

Health Literacy and Patient Education in Osteoporosis Strategies to Improve Treatment Adherence and Fracture Prevention

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HOW TO CITE:

Dorina Ruci, Entela Shkodrani, Krisli Serani, Enri Kaçi, Artur Zoto, Viktoria Ruci, Barbara Shkodrani, Vilson Ruci (2026). Health Literacy and Patient Education in Osteoporosis Strategies to Improve Treatment Adherence and Fracture Prevention. International Journal of Special Education, 41(15s), 01-34

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ABSTRACT:

Background: Osteoporosis remains a major public health issue because poor treatment adherence and weak fracture-prevention behavior increase the risk of avoidable fractures, disability, and reduced quality of life. Limited health literacy, inadequate knowledge, low self-efficacy, and insufficient support often prevent patients from maintaining long-term osteoporosis care.

Purpose: This study examined the effect of health-literacy-tailored osteoporosis patient education on treatment adherence and fracture-prevention behavior. It also tested the mediating roles of osteoporosis knowledge and osteoporosis self-efficacy and the moderating role of social support.

Methods: A quantitative cross-sectional design was used. Data were collected from 513 osteoporosis patients through a structured questionnaire. The study targeted osteoporosis patients receiving osteoporosis education, counseling, treatment, or fracture-prevention services at Mother Theresa University Hospital Center, University Hospital of Trauma, and Pegasus Med Clinic in Tirana, Albania. The data were analyzed using Partial Least Squares Structural Equation Modeling to assess the measurement model, structural model, mediation effects, and moderation effects.

Findings: The findings showed that health-literacy-tailored osteoporosis patient education had a significant positive effect on treatment adherence and fracture-prevention behavior. It also

strongly improved osteoporosis knowledge and osteoporosis self-efficacy. Both osteoporosis knowledge and self-efficacy significantly mediated the relationship between patient education and adherence outcomes, with self-efficacy showing the stronger mediating effect. Social support significantly strengthened the effects of patient education on knowledge and self-efficacy, but it did not significantly moderate the direct relationship between education and adherence behavior.

Conclusion: The study concluded that osteoporosis education should be literacy-sensitive, patient-centered, and confidence-oriented. Improving knowledge and self-efficacy through clear education may enhance treatment adherence and fracture-prevention behavior among osteoporosis patients.

Keywords: Health literacy; osteoporosis patient education; treatment adherence; fracture prevention; osteoporosis knowledge; self-efficacy; social support; PLS-SEM.

Introduction:

All older adults with osteoporosis are at risk of fragility fracture, which are often asymptomatic and become large public health issues due to the fact that they may lead to disability, compromise quality of life, increase health care utilization and lead to death. Poor adherence to pharmacological and/or non-pharmacological management is also likely to contribute to high fracture rates due to poor knowledge about osteoporosis, low personal fracture risk, side effects of fracture prevention medications, lack of confidence in conducting fracture prevention activities such as fall prevention, exercises to promote bone health, calcium and vitamin D supplementation, and follow-up monitoring. Recent studies emphasized that patient-centered patient education, instead of information-focused patient education, customizing to the patient's health literacy, beliefs, and self-efficacy, and adapting to the patient's clinical context, could increase patient's sustained management of osteoporosis, rather than accounting for the information from patient education alone (Eslami-Mahmoodabadi et al., 2024). It is important to note that pathways, through which osteoporosis education may influence osteoporosis medication adherence and fracture-prevention behaviours, have been shown to be knowledge of osteoporosis, knowledge of risk of

fracture and osteoporosis self-care confidence (Chitra, 2021). Hence, studying patient education with a health-literacy based approach is significant for understanding how educational approaches can support and encourage adherence to therapy, and for encouraging preventive measures, with the ultimate goal of reducing the burden of osteoporotic fracture.

While effective osteoporosis treatment and fracture-prevention strategies exist, adherence to these interventions is a long-standing problem, partly because many osteoporosis patients have low health literacy and limited knowledge on osteoporosis, a lack in confidence on how to manage themselves, and a lack of support for long-term therapy. The lack of adequate exploration of the mechanism of action of patient education is shown in more recent studies, as it remains unclear whether using health-literacy-tailored education to improve outcomes is by enhancing knowledge about osteoporosis or by increasing osteoporosis self-efficacy. Educational factors also have been shown to be insufficient to predict adherence, as patient factors like knowledge, adherence beliefs, self-efficacy and social support are shown to play a role in whether patients take their medications as prescribed, attend oral exams or follow-ups, do any exercise, take calcium and/or vitamin D and follow fall-

prevention measures (Kang et al., 2022). Therefore, the problem of this study is that there is a lack of sufficient empirical understanding of the influence of osteoporosis patient education constructed using health-literacy concepts on patient adherence results, while the effects of patient education that create osteoporosis patient knowledge and strengthening patient self-efficacy as mediators in the interaction between patient education and patient fracture prevention behavior are active or not in the osteoporosis patient field.

Because of their theoretical nature, osteoporosis knowledge and self-efficacy were commonly selected as predictors of self-management behavior in past osteoporosis research, while health-literacy–tailored patient education received little attention but has shed some light on the role of patient education and its influence on the relationship between these predictors and self-management behavior. Few studies have examined the influence of predictors on self-management behavior as moderated by social support, and education tailored to the patient's health literacy has been identified as one of the most important moderators of the measures of the predictors and self-management behavior. Because of their theoretical standing, the theoretical construct of patient education, health literacy, knowledge, self-efficacy and adherence has been treated as distinct constructs in the current body of osteoporosis research with only a few studies showing the intervening effect of patient education, knowledge, and self-efficacy in the sequence, and the moderating effect of social support in the same sequence (Noel et al., 2020). This theoretical gap has not been examined remains unanswered: While information exposure is sufficient to bring about behaviour change, other models such as the Health Belief Model, Social Cognitive Theory, and care approaches based on health literacy claim that this exposure alone is not enough to induce behaviour change because other factors including perceived capabilities, understanding, beliefs, and supportive care environments are also at play. From a practical perspective, many of the pieces of new evidence published about

patient education in medicine indicate that this educational technique could have an effect on medication adherence, but the findings with respect to quality of life, fall prevention, physical activity, and fracture reduction others are not as solid, partly because of the lack of baseline measurements, random assignment, and mediation-moderation testing (Astrone et al., 2022). Complementing the foregoing, recent studies have shown that knowledge, self-efficacy, contextual barriers and social support have been found to be the influencing factors of osteoporosis self-care, but interactions between those factors have not received sufficient research attention in real-world setting in the treatment of osteoporosis (Ramchand & Leder, 2024). Furthermore, the services of fracture liaison and primary care are yet to be studied on the follow-up after a fracture in both the long and short term; and patient counselling and follow-up adherence support is still lacking, not only in terms of its effectiveness, but how and when it is effective, meaning that empirical research is necessary to understand the recommended methods of promoting adherence and fracture-prevention outcomes (Diana et al., 2021). Overall, this study has the potential to advance healthcare of osteoporosis by gaining a better understanding of how patient education modified by health literacy could help enhance fracture-prevention behaviors, treatment adherence, and social support as a context that could buffer (or negatively condition) patient engagement. In summary, this study will aid in enhancing patient's knowledge of their disease, compliance with therapy, the use of fall prevention strategies, and reducing risk of preventable fracture. The goal of the research is to support healthcare management, osteoporosis clinics, primary care and fracture liaison programs with the evidence they need to create a better patient education system, counseling program, follow-up system, and adherence-support system, all tailored to patients' literacy and support needs. More recently, there have been reports suggesting that poor adherence to medication, insufficient long-term follow-up, poor service coordination, and poor secondary fracture prevention remain treatment gaps,

which points towards the need of interventions to improve the quality of osteoporosis treatment and support goals, such as preventing unnecessary fractures (Keller et al., 2025).

