AI-ENHANCED EXPLORATION OF DEPRESSION AMONG WOMEN DURING MENOPAUSE: IMPLICATIONS FOR HEALTH EDUCATION

Oyebode, Patience Adekemi* Osuagwu, Eucharia Nonye
****Okunneye, Rafiu Olaolu****
**Department of Human Kinetics, Sports and Health Education,*
Lagos State University, Ojo, Lagos State, Nigeria
***Department of Human Kinetics, Sports and Health Education,*
Lagos State University of Education (LASUED), Ijanikin, Lagos State, Nigeria.

Abstract
Depression affects millions of women worldwide, particularly during menopausal transitions. Artificial intelligence (AI) technologies now offer innovative approaches to the awareness, early identification, and educational management of depression, complementing conventional healthcare interventions.Theauthors explored depression across menopausal stages;premenopause, perimenopause, and postmenopause while examining how AI-enhanced tools, including chatbots and machine learning algorithms, can improve health education outcomes for women experiencing perimenopausal depression. A narrative review synthesised literature from PubMed and related databases covering depression epidemiology during menopause and AI applications in women's mental health education. Studies from 2020 to 2025 were reviewed, with particular attention to recent longitudinal evidence, systematic reviews, and AI intervention trials. Depression was assessed using validated screening instruments, including the Patient Health Questionnaire-9 (PHQ-9) and the Centre for Epidemiologic Studies Depression Scale (CES-D). Depression prevalence increases significantly during perimenopause compared to premenopause, declining after postmenopause. Risk factors include hormonal fluctuations, prior depression, stress, sleep disturbance, and poor social support. AI interventions show promise: cognitive behavioural therapy-based chatbots significantly reduce depression symptoms, while machine learning algorithms achieve high accuracy in identifying depression-indicative patterns. These tools hold considerable potential for health education, awareness creation, and early referral support. Integrating AI-powered tools with conventional health education offers scalable, accessible support for perimenopausal women, particularly those facing barriers to conventional healthcare services.

Keywords: Depression, Menopause, Artificial intelligence, Premenopause, Postmenopause, health education, Digital health literacy

Introduction

Depression is a leading contributor to the global burden of disease and disproportionately affecting women, with vulnerability markedly elevated during the menopausal transition (Bromberger & Epperson, 2021). Depression during this period presents significant public health challenges, affecting women's quality of life, family functioning, and work productivity. Literature confirms that hormonal sensitivity varies considerably among women, with reproductive mood history including premenstrual dysphoric disorder and postpartum depression serving as strong predictors of perimenopausal depression risk (Gordon et al., 2021; Maki et al., 2022). Literature on technological advances alluded to the fact that it offers transformative opportunities for mental health education and awareness. Artificial intelligence applications particularly chatbots delivering cognitive behavioural therapy and machine learning algorithms for early depression identification demonstrate significant potential in supporting health education efforts targeting depression among midlife women (Cuijpers et al., 2023; Thieme et al., 2023). These technologies provide accessible, stigma-free support that complements conventional healthcare, addressing barriers including limited provider availability, geographic isolation, and cost constraints.

This paper examined depression across menopausal stages while exploring how AI-enhanced tools can improve detection support, educational accessibility, and health promotion outcomes for affected women. The paper was written from a health education perspective and does not engage with clinical diagnosis, pharmacological management, or psychiatric treatment. Rather, it focuses on awareness creation, early recognition, referral pathways, and digital health literacy.

Concept of Menopause

Menopause refers to the permanent cessation of menstruation resulting from the loss of ovarian follicular activity and is defined retrospectively after twelve consecutive months without a menstrual period. It is a natural biological process typically occurring in women between the ages of 45 and 55 years (Santoro et al., 2021). Understanding menopause requires distinguishing three related but distinct stages that carry different health implications.Premenopause refers to the period during which a woman's menstrual cycles remain regular and ovarian function is intact. Hormonal levels, particularly oestrogen and progesterone, remain relatively stable during this stage, and most women do not experience mood disruptions attributable to hormonal changes.

Perimenopause, also referred to as the menopausal transition, encompasses the years preceding the final menstrual period and extends up to one year after it. This stage is characterised by irregular menstrual cycles, hormonal fluctuations, vasomotor symptoms such as hot flushes and night sweats, and significant psychological changes including increased vulnerability to depression. Perimenopause typically spans two to ten years and is considered

the period of greatest psychiatric risk for women predisposed to mood disorders (Bromberger & Epperson, 2021; Maki et al., 2022).

