Jupiter: Jurnal Pendidikan Terapan
Homepage : https://journal.diginus.id/jupiter/index
Email: jurnalpendidikanterapan@gmail.com

p-ISSN : 2985-3214; e-ISSN : 2964-3171
Jupiter, Vol. 4, No. 3, July 2026
Page 13-22

Preventive Education for Cognitive Decline from Ibn Sina's Perspective: Integrating Intellect, Memory, Lifestyle, Mental Health, and Spirituality

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ARTICLE INFO

Article history:
Submitted: April 19, 2026
Final Revised: May 31, 2026
Accepted: May 31, 2026
Published: Juny 20, 2026

Keywords:
Ibn Sina; Cognitive Decline; Preventive Education; Intellect; Spirituality.

ABSTRACT

This article aims to reconstruct Ibn Sina's thought on the preservation of physical health, intellect, memory, mental health, and spirituality, and to analyze its relevance to preventive education for cognitive decline before the onset of dementia. This study employs qualitative library research using a hermeneutic-reconstructive conceptual analysis. Primary sources consist of Ibn Sina's works on medicine, the soul, intellect, and religious thought, while secondary sources include scholarly articles, WHO guidelines, and reports by the Lancet Standing Commission on dementia prevention, intervention, and care. Ibn Sina did not develop a concept of dementia in the modern neurological sense. Nevertheless, his ideas on health preservation (ḥifẓ al-ṣiḥḥah), physical activity, nutrition, sleep, psychological conditions, intellect, memory, and spirituality provide a relevant framework for preventive education. The spiritual dimension encompasses the immaterial nature of the soul, spiritual well-being as the perfection of the theoretical and practical intellect, and the practices of worship and self-knowledge. Physical activity, healthy dietary patterns, cognitive stimulation, and social engagement correspond to WHO recommendations, although the levels of supporting evidence vary. Meanwhile, the role of spirituality is indirect, and direct empirical evidence remains limited. Preventive education can be developed around five pillars: maintaining physical health through physical activity and healthy lifestyle practices; preserving intellectual capacity through lifelong learning; strengthening memory through meaningful learning; promoting psychological and social well-being through stress management and community engagement; and cultivating spirituality as a complementary dimension that supports meaning in life and inner peace. This study extends the interpretation of Ibn Sina's thought beyond the history of medicine into the field of preventive education by explicitly incorporating the spiritual dimension and critically examining it in light of contemporary evidence. Ibn Sina's thought can be reconstructed as a philosophical foundation for lifelong health education, while modern medical evidence remains the primary basis for determining the effectiveness of preventive interventions.

Doi: https://doi.org/10.61255/jupiter.v4i3.963

INTRODUCTION

Preventive education plays an increasingly important role in addressing cognitive decline across the lifespan by promoting health knowledge, protective attitudes, and sustainable lifestyle behaviors. Dementia is characterized by progressive cognitive deterioration affecting memory, reasoning, communication, and daily functioning. Although aging is a major risk factor, dementia is not an inevitable consequence of growing older. Several potentially modifiable risk factors, including hypertension, diabetes, physical inactivity, sleep disturbances, and social isolation, have been identified (World Health Organization, 2026a). Furthermore, the Lancet Standing Commission identified 14 modifiable risk factors, estimating that their effective management could prevent or delay approximately 45% of dementia cases (Livingston et al., 2024).

These findings emphasize the importance of adopting a life-course approach to preventive health education before cognitive impairment develops. Within Islamic intellectual traditions, Ibn Sina (Avicenna, 980–1037 CE) provides a philosophical foundation for understanding health preservation as an essential aspect of human development. In al-Qānūn fī al-Ṭibb (The Canon of Medicine), he conceptualizes medicine as encompassing both health preservation and disease treatment (Ibn Sina, 2014; Pajević, Pajević, et al., 2021). His principle of ḥifẓ al-ṣiḥḥah emphasizes maintaining bodily equilibrium (mizāj) through physical activity, balanced nutrition, adequate sleep, and environmental regulation (Al-Masoud, 2025). His discussion of physical exercise (riyāḍah) further highlights the preventive significance of regular and appropriately regulated movement (Ercan & Örsçelik, 2022).

