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Improving Job Performance by Artificial Intelligence (AI): An Integrated Framework for Biomedical Engineers

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Abstract
This study proposes an integrated framework that explains how competencies that encompass knowledge, skills, abilities, and attitudes (KSAA) influence job performance through Artificial Intelligence (AI) readiness among biomedical engineers. As AI continues to transform healthcare operations, biomedical engineers must demonstrate not only technical competence but also readiness to effectively adopt and use AI-driven tools. Drawing on human capital theory (Becker, 1993), and the capability-motivation-opportunity (AMO) model Appelbaum et al., (2000), and the KSAA framework, this study conceptualizes AI readiness as a mediating mechanism that strengthens the relationship between competency (independent variable) and job performance (dependent variable). This framework suggests that while competency provides a foundational capability for performance, AI readiness amplifies its impact by enhancing decision-making accuracy, innovation, and operational efficiency in AI-driven healthcare settings. These findings offer theoretical and practical implications whereby universities can embed AI readiness components into engineering curricula, and healthcare organizations can integrate AI competency assessments into professional development systems to prepare biomedical engineers for the challenges of Industry 4.0.
Keywords: AI Readiness, Biomedical Engineers, Competency Framework (KSAA), Human Capital Theory and Job Performance

Introduction

Biomedical engineering plays a vital interdisciplinary role by connecting technology and medicine, contributing to better patient care, safety, and hospital efficiency. Historically, biomedical engineers focused on conventional technical duties such as maintaining, repairing, and calibrating medical devices to ensure equipment reliability. However, the rapid digital transformation of the healthcare sector has expanded their responsibilities far beyond traditional maintenance work. In modern hospitals, biomedical engineers must now work with AI-driven systems, interpret clinical and equipment data, and manage digital monitoring platforms that support clinical decision making (Zhou et al., 2022). This evolution has increased demand not only for technical expertise, but also for higher levels of digital literacy and analytical capabilities, particularly in areas related to data analytics, automation, and AI readiness (Wang & Li, 2020).

Despite the strategic importance of these evolving competencies, empirical studies indicate that a gap remains between what biomedical engineers learn and what they can apply in real healthcare settings. A pilot investigation under HRMARS titled "Improving Industry Readiness: Insights from a Pilot Study of Biomedical Engineering Program" (Mahmod et al., 2024) revealed that although graduates possess adequate theoretical knowledge, they lack hands-on experience and confidence in applying AI tools within actual hospital environments. This gap limits their effectiveness in data-driven healthcare ecosystems and reduces the potential benefits of digital transformation in hospitals (Lee et al., 2021; Zhang et al., 2022).

To address this industry academia disconnects, a subsequent pilot validation study (Mahmod et al., 2025) developed a multidimensional instrument that measures competencies including knowledge, skills, abilities, and attitudes alongside AI readiness and perceived organisational support. The instrument produced strong reliability values (α = 0.823–0.897), demonstrating its suitability for assessing the extent to which these competencies influence job performance when biomedical engineers interact with AI-enabled systems. Findings from the study emphasize that competency alone is insufficient; meaningful improvements in job performance occur only when competency is reinforced by a high level of AI readiness.

This research therefore highlights the mediating role of AI readiness in translating competencies into enhanced job performance. While competencies form the essential foundation, AI readiness enables biomedical engineers to make accurate decisions, minimise operational errors, and optimise the use of intelligent technologies. The implications of these findings benefit multiple stakeholders. Healthcare organisations can use the framework to design targeted AI upskilling strategies and improve workforce efficiency. Universities and training institutions can incorporate AI readiness elements into curricula to reduce the industry academia skill gap. Biomedical engineers and students themselves can use the competency framework to understand what is required to remain employable and competitive in the era of healthcare digitalisation. Ultimately, equipping biomedical engineers with both technical expertise and the ability to integrate AI into daily work is no longer optional it is critical for achieving high job performance, sustaining innovation, and driving Industry 4.0 transformation within the healthcare sector (Wong et al., 2023).