Postmenopause begins one year after the final menstrual period and continues for the remainder of a woman's life. Oestrogen levels stabilise at a lower baseline during this stage, and, for many women, depressive symptoms that emerged during perimenopause tend to decline. However, women with persistent risk factorssuch as sleep disturbance, chronic illness, or psychosocial stressors may continue to experience depression during postmenopause (Santoro et al., 2021). Clear differentiation of these stages is essential for health education programme design, as risk communication, awareness messaging, and referral strategies must be tailored to the specific stage a woman occupies at the time of intervention.

Depression during Menopause

Epidemiological studies consistently document a significantly elevated risk of major depressive disorder during perimenopause compared with premenopause. The study of Women's Health Across the Nation (SWAN) a multisite investigation conducted across the United States has provided foundational longitudinal data on this association, with recent follow-up analyses continuing to confirm heightened depression vulnerability during the menopausal transition (Bromberger & Epperson, 2021; Joffe et al., 2020). The Penn Ovarian Aging Study (POAS), similarly, documented elevated rates of probable major depressive disorder using validated self-report instruments among perimenopausal participants, with hormonal fluctuation identified as a primary biological driver.

More recent systematic reviews and meta-analyses have corroborated these findings across diverse geographic and cultural populations. Maki et al. (2022) synthesised evidence from multiple cohorts and reported that perimenopausal women face a two- to four-fold increased risk of depression relative to premenopausal comparators. Soares (2020) similarly reviewed the epidemiological landscape and concluded that the perimenopause-to-early-postmenopause window constitutes a period of heightened neurobiological sensitivity to depression. Depression risk generally declines after the early postmenopausal period, particularly among women whose depressive episodes occurred exclusively in relation to hormonal transition rather than as part of a recurrent depressive disorder (Maki et al., 2022).

Risk Factors Associated with Depression During Menopause

Multiple interconnected factors influence depression vulnerability during the menopausal transition. Prior depression history remains the strongest predictor: women with a history of major depressive disorder or reproductive mood disorders including premenstrual dysphoric disorder and postpartum depression face substantially elevated risk, consistent with a hormonal sensitivity phenotype (Gordon et al., 2021; Maki et al., 2022). Demographic and socioeconomic factors, including low educational attainment, financial insecurity, and limited

social support, compound vulnerability, particularly in low- and middle-income settings (Ahuja et al., 2022; Salagre et al., 2021).

Psychosocial stressors including adverse life events, chronic difficulties, and childhood adversity significantly elevate depression risk during the menopausal transition (Gordon et al., 2021). Sleep disturbance shows a particularly strong bidirectional relationship with perimenopausal depression: vasomotor symptoms disrupt sleep architecture, which in turn amplifies depressive symptomatology, creating a self-reinforcing cycle (Baker et al., 2023; Joffe et al., 2020). Physical inactivity, smoking, and chronic medical conditions also correlate with elevated depression risk, while regular physical activity has been consistently identified as a protective factor (Salagre et al., 2021).

Negative attitudes towards menopause, neuroticism, and ruminative cognitive styles predict depression onset, while positive social relationships and strong self-efficacy confer protection (Ahuja et al., 2022). Biological factors, including inflammatory processes, hypothalamic-pituitary-adrenal axis dysregulation, and genetic predispositions, interact with hormonal changes through complex psychobiological pathways (Bromberger & Epperson, 2021; Baker et al., 2023). Understanding these risk factors is directly relevant to health education programme design. Educators can use this evidence base to develop targeted awareness campaigns, early warning communication materials, and community outreach initiatives that identify and prioritise high-risk groups.

Artificial Intelligence and Depression Awareness

Artificial intelligence encompasses a range of computational technologiesincluding machine learning, natural language processing, and deep learning capable of analysing large volumes of data to identify patterns, make predictions, and support decision-making. In the context of women's mental health and health education, AI tools offer new avenues for depression awareness, early recognition, and community-level education without encroaching upon clinical or diagnostic roles (Thieme et al., 2023).

