, M., Bartnikowska, W., Janik, M., Czogalik, Ł., Dudek, P., Magiera, M. & Lis, A. 2023. What is machine learning, artificial neural networks and deep learning?—Examples of practical applications in medicine. *Diagnostics* 13(15): 2582. https://doi.org/10.3390/diagnostics13152582

Lambin, P., Leijenaar, R. T., Deist, T. M., Peerlings, J., De Jong, E. E., Van Timmeren, J., Sanduleanu, S., Larue, R. T., Even, A. J. & Jochems, A. 2017. Radiomics: the bridge between medical imaging and personalized medicine. *Nature reviews Clinical oncology* 14(12): 749-762. 10.1038/nrclinonc.2017.141

Larue, R. T., Defraene, G., De Ruysscher, D., Lambin, P. & Van Elmpt, W. 2017. Quantitative radiomics studies for tissue characterization: a review of technology and methodological procedures. *The British Journal of Radiology* 90(1070): 20160665. 10.1259/bjr.20160665.

Liao, C.-Y., Lee, C.-C., Yang, H.-C., Chen, C.-J., Chung, W.-Y., Wu, H.-M., Guo, W.-Y., Liu, R.-S. & Lu, C.-F. 2023. Predicting survival after radiosurgery in patients with lung cancer brain metastases using deep learning of radiomics and EGFR status. *Physical and Engineering Sciences in Medicine* 46(2): 585-596.10.1007/s13246-023-01234-7.

Meißner, A.-K., Gutsche, R., Galldiks, N., Kocher, M., Jünger, S. T., Eich, M.-L., Nogova, L., Araceli, T., Schmidt, N. O. & Ruge, M. I.

2023. Radiomics for the non-invasive prediction of PD-L1 expression in patients with brain metastases secondary to non-small cell lung cancer. *Journal of Neuro-Oncology* 163(3): 597-605. 10.1007/s11060-023-04367-7.

Munai, E., Zeng, S., Yuan, Z., Yang, D., Jiang, Y., Wang, Q., Wu, Y., Zhang, Y. & Tao, D. 2024. Machine learning-based prediction model for brain metastasis in patients with extensive-stage small cell lung cancer. *Scientific reports* 14(1): 28790. s41598-024-80425-y.

Nowakowski, A., Lahijanian, Z., Panet-Raymond, V., Siegel, P. M., Petrecca, K., Maleki, F. & Dankner, M. 2022. Radiomics as an emerging tool in the management of brain metastases. *Neuro-Oncology Advances* 4(1): 141. 10.1093/noajnl/vdac141.

Peng, L. K., Parekh, V., Huang, P., Lin, D. D., Sheikh, K., Baker, B., Kirschbaum, T., Silvestri, F., Son, J., Robinson, A., Huang, E., Ames, H., Grimm, J., Chen, L. D., Shen, C., Soike, M., Mctyre, E., Redmond, K., Lim, M., Lee, J., Jacobs, M. A. & Kleinberg, L. 2018. Distinguishing True Progression From Radionecrosis After Stereotactic Radiation Therapy for Brain Metastases With Machine Learning and Radiomics. *International Journal of Radiation Oncology Biology Physics* 102(4): 1236-1243. 10.1016/j.ijrobp.2018.05.041

Perniciano, A., Loddo, A., Di Ruberto, C. & Pes, B. 2025. Insights into radiomics: impact of feature selection and classification. *Multimedia Tools and Applications* 84(26): 31695-31721. 10.1007/s11042-024-20388-4.

Sim, J. Z. T., Fong, Q. W., Huang, W. & Tan, C. H. 2023. Machine learning in medicine: what clinicians should know. *Singapore medical journal* 64(2): 91-97. 10.11622/smedj.2021054.

Staartjes, V. E. & Schröder, M. L. 2018. Class imbalance in machine learning for neurosurgical outcome prediction: are our models valid? *Journal of Neurosurgery: Spine* 29(5): 611-612. 10.3171/2018.5.SPINE18543.

Tan, D., Mohamad Salleh, S. A., Manan, H. A. & Yahya, N. 2023. Delta-radiomics-based models for toxicity prediction in radiotherapy: A systematic review and meta-analysis. *Journal of Medical Imaging and Radiation Oncology* 67(5): 564-579. 10.1111/1754-9485.13546.

Traverso, A., Wee, L., Dekker, A. & Gillies, R. 2018. Repeatability and reproducibility of radiomic features: a systematic review. *International Journal of Radiation Oncology* Biology* Physics* 102(4): 1143-1158. 10.1016/j.ijrobp.2018.05.053.

Tulum, G. 2023. Novel radiomic features versus deep learning: differentiating brain metastases from pathological lung cancer types in small datasets. *The British Journal of Radiology* 96(1146): 20220841. 10.1259/bjr.20220841

Umaru, A., Abdul Manan, H., Kumar Athi Kumar, R., Hamsan, S. K. & Yahya, N. 2025. Utilizing radiomics as predictive factor in brain metastasis treated with stereotactic radiosurgery: systematic review and radiomic quality assessment. *iRADIOLOGY* 3(2): 132-143. https://doi.org/10.1002/ird3.70007

Umaru, A., Abdul Manan, H., Tan, D., Kumar, R. a. K., Hamsan, S. K. & Yahya, N. 2026. Enhancing treatment response prediction in brain metastases: A multi-modal radiomics approach using MRI and CBCT. *Heliyon* 12(11): e45076. 10.1016/j.heliyon.2026.e45076.

