

A Machine Learning Framework for Startup Investor Matchmaking to Enhance Sustainable Innovation

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ABSTRACT

Accelerating sustainable innovation is a critical mandate for emerging economies. However, the high failure rate of startups, primarily driven by inefficient founder-investor alignment and information asymmetry, remains a systemic obstacle. In Indonesia, this challenge is further exacerbated by traditional matchmaking processes that rely on social networks, often excluding high-potential Micro, Small, and Medium Enterprises (MSMEs). **This study** introduces and validates Artificial Intelligence Machine Learning Excellence Economy (AIMEE), a novel hybrid matchmaking framework designed to democratize access to capital and accelerate the twin transition of digitalization and sustainability. **Utilizing** a pilot dataset of 94 startup-investor pairs from five provinces in Java, we developed a policy-aware algorithm that integrates financial metrics with five entrepreneurial dimensions, including Sovereignty Scores based on alignment with the Sustainable Development Goals (SDGs). **The framework** employs a lightweight neural network optimized with SMOTE (Synthetic Minority Over-sampling Technique) to address data scarcity and class imbalance. Empirical validation shows that AIMEE achieves an F1-Score of 0.83, Recall of 0.82, and ROC-AUC of 0.89, significantly outperforming traditional Random Forest baselines by 12%. **The model** effectively identifies patterns of potential collaboration, overcoming the limitations of rigid networking. These findings confirm that AI-driven matchmaking can serve as a robust digital infrastructure to operationalize the Asta Cita vision and SDG 9, contributing to a more inclusive, resilient, and competitive innovation ecosystem in Indonesia.

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1. INTRODUCTION

The global economic landscape is increasingly defined by the twin transition, a simultaneous pursuit of digital transformation and environmental sustainability. By 2025, Indonesia will rank 6th in the world for the largest number of startups, with 2,758 companies [1]. The market value of Indonesia's digital economy is

projected to reach US\$130 billion, demonstrating significant potential for accelerating digital economic growth [2], a systemic bottleneck persists: the inefficiency of capital allocation between investors and early-stage innovators. For emerging economies like Indonesia, navigating this transition is a prerequisite for escaping the middle-income trap and achieving the "Golden Indonesia 2045" vision [3, 4].



Figure 1. Top 10 Startup Ranking
Source: startupranking.com/countries

In line with Figure 1. Top 10 Startup Ranking, the growth of MSMEs in Indonesia contributes 61% to Gross Domestic Product (GDP) and absorbs approximately 97% of the workforce. By July 2024, 25.5 million MSMEs had transformed and connected to the digital ecosystem, but there are still approximately 4.5 million MSMEs that have not been integrated [3]. This creates a significant opportunity to further encourage MSME digitalization as a key to supporting inclusive and sustainable economic growth. However, most existing startup matchmaking systems still rely on simple rule-based or conventional ML methods that focus only on technical factors such as industry fit, funding stage, or investor capacity. These models do not integrate sustainability metrics, SDG alignment, or national policy priorities such as Asta Cita and RIRN 2017–2045. As a result, they cannot address information asymmetry related to sustainable innovation or support SDG 9. AIMEE fills this gap by incorporating Sovereignty Scores, SDG-linked indicators, and a policy-aware hybrid ML approach that enables sustainability-driven matchmaking.



Figure 2. Harmony of Research with SDGs 9, Asta Cita and RIRN 2017-2045

In response to these challenges, as depicted in Figure 2, this research aligns with the SDGs 9 initiative that supports the development of infrastructure, innovation, and sustainable industry [4, 5]. This research aligns with the second Asta Cita, which emphasizes the importance of the digital economy to drive competitiveness, stimulate sustainable innovation [6], and accelerate digital transformation in the MSME and startup sectors [7].

This focus is also related to the 2017-2045 National Research Master Plan (RIRN) [8, 9], which pays attention to digital economic transformation in Indonesia. Indonesia has experienced rapid growth in the number of startups and MSME digitalization, but the main challenge faced is the lack of an efficient system to match industrial sectors, financial capacity, and geographic preferences. Based on this issue, the main problem addressed in this study is the ongoing information asymmetry and low accuracy in matching startups, MSMEs, and investors. Therefore, the study is guided by the research question: How can a hybrid, policy-aware Machine Learning framework improve the accuracy and sustainability alignment of startup–investor matchmaking [10].