AI-driven mobile applications and chatbot platforms have demonstrated capacity to provide psychoeducation information about depression symptoms, risk factors, coping strategies, and when to seek professional help in accessible and engaging formats. These tools can reach women in underserved communities where healthcare provider availability is limited, offering a scalable supplement to conventional health education services (Abd-Alrazaq et al., 2020; Inkster et al., 2021).AI-powered data analytics have also been employed in public health surveillance to identify population-level trends in depression, enabling health educators and programme planners to direct resources more effectively. Social media-based AI monitoring tools, for example, have been used to detect community-level increases in depressive language patterns, providing early signals that may guide public health responses (Cao et al., 2024; Nabi et al., 2023).

AI Tools for Screening Support and Early Identification

While clinical diagnosis of depression remains exclusively within the purview of qualified healthcare professionals, AI tools can support early identification efforts by assisting non-clinical users in recognising potential symptoms and facilitating timely referral. This function aligns directly with the health education mandate of promoting early help-seeking and reducing barriers to care access (Inkster et al., 2021; Thieme et al., 2023).

Chatbot platforms delivering cognitive behavioural therapy-based content have demonstrated effectiveness in reducing depression symptoms and supporting emotional wellbeing among adults. Bunge et al. (2020) described chatbot usage patterns for depression support, identifying high engagement among users seeking mental health assistance during non-traditional hours when human providers were unavailable. Wang et al. (2025) examined a cognitive behavioural therapy-based AI chatbot among university students experiencing financial stress, demonstrating substantial depression and loneliness reduction, with 24/7 availability and personalised responses enhancing engagement. Russell et al. (2025) evaluated an AI platform delivering behavioural interventions through a randomised clinical trial, reporting significant depression and anxiety symptom reduction comparable to human-delivered care. Chen et al. (2025) compared an AI chatbot with a nurse hotline for anxiety and depression support, finding similar outcomes suggesting that AI tools can match conventional support services in effectiveness while offering greater reach and scalability.

Machine learning algorithms analyse diverse data including language patterns, sleep data, and physical activity indicators to identify individuals whose profiles suggest elevated depression risk. Cuijpers et al. (2023) documented advances in deep learning applications for depression detection, highlighting algorithms that analyse speech patterns, facial expressions, and behavioural data to flag potential depression early. Luo et al. (2024) reviewed remote deep learning algorithms for depression prediction, noting advantages of continuous monitoring and scalability alongside important limitations, including data privacy concerns and the need for external validation. It bears emphasis that these tools are intended to support early recognition and referral not to substitute for professional clinical assessment.

Validated self-report screening instruments notably the PHQ-9 and the CES-D have been integrated into digital and AI-enabled platforms to allow women to self-monitor their mood states. Within a health education context, these tools are best understood as awareness and referral facilitation instruments rather than diagnostic tools. Health educators can promote and contextualise their use as part of broader depression literacy programmes, emphasising that positive screens represent a signal to seek professional evaluation rather than a diagnosis (Abd-Alrazaq et al., 2020).

Implications for Health Education

Health educators occupy a central role in promoting awareness of perimenopausal depression and the availability of AI-enhanced educational and self-monitoring tools. The primary contribution of health education to this field lies in awareness creation, early recognition

support, referral facilitation, and digital health literacy development not in clinical assessment or treatment delivery.

Educational initiatives should inform women about depression risk during the menopausal transition, normalising help-seeking behaviour and reducing the stigma that frequently prevents women from disclosing mental health concerns. Women require accessible information about hormonal changes, mood symptom recognition, available support services, and AI-enhanced educational options. Community-based programmes can demonstrate chatbot usage, address technology concerns, and integrate AI tools within comprehensive wellness and health promotion approaches (Wu et al., 2025; Inkster et al., 2021).

Health educators must also address digital divide issues, ensuring equitable access to AI-enhanced tools across socioeconomic, educational, and geographic contexts. Training programmes should build digital literacy skills that enable effective technology utilisation among women who may be unfamiliar with mental health applications or mobile health platforms. Culturally tailored educational materials must reflect diverse populations' values, beliefs, and experiences regarding menopause, mental health, and technology adoption (Ahuja et al., 2022). Collaboration between health educators, healthcare providers, and technology developers is essential to ensure that AI interventions meet women's actual needs and cultural expectations.