Literature Review

This literature review discusses key topics such as the importance of competencies in biomedical engineering, the role of AI readiness as a mediator, the skill gap in AI adoption, and the implications for training and professional development. It also incorporates insights from Mahmod et al. (2024) to highlight existing research and gaps in AI-related competencies. There are gaps in AI-related competencies below:

Competency Requirements in Biomedical Engineering

Biomedical engineering is an interdisciplinary field that integrates technology and medicine to enhance healthcare delivery and patient outcomes. The core competencies required of biomedical engineers encompass technical knowledge of medical equipment, practical skills in maintenance and repair, and the capacity to interact with advanced technologies such as artificial intelligence (AI), data-driven devices, and digital monitoring systems. These competencies are increasingly vital as healthcare systems transition toward automation and data-intensive decision-making processes (Zhou et al., 2022). The rapid pace of technological advancement now requires biomedical engineers to continuously adapt to digital and AI-based technologies in their daily tasks. Zhou et al. (2022) highlighted that the expanding applications of AI in medicine is particularly in medical imaging and clinical decision-making necessitate engineers who possess not only strong technical proficiency but also digital literacy and analytical capabilities to operate and optimize these intelligent systems. Consequently, digital competency has become a fundamental requirement that must be incorporated into biomedical engineering training and professional development programs (Zhou et al., 2022; Wang & Li, 2020).

As the healthcare sector continues its progression toward greater AI integration, biomedical engineering education must evolve accordingly. It is no longer sufficient for engineers to rely solely on traditional technical skills; they must be equipped to collaborate with and manage AI-based systems effectively. To achieve this, biomedical engineering programs should embed AI-related competencies within their curricula, providing students with both theoretical understanding and hands-on experience in AI-enabled tools (Wang & Li, 2020). Educational institutions therefore need to prioritize AI readiness as an essential component of competency development, ensuring that future biomedical engineers are prepared to thrive in technology-driven healthcare environments. Integrating AI competencies into the curriculum will bridge the gap between conventional engineering practices and the emerging digital health ecosystem (Zhou et al., 2022; Wong et al., 2023).

AI Readiness as a Mediating Factor

AI readiness plays a crucial role in determining the success of biomedical engineers in technology-intensive healthcare settings. Conceptually, Technology Readiness Index (TRI) positions readiness as an individual’s propensity to embrace and effectively use new technologies shaped by optimism, innovativeness, discomfort, and insecurity thereby influencing adoption and performance outcomes (Parasuraman, 2000). From a capability perspective, Human Capital Theory (HCT) explains how investments in competencies (knowledge, skills, abilities, attitudes) translate into productivity; when those competencies are coupled with high AI readiness, their effect on job performance is amplified (Becker, 1964). Empirically, biomedical engineers with greater AI readiness show higher performance in managing equipment and data-intensive systems, supporting a mediating role whereby readiness strengthens the link between technical competencies and job outcomes (Lee et al., 2021). In practice, engineers who are prepared to use AI tools achieve greater accuracy in patient monitoring and data management, converting competence into measurable performance more efficiently and reliably (Lee et al., 2021).

Skills Gap in Biomedical Engineering

The growing skills gap in artificial intelligence (AI) technology among biomedical engineers has become an emerging concern in both educational and professional literature. Although many biomedical engineering programs offer comprehensive curricula in fundamental medical and engineering disciplines, they often lack sufficient emphasis on the integration of AI technologies into practical applications (Wang & Li, 2020; Zhou et al., 2022). This deficiency limits graduates' ability to translate theoretical knowledge into practice, particularly in environments that require interaction with AI-based diagnostic, monitoring, and decision-support systems.

According to Wang and Li (2020), biomedical engineering students and practitioners typically possess strong conceptual understanding but insufficient hands-on experience with AI-powered tools widely used in healthcare operations. Similar findings by Zhang et al. (2022) and Wong et al. (2023) indicated that biomedical professionals face challenges in adapting to AI-driven workflows due to a lack of structured experiential learning and interdisciplinary exposure. From the perspective of Human Capital Theory (Becker, 1993), this gap represents an underinvestment in technological competencies that limits productivity and innovation potential in healthcare organizations.

To address this issue, educational programs should emphasize competency-based learning and simulations that reflect real-world healthcare applications, aligning with the Technology Readiness Index (TRI) perspective that individuals' readiness to embrace new technologies is shaped by training, exposure, and confidence (Parasuraman, 2000). Continuous professional development initiatives, such as modular AI training, internships, and applied research collaborations, can bridge this gap by enhancing both technical capability and technology adoption readiness (Lee et al., 2021; Wong et al., 2023). Strengthening these components will not only elevate the digital literacy of biomedical engineers but also ensure that the workforce remains responsive to the evolving demands of AI-integrated healthcare systems.