Umaru, A., Manan, H., Kumar, R., Hamsan, S. & Yahya, N. 2025. The impact of intensity discretisation and filtration on the performance of the radiomic and machine learning models in brain metastasis patients treated with gamma knife radiosurgery. *Radiography* 31(5): 103010. 10.1016/j.radi.2025.103010.

Umaru, A., Manan, H. A., Kumar, R. K. A., Hamsan, S. K., Tan, D. & Yahya, N. 2026. Development and external validation of an MRI radiomics-based machine learning model to predict tumour recurrence in brain metastases treated with Gamma Knife radiosurgery. Radiotherapy and Oncology 216(111362.https://doi.org/10.1016/j.radonc.2025.111362

Xia, X., Wu, W., Tan, Q. & Gou, Q. 2025. Interpretable Machine Learning Models for Differentiating Glioblastoma From Solitary Brain Metastasis Using Radiomics. *Academic Radiology* (32):9 5388-5400. https://doi.org/10.1016/j.acra.2025.05.016.

Yahya, N., Ebert, M. A., Bulsara, M., House, M. J., Kennedy, A., Joseph, D. J. & Denham, J. W. 2016. Statistical-learning strategies generate only modestly performing predictive models for urinary symptoms following external beam radiotherapy of the prostate: A comparison of conventional and machine-learning methods. *Medical Physics* 43(5): 2040-2052. 10.1118/1.4944738.

Yoon, C. H., Torrance, R. & Scheinerman, N. 2022. Machine learning in medicine: should the pursuit of enhanced interpretability be abandoned? *Journal of Medical Ethics* 48(9): 581-585. 10.1136/medethics-2020-107102.

Zhang, W., Guo, Y. & Jin, Q. 2023. Radiomics and its feature selection: a review. *Symmetry* 15(10): 1834. https://doi.org/10.3390/sym15101834.

Zwanenburg, A., Vallières, M., Abdalah, M.A., Aerts, H.J., Andrearczyk, V., Apte, A., Ashrafinia, S., Bakas, S., Beukinga, R.J., Boellaard, R. and Bogowicz, M., 2020. The image biomarker standardization initiative: standardized quantitative radiomics for high-throughput image-based phenotyping. Radiology, 295(2), pp.328-338. https://doi.org/10.1148/radiol.2020191145

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Artikel Asli /*Original Article*

Short-term Exposure to Monosodium Glutamate Elevates Blood Pressure Prior to Reduced Cardiac Antioxidants in Rats

Pendedahan Jangka Pendek Kepada Monosodium Glutamat Meningkatkan Tekanan Darah Mendahului Penurunan Antioksidan Jantung pada Tikus

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ABSTRACT

Monosodium glutamate (MSG) is a globally ubiquitous flavor enhancer, yet growing evidence suggests its overconsumption may pose significant cardiovascular and metabolic risks. However, the short-term physiological responses to brief exposures remain poorly understood. This study aimed to evaluate the short-term effects of orally administered MSG on cardiovascular parameters, cardiac antioxidant marker, and metabolic indicators in adult male rats. Eight rats were divided into two groups: a control group receiving distilled water and a MSG group receiving MSG at 4 g/kg/day orally for seven consecutive days. Body weight, food and water intake, and blood pressure were monitored throughout the treatment period. Post-treatment, cardiac tissue was analyzed for total protein and reduced glutathione (GSH) levels. MSG administration did not significantly affect body weight or food intake. However, water intake increased markedly, suggesting sodium-induced polydipsia. Systolic, diastolic, and mean arterial pressures were significantly elevated in the MSG group, indicating early cardiovascular stress. No significant changes were observed in cardiac protein content or GSH levels, suggesting that short-term exposure may not be sufficient to induce measurable oxidative stress. In conclusion, short-term oral MSG exposure induces hemodynamic alterations without overt oxidative stress in cardiac tissue, highlighting its potential to disrupt cardiovascular homeostasis even in brief exposures.

Keywords: blood pressure; cardiovascular system; glutamate monosodium; oxidative stress

ABSTRAK

Monosodium glutamat (MSG) merupakan penambah perisa yang digunakan secara meluas di seluruh dunia, namun semakin banyak bukti menunjukkan bahawa pengambilannya secara berlebihan berpotensi mendatangkan risiko kardiovaskular dan metabolik yang signifikan. Walau bagaimanapun, tindak balas fisiologi akut terhadap pendedahan yang singkat masih kurang difahami. Kajian ini dijalankan bagi mengenalpasti kesan jangka pendek pemberian MSG secara oral kepada parameter kardiovaskular, aras antioksidan jantung, serta indikator metabolik pada tikus jantan dewasa. Sebanyak lapan ekor tikus dibahagikan kepada dua kumpulan, kumpulan kawalan yang menerima air suling dan kumpulan MSG yang menerima administrasi MSG pada dos 4 g/kg/hari secara oral selama tujuh hari berturut-turut. Berat badan, pengambilan makanan dan minuman, serta tekanan darah diukur sepanjang eksperimen berjalan. Di hujung eksperimen, tisu jantung diambil bagi mengukur aras protein jumlah dan glutation terturun (GSH). Administrasi MSG didapati tidak memberi kesan yang signifikan kepada berat badan dan pengambilan makanan tikus. Namun, didapati pengambilan air meningkat dengan ketara, menunjukkan kesan polidipsia akibat aruhan sodium. Tekanan darah sistolik, diastolik dan min tekanan arteri didapati meningkat