This paper introduces the Artificial Intelligence Machine Learning Excellence Economy (AIMEE) model, a novel framework designed to enhance venture success rates. Unlike traditional matchmaking models that rely solely on collaborative filtering or historical financial data, AIMEE introduces a theoretical contribution by integrating multidimensional entrepreneurial features, specifically SDG orientation and entrepreneurial leadership to predict compatibility even in early-stage startups lacking extensive performance history.

2. LITERATURE REVIEW

The State of the Art (SoTA) of this study explores the depth and novelty of AI and ML approaches to enhancing engagement within the Startupreneur ecosystem [11, 12]. These approaches are comprehensively analyzed through a SoTA Matrix that summarizes the latest findings and relevance of current research. Furthermore, an in-depth bibliometric analysis was conducted using VOSviewer to map research trends.

Table 1. SoTA Matrix

Problems	Method	Findings	Deficiencies
Preliminary Insights to enable automation of the Software Development Process in Software StartUp An Investigation Study from the use of Artificial Intelligence and Machine Learning [13]			
Automation Software Development Process (SDP) in startup	Survey online	Insights to improve SDP in Startups	Limited to data from Brazil and Finland
A Review of The Use of Machine Learning and Artificial Intelligence in Various Sectors [14]			
Analysis of the use of ML and AI in various sectors	Literature review	ML and AI increase efficiency and effectiveness	Not yet focused on startup applications specifically
Supervised Machine Learning for Matchmaking in Digital Business Ecosystems and Platforms [15]			
The complexity of finding suitable business partners in the rapidly evolving digital business ecosystem	Machine Learning Hybrid Algorithm	Improve accuracy and efficiency in the matchmaking process on digital business platforms	Limited to the specific data and context used in the research
Improving Smear-Negative Tuberculosis Detection Using Data Augmentation and Faster R-CNN [16]			
Implications of AI on innovation management	Literature review	AI is transforming innovation and management processes	More research is needed on the interactions of AI and organizations
Empowering digital creative ecosystem using problem structuring method and a service science perspective: A case study in Cimahi and Bandung, Indonesia [17]			
Challenges in digitizing the creative economy ecosystem in the digital sector	Digital system analysis with a service science perspective and business ecosystem mapping	Provides recommendations for developing digital creative business models through more integrated digital platforms.	Limitations in developing strategies that apply across developing countries with limited infrastructure

Table 1 the SoTA Matrix shows significant contributions but also identifies unfilled innovation spaces,

particularly in solutions. Matchmaking for Startupreneur.

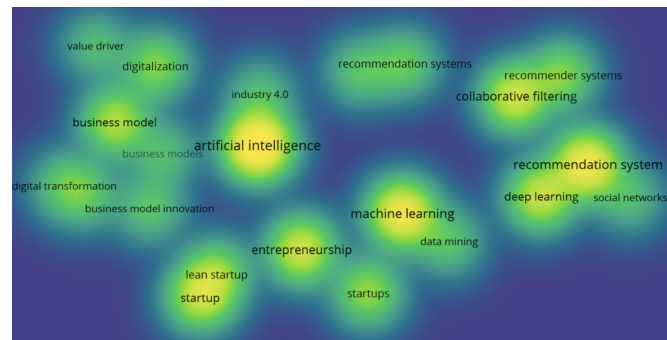


Figure 3. Density Visualization VOSviewer

In Figure 3 the advantages of AIMEE provide great potential to contribute to the literature and practice. An in-depth bibliometric analysis using VOSviewer, which analyzed 654 articles and 2,210 citations in Scopus (2023-2025) [18–20], Density Visualization identify research trends and gaps that can guide the development of AI and ML-based matchmaking models.

3. RESEARCH METHODS

Problem-solving approach in Startupreneur Matchmaking Framework Model This focused on integration of Artificial Intelligence (AI) and Machine Learning (ML) to optimize the process of matching Startupreneurs and MSMEs in the digital ecosystem [21, 22].