Implications for Training and Professional Development

The rapid adoption of artificial intelligence (AI) and digital technologies in healthcare underscores the urgent need for continuous training and professional development among biomedical engineers. In line with Human Capital Theory (HCT), investments in education, upskilling, and experiential learning enhance employees' productivity and innovation capacity by expanding their technical and cognitive competencies (Becker, 1993). In this context, structured AI-oriented training programs represent a strategic investment that strengthens the capability base of biomedical engineers, enabling them to operate effectively in data-driven healthcare systems (Wang & Li, 2020; Lee et al., 2021).

Wong et al. (2023) found that ongoing AI-related training significantly improves engineers' adaptability and readiness to integrate emerging technologies into clinical and technical practices. Similarly, Zhang et al. (2022) demonstrated that engineers with advanced AI literacy exhibit improved decision-making accuracy and operational performance in managing AI-enabled medical devices. These findings are aligned with the Technology Readiness Index (TRI) framework, which asserts that individuals' readiness to embrace technology can be cultivated through targeted exposure, skill reinforcement, and organizational support (Parasuraman, 2000). Thus, training programs that build confidence, reduce discomfort, and foster innovation contribute directly to higher AI readiness levels and job performance.

Beyond technical skill enhancement, organizational culture and leadership play pivotal roles in sustaining professional growth. Zhou et al. (2022) and Wong et al. (2023) emphasized that supportive management practices such as resource allocation, mentorship, and recognition to create a conducive environment for technology adoption and lifelong learning. From a human capital perspective, these institutional investments generate long-term returns by improving efficiency, reducing skill obsolescence, and promoting innovation within healthcare systems (Becker, 1993). Consequently, professional development initiatives must integrate both technical and behavioral components, focusing not only on how engineers use AI tools but also on how they perceive, trust, and champion such technologies in practice (Parasuraman, 2000; Lee et al., 2021).

Ultimately, the integration of AI training within biomedical engineering education and workplace development ensures that engineers remain agile and responsive to evolving technological demands. A holistic approach combining technical proficiency, digital readiness, and organizational learning bridges the gap between knowledge acquisition and practical application, reinforcing the mediating role of AI readiness in achieving sustainable job performance outcomes (Wang & Li, 2020; Wong et al., 2023; Zhang et al., 2022).

The Impact of AI on Biomedical Engineers' Job Performance

AI has become a transformative force in healthcare, significantly improving diagnostic precision, accelerating treatment processes, and enabling more efficient patient data management across clinical settings. From a Human Capital Theory (HCT) perspective, the integration of AI technologies enhances the productivity of biomedical engineers by augmenting their existing competencies which are knowledge, skills, abilities, and attitudes with data-driven decision-making capabilities (Becker, 1993). As organizations invest in developing AI-related competencies, the returns manifest in improved operational outcomes, innovation, and overall job performance (Wong et al., 2023; Zhou et al., 2022).

Empirical studies reinforce this relationship between AI readiness and job performance. Zhang et al. (2022) found that biomedical engineers trained in AI technologies performed more effectively in managing AI-powered medical equipment and clinical information systems. Their findings revealed that AI readiness directly contributes to greater operational accuracy, quicker decision-making, and enhanced problem-solving in data-intensive environments. Similarly, Lee et al. (2021) observed that engineers with higher levels of AI readiness not only achieved superior technical precision but also demonstrated better adaptability and teamwork in digital healthcare ecosystems. This outcome aligns with the Technology Readiness Index (TRI) framework, which posits that individuals with higher levels of technological optimism and innovativeness tend to adopt and utilize advanced technologies more effectively (Parasuraman, 2000). Biomedical engineers who exhibit greater readiness to integrate AI tools are thus better positioned to translate their technical competencies into tangible performance outcomes such as reduced error rates, faster troubleshooting, and improved system maintenance (Wang & Li, 2020; Zhang et al., 2022).

Consequently, enhancing AI readiness serves as a strategic lever to boost job performance among biomedical engineers. Targeted training, exposure to AI-integrated environments, and supportive organizational practices can elevate both cognitive and behavioral readiness toward technology adoption. When these readiness factors interact with existing technical competencies, they create a synergistic effect that maximizes efficiency, innovation, and professional growth within AI-driven healthcare systems (Becker, 1993; Parasuraman, 2000; Wong et al., 2023).