Educational initiatives must make clear that AI tools complement rather than replace human connection and clinical judgement. Women need guidance about when chatbot support is appropriate versus when professional evaluation is necessary. Health educators play a vital triage facilitation role, connecting women experiencing severe symptoms, persistent distress, or functional impairment with specialist care while supporting those with mild or subclinical symptoms through AI-assisted self-monitoring and community programmes.Furthermore, health educators should advocate for menopause-inclusive mental health curricula in schools, community centres, and workplaces. Given that perimenopausal depression disproportionately affects women during peak working years, occupational health settings represent an important site for AI-supported mental health promotion programming. Peer educator models — in which women trained in depression literacy and AI tool use support their peers offer a culturally resonant and scalable strategy for underserved communities in Lagos State and beyond (Salagre et al., 2021).

Challenges of AI Use in Women's Mental Health Education

Despite promising results, AI interventions in mental health education face considerable challenges. Algorithmic bias represents a significant concern: if training datasets lack diversity with respect to age, ethnicity, socioeconomic status, and cultural background, AI tools may perform less accurately for women from minority or underserved populations precisely those most likely to be targeted by community health education programmes (Cao et al., 2024;

Thieme et al., 2023). Developers and health educators must advocate for more representative and inclusive AI training datasets.

Data privacy and security present additional barriers. Mental health data are among the most sensitive categories of personal information, and women in many cultural contexts may be reluctant to engage with digital platforms that collect or store such data. Health education programmes integrating AI tools must provide transparent information about data handling practices and build trust with community members before widespread tool adoption can be expected (Inkster et al., 2021).Digital literacy and technology access remain uneven. In underserved communities across Lagos State and comparable settings in sub-Saharan Africa, limited smartphone access, unreliable internet connectivity, and low technology confidence may prevent women from benefiting from AI-enhanced health education tools. Health education programmes must therefore include device access support, digital literacy training, and offline educational alternatives (Ahuja et al., 2022; Abd-Alrazaq et al., 2020).

Regulatory and quality assurance frameworks for AI mental health tools remain underdeveloped. Health educators and public health advocates should engage with policymakers to establish standards ensuring that AI tools promoted in health education contexts are evidence-based, culturally appropriate, and subject to ongoing efficacy monitoring (Thieme et al., 2023).

Conclusion

Depression during the menopausal transition represents a significant public health concern affecting substantial proportions of the female population during midlife. Recent epidemiological evidence confirms elevated risk during perimenopause, driven by complex interactions among hormonal fluctuations, genetic vulnerability, psychosocial stressors, health behaviours, and life circumstances (Bromberger & Epperson, 2021; Maki et al., 2022). Whilst evidence-based clinical treatments effectively reduce symptoms, the primary contribution of health education to this challenge lies in awareness creation, risk communication, early recognition support, and referral facilitation.

AI-enhanced tools including chatbots, machine learning-based screening aids, and digital health platforms offer scalable, accessible options that complement conventional health education and community-based mental health promotion. When health educators are trained to incorporate these tools appropriately, and when communities are equipped with the digital literacy and access needed to use them, AI technologies can extend the reach and impact of mental health promotion programmes targeting perimenopausal women (Cuijpers et al., 2023; Wu et al., 2025). Future work should prioritise culturally adapted AI tools validated for African and other diverse populations, ensuring that technological innovation serves equity as well as efficiency.Based on the evidence reviewed, the following recommendations were made:

i. Health educators should develop community-based awareness programmes that provide women with accessible information about depression risk during menopausal transitions, normalising help-seeking and reducing stigma.

ii. AI-powered chatbots and mobile health applications should be incorporated into health education programmes as awareness and self-monitoring tools, with clear messaging that these instruments support early recognition and referral rather than diagnosis.

iii. Digital health literacy training should be integrated into health education curricula targeting midlife women, particularly in underserved communities where technology access and confidence may be limited.

iv. Health educators should develop and promote clear referral pathways connecting women who self-identify depressive symptoms — including through AI-assisted screening with qualified healthcare professionals.

v. Public health authorities should invest in the development and validation of culturally adapted AI mental health education tools for Nigerian and sub-Saharan African populations.

vi. Researchers should examine AI intervention effectiveness specifically within the context of health education for perimenopausal women in African settings, with attention to equity, cultural acceptability, and community impact.

vii. Policy frameworks should establish ethical standards for AI applications in health education, including data privacy protections, algorithmic transparency, and ongoing quality assurance monitoring.

viii. Intersectoral collaboration among health educators, healthcare providers, technology developers, and community representatives should guide the co-design of AI-enhanced health education programmes targeting menopausal depression.

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