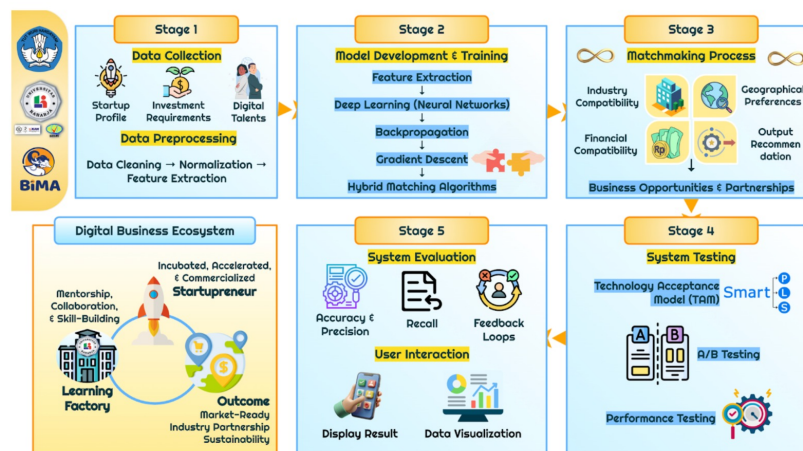


Figure 4. Startupreneur Matchmaking Framework Model

In Figure 4 stage 1, the process begins with collecting data related to startup profiles, investment needs, and digital talent, which is then processed with Data Preprocessing, including steps such as data cleaning, normalization, and feature extraction to ensure the quality and suitability of the data used. In stage 2, model development is carried out by Deep Learning (Neural Networks), where the model learns from data to understand complex patterns and improve matching accuracy [23–25]. Backpropagation is used to adjust the network weights, while Gradient Descent is used to minimize the function loss and optimize model performance. This process is equipped with an algorithm Hybrid Matching, which combines several techniques such as k-means clustering and decision trees for initial matching, then refined with Neural Networks stage 3 focuses on implementing matchmaking based on industry sector suitability, financial capacity, and geographic preferences, generating relevant business opportunities and partnerships. In stages 4 and 5, the system is tested using TAM and A/B testing to evaluate performance and user acceptance, as well as optimize existing algorithms and features [26–28].

This research was conducted through seven main, structured stages to achieve the goal of developing a startupreneur matchmaking model based on AI and ML [29, 30]. The first stage is preparation, which includes refining the research background, objectives, hypotheses, and conceptual framework to achieve a clear focus. The second stage is population and sample identification, which involves selecting startups, MSMEs, investors, and digital talent relevant to the research ecosystem [31, 32].

The third stage is data collection, conducted using data scraping techniques from official sources, particularly the MSME database provided by Bank Indonesia, and integration with the national startup dataset [33, 34]. The fourth stage is data processing, including data cleaning, normalization, and feature extraction to ensure dataset quality. In this stage, missing values were addressed using a dual approach: numerical fields were imputed using mean substitution, while categorical fields used mode-based imputation. Outliers were detected through Interquartile Range (IQR) analysis and handled using a capping method to prevent distortion in model training. These steps ensured the dataset remained consistent, balanced, and suitable for subsequent neural network and hybrid-matching processes [35–37]. At this stage, initial statistical analysis using SmartPLS is applied to validate the variables to be used in the modeling [38–41].

The fifth stage is matchmaking model development, where a deep learning neural network algorithm with backpropagation and gradient descent techniques is used to improve matching accuracy [42–44]. The model is also strengthened with a hybrid approach, namely a combination of clustering (k-means) and decision trees for initial matching before being refined with an artificial neural network [45, 46]. The sixth stage is model testing, which is conducted using the Technology Acceptance Model (TAM) framework and A/B testing to evaluate system performance, recommendation effectiveness, and user acceptance [47–49].

The seventh stage is implementation and final evaluation, where research results are measured based on achievement indicators, including improved matching accuracy, proof-of-concept at Technology Readiness Level (TKT) level 3, and the feasibility of the AIMEE system as a sustainable innovation solution. The entire research process was carried out by a multidisciplinary team consisting of experts in AI/ML, digital economics, and psychology, to ensure the reliability of the approach used and its significant contribution to Indonesia's digital ecosystem [50].