The novelty of this study is its development and testing of an integrated osteoporosis patient education model explaining how knowledge of osteoporosis and self-efficacy with respect to osteoporosis through two psychological and cognitive pathways (knowledge and self-efficacy) impact on patient adherence with and behavior regarding osteoporosis treatment; social support, too, is explored as a moderating factor. Although a range of studies have indicated that osteoporosis education could potentially impact medication adherence, health literacy, self-efficacy and carefully considered actions for prevention, the evidence that we have to date examines these health outcomes individually or as predictors (Ariza-Vega et al., 2024). This study is distinguished from other studies by its emphasis not only on the effectiveness of patient education, but also on the “how and why” of its effectiveness in the real world of osteoporosis clinical care. This study becomes important in providing new theoretical and empirical perspective to fracture liaison programs on primary care and osteoporosis clinics who want to provide a holistic approach to foster long term patient engagement and to promote the fracture-prevention behaviors by working as a connected system of health literacy, education, knowledge, self-efficacy, social support, adherence, and fracture-prevention behavior. There is also an opportunity to study the health literacy and patient education in osteoporosis, since many fractures are preventable, but arguably, the proportion at risk taking medication, doing follow-up, exercise or nutritional or fall prevention are not lasting long enough to be deemed safe for fracture prevention. In addition to the availability of medications for osteoporosis, there are a variety of factors that influence both treatment uptake and fracture prevention among patients with osteoporosis, such as knowledge (Zhang et al., 2022), self-efficacy (Macías et al., 2020), risk perception (Rodrigues, 2021), social support,

and access to clear health information (Golden et al., 2021). It is therefore important to carry out this study to understand how health-literacy tailored patient education increases the adherence by increasing their knowledge and self-efficacy and if social support facilitates this effect in a real healthcare setting. This evidence is pertinent to healthcare managers, primary care practitioners and osteoporosis clinics as well as fracture liaison services; tailored education, counseling, follow up and adherence support programs can be designed based on this data to ensure there are fewer treatment gaps, increased patient frax involvement and fewer unnecessary osteoporotic fractures occur (Li et al., 2022).

Patients' education based on the osteoporosis level of understanding (HLPO), aimed at raising the patients' level of understanding to facilitate fractured behavior as well as improving their self-efficacy and knowledge of osteoporosis, is of great importance for the physical wellbeing as it can improve the patients' adherence to care and in turn facilitate the fractured behavior, and because the social support may enhance the patients' adherence with the prevention of fractures care. Theoretically, the study fills a gap in the use of mediation–moderation models in studies examining osteoporosis self-management as there are three mediators (health-literacy, patient education, knowledge, self-efficacy, social support), adherence and fracture prevention all included in the study model. From a practical perspective it is important to recognise that the understanding and adherence of patients, as well as follow up and holistic fracture prevention services, especially in primary care, osteoporosis clinics and fracture linkage services (FLS) has not yet been optimised in the management of osteoporosis and related conditions (Guzman et al., 2023). The findings will have practical implications for osteoporosis patients, enabling better education and empowerment to self-manage their condition; for health providers, as it will help guide health provider counselling and adherence-support; for health managers, as it will enable targeted and efficient development of literacy-sensitive education programmes,

follow-up systems, and quality improvement of health services; for policy makers, as it will provide evidence to inform strengthening of fracture prevention and the incorporation of osteoporosis into healthcare pathways and services. In general, it helps to decrease preventable fractures, enhance clinical outcomes and facilitate optimized provision of osteoporosis services (Senay et al., 2019).

Indeed, the relations between health-literacy-based patient education, osteoporosis knowledge, feeling competent, or social support, and adherence to treatment, as well as fracture prevention behaviour, represent a real-life problem in the care of patients suffering from osteoporosis: the patient may manage to receive information on osteoporosis treatment, but not necessarily to understand this information, to believe it, to feel competent or to be given an appropriate level of social support to help them sustain behaviour change. Previous studies have examined relevant partnerships where bone health literacy is related to self-efficacy, patient education and adherence to treatment (Han, 2021), and the relationships between knowledge, beliefs, and social support with respect to the use of treatment and the self-management of osteoporosis (Shimodan et al., 2020). The uniqueness of this study is that these relationships were combined into one by investigating the interaction between patient education and improving patient adherence and fracture-prevention behavior through providing osteoporosis knowledge and patient self-efficacy, and the influence of social support on the interaction between knowing and patient self-efficacy and fracture-prevention behavior. This study is different in not only its question of whether education works but when and how it works, a very important question since the more desirable conditions that engender education greatest success in enhancing patient outcomes in osteoporosis care (Wang & Voss, 2021).

This study aims to investigate the impact of health-literacy-tailored osteoporosis patient education on treatment adherence and fracture-prevention behavior of osteoporosis patients. In particular, the study will assess the effect of

health-literacy-tailored patient education on knowledge about osteoporosis, patient education's effect on osteoporosis self-efficacy, the direct effect of patient education on treatment adherence/fracture-prevention behaviors, the indirect direct effects of patient education on treatment adherence/fracture-prevention behaviors via the mediation of osteoporosis knowledge and osteoporosis self-efficacy, and the direct effect of patient education on the relationship between social support and adherence/fracture-prevention behaviors (Palcu et al., 2020). Overall the study proposes to examine how patients' education is a blend of (what, how, and why) does it help patients 'live with their osteoporosis' and prevent fractures? And, where does patients' education take place?

Literature Review

Theoretical Foundation

Health-literacy-tailored patient education in osteoporosis is based on the theoretical models of the Health Literate Care Model and the Health Belief Model. Based on this notion, the Health Literate Care Model suggests that the model is healthcare and not healthcare when consumers are given more ease in understanding and using health information, the model has aspects of a teach-back, culturally appropriate information is used, and patient-centered counseling begins. Educating in osteoporosis treatment should include information regarding bone health, use of medications, exercise, calcium and vitamin D, and fall preventive strategies as well as adjusting the education to the patient's literacy and capacity to utilize information in daily life. The Health Belief Model also provides an explanation for why patients engage in preventive activities: if they feel vulnerable to fracture caused by osteoporosis, see fractures as both serious and preventable, and facing few barriers to acting on prevention, they are more likely to engage in it (McCloskey et al., 2022). This idea has been validated by recent osteoporosis research (Ma et al., 2025) focusing on the importance of patient education, health literacy and the understanding

of the osteoporosis risk to improve the management of osteoporosis and adherence performance.

The variables that are deemed to influence the relationship between other variables are mediated variables which are theoretically supported by Social Cognitive Theory and Knowledge - Attitude - Practice model, namely: osteoporosis knowledge and osteoporosis self-efficacy. Social Cognitive Theory suggests that behaviour change is correlated with learning which occurs when people learn new skills, develop their belief in self-efficacy to perform a skill, their awareness of cues for facilitating the skill and their expectancy regarding the consequences of a given behaviour (Ziebart & MacDermid, 2022). Relevance of knowledge about osteoporosis to this study is important because knowledge has the potential to provide health care consumers with improved information on causes, risk, benefits of treatment, medications required and lifestyle changes, fall prevention. But it is not enough to know what to do, there is a great need to have self-efficacy confidence, i.e., the conviction that one can take the medicine as prescribed, exercise safely, go to preventive tests and carry out preventive acts with long-term. This theoretical connection of bone health literacy, knowledge, self-efficacy, and patient centered beliefs with behaviors for osteoporosis management and adherence with medication, respectively, is also supported by recent studies (Lin et al., 2022).

The theoretical background of this moderator and the treatment adherence/fracture prevention behavior as a dependent variable can be supported by conclusive theories, which include: Social Support Theory, Theory of Planned Behavior and COM-B. Social Support Theory states that families, caregivers, peers and care providers are able to offer support of three types—emotional, informational, or practical—which improves patients' coping ability as well as their ability to adopt healthful behaviors, especially for chronic diseases (Lyu et al., 2024). According to the Theory of Planned Behavior (TPB), attitudes and perceived control as well as

social influence are determinants of adherence and the COM-B model posits adherence is determined by capability, opportunity, and motivation (Schinas et al., 2024). So, if knowledge and self-efficacy rise among patients due to the education, then adherence could be greater for patient groups that suffer a loss of independence and a need for social support if reminders, encouragement, transportation, bill paying and managing appointments or medication regimens are required. The theoretical model, as stated above, has been supported by a recent study which found that whilst patient education (content or approach) positively influences adherence to osteoporosis treatment, it may not necessarily impact adherence to fracture prevention-behaviour – the interaction of patient education, self-efficacy, social support, access to care and follow-up systems, determined how and under what conditions patient education is likely to have a positive influence on adherence to osteoporosis treatment and fracture prevention-behaviour (Sanchez-Trigo et al., 2023).

Models in the attached: Health Literacy-Bridged Patient Education for Osteoporosis (HEPAOE): Direct and indirect effects of health-literacy-tailored osteoporosis patient education on osteoporosis treatment adherence and fracture-prevention behavior are hypothesized to go through the mediators of osteoporosis knowledge and osteoporosis self-efficacy. It also suggests that the impact of adherence and both mediators are also strengthened by social support. Therefore, direct effects, mediation effects, and moderation effects are proposed in the proposed model (Schousboe et al., 2019).

Hypotheses development:

H1: Health-literacy-tailored osteoporosis patient education has a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

Patient education regarding osteoporosis should be designed to be optimally health-literacy, which would result in improved health-literacy-appropriate patient understanding of health

messages, leading to enhanced adherence to both osteoporosis and fracture prevention treatment regimens and to behaviors. The Health Literate Care Model is a concept that has been proposed that would make healthcare information more understandable and easier to put into practice, specifically for people with chronic diseases. Behaviors are relevant in osteoporosis because they should be repeated and performed for a prolonged time, e.g., taking medication, having follow-ups, eating calcium and vitamin D, exercising appropriately, and avoiding falls (Badawy et al., 2024).

