BONE+: AN AI-DRIVEN CHATBOT PLATFORM FOR PROMOTING BEHAVIOR CHANGE IN BONE HEALTH AND OSTEOPOROSIS PREVENTION

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ABSTRACT

Osteoporosis is a prevalent medical condition characterized by a reduction in bone mass and density, which significantly increases the risk of fractures. In order to promote optimal bone health, it is essential to acquire relevant information and adopt a lifestyle that safeguards bone integrity. In light of this, the present study employed the Health Belief Model as a framework to design and develop the Bone+ mobile health chatbot platform. Leveraging artificial intelligence technology, the platform utilizes image analysis of X-rays to assess bone density and predict the likelihood of bone loss. Moreover, it offers comprehensive information on osteoporosis prevention, empowering users to make well-informed decisions regarding their bone health. The results obtained from the heuristic evaluation questionnaire of the chatbot platform demonstrated satisfactory usability, thereby further supporting its efficacy as a valuable tool in osteoporosis prevention.

KEYWORDS

Osteoporosis, Bone Health, Mobile Health, AI Chatbot, Health Belief Model, Heuristic Evaluation

1. INTRODUCTION

Osteoporosis, a condition that primarily affects older individuals and postmenopausal women, is characterized by a loss of bone mass and density, leading to a higher risk of fractures (IOF, 2023). However, despite being a preventable condition, osteoporosis is often misconceived as an age-related disease (Stetzer, 2011). To effectively prevent osteoporosis, it is crucial to educate individuals about bone health and promote a lifestyle that safeguards bone health (Chan et al., 2018). Unfortunately, studies have shown insufficient public awareness of osteoporosis, resulting in a lack of preventive measures (D'Silva and Pinto, 2017). Although people may possess some knowledge and beliefs about osteoporosis, they often fail to take action to protect their bones due to their beliefs, diets, and lifestyles. Therefore, addressing the knowledge and practice gaps related to osteoporosis is essential for future prevention efforts.

Technology plays a vital role in identifying osteoporosis and facilitating long-term health tracking and educational interventions for patients (Chan et al., 2022). Mobile health (mHealth) can facilitate convenient monitoring of health status over time. mHealth is a public health and medical strategy that utilizes mobile technology, including cell phones, to provide assistance. It encompasses the development and utilization of more advanced functions and applications beyond simple mobile devices (WHO, 2011). With mHealth, users can easily monitor their health status and access remote medical advice regardless of time and location, enabling effective management of chronic conditions such as osteoporosis.

The Health Belief Model (HBM) is a widely used theoretical framework for developing and evaluating health interventions. It incorporates psychological and sociological concepts to examine individuals' attitudes and behaviors regarding health promotion, self-actualization, and fulfillment (Rosenstock, 2005). A study by Song et al. (2022) demonstrated that using the Health Belief Model (HBM) in a WeChat-based educational intervention improved disease knowledge, self-efficacy, and exercise adherence in patients with Ankylosing Spondylitis. This study highlighted the feasibility and effectiveness of WeChat-based patient education for

individuals with chronic diseases. Alharbey and Chatterjee (2019) developed an innovative mobile device-based assistive technology grounded in the HBM to empower patients with Chronic Obstructive Pulmonary Disease, raising awareness and promoting engagement in self-care management activities. In the context of osteoporosis prevention, HBM-based health interventions can effectively promote the adoption of nutritionally healthy behaviors, enhance knowledge, and induce attitudinal changes, thereby mitigating the risk of osteoporosis (Panahi et al., 2021). Behavioral research often incorporates elements such as disease awareness and information access as conceptual frameworks to study people's health behaviors. Thus, the development of the Bone+ platform is guided by the usage of HBM as a theoretical framework in this study.

This study introduces Bone+, an mHealth service that utilizes AI and HBM to detect osteoporosis risk. The chatbot analyzes X-rays, predicts bone density, and educates users about their bone health. The community feature assesses risk and provides treatment information. By promoting healthy behaviors and preventive measures, the study aims to reduce fractures and raise awareness of osteoporosis.

2. MATERIALS AND METHODS

2.1 Enhancing Users' Perception of Susceptibility through Online Testing and Personalized Health Profiles

Perceived susceptibility plays a crucial role in motivating healthy behaviors, but misconceptions can hinder risk recognition. To address this, Bone+ employs personalized health profiles and an online tool to assess osteoporosis risk. Unlike conventional tools, Bone+ takes into account the user's specific body data and incorporates AI image interpretation of X-ray films to improve the accuracy of risk prediction for osteoporosis and fractures. Following the risk assessment, Bone+ displays the results, provides health advice, and offers feedback (refer to **Error! Reference source not found.**).

Figure 1. Personal health profile and online risk assessment for osteoporosis (left); personalized graded health education guidance for enhancing consumers' comprehension of osteoporosis risks (right)

2.2 Providing a Personalized Graded Health Information Guide to Enhance Consumers' Understanding of the Perceived Severity of Osteoporosis

Perceived seriousness refers to an individual's comprehension of the severity of their osteoporosis and the potential consequences of not receiving proper treatment. Osteoporosis can significantly impact an individual's quality of life, including daily activities and social interactions, and may even lead to depression, paralysis, and death (Panahi et al., 2021). In addition to offering a general introduction to osteoporosis, Bone+ evaluates and categorizes users' body data to deliver customized health education content tailored to their specific condition. The personalized graded health information guide, as depicted in **Error! Reference source not found.**, aims to enhance consumers' understanding of the perceived danger of osteoporosis and motivates them to take appropriate action.