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dengan signifikan pada kumpulan MSG berbanding tikus kawalan normal, mencadangkan tekanan kardiovaskular awal berlaku. Tiada perubahan yang signifikan diperhatikan pada aras protein jumlah dan GSH, menunjukkan pendedahan MSG jangka pendek mungkin tidak mencukupi untuk memberikan kesan tekanan oksidatif yang boleh diukur. Kesimpulannya, pendedahan MSG jangka pendek secara oral didapati mengaruh perubahan hemodinamik tanpa menyebabkan tekanan oksidatif pada tisu jantung, seterusnya menjelaskankan potensi MSG dalam menganggu homeostasis kardiovaskular walaupun pada pendedahan yang singkat.

Kata Kunci: monosodium glutamat; sistem kardiovaskular; tekanan darah; tekanan oksidatif

INTRODUCTION

Monosodium glutamate (MSG) is a sodium salt of glutamic acid [C5H8NO4Na.H2O] and one of the most abundant non-essential amino acids in nature. It is widely used as a flavor enhancer in culinary practices across the globe, particularly in Chinese, Japanese, Thai, and processed foods such as soups, sauces, snacks, and instant noodles. Its umami taste arises from its interaction with specific receptors on the tongue, transmitting signals that enhance food palatability (Wu et al. 2022). Physically, MSG is a white, odorless, water-soluble crystalline powder composed of approximately 78% glutamic acid, 21% sodium, and 1% water and impurities. It was first patented in 1908 by Japanese chemist Kikunae Ikeda (Sano 2009). While the U.S. FDA classifies MSG as "generally recognized as safe" (GRAS), the European Food Safety Authority (EFSA) re-evaluated it in 2017 and set an acceptable daily intake (ADI) of 30 mg/kg body weight (EFSA Panel on Food Additives and Nutrients Sources Added to Food (2017).

Because of the absence of formal global consumption limits, MSG is often used in excessive and unregulated quantities, especially in fast foods and street meals. For instance, Thai food packaging recommends 4 g per dish, while studies in rural Thai populations report an average intake of 4.0 ± 2.2 g/day (ranging from 0.4 to 14 g). In the U.S., average daily intake ranges from 0.2 to 0.5 g, compared to 1.6 g/day in Korea (Insawang et al. 2012).

While MSG improves food palatability, increasing evidence suggests potential health risks, especially with chronic or high-dose exposure. Experimental and epidemiological data have linked MSG overconsumption with a range of adverse effects. These include metabolic syndrome and obesity, independent of high caloric intake and lack of physical activity (Olguin et al. 2018; Kayode et al. 2023). Evidence also suggests neurotoxicity, particularly in neonatal rat model with immature blood–brain barriers (Rosa et al. 2018). In addition, MSG has been associated with hepatotoxicity (Maulina et al. 2024), nephrotoxicity (Abd-Elkareem et al. 2022), and retinal damage (Liberatore et al. 2017). Reproductive toxicity has been observed, including reduced testosterone levels, testicular lesions, and abnormal sperm morphology (Jubaidi et al. 2019). Furthermore, psychiatric and neurological symptoms, such as depression, mood swings, headaches, and dizziness, have been documented (Arunkumar et al. 2018; Subramanian et al. 2023).

MSG is considered a potent inducer of oxidative stress, contributing to the pathogenesis of conditions like atherosclerosis and metabolic disturbances. Studies have shown increased lipid peroxidation and oxidative injury in cardiac, hepatic, renal, pancreatic, and nervous tissues following chronic MSG exposure (Majewski et al. 2018; Cunha et al. 2010; Eweka & Om'Iniabohs 2007).

Although studies on MSG's cardiovascular effects remain limited and sometimes contradictory, emerging evidence highlights several potential impacts. MSG may increase mean arterial pressure (MAP) and heart rate, alter endothelial function and vascular reactivity, and promote oxidative stress in cardiac tissue. It has also been reported to elevate pro-inflammatory mediators such as prostaglandins (e.g., PGE_2) and to modulate the expression of key enzymes, including COX-2 and eNOS (Majewski et al. 2018). Collectively, these changes may exacerbate the risk of hypertension, particularly in the presence of poor dietary habits and alcohol consumption.