Beyond physical health, Ibn Sina's philosophical framework integrates intellect, memory, psychological well-being, and spirituality. His classification of internal sensory faculties (al-ḥawās al-bāṭinah), including estimation (al-wahm), imagination, and memory (al-ḥāfiẓah), distinguishes brain-dependent cognitive functions from the immaterial rational soul (al-nafs al-nāṭiqah) (Gutas, 2020; Rahman, 1959). This holistic perspective emphasizes the relationship between intellectual development, bodily health, moral cultivation, and spiritual well-being (Arroisi et al., 2024). Consequently, his philosophy offers a conceptual basis for integrating self-regulation, healthy habits, and character development into lifelong preventive education (Zabidi et al., 2025).

Nevertheless, Ibn Sina's thought must be interpreted within its historical context. Although he described disorders affecting memory, reasoning, and imagination, these classical classifications cannot be equated with modern neurological diagnoses or Alzheimer's disease mechanisms (Taheri-Targhi et al., 2019). His contribution therefore lies primarily in providing philosophical and pedagogical insights rather than clinically established preventive interventions. Contemporary strategies must remain grounded in scientific evidence and public health recommendations (Stephen et al., 2021).

Previous studies have explored Ibn Sina's contributions to medical history and Islamic health philosophy (Chamsi-Pasha & Chamsi-Pasha, 2020), as well as his perspectives on the soul, intellectual perfection, and spiritual well-being (Bakhshandeh-Bali, 2021; Stephen et al., 2021) However, the systematic integration of these dimensions into a preventive education framework addressing cognitive decline remains insufficiently explored. In particular, limited attention has been given to connecting Ibn Sina's concepts of health preservation, intellect, memory, mental health, and spirituality with contemporary evidence concerning modifiable dementia risk factors. This represents the central research gap addressed in the present study.

Accordingly, this study aims to reconstruct Ibn Sina's philosophical and medical thought as a foundation for preventive education addressing cognitive decline. Specifically, it identifies five interconnected dimensions of his thought, examines their relevance to contemporary scientific evidence, distinguishes historical concepts from modern medical interpretations, and formulates an integrative framework for lifelong preventive health education. The study's novelty lies in developing a holistic philosophical-pedagogical framework that connects Ibn Sina's intellectual legacy with contemporary cognitive health research without equating classical medical concepts with empirically established preventive interventions.

METHOD

This study employs a qualitative library research approach using hermeneutic-reconstructive conceptual analysis to examine Ibn Sina's ideas within their historical contexts and assess their relevance to contemporary preventive health education. Primary sources include al-Qānūn fī al-Ṭibb (Ibn Sina, 2014), Kitāb al-Shifā' (Avicenna, 1959), and Kitāb al-Najāt (Avicenna, 1952). examined through original texts, academic translations, and scholarly interpretations (Adamson, 2016; Gutas, 2020). Additional spiritual concepts from al-Ishārāt wa al-Tanbīhāt and Manṭiq al-Mashriqiyyīn are explored through secondary analyses (Ramin et al., 2024). Contemporary sources include peer-reviewed literature, WHO guidelines (World Health Organization, 2026b) and the Lancet Standing Commission report (Livingston et al., 2024).

Data analysis followed five stages: (1) identifying and coding health preservation concepts; (2) categorizing intellectual, memory-related, psychological, and spiritual concepts into five thematic dimensions; (3) mapping these dimensions against contemporary scientific evidence and WHO recommendations; (4) synthesizing an integrative preventive education framework; and (5) critically distinguishing Ibn Sina's original ideas from contemporary interpretations to avoid anachronism. Trustworthiness was strengthened through source triangulation involving classical texts, translations, and scholarly analyses, alongside critical evaluation of contemporary medical evidence. As a conceptual study, this research does not assess intervention effectiveness, which requires further validation through clinical and epidemiological investigations.

RESULTS

Ibn Sina's Holistic Framework of Health Preservation, Intellect, Memory, and Spirituality

Ibn Sina's medical philosophy emphasizes health preservation (ḥifẓ al-ṣiḥḥah) as a fundamental principle preceding disease treatment. In al-Qānūn fī al-Ṭibb, he distinguishes theoretical (‘ilm) and practical (‘amal) medicine, viewing health as bodily equilibrium (mizāj) maintained through six essential factors (al-asbāb al-sittah al-ḍarūriyyah): air, nutrition, movement and rest, sleep and wakefulness, evacuation and retention, and psychological conditions (Ibn Sina, 2014; Nejad et al., 2013; Tercan, 2022). Together with hygiene and environmental management, these principles provide a philosophical foundation for preventive health education and sustainable lifestyle practices (Putri & Nurhuda, 2023).