2.3 Enhancing Users' Perceived Benefits through Medication Reminders and Personal Nutrition Records and Analysis

The adoption of healthy behaviors is influenced by individuals' perception of the benefits. After bone testing and health education, users gain increased awareness of osteoporosis, calcium intake, and the detrimental effects of caffeine consumption. To support medication adherence and motivate users, Bone+ incorporates feedback on medication usage and provides reminders. The nutritional record section offers users a seven-day analysis of their dietary intake, including statistics for each meal, enabling them to track their progress and identify any nutritional deficiencies. The images depicted in Figure 2 illustrate that users can access their medication reminders and associated information on the left-hand side of the interface. Meanwhile, the right-hand side of the image displays users' dietary intake record along with corresponding analysis.

Figure 2. Medication reminders and information (left), diet records and analysis (middle-left), online AI X-Ray image analysis (middle-right), and the osteoporosis community (right)

2.4 Facilitating Access to Medical Services Recommendations to Reduce Perceived Barriers

Modifying health behaviors can be challenging due to perceived barriers. A study by Chan et al. (2022) revealed that only 41.86% of osteoporosis patients effectively changed their lifestyles. Regular educational reinforcement and visits were found to improve knowledge and habits. To address these perceived barriers, Bone+ has been designed to facilitate users' access to medical service recommendations through a systematic approach. The middle-right section of Figure 2 illustrates this feature, enabling users to conveniently take online tests and select the most suitable list of doctors on their mobile devices. This approach helps mitigate any conscious mobility limitations that users may have.

2.5 Facilitating the Adoption of Healthy Habits through the Osteoporosis Community as Action Cues

Action cues, such as public health campaigns, peer support, and educational resources, play a crucial role in motivating individuals to take action. These cues indirectly fulfill expectations of efficacy and efficiency. To promote the adoption of osteoporosis prevention habits, Bone+ provides users with a conversational platform where they can acquire health-related information and guidance from other users within the osteoporosis community. This feature is illustrated on the right-hand side of Figure 2.

2.6 Enhancing Users' Self-Efficacy through Personalized and Tailored Health Guidance

Self-efficacy, which refers to the belief in one's ability to overcome obstacles and adopt healthy behaviors, is vital for driving behavior change. Osteoporosis patients often work on increasing their self-assurance and control over their condition by learning about the illness, the risk of fracture, available treatments, self-management techniques, and engaging in informed decision-making with healthcare professionals (Ganda et al., 2013). Bone+ enhances self-efficacy by providing personalized health recommendations based on users' information (**Error! Reference source not found.**, right side). With practical guidance, Bone+ empowers users, fostering autonomy and self-efficacy.

3. SYSTEM VALIDATION

The system validation approach utilized in this study was based on the mobile device interface heuristic evaluation proposed by Yáñez Gómez et al. (2014). The usability evaluation involved the use of the remaining 12 mobile-specific heuristic assessment questions derived from the original set of 13 usability heuristics by Yáñez Gómez et al. (2014), with the exclusion of the "Help and Documentation" item. To assess the usability of the system, five designers and specialists in interactive interface design and mobile application development were recruited to conduct tests and evaluate the system's usability using a mobile-specific post-development checklist. Through discussions and the exchange of ideas, these professionals aimed to identify design flaws and describe any usability difficulties encountered. The findings of the usability assessment, based on the 12 heuristic evaluation guidelines, are presented below:

(1) Visibility of system status: The system effectively displays its status, making it easy for users to identify the current function and access information.

(2) Correspondence between system and the real world: Users can observe immediate changes in the interface as they interact with different functions, ensuring correspondence between the system and real-world actions.

(3) User freedom and control: The system provides clear execution of functions, offering users a sense of freedom and control.

(4) Standards and consistency: The system adheres to design principles by maintaining consistency in the use of fonts, colors, and icons.

(5) Error prevention: While there is no specific error handling mechanism in place, the system's ease of use contributes to minimizing the likelihood of errors.

(6) Recognition rather than recall: To enhance system recognition and reduce cognitive burden, the system provides text options alongside icons.

(7) Flexibility and efficiency of use: The system's functions are clearly visible and do not require specialized memory or extensive searching.

(8) Aesthetic and minimalist design: The interface is visually appealing, clear, and straightforward in its design.

(9) Help users recognize, diagnose, and recover from errors: It is recommended to incorporate a problem-solving feature to facilitate users' understanding of the system's functionality, particularly for new users.

(10) Compatibility with technical standards: Technical operations align with users' typical operational capabilities.

(11) Pleasant and courteous interaction: Users can easily obtain the required information and answers by selecting the desired mode through the dialogue.

(12) Privacy: Due to the sensitive nature of health analysis and the collection of personal information, concerns arise about ensuring the security and privacy of user data.

4. CONCLUSION

This study aimed to develop Bone+, an AI chatbot that incorporates the Health Belief Model (HBM) to raise awareness of osteoporosis. The chatbot provides remote medical advice and access to osteoporosis health information resources. To further enhance the Bone+ chatbot platform, comprehensive user testing will be conducted in authentic scenarios with osteoporosis patients and potential patients, including older individuals and postmenopausal women. This approach will gather realistic and reliable data on user engagement, satisfaction, and the effectiveness of the system. In addition, longer-term trials and randomized controlled trials in clinical settings will be conducted to optimize the system's effectiveness. These trials will provide valuable insights and improve the recommendations for Bone+, ensuring enhanced functionality and practicality.

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