Although MSG is officially recognized as safe when consumed in moderate amounts, accumulating experimental data, especially from rodent models, indicate that chronic and high-dose exposure can induce multisystem toxicity, including cardiovascular, hepatic, renal, and neurological damage (Eweka & Om'Iniabohs 2007; Cunha et al. 2010; Dixit et al. 2014; Rosa et al. 2018; Majewski et al. 2018; Abd-Elkareem et al. 2022; Maulina et al. 2024). These findings raise concerns about its widespread and uncontrolled use in processed and fast foods, particularly in populations with sedentary lifestyles and high reliance on industrial meals. Further studies are necessary to establish definitive human health risk thresholds and safe exposure limits. While the long-term toxicity of MSG is well-documented, the early hemodynamic and physiological responses that precede chronic damage remain less understood. Given these concerns, this study was conducted to evaluate the short-term cardiovascular effects of MSG in rats following 7 days of administration, thereby providing preliminary evidence on its short-term impact on cardiac physiology.

MATERIALS AND METHODS

ANIMALS

All animal were acquired from Animal Unit, Faculty of Medicine, Universiti Kebangsaan Malaysia (UKM). A total of eight adult male rats were housed in standard laboratory conditions (temperature-controlled room (26 ± 2 °C), free access to food and water) inside a separate cage each and were acclimatized for seven days within the laboratory condition prior to experiment.

STUDY DESIGN

Adult Male Sprague-Dawley rats weighing 350-400 g were randomly assigned to two groups (n = 4 per group): a control group, receiving distilled water orally, and an MSG-treated group, receiving MSG at a dose of 4 g/kg body weight/day by oral gavage (Dixit et al. 2014). The treatment lasted for 7 consecutive days (Figure 1).

Baseline measurements of body weight, blood pressure, food intake, and water intake were recorded prior to treatment (Day 0). Animals in the control group (Sham) received distilled water orally once daily for 7 consecutive days, whereas the treatment group received MSG at a dose of 4 g/kg/day by oral gavage over the same period. At the end of the treatment (Day 7), body weight, blood pressure, food and water intake were re-evaluated. Following sacrifice, blood and tissue samples were collected to determine markers of oxidative stress by measuring the cardiac level of reduced glutathione (GSH) (Figure 1). All experimental procedures were approved by the UKM Animal Ethics Committee (approval no. FSK/2022/SATIRAH/28-SEPT./1275-OCT.-2022-APRIL-2024).

BASELINE AND FINAL ASSESSMENTS

All animals underwent baseline measurements on Day 0 before the start of treatment, including body weight, food and water intake, and blood pressure. These same parameters were reassessed after the end of the 7 days treatment period, along with blood and tissue sampling for biochemical analyses.

FOOD AND WATER INTAKE

Food and water intake were recorded on Day 7. Food intake was calculated as the difference between the weight of chow provided and the weight of remaining chow after the experience. Water intake was assessed similarly, by measuring the difference in volume between the water provided and the remaining volume in the water bottle. Results were averaged per animal (n=4) and per group.

BLOOD PRESSURE MEASUREMENT

Non-invasive systolic blood pressure was measured on Day 0 and Day 7 using the CODA tail-cuff blood pressure system (Kent Scientific, USA). Rats were placed in restraining holders on a warming platform (maintained at 32–34°C) to promote tail blood flow. Animals were acclimatized to the device for few days prior to measurement to reduce stress-induced variability. At least 5 consistent measurements per animal were recorded, and the average pressure was used for analysis.

TOTAL PROTEIN AND GLUTATHIONE LEVELS

Heart samples were excised immediately after sacrifice, rinsed with ice-cold phosphate-buffered saline (PBS, pH 7.4) to remove blood residues, and weighed. Approximately 100 mg of tissue was homogenized in 1 mL of cold PBS using a tissue homogenizer on ice. The homogenates were centrifuged at 10,000 rpm for 10 minutes at 4°C, and the supernatants were collected for biochemical analyses.

Total protein concentration was determined using Lowry method (Hartree 1972). 100 µL of heart homogenate was mixed with 1 mL of Lowry reagent and incubated at room temperature for 30 minutes in the dark. Then, 100 µL of Folin-phenol reagent was added to the mixture. After incubation for 30 minutes at room temperature and in the dark, absorbance was measured at 600 nm using a spectrophotometer. A standard curve was prepared with bovine serum albumin.

Reduced glutathione (GSH) was quantified using method by Ellman (1959). For each assay, 100 µL of tissue homogenate was added to 900 µL of phosphate buffer (0.1 M, pH 7.4) and 100 µL of 5,5 dithiobis [2-nitrobenzoic] (DTNB) reagent (0.01 M). The mixture was incubated for 10 minutes at room temperature, and absorbance was measured at 415 nm. GSH concentration was determined using a standard curve prepared with reduced glutathione and expressed as mmol GSH per g protein, with normalization based on the protein concentration.

RESULTS AND DISCUSSION

In this study, no significant changes were seen in the body weight of MSG-treated rats after 7 days of MSG treatment, when compared to normal rats (Figure 2). It is worth noting that the route of administration (oral gavage) may represent a potential source of variability, as MSG absorption might not have been homogeneous among all treated rats, which could have influenced the magnitude of the weight gain observed. These findings suggest that, over a short-term exposure, MSG did not markedly alter weight gain beyond the normal physiological growth observed in rats.