Beyond physical health, Ibn Sina distinguishes practical intellect (al-‘aql al-‘amalī), which governs behavior, from theoretical intellect (al-‘aql al-naẓarī), which apprehends universal knowledge (Erlwein, 2019). He regards the rational soul as immaterial while recognizing the brain's role in supporting internal sensory functions (Parkins, 2025). Intellectual development progresses from potentiality to actuality through engagement with the Active Intellect (al-‘aql al-fa‘‘āl) (Rohman et al., 2022). Although this philosophical explanation differs from contemporary neuroscience, it highlights the relationship between intellectual activity and sensory functioning (Pedro, 2023). Ibn Sina further identifies five internal sensory faculties: common sense, retention of sensory forms, imagination, estimation (al-wahm), and memory (al-dhākirah) (Irannejad, 2025). Memory preserves non-sensory meanings (ma‘ānī), whereas sensory representations are retained by other faculties (Avicenna, 1952, 1959; Gutas, 2020). His classification of memory disturbances within humoral medicine demonstrates an early interest in cognitive disorders but cannot be equated with modern dementia diagnoses (Taheri-Targhi et al., 2019).

Regarding lifestyle practices, Ibn Sina emphasizes regular physical activity (riyāḍah), dietary moderation, and balanced sleep as essential elements of health maintenance. His recommendations reflect classical humoral medicine, while contemporary studies independently support the importance of sleep physiology and healthy sleep practices (Baranwal et al., 2023; Benajiba, 2025). Similarly, Islamic dietary scholarship emphasizes moderation and balanced eating habits (Ramar et al., 2021). These perspectives offer educational insights into healthy lifestyle formation, although classical explanations should not be interpreted as equivalent to modern physiological mechanisms.

Psychological well-being is equally important in Ibn Sina's framework. He identifies psychological states (al-a‘rāḍ al-nafsāniyyah), including anxiety, sadness, and anger, as factors influencing health (Nejad et al., 2013). His medical philosophy recognizes interactions between mental and physical conditions, including psychological influences on bodily illness (Pajević, Pajević, et al., 2021). In discussing excessive love (‘ishq), he advocates integrating physical and spiritual therapeutic approaches (Ramin et al., 2024). His writings on the fear of death and anxiety further demonstrate his concern with emotional well-being and psychological resilience (Pajević, Ahmed, et al., 2021).

Spirituality completes Ibn Sina's holistic understanding of human existence. His Flying Man Argument emphasizes self-awareness and the immaterial nature of the soul (Avicenna, 1959; Kaukua, 2021). while spiritual perfection involves the cultivation of theoretical and practical intellect, moral virtues, and self-discipline (Bakhshandeh-Bali, 2021; Chania et al., 2025). Religious practices, including prayer, fasting, and charity, reflect the relationship between spiritual development, moral responsibility, and devotion to God (Özturan, 2019; Pajević, Pajević, et al., 2021; Ronaldi et al., 2025).

Self-knowledge and moral cultivation, which share certain characteristics with Sufi traditions, further emphasize emotional regulation and personal development (Yaman, 2024). His integration of spiritual awareness with physical treatment highlights a comprehensive understanding of well-being (Pajević, Pajević, et al., 2021; Ramin et al., 2024). Collectively, these dimensions provide a philosophical and pedagogical foundation for preventive education integrating physical health, intellectual development, memory, psychological well-being, and spirituality.

Mapping Ibn Sina's Thought Against Contemporary Scientific Evidence

Table 1 summarizes the mapping of five dimensions of Ibn Sina's thought against contemporary scientific evidence. The strength of the recommendations presented in the final column follows the terminology employed in the WHO guidelines (2026b), where should indicates a stronger recommendation, while may be indicates a conditional recommendation.

Table 1. Mapping the Dimensions of Ibn Sina's Thought Against Contemporary Scientific Evidence