Educating patients has established connections to the adherence to the treatment results in recent evidence. Rubæk et al. (2026) found mixed results on outcomes for patients in the studies in their review, while beneficial effects were seen in patients who attended osteoporosis patient education programs. Education to patients, counselling and provision of support to ensure that patients follow treatment guidelines are crucial areas of post fracture osteoporosis management in the context of preventing future fractures, Noble et al. (2021) said. Likewise, health education and physical exercise programmes for the management of osteoporotic vertebral fracture resulted in an improvement in health-literacy and its associated outcomes (Neha et al., 2024). Thus, it seems reasonable to hypothesize that health-literacy-tailored patient education has a positive impact on osteoporosis treatment adherence and fracture-prevention behavior.

H2: Health-literacy-tailored osteoporosis patient education has a positive effect on osteoporosis knowledge.

Health-literacy-tailored osteoporosis patient education is anticipated to lead to increased osteoporosis knowledge as educational interventions are designed to give osteoporosis patients information about disease facts and their risk of developing osteoporosis, diagnosis, risk for fracture, treatment options, benefits of medication, lifestyle modification and fall prevention. KAP is being looked at from a Knowledge-Attitude-Practice perspective; thus

KAP knowledge as a first step, followed by the patient's attitude, which should be followed by steps in patient practice following the attitude. The provision of information that is presented in simple terms with visual aids, presented in listening back to the information and provided in relation to what their fracture risk is, will be easier for patients to retain and apply their knowledge of osteoporosis.

The value of knowledge as a major concern in dealing with osteoporosis-related issues was recently found in a study. Agh et al. (2024) stressed the links between osteoporosis knowledge, beliefs and actions for the older age groups. The study by Cunningham et al. (2019) suggested that there is a relationship between bone health literacy and osteoporosis-related self-efficacy as well as osteoporosis risk perception, meaning that patient's understanding of bone health plays a pivotal role in patient osteoporosis management. (Safdari et al., 2020) added that beliefs and knowledge of patients as individual patients is a patient-centered factor which contributes to non-adherence to medications in primary osteoporosis patients. For this reason, the provision of education geared towards health literacy is likely to increase osteoporosis knowledge.

H3: Health-literacy-tailored osteoporosis patient education has a positive effect on osteoporosis self-efficacy.

This health-literacy-tailored approach to patient education about osteoporosis is also hypothesized to have a beneficial impact on osteoporosis self-efficacy; being able to clearly understand what patients need to do and how to do it is expected to boost patients' self-efficacy. In Social cognitive theory (Kim et al., 2022), self-efficacy is built when an individual is provided with skills and information to gain, feedback, encouragement and the chance to practice health behavior(s). Patients who were least worried about taking the medication wrong were the least self-efficacy in osteoporosis treatment, with patients who were least likely to have worried about getting hurt when exercising, the least likely to forget, or the least

likely to skip appointments were the most self-efficacy.

This is substantiated by empirical evidence. Ziebart et al. (2021) found that self-efficacy explained the association between bone health literacy and perceptions of osteoporosis. Those findings are corroborated by the fact that education is a tool that can be used to raise women's vitamin D knowledge and self-efficacy regarding bone health as suggested by Barton (2026). Additionally, Messina et al. (2022) noted that beliefs and self-efficacy, among other factors, and health care providers influence osteoporosis self-care. Therefore, it is anticipated that education in osteoporosis to become health literate will enhance the osteoporosis subscale of self-efficacy.

H4: Osteoporosis knowledge has a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

Worse adherence and fracture prevention behaviour is expected to result as awareness increases; less knowledgeable as more likely to not fully understand the consequences of no adherence and effect of taking preventive measures. This relationship is endorsed by Health believing model, which suggests that patients will increase their participation in the Health behaviour when they think that they are vulnerable to the disease, the disease is threatening health, they think that the Health behaviour is helpful and they do not face any obstacles to do it. In osteoporosis, once patients learn that they have a risk of fracture, even though they don't have any symptoms, they need to follow-up on treatment and behavior modification on an on-going basis.

The keyword search revealed that knowledge has been gaining increased importance when it comes to self-management of osteoporosis in recent times. Ukon et al. (2019) detected correlation between knowledge, beliefs and behaviour in preventing osteoporosis among the old population. Consequently, by concluding from their study Marozik et al. (2019) found a relationship between knowledge, beliefs and patient-centered to medication adherence in

patients with primary osteoporosis. In addition, Hagino et al. (2023) demonstrated that knowledge, attitudes and practices are crucial in cases of conditions related to bone, like Osteosarcopenia. Thus, the patient level of osteoporosis knowledge is positively related to higher adherence to treatment and to patients' fracture-prevention behavior.

H5: Osteoporosis self-efficacy has a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

A relationship between OSEF and treatment adherence and fracture prevention behavior is hypothesized to exist because those who believe they cannot cope with osteoporosis will be less likely to have a potentially hard or long lifestyle changes. Self-efficacy is an important factor in the social cognitive theory influencing behavior change, as it influences effort, perseverance and post-outcomes when obstacles are encountered. Patients face barriers to increased adherence to osteoporosis therapy such as fear of side effects/exercise, pain, lack of time, fear of falling, low motivation and uncertainty with exercise, and self-efficacy can help remove these barriers.

Recent studies and SE has a significant role in the adherence and prevention. In the study, Xu et al. (2024) determined that self-efficacy on osteoporosis is an essential determinant to layperson's bone health literacy and risk perception. In this paper, considering Pender Health Promotion Model, Casado et al. (2022) developed an Osteoporosis Prevention Behaviors questionnaire on which two of most important psychosocial factors are self-efficacy and social support. Moreover, Tan et al. (2026) have reported that the treatment adherence is a mediating variable between self-efficacy and fracture patients. Hence, osteoporosis self-efficacy should boost the adherence to the treatment and fracture prevention actions.

H6: Social support moderates the relationship between health-literacy-tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

Based on the above, we hypothesized that the relationship between health-literacy–tailored patient education and adherence/fracture-prevention behaviour would be moderated by the level of social support provided by a person close to the patient, such as a health-care provider, that would encourage, remind, provide emotional support, and help the patient with adherence/fracture-prevention behaviour, and follow it up. Social Support Theory (SST) contains components that a healthcare provider must provide to patients to lessen stress, increase motivation and provide resources that help patients take the actions required to support healthy living, all of which creates better health behaviors. Education, however, may not as well be translated into adherence for two patients when having the same amount of education, but the other patient has a higher amount of social support.

Supporting this moderating logic is recent information from literature about osteoporosis and literature from older adults. According to Bennett (2025), family and social support is important to LTOP. Chotiyarnwong et al. (2023) found that motivation, social support, access to care and efficiency of the health system were relevant factors regarding osteoporosis preventive behaviors. Following Choong et al. (2023), in general, fall awareness and social support of the elderly with functional impairments in the community is mentioned. Therefore, high levels of adherence and fracture-prevention behaviors were expected among those who were educated in a way that reflects the level of their health literacy and people who had high levels of social support.

H7: Social support moderates the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis knowledge, such that the relationship is stronger when social support is high.

Social support is expected to moderate the relationship between health-literacy–tailored patient education and osteoporosis knowledge, as patients might use social support from either

family members, caregivers or other healthcare professionals to help them make sense of or remember information they will receive in their patient education. Having low health literacy might make it more difficult for patients to understand health information, and social support can be valuable to patients when explaining health information (or anything else) and/or clarification of medication, dietary or lifestyle advice, health information and attendance to health consultations. This is a process that is not merely enabling of the knowledge building activity, but it enriches it, and thus social support is a part of knowledge building as a role of education.

Social support has been shown to have a positive effect on learning and health literacy, as shown in recent evidence. Middle aged and elderly women with breast cancer undergoing endocrine therapy were among subjects, and their bone health literacy was associated with education level, self-efficacy and social support, which are previously reported associations in women with breast cancer (Bell et al., 2020). Doinn et al. (2020) examined how social support and health literacy and functional outcomes are related in older adults. Barton et al. (2021) also found interventions that focused on health literacy can positively impact patient outcomes and could facilitate the ability of informal caregivers. Therefore, the correlation between patient education and osteoporosis knowledge will be improved if there is a growth in the increase of social support.

H8: Social support moderates the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis self-efficacy.

Personally delivered patient education as a consequence of high health-literacy is expected to buffer the association between social support and patients' self-efficacy in osteoporosis self-management as the supportive social environment may reinforce patients' self-efficacy in self-management behaviors. Information and skills transfer in education can support patients with this, but encouragement and practice may

be necessary to help them to believe this. Various aspects of medication management and duty of care can be managed by the patient, as can safe exercise, attendance at appointments, avoidance of falls hazards and far more. The Social Cognitive Theory was suggested as one of the alternative factors in enhancing self-efficacy: verbal encouragement, role modelling, emotional reassurance and mastery experiences.