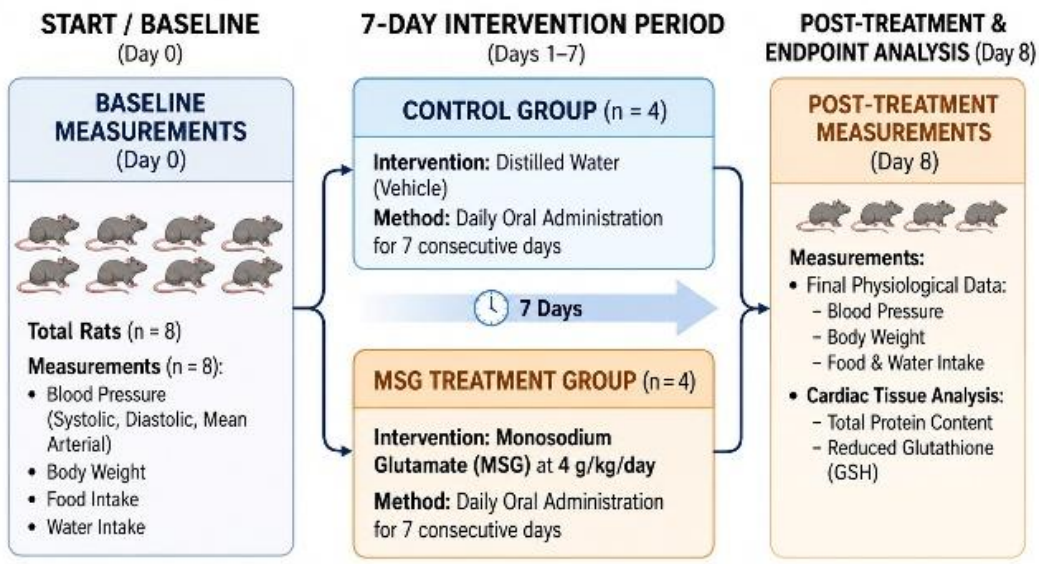


FIGURE 1 Study design

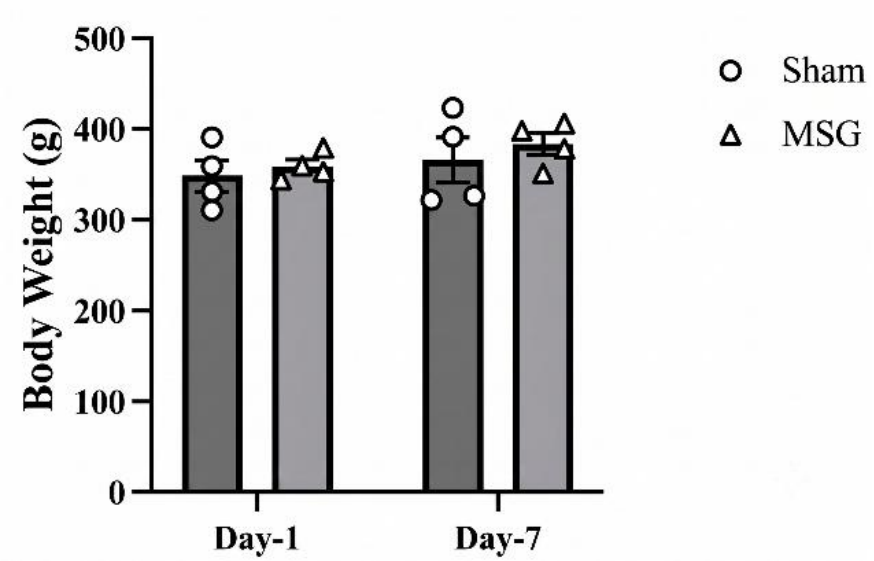


FIGURE 2 Comparison of body weights for the two groups during the experiment

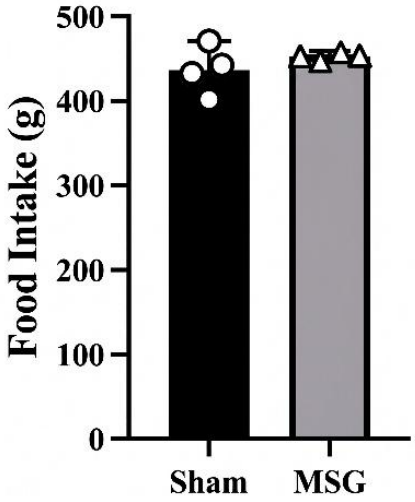


FIGURE 3 Comparison of the food intake for the two groups during the experiment

Total food intake measured over the 7 days of experimental period was comparable between Sham and MSG-treated rats, with no significant difference between the groups (Figure 3). Both groups consumed approximately similar amounts of chow, suggesting that MSG administration did not markedly affect feeding behavior under these conditions.

In contrast, water intake was markedly higher in MSG-treated animals compared to Sham controls (Figure 4). While Sham rats consumed around 1 L of water, MSG-treated rats showed a nearly 1.5 fold increase, reaching values close to 1.6 L over the same period. This elevation in water consumption indicates the presence of polydipsia, which may be attributed to the sodium load introduced by MSG. Similar observation was noted by Moldovan et al. (2023) in their study, suggesting that the MSG intake results in polydipsia due to the high sodium ion content.

Together, these findings suggest that short-term MSG administration does not significantly alter food intake but does increase water intake, consistent with its osmotic and sodium-related effects.