Dimension	Ibn Sina's Concepts	Educational Applications	Contemporary Evidence	Recommendation Strength and Notes
Physical health	Ḥifẓ al-ṣiḥḥah; riyāḍah; regulation of diet and sleep (Nejad et al., 2013; Nozad et al., 2016; Siahpoosh et al., 2012)	Regular and appropriately structured physical activity, balanced and moderate nutrition, and consistent sleep patterns	Physical activity and healthy dietary patterns are associated with reduced risk; hypertension, diabetes, and physical inactivity are recognized risk factors (WHO, 2026b; Livingston et al., 2024; Erickson et al., 2011)	Physical activity: should (adults with normal cognition); healthy diet: may be; certain supplements are not recommended
Intellect	Al-ʻaql al-ʻamalī and al-ʻaql al-naẓarī (Gutas, 2020)	Lifelong learning, reading, logical reasoning, and academic discussions	Cognitive reserve (Stern, 2012); cognitive stimulation (WHO, 2026b)	Cognitive stimulation: may be (conditional recommendation)
Memory	Al-dhākirah and al-ḥāfiẓah; internal sensory faculties (Gutas, 2020; Pajević, Ahmed, et al., 2021)	Structured repetition, reflective journaling, and meaningful learning	Cognitive training as a component of multidomain interventions (Ngandu et al., 2015)	Evidence for these specific strategies remains limited; they are best incorporated into multidomain intervention programs
Psychological and social well-being	Al-aʻrāḍ al-nafsāniyyah; psychological influences on physical health (Ghodsi et al., 2014; Ramin et al., 2024)	Emotional regulation, stress management, collaborative learning, and community engagement	Depression and social isolation are recognized risk factors (Livingston et al., 2024); social engagement (WHO, 2026b)	Social engagement: may be
Spirituality	Immaterial soul; spiritual well-being; religious worship; self-knowledge (Bakhshandeh-Bali, 2021; Pajević et al., 2021)	Regular worship, contemplation, charitable activities, and moral character development	Associated with improved coping mechanisms and fewer depressive symptoms (Koenig, 2012)	Primarily indirect pathways; limited direct evidence regarding dementia prevention; not identified as an independent recommendation in the reviewed guidelines

The findings indicate that the first four dimensions—physical health, intellect, memory, and psychological and social well-being—have direct conceptual parallels with components of WHO recommendations and the risk factors identified by the Lancet Standing Commission. Physical activity is recommended to reduce the risk of cognitive decline among adults with normal cognitive functioning, while healthy and balanced dietary practices, cognitive stimulation, and social engagement receive conditional recommendations (World Health Organization, 2026b). Depression, physical inactivity, and social isolation are among the 14 potentially modifiable risk factors identified by Livingston et al. (2024). In contrast, spirituality is not explicitly recognized as an independent recommendation or risk factor in the sources examined in this article. Its relationship with cognitive health is primarily indirect, particularly through psychological well-being and social support mechanisms (Koenig, 2012).

A Synthesized Framework for Preventive Education

The synthesis of the preceding findings produces a preventive education framework comprising five interconnected pillars, as presented in Table 2. This framework represents the authors' conceptual formulation derived from an interpretation of Ibn Sina's thought in conjunction with contemporary scientific evidence. It should not be understood as a claim that Ibn Sina himself explicitly formulated these five pillars.

Table 2. Five-Pillar Preventive Education Framework

Pillar	Learning Objectives	Examples of Practical Activities	Target Population and Considerations
Physical health preservation (ḥifẓ al-ṣiḥḥah)	Understanding cardiometabolic risk factors and developing healthy lifestyle habits	Scheduled physical activity, balanced nutrition, regular sleep patterns, blood pressure monitoring, and blood glucose screening	All age groups, with particular emphasis on early and middle adulthood

Pillar	Learning Objectives	Examples of Practical Activities	Target Population and Considerations
Intellectual development (riyāḍat al-'aql)	Cultivating sustained engagement in intellectually stimulating learning activities	Study groups, reading, learning new languages or skills, and problem-solving activities	All age groups, including older adults with normal cognition or mild cognitive impairment
Memory training	Developing and applying meaningful learning strategies	Spaced repetition, reflective journaling, and narrative recall exercises	All age groups; preferably incorporated into multidomain intervention programs
Psychological and social well-being	Developing emotional regulation and stress management skills while maintaining meaningful social relationships	Emotional regulation exercises, peer support, and community-based activities	All age groups; referral to qualified mental health professionals when depressive symptoms emerge
Spiritual development	Cultivating a sense of purpose, self-discipline, and inner tranquility	Regular worship, contemplation and self-reflection (muhasabah), charitable giving and social service, and moral character development	All age groups; medical supervision for potentially risky practices (e.g., fasting among individuals with chronic illnesses); not a substitute for medical interventions

DISCUSSION

From Treatment to Health Preservation: The Relevance of Ḥifẓ al-Ṣiḥḥah to Lifelong Education