The relationship has been confirmed recently with research. Cauley & Giangregorio (2020) found that there was relation between social support, self-efficacy and bone health knowledge. McConnell & Shieh (2022) determined that health literacy is related to self-efficacy and concluded that quality of life is related to confidence for those who have a chronic disease, demonstrating the importance of confidence in living with a chronic disease. Booher 2026 also explored the construct of adherence to exercise and the factors of self-efficacy and social support that relate to this. Information is therefore expected to be high level of social support to support the patient's education to increase patient self-efficacy.

H9: Osteoporosis knowledge mediates the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

This state of knowledge was hypothesized to be an intervening variable between health literacy–tailored patient education and adherence or fracture-prevention behavior: If patient education could improve this state of knowledge, then patient education would lead to improvement in patient understanding of osteoporosis, which would lead to better adherence to the treatment and/or preventive services. The intervention is the patient education, the cognitive process is the osteoporosis knowledge, and the behavioral process is adherence/fracture-prevention behavior. It is recommended in the Knowledge-Attitude-Practice model that this there needs to be knowledge as a pre-requisite for the act of

choosing a health behaviour and this concept helps with that.

Recent studies backs-up this mediation assumption. Mohamed et al. (2024) found that patient education with regard to osteoporosis was positively associated with the use of the medications. Reginster et al. (2019) reported that knowledge and beliefs are correlated with osteoporosis behaviours. Manirajan et al. (2024) also pointed out that knowledge is one of the patient-oriented determinants which affects adherence in primary osteoporosis. Therefore, knowledge of osteoporosis can be applied to the understanding of how health-literacy–tailored education can be used to improve treatment adherence and fracture-prevention behavior.

H10: Osteoporosis self-efficacy mediates the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

Based on the conceptual framework, it is hypothesized that the link between health-literacy–tailored patient education and adherence/treatment behavior for fracture prevention could be mediated by osteoporosis self-efficacy, as could the link between health-literacy–tailored patient education and adherence/treatment behavior for chronic disease self-management. Being easily understood, demystifying fear, confronting misinformation, and strengthening skills and encouraging patients to feel empowered are all educational approaches which can make a difference to self-efficacy by offering health-literacy appropriate information. Self-efficacy is an important mechanism linking learning experiences to actions and provides a strong support for this.

Empirical evidence came up to support the role of self-efficacy as a mediator in health behavior in recent times. In contrast to the association between the osteoporosis risk and bone health literacy, mediation by osteoporosis self-efficacy was demonstrated (Reytor-González et al., 2025). (Gómez et al., 2021) confirmed that self-efficacy explained the relationships between

treating the illness and perceived usefulness of wearing the devices for people with fractured. Another key component that was mentioned by Tilahun et al. (2021) is self-efficacy in the management of physical activity for frail older

adults. Therefore, it is hypothesized that self-efficacy would explain the relationships between health-literacy–tailored education and adherence/fracture prevention behavior.

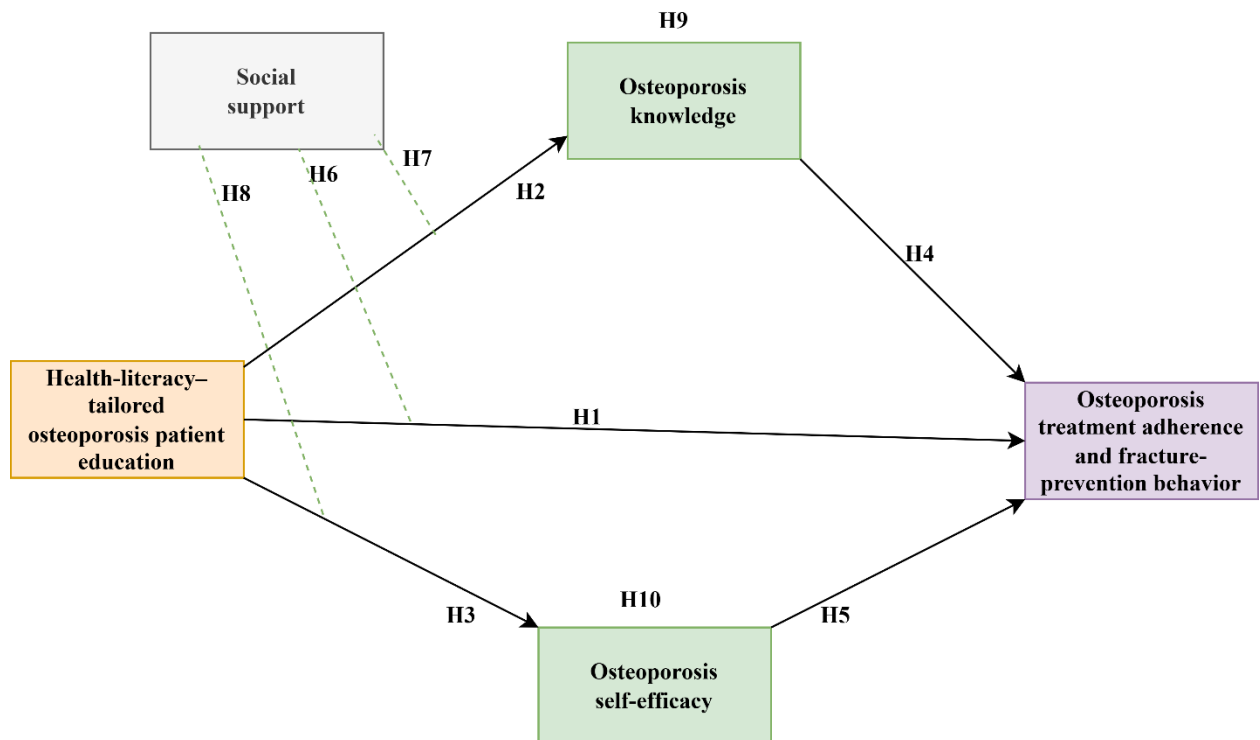


Figure 1: Proposed Research Model

Research Methodology

Research Design

Explanatory research design was applied in this study as it had intent to study relationships, while quantitative design was used to investigate and explain osteoporosis patient education behaviours, and cross sectional research was applied to investigate and explain the relationships between the six variables. Structured questionnaire was used for the collection of data and SEM was used for the analysis and application of the mediation and moderation model was applied among the patients with osteoporosis. Because the model that explains the variables is complex, multiple direct, mediating and moderating relationships are included, and multiple latent variables are included, the use of PLS-SEM was considered appropriate. The analysis was performed in two steps: firstly, the measurement model was

examined using indicator reliability, internal consistency reliability, convergent validity and discriminant validity assessment tests, and secondly, the structural model was examined by assessing the path coefficients, coefficient of determination, effect size, predictive relevance, mediation effect, moderation effect, and significance of relationships (El Miedany et al., 2021).

Measurement Instruments:

The instruments included in the study included five constructs of health-literacy–tailored patient education related to osteoporosis, osteoporosis knowledge, osteoporosis self-efficacy, social support and osteoporosis treatment adherence/fracture-prevention behavior (table 1). Each of the four variables was measured through validated literature from a variety of sources – and therefore some were adapted to best fit the measure (Gomez et al., 2019). These

objects were appropriate to use in a survey type

data collection and analysis using the PLS-SEM.

Table 1. Measurement instruments

Variable	Code	Measurement items	Sources
Health-literacy– tailored osteoporosis patient education	HTOPE1	The osteoporosis education I received was easy to understand.	Koh et al. (2013); Nielsen et al. (2010);
	HTOPE2	The education used simple language to explain osteoporosis and fracture risk.	Rubæk et al. (2026); Huang et al. (2026)
	HTOPE3	The education clearly explained how osteoporosis medication should have been taken.	
	HTOPE4	The education helped me understand calcium, vitamin D, exercise, and fall-prevention practices.	
	HTOPE5	The healthcare provider checked whether I understood the osteoporosis information.	
	HTOPE6	The education materials were suitable for my level of health understanding.	
Osteoporosis knowledge	OK1	I understood that osteoporosis could increase the risk of fragility fractures.	Kim et al. (1991);
	OK2	I knew that osteoporosis could occur without obvious symptoms before a fracture.	Winzenberg et al. (2003); Bailey and Lin (2021);
	OK3	I understood the benefits of taking osteoporosis medication as prescribed.	Dabas and Singh (2024); Gai et al. (2024)
	OK4	I knew that calcium and vitamin D were important for bone health.	
	OK5	I understood that weight-bearing or strengthening exercise helped support bone health.	
Osteoporosis self- efficacy	OSE1	I felt confident that I could take osteoporosis medication according to instructions.	Horan et al. (1998); Evenson and Sanders (2015); Gai et al. (2024); Ünver et al. (2024);
	OSE2	I felt confident that I could follow recommended calcium and vitamin D intake.	Bernalte-Martí et al. (2026)
	OSE3	I felt confident that I could perform safe bone-strengthening or weight-bearing exercise.	
	OSE4	I felt confident that I could attend follow-up appointments for osteoporosis care.	
	OSE5	I felt confident that I could manage osteoporosis even when I faced barriers.	
	OSE6	I felt confident that I could practice fall-prevention behaviors at home and outside.	
Social support	SS1	My family or close friends encouraged me to follow osteoporosis treatment advice.	Zimet et al. (1988);
	SS2	Someone helped me remember my medication or follow-up appointments when needed.	Sherbourne and Stewart (1991);
	SS3	I received emotional support when I felt worried	Ievers-Landis et