Proposed Integrated Framework

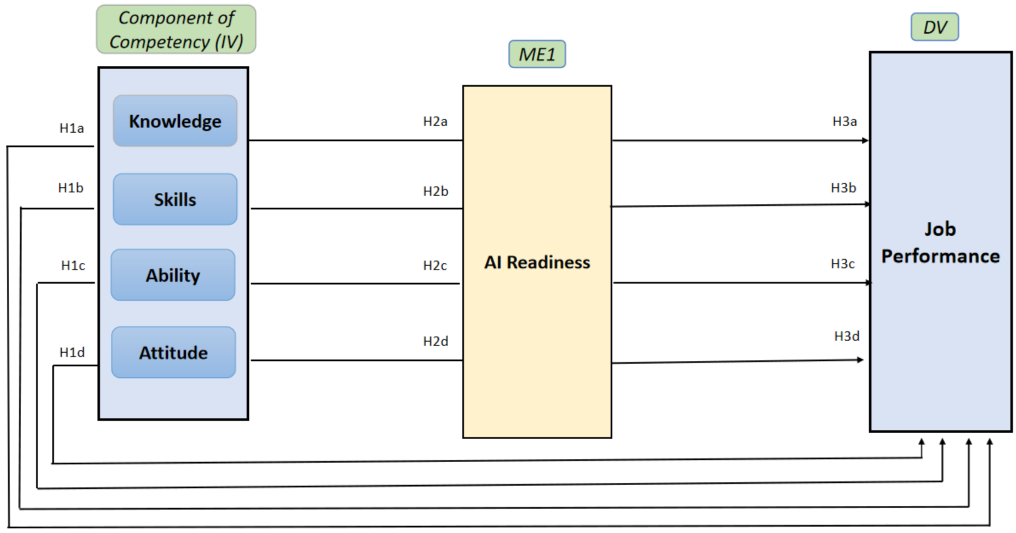

Figure 1.0 Framework

The framework in Figure 1 illustrates how competencies, AI readiness, and job performance are interconnected in the context of biomedical engineering. At the core of the framework, competencies (knowledge, skills, ability, and attitude) serve as the independent variable (IV). These competencies are essential in shaping a biomedical engineer's ability to perform tasks in the healthcare environment. Knowledge (H1a) provides the theoretical understanding of AI tools, while skills (H1b) enable the practical application of these tools. Ability (H1c) facilitates problem-solving and adapting to complex situations, and attitude (H1d) influences openness to new technologies. The framework suggests that the strength of these competencies is foundational in determining how effectively engineers can work with AI systems in healthcare settings (Wang & Li, 2020).

The key mediating factor in the framework is AI readiness (ME1), which reflects the degree to which an individual is prepared to integrate AI tools into their daily work. AI readiness is critical because it enhances the relationship between the competencies of biomedical engineers and their job performance (DV). In the model, AI readiness functions as a mediator (H2a, H2b, H2c, H2d) that strengthens the impact of competencies on job performance. Engineers who possess a high level of AI readiness are better able to leverage their technical knowledge and skills to perform tasks more efficiently and effectively in a technology-driven environment. In other words, AI readiness makes the competencies more valuable by enabling engineers to utilize AI tools to their full potential (Lee et al., 2021).

Finally, job performance (DV) is the dependent variable, representing the goal of the integration of competencies and AI readiness. The framework posits that biomedical engineers with higher AI readiness and strong competencies will exhibit better job performance (H3a, H3b, H3c, H3d). This performance could manifest in various forms, such as improved decision-making, greater accuracy in medical procedures, and enhanced efficiency in managing AI-driven medical systems. Therefore, the framework suggests that fostering both competencies and AI readiness is key to enhancing the performance of biomedical engineers, especially as the healthcare industry continues to adopt more AI-based technologies (Zhang et al., 2022).

This integrated framework provides valuable insights into the relationship between competencies, AI readiness, and job performance in biomedical engineering. It highlights the need for educational and training programs to focus on developing both core competencies and AI readiness to equip biomedical engineers for the challenges of the evolving healthcare landscape. By aligning competencies with AI readiness, biomedical engineers can improve their job performance, ultimately leading to better healthcare outcomes (Wong et al., 2023).