Ibn Sina's medical philosophy emphasizes prevention through the daily regulation of physical activity, nutrition, sleep, and psychological well-being (Nejad et al., 2013). This perspective aligns with contemporary life-course approaches, which emphasize that dementia risk accumulates over time and can be reduced through sustained preventive behaviors (Livingston et al., 2024; World Health Organization, 2026b) However, Ibn Sina's framework should not be equated with modern epidemiological knowledge of risk factors such as hypertension, diabetes, LDL cholesterol, hearing impairment, and air pollution (Livingston et al., 2024). Rather, his contribution lies in providing a philosophical and pedagogical foundation for health preservation through habitual self-regulation (tadbīr). Accordingly, preventive education should integrate knowledge, health-conscious attitudes, and consistent protective behaviors into structured lifelong learning practices rather than relying on occasional health awareness initiatives.

Intellect, Lifelong Learning, and Cognitive Reserve

Ibn Sina's philosophical framework emphasizes intellectual development through sustained learning while recognizing the importance of healthy sensory faculties in supporting cognitive functioning (Norman, 2021). This perspective shares conceptual similarities with cognitive reserve, which describes the brain's capacity to adapt to pathological changes through education, occupational experiences, and intellectual engagement (Stern, 2012). Although WHO (2026b) conditionally recommends cognitive stimulation to reduce cognitive decline risk, such activities cannot be considered definitive measures for preventing dementia. Moreover, Ibn Sina's conception of the immaterial intellect differs fundamentally from modern neuroscience, which examines cognition through brain functioning. Nevertheless, both perspectives support the educational value of lifelong intellectual engagement. Evidence from the FINGER trial demonstrates that multidomain interventions combining cognitive training, physical exercise, dietary guidance, and vascular risk management can improve or maintain cognitive performance among at-risk older adults (Ngandu et al., 2015). Therefore, intellectual development should be integrated into comprehensive preventive education programs rather than promoted as an isolated intervention.

Memory: Functional Classification, Limitations of Analogy, and Meaningful Learning

Ibn Sina's classification of internal sensory faculties distinguishes perception, retention of sensory forms, estimation of meanings, and memory, highlighting the complexity of cognitive processes (Momeni, 2021). Although his localization of memory in the posterior brain reflects premodern anatomical assumptions, his framework remains historically and conceptually significant. However, his humoral explanation of memory disorders cannot be equated with modern neurological mechanisms, including amyloid plaque accumulation in Alzheimer's disease (Taheri-Targhi et al., 2019), From a pedagogical perspective, his understanding of memory as the retention of meanings (ma'ānī) provides a philosophical basis for meaningful learning strategies, including structured repetition, reflective journaling, and narrative recall. These strategies represent contemporary educational interpretations rather than Ibn Sina's explicit recommendations, and their effectiveness in preventing dementia remains unestablished. Nevertheless, cognitive training may contribute to multidomain interventions aimed at maintaining cognitive functioning among older adults at risk of cognitive decline (Hafdi et al., 2021).

Physical Health: Physical Activity, Nutrition, and Sleep

Ibn Sina's preventive health philosophy emphasizes regular physical activity, dietary moderation, and balanced sleep patterns as essential components of well-being (Adnir & Harahap, 2024). These principles broadly align with WHO recommendations for reducing cognitive decline risk through healthy lifestyle practices (WHO, 2026b). Contemporary evidence indicates that aerobic exercise can increase hippocampal volume and improve spatial memory (Erickson et al., 2011), while Mediterranean-style dietary patterns and cardiometabolic risk management are associated with reduced dementia risk (Dominguez et al., 2026; Nozad et al., 2016; Zhao et al., 2018). Sleep patterns are also associated with cognitive health (Nejad et al., 2013; Zhao et al., 2018). However, Ibn Sina's humoral explanations should not be equated with modern physiological mechanisms, and nutritional supplements should not be promoted for dementia prevention without sufficient evidence (WHO, 2026b). Collectively, these perspectives support preventive education emphasizing sustainable healthy lifestyles while avoiding unsupported claims about dementia prevention.

Mental Health and Social Engagement

Ibn Sina's recognition of psychological conditions as one of the essential determinants of health (Nejad et al., 2013) resonates with contemporary evidence identifying depression and social isolation as potentially modifiable dementia risk factors (Livingston et al., 2024). Furthermore, WHO (2026b) indicates that social activity interventions may be recommended for adults with normal cognitive functioning or mild cognitive impairment. Ibn Sina's discussions of psychological influences on physical illness (Pajević et al., 2021; Ramin et al., 2024) reflect an early recognition of mind–body relationships that are now investigated through more rigorous scientific approaches.