Variable	Code	Measurement items	Sources
Osteoporosis treatment adherence and fracture-prevention behavior		about osteoporosis or fractures.	al. (2003); Ma et
	SS4	I had someone who could help me understand osteoporosis-related health information.	al. (2026); Selim et al. (2026)
	SS5	I received practical help for clinic visits, exercise, diet, or fall-prevention activities.	
	SS6	Healthcare providers supported me in managing osteoporosis treatment and prevention.	
	OTAFPB1	I took my osteoporosis medication as recommended by my healthcare provider.	Reynolds et al. (2012); Reynolds
	OTAFPB2	I attended osteoporosis follow-up visits or monitoring appointments as advised.	et al. (2014); Ahn and Oh (2018);
	OTAFPB3	I followed recommended calcium and vitamin D practices.	Askarian et al. (2025); Rubæk et al. (2026)
	OTAFPB4	I engaged in safe physical activity or exercise to support bone health.	
	OTAFPB5	I practiced fall-prevention behaviors to reduce fracture risk.	
	OTAFPB6	I avoided stopping osteoporosis treatment without consulting a healthcare provider.	

Population and Sampling

The population of the study consisted of osteoporosis patients receiving osteoporosis-related education, counseling, treatment, orthopedic care, trauma-related care, or fracture-prevention services at Mother Theresa University Hospital Center, University Hospital of Trauma, and Pegasus Med Clinic in Tirana, Albania. These healthcare settings were targeted because they provided direct access to osteoporosis patients with experience of diagnosis, medication use, follow-up care, patient education, and fracture-prevention practices. A purposive sampling technique was used because the study required respondents who had relevant experience with osteoporosis education and treatment adherence. Patients were included if they had been diagnosed with osteoporosis, had received osteoporosis-related education or treatment services, and were willing to participate voluntarily. After screening incomplete and unusable questionnaires, 513 valid responses were retained for analysis. This sample size was considered adequate for PLS-SEM because it provided sufficient statistical power for testing a complex model involving

direct, mediating, and moderating relationships among latent constructs (Hair et al., 2022; Sarstedt et al., 2023; Sabol et al., 2023; Memon et al., 2020). This revision also aligns with the study's existing methodology section, where the sample consisted of 513 osteoporosis patients and was analyzed using PLS-SEM.

Data Collection

The study targeted osteoporosis patients receiving care at three healthcare settings in Tirana, Albania: Mother Theresa University Hospital Center, University Hospital of Trauma, and Pegasus Med Clinic. These sites were selected because they provided access to patients who had experience with osteoporosis diagnosis, education, counseling, treatment follow-up, orthopedic or trauma-related care, and fracture-prevention services. Data were collected using a structured self-administered questionnaire distributed to eligible osteoporosis patients at these healthcare facilities. Respondents were included if they had received osteoporosis-related education, counseling, or treatment services and were willing to participate voluntarily. Before data collection, respondents

were informed about the study purpose, confidentiality of responses, voluntary participation, and their right to withdraw. After screening incomplete and unusable questionnaires, 513 valid responses were retained for analysis. This approach was consistent with recent osteoporosis survey studies that used structured questionnaires, informed consent, and patient-based data collection in healthcare contexts (Xue et al., 2025; Muhamad Jamil et al., 2024; Sheng et al., 2025; Wang et al., 2026).

Respondents Profile

The demographic profile of the 513 respondents showed that the majority were female, with 371 respondents (72.3%), while 142 respondents (27.7%) were male, which was consistent with osteoporosis studies where women are commonly overrepresented due to higher osteoporosis risk. In terms of age, 61 respondents (11.9%) were 40–49 years, 126 (24.6%) were 50–59 years, 188 (36.6%) were 60–69 years, and 138 (26.9%) were 70 years and above. Regarding marital status, 337 respondents (65.7%) were married, 112 (21.8%) were widowed, 34 (6.6%) were single, and 30 (5.8%) were divorced or separated. Educationally, 124 respondents (24.2%) had no

formal or primary education, 181 (35.3%) had secondary education, 102 (19.9%) had diploma-level education, and 106 (20.7%) had bachelor's degree or above. In relation to employment status, 205 respondents (40.0%) were retired, 139 (27.1%) were homemakers, 103 (20.1%) were employed, 43 (8.4%) were self-employed, and 23 (4.5%) were unemployed. Most respondents were from urban areas, 315 (61.4%), while 198 (38.6%) were from rural areas. Clinically, 93 respondents (18.1%) had been diagnosed with osteoporosis for less than one year, 184 (35.9%) for 1–3 years, 139 (27.1%) for 4–6 years, and 97 (18.9%) for more than six years. A total of 431 respondents (84.0%) were receiving osteoporosis treatment, while 82 (16.0%) were not currently on treatment, and 176 respondents (34.3%) reported a previous fracture history. Overall, the respondents' demographic and clinical characteristics were suitable for examining health-literacy–tailored patient education, osteoporosis knowledge, osteoporosis self-efficacy, social support, and treatment adherence/fracture-prevention behavior among osteoporosis patients, as similar characteristics have been used in osteoporosis survey and adherence studies (Breuil et al., 2012; Aghajanoloo et al., 2023; Xue et al., 2025; Omar et al., 2026).

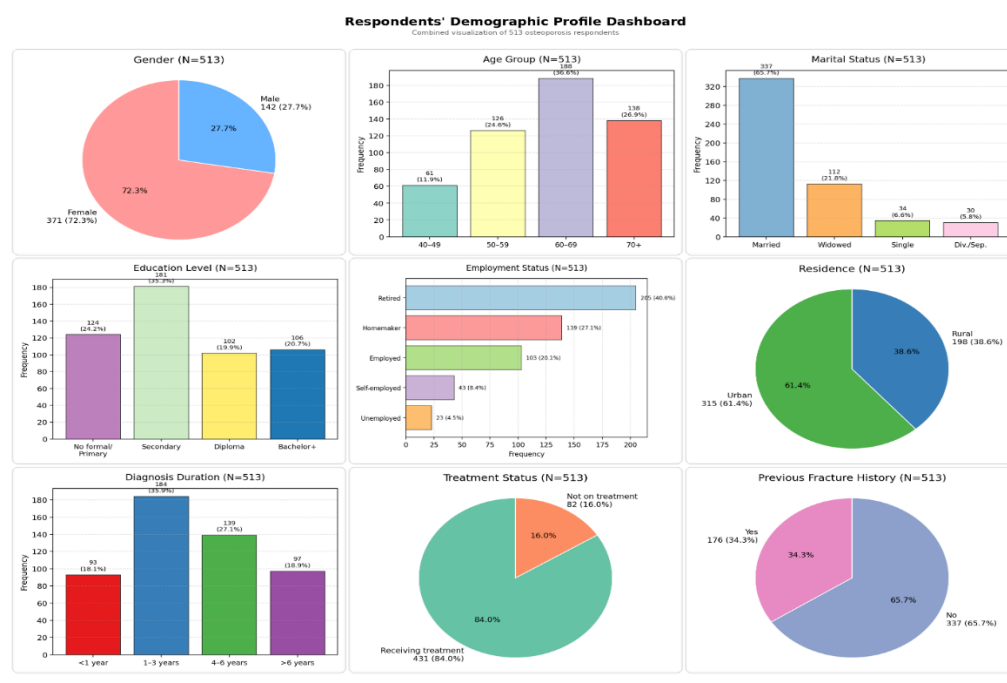


Figure 2: Respondents Profile

Data Analysis Technique

The chosen analytical approach for the study was the partial least squares structural equation modeling (PLS-SEM) analysis due to the research study included direct, mediating and moderating relationships among the latent variables. Prior to primary analysis, all of the data collected were checked for missing cases, outliers, normality issues and common method variance. Descriptive data is used to analyze the responses and the PLS-SEM analysis process is done in two stages. First, measurement model was tested in terms of factor loadings, Cronbach's α , composite reliability, AVE of components and discriminant validity (Fornell-Larcker criterion and HTMT' values). Second, tests using structural models were conducted by performing collinearity test and by t-value, p-value, coefficient of determination, effect of the model, mediating effect and moderating effects. We examined the hypothesized direct effect, indirect effect and interaction effect for the significance using bootstrapping following the procedure of PLS-SEM to conduct mediation and moderation analyses (Rani et al., 2023).