Discussion

This study aimed to examine the relationship between competencies, AI readiness, and job performance among biomedical engineers, as well as to test the role of AI readiness as a mediating factor in the relationship between competencies and job performance. Based on the proposed framework, the findings of this study indicate that both competencies and AI readiness significantly influence job performance, with AI readiness acting as a mediator that strengthens the effect of competencies on job performance. Competencies (knowledge, skills, ability, and attitude) were found to be crucial in determining the effectiveness of biomedical engineers in performing their tasks. Engineers with strong technical knowledge and practical skills are more effective in adapting to technology-driven healthcare environments. AI readiness, as expected, plays a key role in enhancing the relationship between competencies and job performance. Biomedical engineers who are more ready to use AI technology are not only more efficient in utilizing these tools but also able to solve problems more accurately and quickly, improving their overall job performance.

The findings of this study align with previous research indicating that AI readiness improves the effectiveness of technology in the workplace. For example, Lee et al. (2021) found that engineers with higher AI readiness tended to perform better in managing medical equipment that required complex data processing and fast decision-making. Similarly, Mahmod et al. (2024) emphasized that while biomedical engineering students possess strong theoretical knowledge, the lack of practical exposure to AI tools creates a skills gap that needs to be addressed through more intensive training in this area.

Another important aspect of this study is the skills gap among biomedical engineers in utilizing AI technologies. For example, Wang and Li (2020) found that biomedical engineering programs often focus on technical theory without providing sufficient practical training in AI applications. This suggests that while biomedical engineers may have the necessary knowledge and skills in traditional areas, they require more hands-on training focused on new technologies to bridge the existing skills gap.

Conclusion

This study provides strong evidence of the role of AI readiness in enhancing job performance through the competencies possessed by biomedical engineers. It demonstrates that AI readiness acts as a critical mediator, improving the application of technical knowledge, skills, ability, and attitude in a healthcare environment driven by digital technologies. Therefore, it is essential to equip biomedical engineers with both digital competencies and the readiness to utilize AI technologies as part of their training. This dual focus will better prepare them to face the challenges of an increasingly technology-driven healthcare environment. Furthermore, this study offers valuable implications for curriculum development in biomedical engineering education. Educational institutions should integrate AI readiness into their training programs to ensure that future engineers are well-equipped to adapt to and leverage AI tools. Professional training programs for current biomedical engineers should also prioritize developing AI readiness to enhance job performance in high-tech environments. For future research, reliability testing will be conducted to further examine the relationships between the independent variable (competencies), the mediator (AI readiness), and the dependent variable (job performance). This will provide additional validation for the framework and deepen our understanding of how these variables interact in real-world settings.

Theoretical and Contextual Contribution

This research contributes theoretically by integrating Human Capital Theory (Becker, 1993), the AMO model (Appelbaum et al., 2000), and the KSAA competency framework into a single conceptual model that explains how competencies are translated into job performance only when mediated by AI readiness. Unlike previous studies that examine competencies or digital readiness independently, this study positions AI readiness as a mechanistic pathway that strengthens the competency performance relationship in AI-enabled work environments. Contextually, this study advances knowledge within the biomedical engineering and digital healthcare domain by validating an instrument that reflects the unique role of biomedical engineers in smart hospital ecosystems where AI, automation, and data analytics shape daily work routines. The findings demonstrate that competency alone is insufficient unless engineers have confidence, willingness, and preparedness to use AI-based technologies. Thus, the study contributes new insights on how the healthcare sector, universities, and policymakers can design targeted interventions (training, curriculum enhancement, and AI capability frameworks) to reduce the industry and academia competency gap and accelerate workforce readiness in the era of healthcare digitalisation.

Significance of the Study

This study makes an important contribution to the digital healthcare research landscape by demonstrating the critical role of AI readiness as a mediator between competencies and job performance among biomedical engineers. While previous studies have examined competencies or digital readiness separately, very few explain how competencies are transformed into actual job performance within AI-driven hospital environments. This study addresses this gap by developing and validating a multidimensional model that integrates competencies (knowledge, skills, abilities, and attitudes), AI readiness, and perceived organisational support. The findings clearly indicate that competencies alone are insufficient without AI readiness, biomedical engineers may not be able to apply their skills effectively in real working environments.