Consistent with the marked polydipsia induced by MSG treatment, blood pressure measurements revealed alterations in hemodynamic parameters, possibly attributable to the high sodium ion content of MSG (Figure 5). After 7 days, the between-group gap widened substantially, and the time effect across groups is strong ($p<0.001$), consistent with MSG amplifying systolic load over the week.Beyond its high sodium which inreased preload and stroke volume thereby increasing the systolic blood pressure, MSG treatment could also reduce nitric oxide (NO) bioavailability following the induction of oxidative stress. This reduction in promotes vasoconstriction, further contributing to elevated systolic blood pressure.

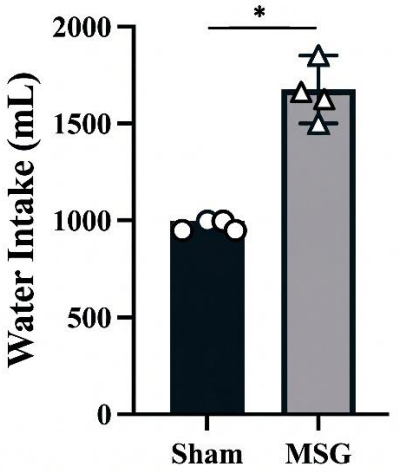


FIGURE 4 Comparison of the water intake for the two groups during the experiment
* $p<0.05$

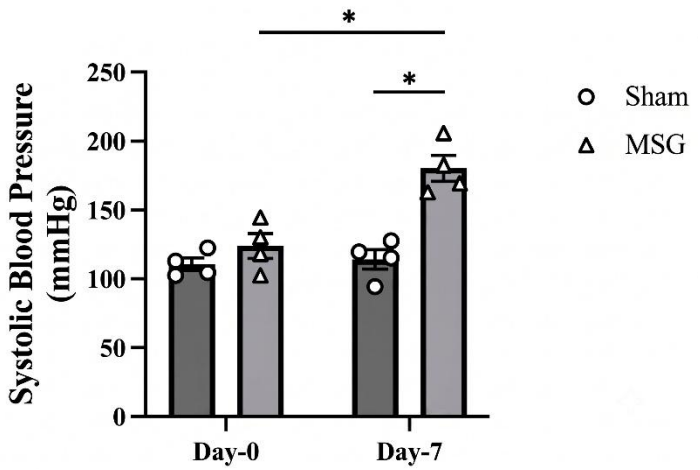


FIGURE 5 Comparison of systolic blood pressure for the two groups before and after treatment
* $p<0.05$

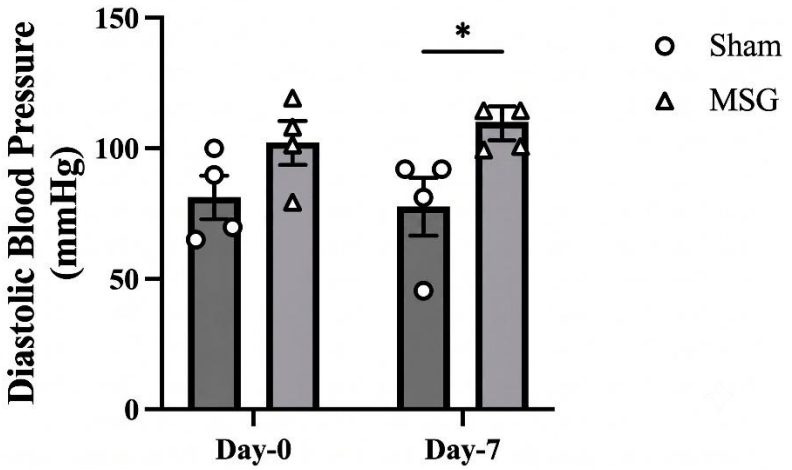


FIGURE 6 Comparison of diastolic blood pressure for the two groups before and after treatment
* $p<0.05$

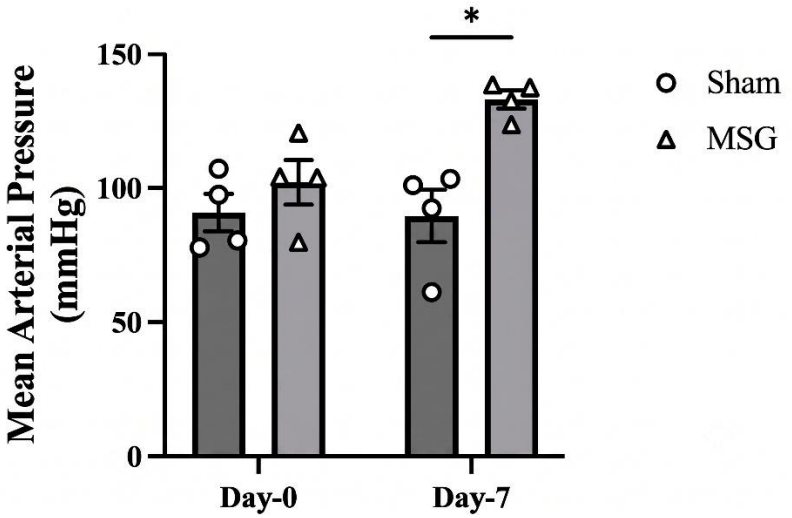


FIGURE 7 Comparison of mean arterial pressure for the two groups before and after treatment
* $p<0.05$