Assessment of Measurement Model

Before testing the structural relationships, the measurement model was tested to make sure all constructs were reliable and valid for testing in PLS-SEM analysis. The reliability of indicators in the study was tested using the outer loading method, and if the loadings of the indicators to the model were ≥ 0.7 , then the model was regarded as very acceptable, and if it was less than 0.7, then it was selected for further examination according to the theoretical content. The reliability of items is examined via internal consistency which is calculated by Cronbach's alpha (ρ_A) and composite reliability above 0.70 is acceptable to have. Convergent validity was measured using the AVEs that exceeded 0.50 indicate that of the indicators >50% of the variance of the constructs could be explained. To demonstrate the discriminant validity, the Fornell-Larcker criterion and the heterotrait-monotrait ratio were used to make sure constructs were

empirically distinct from HTMT' values below the recommended value. For this reason, the results of the measurement model assessment were developed to test the adequacy of reliability and validity of health-literacy-tailored osteoporosis patient education, osteoporosis knowledge, osteoporosis self-efficacy, social support, and osteoporosis treatment adherence/fracture-prevention behavior as per the established guidelines of PLS-SEM (Gupta et al., 2020).

The findings of the measurement model presented in Table 2 showed that every construct had the reliability, validity and low collinearity. The factor loading values ranged from 0.781 to 0.853, and were all greater than the accepted value of 0.70, which means that each item was a good representation of each construct. The Cronbach's alpha value and the composite reliability of each construct were perceived to be good ranging from 0.886 to 0.911, and 0.888 to 0.913 respectively. Results showed that the AVEs for constructs were all above the minimum of 0.50 indicating that constructs were valid with regard to convergent validities. Additionally, the outwards VIF scores have ranged from 1.867 to 2.561, which was below the stringent threshold of 3.0 and indicated that there would not be any issues of multicollinearity among the measures. In general, the results showed a reliable and valid measurement of health-literacy-tailored osteoporosis patient education, osteoporosis knowledge, osteoporosis self-efficacy, social support, and osteoporosis treatment adherence/fracture-prevention behavior and are suitable for further examination of structural models as suggested by PLS-SEM literature (Porcelli et al., 2020).

From the inner VIFs result as shown in Table 3, there was no concern of multicollinearity for the structural model. The VIF values were less than the conservative values of $VIF = 3$, and were even much lower than the maximum value allowed for VIF of 5, which signifies good convergence except for none. This suggested that no predictor constructs would overlap too much in predicting the endogenous constructs,

such as health-literacy–tailored osteoporosis patient education, osteoporosis knowledge, osteoporosis self-efficacy, social support, and their interaction terms. The one with the highest VIF value was the HTOPE → OTAFPB, which was 2.127, but still lies in an acceptable range. Hence, there was no collinearity that could endanger the stability and unbiased results of the structural path estimates in the PLS-SEM framework and the model fulfills the criteria for further testing of hypotheses, mediation analysis and moderation analysis (Donato et al., 2019).

All constructs had discriminant validity according to the Heterotrait-Monotrait ratio, which is shown in Table 4. The HTMT values were found to be in the range of 0.164 to 0.715 that is lower than the conservative limit of 0.85 and more liberal limit of 0.90. The highest value of the HTMT was found between health-literacy–tailored osteoporosis patient education and osteoporosis self-efficacy (0.715) but the value was acceptable and the constructs were shown as related yet empirically separate. So all health-literacy–tailored osteoporosis patient education (HEPE), osteoporosis knowledge (OK), osteoporosis self-efficacy (OSE), social support (SS), and osteoporosis treatment adherence/fracture-prevention behavior (OTAB), as separate theoretical concepts, were revealed as suitable to further test in the structural model as suggested by Aljohani (2023), Jiang et al. (2025), Liang et al. (2025), Paskins et al. (2023) according to PLS-SEM discriminant validity guidelines.

Further, the f-square sizes of the latent-variable relationships, shown in Table 5 as well as the relative contributions of the various predictor variables to these endogenous constructs, were also reported. The values of 0.02, 0.15 and 0.35 indicated small, medium and large effects, respectively; and values less than 0.02 indicated no meaningful effect. This showed that there was a large effect of patient education level grounded in patients' level of health literacy (baseline-knowledge score) on understanding of osteoporosis ($f^2 = 0.403$) and self-efficacy ($f^2 = 0.719$); suggesting a strong contribution of this patient education to patients' understanding and

confidence in self-efficacy regarding the management of osteoporosis. This direct effect on adherence and fracture prevention behavior was however, not very powerful ($f^2 = 0.043$), meaning that indirectly the impact of education was more powerful. Effect of knowledge about osteoporosis ($f^2 = 0.054$) and this definition of the self-efficacy with osteoporosis ($f^2 = 0.136$) on adherence and fracture-prevention behavior was small, being greater with the osteoporosis self-efficacy. Social support had only minor impacts on knowledge and self-efficacy, and no impacts on adherence behaviour. The interaction effects indicate that the association between education and self-efficacy was slightly stronger when interacting with social support; the intervention of the social support was less significant for knowledge and adherence to behavior. In general, it was observed that for the entire sample the teaching of the patient was the factor that explained the highest effect on knowledge and self-efficacy about osteoporosis, according to the PLS-SEM guidelines for the interpretation of effect size as described Choi et al. (2022).

However, the outcomes of the structural model show the following desirable results: good explanatory power, good predictive relevance, and good model fit (see Table 6). The R-square values for the model showed that this model accounted for variance in osteoporosis knowledge with 32.7% of the variance measured in treatment adherence, oversight of fracture-prevention behavior with 47.6% of the variance measured and very close R-square values were observed indicating some stable explanatory power in the model in osteoporosis treatment adherence, and fracture-prevention behavior with 46.8% of the variance measured. The values for Q^2_{predict} for the endogenous constructs were positive for all of them in relation to the model to be considered predictive relevant. The Value of RMSE and MAE gave supplementary evidence to the assessments of the prediction error and with lower values, the predictive performance was considered acceptable. Both the saturated model and the estimated model were within the good

approximate model fit as indicated by low SRMR values (under 0.08) in the model fit. The NFI value was 0.931; which is considered acceptable level of model fit. The overall results indicated that the proposed model was suitable

for hypothesis testing in PLS-SEM as it was able to explain and predict the knowledge and self-efficacy on osteoporosis and adherence/fracture-prevention behavior of the nursing aides (Halim et al., 2022).

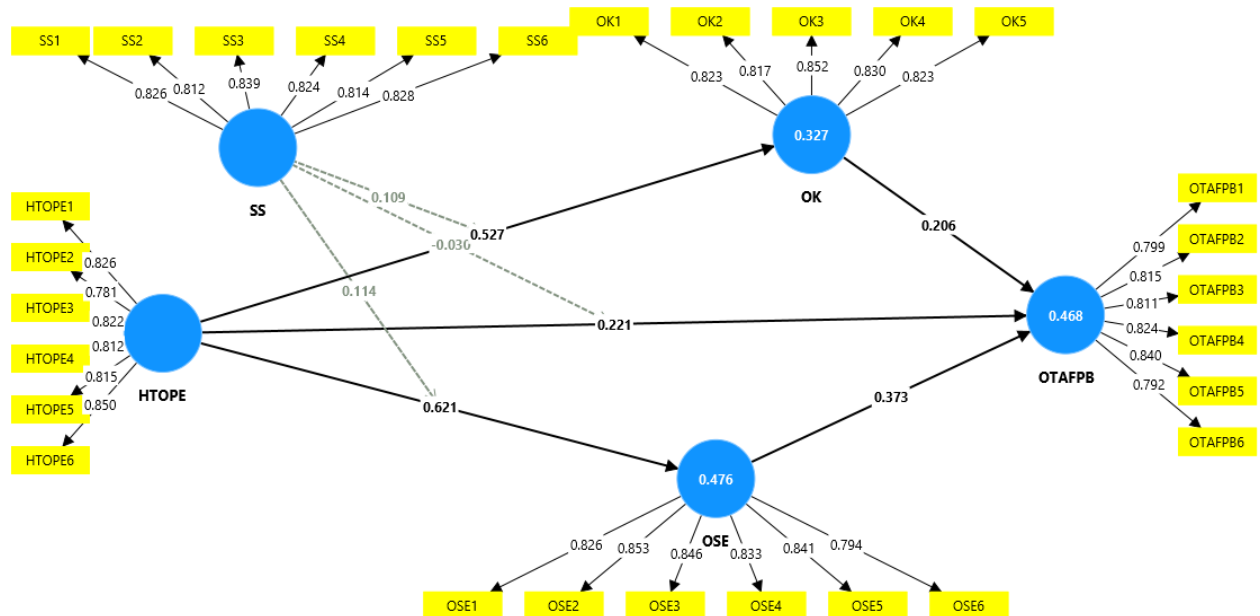


Figure 3: SEM with Factor Loadings

Table 2: Reliability, Validity and Variance Inflation Factor (VIF)