From the perspective of healthcare operators, companies, or policymakers, the findings offer a practical diagnostic framework to assess the preparedness and capability of biomedical engineers working in digital and AI-enabled hospitals. The validated instrument can be used to identify competency gaps, design targeted training and upskilling strategies, and plan workforce development initiatives based on actual organisational needs. Improving AI readiness leads to tangible operational benefits, such as fewer technical errors, faster decision-making, improved patient safety, and more efficient equipment management.

For universities and training providers, this study serves as evidence-based guidance for curriculum enhancement. The competency AI readiness job performance model can inform curriculum design so that learning outcomes align with current industry requirements, especially in smart hospital and Industry 4.0 environments. It ensures that academic programs do not focus solely on theoretical knowledge but also include practical exposure to AI-driven systems, data analytics, and digital monitoring tools. Reducing the academia–industry competency gap will improve graduate employability and workforce readiness.

For biomedical engineers, students, and early career professionals, this study provides a clear developmental roadmap. It enables individuals to understand that success in the digital healthcare landscape requires not only technical proficiency but also digital literacy, analytical thinking, and confidence in interacting with AI-based systems. With this clarity, they can proactively plan their professional growth and position themselves as strategic contributors rather than merely technical support personnel.

At the national and policy level, this study contributes empirical evidence that supports national digital healthcare and Industry 4.0 transformation agendas. The findings may be used to inform workforce planning, accreditation requirements, training investment decisions, and policy formulation related to AI capability development in the healthcare sector. In summary, this study confirms that digital transformation in healthcare cannot succeed through technology investment alone success depends on people's readiness to utilise the technology. By proving the mediating role of AI readiness, this research not only advances academic understanding but also provides a practical tool to help develop a future-ready healthcare workforce.

Future Research Directions

This study has made significant contributions to understanding the role of AI readiness in enhancing job performance through the competencies possessed by biomedical engineers. However, several avenues for future research can be explored to strengthen and expand the findings of this study.

Reliability Testing and Longitudinal Studies

In addition to the proposed reliability testing, future research should incorporate longitudinal studies to further validate the relationships between competencies, AI readiness, and job performance. Longitudinal research can provide valuable insights into how these factors evolve over time and their sustained impact on job performance in the healthcare industry. By tracking biomedical engineers over a longer period, researchers can assess how their competencies and AI readiness develop as they gain more experience and exposure to AI technologies. Such studies would help identify whether the improvements in job performance observed during initial training and adoption of AI technologies are sustained over time, or if additional support and training are needed as the technology continues to evolve. Moreover, longitudinal studies can help uncover long-term effects, such as the continuous adaptation of competencies in response to emerging AI tools or shifts in healthcare practices driven by technological advancements.

By incorporating these longitudinal perspectives, future research could offer more robust evidence for the long-term benefits of AI readiness and competency development, helping to refine training and professional development programmes to ensure their ongoing effectiveness. This will also provide a more comprehensive understanding of how biomedical engineers can continue to improve their job performance and adapt to an ever-changing healthcare landscape.

i. **Examining Other Factors Affecting Job Performance**

While AI readiness plays a crucial role in job performance, future research could explore other factors that may influence job performance in biomedical engineering. These may include factors such as organisational leadership, organisational support for technology adoption, and the work environment that may affect how effectively biomedical engineers can apply their competencies and AI technology in practice.

ii. **Comparative Studies Across Countries and Organizations**

Research involving multiple countries and different healthcare organisations is essential. Differences in technological advancement, organisational culture, and healthcare systems may provide varied insights into AI readiness and job performance. Comparative studies will offer a broader understanding of how these factors influence the application of the proposed model in diverse contexts.

iii. **Development of AI Training Programs for Biomedical Engineers**

Future research could also focus on developing effective AI training programmes for biomedical engineers. Such research could involve experimental or intervention studies to evaluate the effectiveness of various training programmes aimed at strengthening digital competencies and readiness to use AI technologies.

Ethics Approval

Ethical considerations were meticulously adhered to, with approval granted by the UTM Research Ethics Committee (UTM REC) UTM Ethics Approval on July 30, 2025, Bill 8/2025. Approval number: UTMREC-2025-160 verbal and written feedback.

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