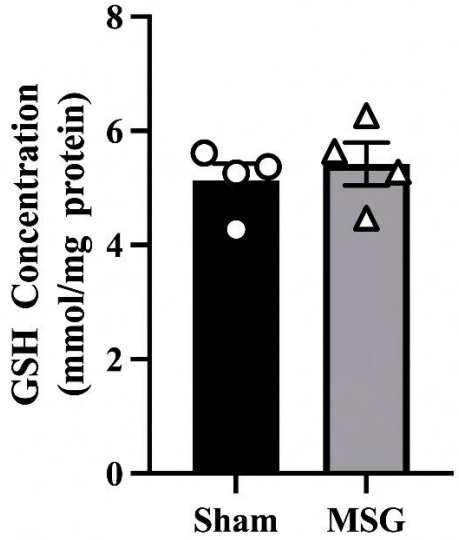


FIGURE 8 Comparison of GSH dosage in the heart for the two groups after treatment

Similarly, diastolic pressure in MSG becomes modestly but significantly higher than Sham ($p>0.05$) (Figure 6). The significant raise in diastolic pressure indicates an increase in peripheral vascular resistance, although its magnitude remained smaller than that of systolic pressure. This typically reflects an early cardiac-output driven response (Lim et al. 2025). The rise in mean arterial pressure (Figure 7), which integrates both cardiac output and systemic vascular resistance, further supports this trajectory: an initial sodium and preload-dependent increase in systolic

In Figure 7, the mean arterial pressure was higher and more pronounced after 7 days of MSG treatment ($p<0.01$). Because mean arterial pressure integrates cardiac output and systemic vascular resistance, this trajectory indicates a combined effect: initial cardiac output/volume driven increase, followed by a contribution from rising systemic vascular resistance.

In cardiac tissue, no significant differences were observed in total protein content or reduced glutathione (GSH) levels between MSG and Sham groups after seven days of treatment (Figure 8). This result is biologically logic, since total protein concentration is a relatively stable endpoint in the myocardium, dominated by abundant structural proteins, and short term oxidative challenges can be compensated by intrinsic antioxidant defenses. It suggesting that the present treatment duration and oral route may not have been sufficient to reveal measurable alterations. Future studies should extend the exposure period.

It should be noted that while the sample size of four animals per group provided adequate statistical power to capture significant physiological shifts in blood pressure and drinking behavior, it represents a limitation of the current study. A smaller cohort size may be underpowered to detect subtle or early-stage fluctuations in cardiac biochemical markers such as GSH. Therefore, these biochemical observations should be interpreted as preliminary, and future investigations employing larger sample sizes and extended exposure periods are warranted to comprehensively evaluate the cardiac molecular impact of short-term MSG exposure.

CONCLUSION

The findings of this study demonstrate that short-term oral administration of MSG in adult rats leads to a significant increase in systolic, diastolic, and mean arterial blood pressure, without notable changes in body weight, food intake, or key biochemical markers such as total cardiac protein and reduced glutathione (GSH). The marked rise in water consumption suggests an osmotic response likely driven by the sodium content of MSG.

These results indicate that even brief exposure to MSG can induce hemodynamic disturbances, potentially through mechanisms involving fluid balance. Although endogenous antioxidant that is GSH remained unchanged, the observed trends warrant further investigation into the cumulative effects and cardiovascular toxicity of MSG. This study underscores the need for tighter regulation of MSG consumption in human diets, particularly in populations with high intake of processed foods, and opens avenues for future research into its molecular impact and clinical relevance.

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REFERENCE

Callister, J.W.D. 2000. *Materials Science and Engineering: An Introduction*. 5th ed. New York: John Wiley & Sons.

Abd-Elkareem, M., Soliman, M., Abd El-Rahman, M. A. M. & Abou Khalil, N. S. 2022. Effect of Nigella sativa L. seed on the kidney of monosodium glutamate challenged rats. Frontiers in Pharmacology 13: 789988. https://doi.org/10.3389/fphar.2022.789988

Cunha, N. V., de Abreu, S. B., Panis, C., Gassiolli, S., Guarnier, F. A., Cecchini, R., Mazzuco, T. L., Pinge-Filho, P. & Martins-Pinge, M. C. 2010. COX-2 inhibition attenuates cardiovascular and inflammatory aspects in monosodium glutamate-induced obese rats. Life Sciences 87(11-12): 375-381. https://doi.org/10.1016/j.lfs.2010.07.014

Dixit, S. G., Rani, P., Anand, A., Khatri, K., Chauhan, R., & Bharihoke, V. 2014. To study the effect of monosodium glutamate on histomorphometry of cortex of kidney in adult albino rats. Renal Failure, 36(2), 266–270. https://doi.org/10.3109/0886022x.2013.846865

EFSA Panel on Food Additives and Nutrient Sources added to Food. 2017. Re-evaluation of glutamic acid (E 620), sodium glutamate (E 621), potassium glutamate (E 622), calcium glutamate (E 623), ammonium glutamate (E 624) and magnesium glutamate (E 625) as food additives. EFSA Journal 15(7): 4910. https://doi.org/10.2903/j.efsa.2017.4910