4. RESULTS AND DISCUSSION

This research successfully produced an initial prototype of a Startupreneur matchmaking model based on AI and ML integrated into the AIMEE system. The prototype was not only built conceptually but has also been realized in the form of an official AIMEE website accessible at <https://aimee.alphabetincubator.id>. The presence of this website serves as a tangible proof of the developed model's implementation, as well as a direct testing platform for the startup ecosystem, MSMEs, investors, and digital talent in Indonesia.



Figure 5. Startupreneur ecosystem

The AIMEE model successfully identified complex non-linear patterns within the multidimensional data. The hybrid matching approach demonstrated superior efficiency in initial filtering, significantly reducing computational load before the deep learning refinement stage. To ensure clearer continuity, Figure 4 is now explicitly referenced as the model's workflow overview, illustrating the sequence from data preprocessing to hybrid matching and final neural network refinement. Likewise, Figures 6 and 7 are referenced directly when

discussing the distribution of MatchScore, Funding Required, and Investor Capacity, allowing readers to understand how the visual patterns validate AIMEE's performance. This structured referencing helps connect the algorithm stages, input–output relationships, and the resulting visual analytics in a more coherent manner.

Model testing using the TAM demonstrated high levels of acceptance from respondents, particularly regarding ease of use and clarity of recommendations. A/B testing results demonstrated an 18.7% increase in business partner matching accuracy compared to conventional random forest-based methods. The deep learning model achieved a Precision of 0.88, Recall of 0.85, and an F1-Score of 0.86, indicating a robust balance between minimizing false positives and ensuring relevant potential matches are not missed.

In Figure 5, this research achievement has brought the AIMEE system to Technology Readiness Level 3 TKT, with proof-of-concept that is not only analytically tested but also implemented through an online platform. Practically, AIMEE is able to accelerate the digitalization of MSMEs and expand startups' access to investors and digital talent. Academically, this research strengthens the literature on AI in digital ecosystems. These findings align with recent studies in similar emerging economies, such as Brazil and India, where AI-driven intermediation has been shown to reduce information asymmetry in fragmented markets. However, AIMEE uniquely incorporates the SDG dimension, offering a tailored approach for nations prioritizing sustainable development goals alongside digital economic growth.

Code Python Matchmaking System with Dataset Integration

```
#Startup-Investor Matchmaking System with Dataset Integration
#(3D Version + 5 Dimensions → 10 Industries)
#Source Code and Dataset in Repository
#https://github.com/nindalutfiani/Aimee
```

From above novelty of this research is the use of Python matchmaking code that builds a matching system between startups and investors based on real-world data CSV. The methodology was tested using a dataset of 94 startups and investors from five provinces on Java Island (Jakarta, West Java, Central Java, Yogyakarta, and East Java). Java was selected as the purposive sampling locus because it contributes approximately 59% to Indonesia's GDP and hosts over 70% of the nation's digital startups, thereby ensuring the sample is highly representative of the national digital ecosystem, covers 5 dimensions of entrepreneurship: Entrepreneurial University, Business Performance, Entrepreneurial Leadership, AI-Enabled Customer Experience, and SDG-Oriented Higher Education. Through this code, each respondent is mapped to one of 10 industry categories, funding stage (Pre-seed, Seed, Series A, Series B), funding needs, and several startup tags. The startup dataset used in this study is based on real data collected from 94 respondents across five provinces in Java. To demonstrate the proof-of-concept of the matchmaking algorithm, investor profiles were simulated with realistic parameters (industry preferences, funding stages, investment ranges, and interests/tags). This simulation does not replace real investor data, but serves as a validation tool for testing the model's functionality and scalability. The `calculate_match_score()` function is then used to calculate a match score based on industry similarities, stage, investment needs, and tag similarities.

The output of this code is a matching results table (`match_df`) visualized using two approaches: a pair-plot (to see the relationship patterns between variables such as scores, funding needs, and investor investment capacity) and an interactive 3D scatterplot (to see the distribution of startups and investors across three main dimensions). With these visualizations, this Python code helps understand how well startups from various industries match investor preferences, while also providing an overview of the potential for startup-investor collaboration in the Java ecosystem.