Construct/Items	Outer VIF values	Factor Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Health-literacy-tailored education	osteoporosis	patient	0.901	0.901	0.669
HTOPE1	2.217	0.826			
HTOPE2	1.867	0.781			
HTOPE3	2.232	0.822			
HTOPE4	2.114	0.812			
HTOPE5	2.177	0.815			
HTOPE6	2.516	0.850			
Osteoporosis knowledge			0.886	0.888	0.687
OK1	2.112	0.850			
OK2	1.988	0.823			
OK3	2.316	0.817			
OK4	2.190	0.852			
OK5	2.052	0.830			

Osteoporosis self-efficacy			0.911	0.913	0.693
OSE1	2.215	0.826			
OSE2	2.561	0.853			
OSE3	2.440	0.846			
OSE4	2.319	0.833			
OSE5	2.406	0.841			
OSE6	2.026	0.794			
Osteoporosis treatment adherence and fracture-prevention behavior			0.898	0.899	0.662
OTAFPB1	2.029	0.799			
OTAFPB2	2.105	0.815			
OTAFPB3	2.081	0.811			
OTAFPB4	2.235	0.824			
OTAFPB5	2.337	0.840			
OTAFPB6	1.969	0.792			
Social support			0.905	0.907	0.679
SS1	2.302	0.826			
SS2	2.160	0.812			
SS3	2.358	0.839			
SS4	2.190	0.824			
SS5	2.044	0.814			
SS6	2.262	0.828			

Table 3: Collinearity Statistics (Inner VIF)

Relationship	VIF	Decision
HTOPE -> OK	1.024	No multicollinearity issue
HTOPE -> OSE	1.024	No multicollinearity issue
HTOPE -> OTAFPB	2.127	No multicollinearity issue
OK -> OTAFPB	1.489	No multicollinearity issue
OSE -> OTAFPB	1.911	No multicollinearity issue
SS -> OK	1.025	No multicollinearity issue
SS -> OSE	1.025	No multicollinearity issue
SS -> OTAFPB	1.127	No multicollinearity issue

SS x HTOPE -> OK	1.002	No multicollinearity issue
SS x HTOPE -> OSE	1.002	No multicollinearity issue
SS x HTOPE -> OTAFPB	1.042	No multicollinearity issue

Table 4: Discriminate Validity Heterotrait-Monotrait (HTMT) Ratio

	HTOPE	OK	OSE	OTAFPB	SS
HTOPE					
OK	0.608				
OSE	0.715	0.465			
OTAFPB	0.647	0.548	0.675		
SS	0.164	0.242	0.328	0.260	

Table 5: Effect Size of Latent Variables

Path	f-square	Effect Size
HTOPE -> OK	0.403	Large effect
HTOPE -> OSE	0.719	Large effect
HTOPE -> OTAFPB	0.043	Small effect
OK -> OTAFPB	0.054	Small effect
OSE -> OTAFPB	0.136	Small effect
SS -> OK	0.027	Small effect
SS -> OSE	0.077	Small effect
SS -> OTAFPB	0.003	No effect
SS x HTOPE -> OK	0.017	No effect
SS x HTOPE -> OSE	0.024	Small effect
SS x HTOPE -> OTAFPB	0.002	No effect

Table 6: Model Fit

	R-sq	Adj R-sq	Q²predict	RMSE	MAE	Saturated Model	Estimated Model
OK	0.327	0.323	0.319	0.828	0.666		
OSE	0.476	0.473	0.468	0.732	0.596		
OTAFPB	0.468	0.462	0.352	0.808	0.657		
SRMR						0.038	0.038
NFI						0.931	0.931

Hypothesis Testing:

H1: Health-literacy–tailored osteoporosis patient education had a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

Table 7 showed that HTOPE had a positive and significant effect on OTAFPB ($\beta = 0.221$, $t = 4.492$, $p = 0.000$). Hence, it is concluded that null hypothesis H 1 is accepted. The implication of this finding was that education on osteoporosis would more easily be achieved by tailoring the program to the health literacy of the patient.

It was suggested that health literacy of patients dictates how much osteoporosis education is needed, so increasing their health literacy would lead to better treatment adherence and fracture avoidance behavior (Alexander et al., 2025).

H2: Health-literacy–tailored osteoporosis patient education had a positive effect on osteoporosis knowledge.

Table 7 showed that HTOPE had a positive and significant effect on OK ($\beta = 0.527$, $t = 15.326$, $p = 0.000$). Thus H2 was advocated. This suggested that, where there was a message and comprehension, and literacy sensitivity, osteoporosis education improved patients' knowledge of osteoporosis and fracture risk, as well as treatment, diet, PA and fall prevention (Popa et al., 2024).

H3: Health-literacy–tailored osteoporosis patient education had a positive effect on osteoporosis self-efficacy.

Table 7 showed that HTOPE had a positive and significant effect on OSE ($\beta = 0.621$, $t = 23.377$, $p = 0.000$). There was thus approval for H3.

This evidence has demonstrated the ease with which any patient could use osteoporosis educational advice tailored to them to manage their treatment, follow-up, safe exercise and fracture prevention measures (Jones et al., 2022).

H4: Osteoporosis knowledge had a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

Table 7 showed that OK had a positive and significant effect on OTAFPB ($\beta = 0.206$, $t = 5.041$, $p = 0.000$). But the issue of H4 was supported.

These patients were more likely to attend treatment behaviors and fracture-prevention behaviors, as they had a clear understanding of the need to take medications and pursue good maintenance of bone health, as well as their awareness of the importance of fall-risk-reduction (Ackermann et al., 2023).

H5: Osteoporosis self-efficacy had a positive effect on osteoporosis treatment adherence and fracture-prevention behavior.

Table 7 showed that OSE had a positive and significant effect on OTAFPB ($\beta = 0.373$, $t = 7.851$, $p = 0.000$). For this reason, H5 was backed-up.

This indicated that self-efficacy, not knowledge was important to the patients in their confidence of their ability to manage osteoporosis, while also being indicated to be better predictor of adherence and fracture prevention behaviour as compared to knowledge (Penoni et al., 2023).

H6: Social support moderated the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

The interaction effect (SS x HTOPE) was non-significant and negative (Table 7: $\beta = -0.030$, $t = 0.930$, $p = 0.353$). This meant that H6 would not be given support.

This implied that the social support factor was not found to be a significant factor in reinforcing the direct link between patient education and treatment adherence/fracture-prevention behavior in this study (Chotiarnwong et al., 2022).

H7: Social support moderated the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis knowledge.

The interaction effect (SS x HTOPE) was significant and positive for OK ($\beta = 0.109$, $t =$

3.251, $p = 0.001$) suggesting that the combination of these factors is more influential to OK than either of them alone. So, it was suggested that H7 should be promoted.

It recommended the implementation of social support that would make the impact of the health-literacy–tailored education more effective; that is, people who receive more social support would have more capacity to understand and remember, as well as apply, the information about osteoporosis (Lee & Son, 2022).

H8: Social support moderated the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis self-efficacy.

This interaction of SS $\times$ HTOPE was significantly positive ($\beta = 0.114$, $t = 3.955$, $p = 0.000$) (Table 7). Hence, H8 was given an endorsement of approval.

This indicated that social support activated the impact of patient education for osteoporosis self-efficacy: encouragement and help from members of the family, the healthcare provider, as well as friends contributed to patients' self-efficacy of osteoporosis (Shi et al., 2024).

H9: Osteoporosis knowledge mediated the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

The indirect effect of HTOPE on OTAFPB (Ok) was positively significant ($\beta = 0.109$, $t = 4.833$, $p = 0.000$). The support and demonstration of partial mediation in H9 occurred as a result. It suggested that the higher overall acceptance of fracture prevention behaviours was indirectly associated with patient education (via the pathway of increased knowledge about osteoporosis as an awareness)

and was directly associated with HTOPE as well (Reid & McClung, 2024).

H10: Osteoporosis self-efficacy mediated the relationship between health-literacy–tailored osteoporosis patient education and osteoporosis treatment adherence/fracture-prevention behavior.

To support this, table 7 showed that two variables HTOPE and OTAFPB, based on the consideration of intervening variables OSE, were positively related and statistically significant. ($r = 0.232$, $t = 7.414$ and $p = 0.000$).

Therefore the confirmation and demonstration of the H10 was confirmed and confirmed to have a mediating quality. This suggested the teaching tailored to patients' health-literacy contributed to adherence and fracture prevention behaviors, partially through an increase in the care-taking confidence about osteoporosis, and directly through the teaching (Lambertini et al., 2023).