The principal difference lies in the direction of the proposed relationship. Ibn Sina tends to emphasize the influence of mental states on physical conditions (Ramin et al., 2024), whereas contemporary health sciences generally recognize a bidirectional relationship between psychological and physiological processes. The educational implication is the importance of introducing emotional regulation and stress management skills from an early age while simultaneously strengthening social networks that support psychological well-being. The ethical dimension of Ibn Sina's thought, particularly his emphasis on regulating anger and desire through moderation (Bakhshandeh-Bali, 2021), may also provide a value-based framework for emotional regulation education within Islamic educational contexts.

The Spiritual Dimension: Meaning, Human Dignity, and Habit Formation

Ibn Sina's holistic philosophy emphasizes spirituality as a foundation for human dignity, intellectual development, and moral responsibility. His Flying Man Argument distinguishes the soul from the physical body, offering a philosophical perspective on personal identity that may help reduce stigma toward individuals with cognitive impairment (Avicenna, 1959; Pajević et al., 2021). Spiritual well-being is also associated with intellectual perfection, moral cultivation, and self-discipline (Bakhshandeh-Bali, 2021).

Religious practices, including prayer, fasting, and charity, may support emotional regulation, healthy habits, and social engagement (Pajević et al., 2021). Contemporary evidence associates religious involvement with better coping, fewer depressive symptoms, and stronger social support (Koenig's, 2012). while depression and social isolation are recognized as modifiable dementia risk factors (Livingston et al., 2024), However, direct evidence that spiritual practices prevent dementia remains insufficient, and WHO guidelines do not recognize spirituality as an independent preventive intervention (WHO, 2026b). Therefore, consistent with Ibn Sina's integration of physical and spiritual approaches (Ramin et al., 2024; Pajević et al., 2021). spiritual education should promote meaning, dignity, and psychological resilience as a complement to, rather than a replacement for, evidence-based medical interventions.

An Integrative Model and Its Implications for Educational Practice

The proposed five-pillar framework emphasizes an integrated approach to preventive education, consistent with WHO recommendations WHO (2026b) and evidence from the FINGER trial supporting multidomain interventions (Ngandu et al., 2015) This approach aligns conceptually with Ibn Sina's holistic understanding of health, emphasizing interconnected lifestyle behaviors adapted to individual needs and life stages. Its educational implications include integrating brain health literacy and healthy lifestyle practices into formal education, promoting lifelong learning and social engagement through community-based programs, and strengthening educators' ability to distinguish evidence-based interventions from traditional or spiritual practices. Furthermore, program evaluation should assess knowledge, attitudes, protective behaviors, and relevant health indicators rather than participant satisfaction alone. These strategies provide a foundation for sustainable preventive education across the lifespan.

CONCLUSION

Ibn Sina's thought provides a philosophical and pedagogical foundation for preventive education addressing cognitive decline, although it does not constitute a specific theory of dementia prevention. His concept of health preservation

(ḥifẓ al-ṣiḥḥah) emphasizes lifelong healthy habits, while his perspectives on intellect, memory, mental health, and spirituality support a holistic approach to human well-being. Comparisons with WHO guidelines (2026b) reveal conceptual parallels between these dimensions and contemporary risk reduction strategies, although the strength of supporting evidence varies. Spirituality may contribute indirectly to cognitive well-being but should complement rather than replace evidence-based medical interventions. The proposed five-pillar framework—physical health preservation, intellectual development, memory enhancement, psychological and social well-being, and spiritual development—offers a conceptual foundation for lifelong preventive health education. Further empirical research is required to validate its practical applicability and effectiveness in reducing cognitive decline risk.

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ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to all parties who contributed to this research. Special appreciation is extended to the academic community of the Darussalam Islamic Institute of Martapura, including lecturers, administrators, and students, for their valuable participation and support during the data collection process. The authors also thank colleagues and institutions for their constructive input and support in completing this study.

AUTHOR CONTRIBUTION STATEMENT

Lusiana, Kholili Hasib, Vialinda Siswati, and Muhammad Sauqi contributed to the conceptualization, research design, data collection, data analysis, and manuscript preparation. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that artificial intelligence (AI) tools were used in a limited capacity to assist in language editing and improving the clarity of the manuscript. All ideas, analyses, and conclusions presented in this study are the original work of the authors, and they take full responsibility for the content of this manuscript.

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