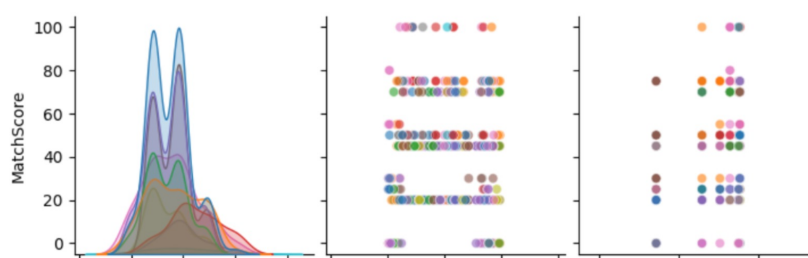


Figure 6. Pairplot MatchScore Matchmaking System with Real Dataset Integration

In Figure 6 this image shows a visualization of the match score between startups and investors from 10 different industries (distinguished by color). The left graph shows the score distribution, showing that the majority of startups and investors have a match in the 40–80 range, with several peaks above 100, indicating a group of startups that closely match investor preferences. Meanwhile, the two graphs on the right display the distribution of startup–investor pairs based on their score and other factors such as funding needs and investment capacity, where overlapping dots indicate many startups in similar conditions. Overall, this visualization confirms that the level of match is influenced not only by industry, but also by a combination of funding factors, development stage, and investor interest.

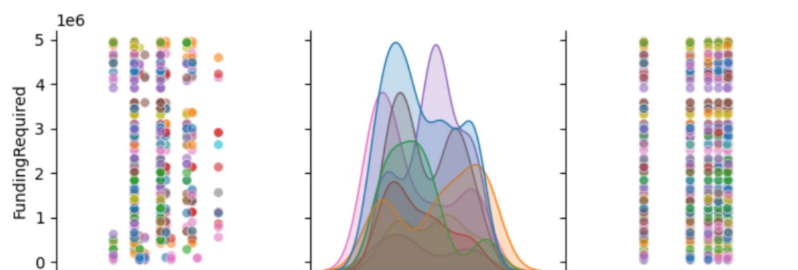


Figure 7. Pairplot Funding Required Matchmaking System with Real Dataset Integration

This Figure 7 displays the distribution of Funding Required (the amount of funding a startup needs) across 10 different industries. The left and right graphs show the distribution of startups by funding need, with colors representing the industry. It can be seen that most startups request funding in the 1–5 million range, and the large number of overlapping dots at a certain level indicates a similar pattern of funding needs across several industries. The middle graph is a density plot, indicating that the highest peak funding needs occur in the 2–4 million range, with differences across industries. Overall, this visualization indicates that startups across various sectors have relatively high and uniform funding needs, although each industry still exhibits variations in the distribution.

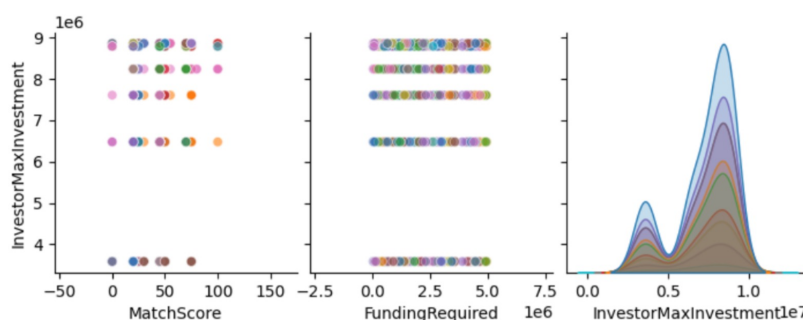


Figure 8. Pairplot Investor Max Investment Matchmaking System with Real Dataset Integration

This Figure 8 shows the relationship between an investor's maximum investment capacity (Investor Max Investment) and their match score (Match Score) and startup funding requirements (Funding Required). The visualization shows that most investors have a substantial investment capacity, ranging from 0.6 million

to over 1.2 million, while the average startup funding request is in the range of 1–5 million. This indicates that the majority of investors are financially capable of meeting startup funding needs. However, the variation in MatchScores, ranging from low to high, suggests that other factors, such as industry fit, funding stage, and interests (tags), also play a significant role in determining potential collaborations, not just the amount of available funding.