Ellman, G. L. 1959. Tissue sulfyhyfryl groups. Archives of Biochemistry and Biophysics

82(1): 70–77. https://doi.org/10.1016/0003-9861(59)90090-6

Eweka, A. O. & Om'Iniabohs, F. A. E. 2007. Histological studies of the effects of monosodium glutamate on the liver of adult Wistar rats. Annals of Biomedical Sciences 6(2): 45–52. https://doi.org/10.4314/abs.v6i1.40690

Hartree, E. F. 1972. Determination of protein: a modification of the Lowry method that gives a linear photometric response. Analytical Biochemistry 48(2): 422–427. https://doi.org/10.1016/0003-2697(72)90094-2

Insawang, T., Selmi, C., Cha'on, U., Pethlert, S., Yongvanit, P., Areejitranusorn, P. et al. 2012. Monosodium glutamate (MSG) intake is associated with the prevalence of metabolic syndrome in a rural Thai population. Nutrition & Metabolism 9: 50. https://doi.org/10.1186/1743-7075-9-50

Jubaidi, F. F., Mathialagan, R. D., Noor, M. M., Taib, I. S. & Budin, S. B. 2019. Monosodium glutamate daily oral supplementation: study of its effects on male reproductive system on rat model. Systems Biology in Reproductive Medicine 65(3): 194–204. https://doi.org/10.1080/19396368.2019.1573274

Kayode, O. T., Bello, J. A., Oguntola, J. A., Kayode, A. A. A. & Olukoya, D. K. 2023. The interplay between monosodium glutamate (MSG) consumption and metabolic disorders. Heliyon 9(9): e19675. https://doi.org/10.1016/j.heliyon.2023.e19675

Liberatore, F., Bucci, D., Mascio, G., Madonna, M., Di Pietro, P., Beneventano, M. et al. 2017. Permissive role for mGlu1 metabotropic glutamate receptors in excitotoxic retinal degeneration. Neuroscience 363: 142–149. https://doi.org/10.1016/j.neuroscience.2017.09.005

Lim, H. S., Vondrakova, D., Belohlavek, J., Rokyta, R., & Ostadal, P. 2025. Diastolic Perfusion Pressure Predicts Response to Inotropes and Vasopressors and Benefit from Mechanical Circulatory Support in Cardiogenic Shock. *Circulation. Heart failure*, *18*(7), e012847. https://doi.org/10.1161/CIRCHEARTFAILURE.125.012847

Majewski, M., Jurgoński, A., Fotschki, B. & Juśkiewicz, J. 2018. The toxic effects of monosodium glutamate (MSG). The involvement of nitric oxide, prostanoids and potassium channels in the reactivity of thoracic arteries in MSG-obese rats. Toxicology and Applied Pharmacology 358: 1–9. https://doi.org/10.1016/j.taap.2018.09.016

Maulina, N., Zachreini, I., Gholib, G., Suwandi, A. & Akmal, M. 2024. Black garlic exhibited hepatoprotective effect against monosodium glutamate-induced hepatotoxicity in animal model. Narra J 4(2): e799. https://doi.org/10.52225/narra.v4i2.799

Moldovan, O. L., Vari, C. E., Tero-Vescan, A., Cotoi, O. S., Cocuz, I. G., Tabaran, F. A. et al. 2023. Potential defence mechanisms triggered by monosodium glutamate sub-chronic consumption in two-year-old Wistar rats. Nutrients 15(20): 4436. https://doi.org/10.3390/nu15204436

Olguin, M. C., Posadas, M. D., Revelant, G. C., Marinozzi, D., Labourdette, V. & Venezia, M. R. 2018. Monosodium glutamate affects metabolic syndrome risk factors on obese adult rats: a preliminary study. J. Obes. Weight. Medicat. 4: 23. https://doi.org/10.23937/2572-4010.1510023

Rosa, S. G., Chagas, P. M., Pesarico, A. P. & Nogueira, C. W. 2018. Monosodium glutamate induced nociception and oxidative stress dependent on time of administration, age of rats and susceptibility of spinal cord and brain regions. Toxicology and Applied Pharmacology 351: 64–73. https://doi.org/10.1016/j.taap.2018.05.019

Sano, C. 2009. History of glutamate production. The American Journal of Clinical Nutrition 90(3): 728S–732S. https://doi.org/10.3945/ajcn.2009.27462F

Subramanian, A., Tamilanban, T., Sekar, M., Begum, M. Y., Atiya, A., Ramachawolran, G. et al. 2023 Neuroprotective potential of Marsilea quadrifolia Linn against monosodium glutamate-induced excitotoxicity in rats. Frontiers in Pharmacology 14: 1212376. 10.3389/fphar.2023.1212376

Wu, B., Eldeghaidy, S., Ayed, C., Fisk, I. D., Hewson, L. & Liu, Y. 2022. Mechanisms of umami taste perception: from molecular level to brain imaging. Critical Reviews in Food Science and Nutrition 62(25): 7015–7024. https://doi.org/10.1080/10408398.2021.1909532

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