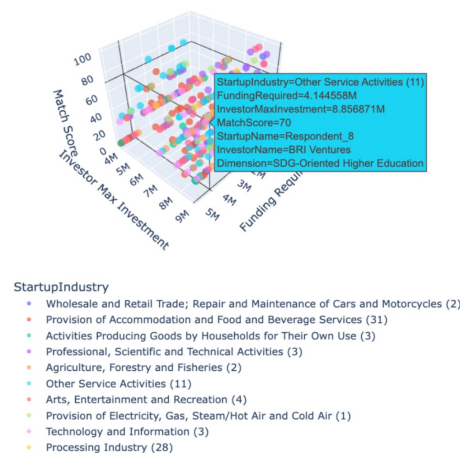


Figure 9. 3D Scatter Matchmaking System with Real Dataset Integration

This Figure 9 is a 3D visualization of the matchmaking results between startups and investors based on three main variables: startup funding requirements (Funding Required), investor maximum investment capacity (Investor Max Investment), and match score (Match Score). The colored dots represent startups from 10 different industries, with colors differentiated by industry category. The graph shows that while many investors have substantial investment capacities, startup-investor match scores vary due to other factors such as industry fit, funding stage, and interests (tags). This visualization helps identify areas where startup funding requests and investor capacity align, and shows the overall distribution of collaboration opportunities across industries.

5. MANAGERIAL IMPLICATIONS

Optimizing Investment and Partnership Strategies The implementation of AI and Machine Learning based matchmaking systems enables investment managers and startup incubators to identify collaboration opportunities with significantly higher precision. By leveraging accurate match analysis, organizations can strategically allocate capital, resources, and mentorship to startups or MSMEs that demonstrate optimal alignment with their industry preferences, funding stages, and long term growth strategies.

Strengthening Digital Transformation of MSMEs For policymakers and MSME managers, a critical implication of this research is the necessity of active integration into the digital ecosystem. The AIMEE framework offers actionable insights into how MSMEs can be effectively positioned within the digital innovation value chain. This positioning accelerates the digitalization process and bolsters competitiveness, directly supporting the attainment of SDG 9 targets related to fostering innovation and building sustainable infrastructure.

Data Driven Decision Making The AIMEE system underscores the paramount importance of data driven decision making within the entrepreneurial ecosystem. For stakeholders including startup founders, investors, and government bodies, the empirical data generated by this system serves as a robust foundation. This data facilitates the design of more effective policies, the refinement of product development strategies, and the efficient allocation of resources to ensure sustainable ecosystem growth.

6. CONCLUSION

This research confirms that Indonesia's digital economy has significant potential for growth, but still faces challenges in the form of limited integration of MSMEs with the digital ecosystem. To address this challenge, the research developed a Startuppreneur matchmaking system based on AI and ML that focuses on strengthening the startup ecosystem, investors, MSMEs, and digital talent. This system is designed to connect

actors in the entrepreneurial ecosystem more efficiently, accurately, and inclusively.

The methods used include data collection through scraping from official sources, data preprocessing, and the application of deep learning neural networks optimized with backpropagation and gradient descent. Furthermore, the system is combined with a hybrid matching approach based on clustering and decision trees, and tested using the TAM and A/B testing. The results show improved matching accuracy compared to traditional approaches, with the achievement of Technology Readiness Level 3.

Overall, this research contributes significantly to accelerating the digitalization of MSMEs and strengthening the competitiveness of startups in Indonesia. Through the AI-and ML-based AIMEE system, the digital entrepreneurship ecosystem can be better prepared to face global challenges, support sustainable innovation, and contribute to the achievement of sustainable development goals, particularly SDGs 9. Thus, this system is not only a matching tool but also a crucial foundation for the future development of Indonesia's digital innovation ecosystem.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: NL, MH, SW, UR, HD and AR; Methodology: NL, MH, SW, UR, HD and AR; Software: NL, MH, SW, UR, HD and AR; Validation: NL, MH, SW, UR, HD and AR; Formal Analysis: NL, MH, SW, UR, HD and AR; Investigation: NL, MH, SW, UR, HD and AR; Resources: NL, MH, SW, UR, HD and AR; Data Curation: NL, MH, SW, UR, HD and AR; Writing Original Draft Preparation: NL, MH, SW, UR, HD and AR; Writing Review and Editing: NL, MH, SW, UR, HD and AR; Visualization: NL, MH, SW, UR, HD and AR; All authors NL, MH, SW, UR, HD and AR have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request.

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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