The overall results of Table 7 showed that the proposed model was well supported; a direct relationship between education and adherence/fracture prevention behavior by social support was found not to strongly support the proposed model.

Achievement of health-literacy–tailored patient education on osteoporosis was found to have a direct effect on adherence outcomes, an indirect effect through a self-efficacy–mediated pathway, and indirectly through achieved health-literacy–promoted patient education regarding knowledge of osteoporosis.

The results of the tests of t-value and p-value were used to test the significance of path coefficients and the t-value was also used to test the direct and indirect paths for mediation, the results of both of which were congruent with the above-mentioned inferences (Patel et al., 2025).

Table 7: Hypotheses Testing (Bootstrapping)

Hypothesis	Relationship	Path Coefficient	Standard deviation	t-Value	P values	Result
H1	HTOPE → OTAFPB	0.221	0.049	4.492	0.000	Supported
H2	HTOPE → OK	0.527	0.034	15.326	0.000	Supported
H3	HTOPE → OSE	0.621	0.027	23.377	0.000	Supported
H4	OK → OTAFPB	0.206	0.041	5.041	0.000	Supported
H5	OSE → OTAFPB	0.373	0.047	7.851	0.000	Supported
H6	SS x HTOPE → OTAFPB	-0.030	0.032	0.930	0.353	Not Supported
H7	SS x HTOPE → OK	0.109	0.033	3.251	0.001	Supported
H8	SS x HTOPE → OSE	0.114	0.029	3.955	0.000	Supported
H9	HTOPE → OK → OTAFPB	0.109	0.022	4.833	0.000	Complementary Partial Mediation
H10	HTOPE → OSE → OTAFPB	0.232	0.031	7.414	0.000	Complementary Partial Mediation

Discussion:

As indicated by the results from Table 7, the health-literacy-tailored patient education about osteoporosis resulted in a significant increase in adherence to osteoporosis treatment and fracture prevention behavior. This statement was validating the theory, which promotes the idea that that patient education would be more effective if information is simplified, understandable and appropriate to the health literacy level of the patient. The results concurred with Geusens et al. (2024) who noted that education on osteoporosis led to an improvement in patients' knowledge of osteoporosis and medication adherence, and with Guillemot et al. (2025) who suggested that coordinated education coupled with ongoing follow up and patient counselling was necessary for the promotion of long-term fracture prevention care. Similarly, Mohammad et al. (2024) found that digital osteoporosis SME can benefit patient's understanding and adherence behavior. Some studies, however, suggested that

education alone does not always seem to have a significantly greater impact on behavioral outcomes; rather, along with education, concerns about medications, access to care, side effects and medication costs, follow-up systems, and personal motivation also play a role in adherence. (Yu et al., 2023) This was because of the importance of the direct relationship of education with adherence and fracture-prevention behaviors being smaller than the relationships between education, knowledge, and self-efficacy.

Other outcomes of this research were finding strong positive effect of the patient education tailored to health-literacy on patient knowledge about osteoporosis and on osteoporosis self-efficacy. These clearly showed that being well educated and responsive to literacy had a significant impact on patients' understanding of osteoporosis risk, benefits of treatment, medication management, calcium and vitamin D consumption, exercise and fall prevention. Medina-Aedo et al. (2024) found that bone

health literacy is correlated with the osteoporosis. Hong et al. (2024) revealed that the patient-based factors of knowledge and self-efficacy in osteoporosis medication adherence. Results also corroborated the results of Samieva et al. (2023) who reported that beliefs, confidence, contextual factors and provider-patient communication impacted osteoporosis self-care. Contrary to this, Falossi et al. (2022) found knowledge and adherence to osteoporosis education to actually increment, but not necessarily enhance all aspects of self-efficacy. Variation in intervention design, timing of measurement, patient characteristics or if they received a health literacy tailored education account for this difference.

The results also indicated that the knowledge and OSCSE on osteoporosis significantly contributed to the adherence to treatment and fracture-prevention behavior. That meant it was beneficial to get the information about the disease because having a level of control over the disease resulted in a higher likelihood of treatment and prevention adherence as well as knowledge of the disease. The study's results were similar to those of the studies carried out by Dabas, Singh 2024 which showed that the knowledge, confidence, and practices associated with osteoporosis were closely connected in older adults and Tay et al. (2022) that indicated that self-efficacy was an essential concept in studying osteoporosis-preventive behaviors. Alawi et al., (2025) also confirmed that self-efficacy mediated the association between the bone health literacy and the perception and behaviors of osteoporosis. Results, however, showed that self-efficacy had a stronger impact than the knowledge; knowledge about osteoporosis was a strong factor but was not sufficient. It was important patients had "confidence, skills, reminders and practicality" to "act". This enhanced the concept of distress and empowerment through cognitive understanding from the perspective of behavior change in osteoporosis treatment.

The results showed that there was conflicting evidence regarding the findings carried out by the moderator. Social support did not have any

significant moderation effect on the direct links of HLT–Patient Education with adherence to treatment/fracture prevention behavior and the direct link of HLT–Patient Education with osteoporosis knowledge; however, the direct association of HLT–Patient Education and osteoporosis self-efficacy was significantly moderated by social support. The results indicated that social support promoted comprehension and adoption of the education message and consequently, the confidence of patients but did not affect the step from 'education' to 'adherence behaviour'. This supported the work of Jackson et al. (2023) that found that social support influenced the mediating relationship between knowledge and self-efficacy in the context of osteoporosis treatment adherence, as well as Drummond et al. (2022) , who found that the motivation, support, access and health care influenced preventive behavior. The lack of moderation for adherence behavior might be explained since adherence is more than just being encouraged, it may be affected by medication availability and costs, side effects, treatment complexity, appointment availability, physical limitations and provider followup. Social support was thus seen to be more supportive in knowledge building and confidence building, but not vice versa, that is, not directly influencing adherence behavior.

Mediation analyses showed that both health-literacy–tailored patient education and treatment adherence/fracture-prevention behavior was mediated by osteoporosis knowledge and osteoporosis self-efficacy. The two mediations were complementary partial mediations as the direct effect of education was significant, the indirect effects of education via knowledge and self-efficacy were significant as well. It was suggested that patient education played a role in supporting patient adherence both by increasing patient understanding/knowledge and by increasing patients' self-efficacy to engage in behaviors associated with osteoporosis self-management. This health care construct, which includes health literacy, self-efficacy, knowledge and contextual support, was presented by Ali et al. (2024). The more positive mediation was by

self-efficacy, which meant that self-efficacy proved to be more motivational than knowledge. This result was also in line with Social Cognitive Theory, which suggests that more likely to engage in a health behavior is the perception that they can do the action that successfully.

As a whole, the results further suggest that a health-literacy tailored osteoporosis patient education could be an important strategy to boost willingness to adhere to an osteoporosis treatment and fracture-prevention behavior, particularly through the bone-health knowledge and more particularly the bone-health self-efficacy. While findings from the study were similar as several recent studies on osteoporosis and health outcomes literacy, some differences to previous studies might be attributable to varying intervention intensity, health care setting, or patient characteristics, or to the method of assessing health-literacy outcomes (Ruggiero et al., 2024). The practical application of the results being presented suggested that osteoporosis education programs should not only be provided with information, but also through simple language, teach-back, patient-centred counselling, family/visitors role involvement and the integration of strategies to build confidence to improve compliance and fracture prevention.

Theoretical implications

The findings of this study contributed to the knowledge of literature on osteoporosis self-care in a model that built healthy-literacy-tailored patient education as a starting point and added the domains of osteoporosis knowledge and osteoporosis self-efficacy, social support and osteoporosis treatment adherence/fracture prevention behavior. Results of the significant first pathway of health-literacy-tailored education on adherence outcomes supported the Health Literate Care Model proposed in the literature that more likely health outcomes are used when information is presented, understood and adapted to health-literacy level of patient. Results also supported the Health Belief Model as they revealed that knowledge of increased risk

of osteoporosis, benefits of treatment, and fracture prevention behaviors impacted adherence to the behavior. This corresponded to the recent studies on osteoporosis, such as the one by (Moldovan & Moldovan, (2025) , which suggested that patient health literacy and health education could play a critical role in osteoporosis prevention measures, or the study by Gong et al., (2024) and study by Temel et al. (2024), which showed that cultural context is parameters have an influence on osteoporosis knowledge.

The study also supported the tenets of the social cognitive theory by demonstrating that greater factors of treatment adherence and fracture prevention behavior are predicted by osteoporosis self-efficacy rather than knowledge. Despite the fact that the knowledge of the patients regarding osteoporosis significantly mediated the association of patient education with adherence outcomes, self-efficacy in osteoporosis displayed stronger mediating effect, this suggests that to create an impact in actual practice patients must not only possess the knowledge about osteoporosis, but they should be confident to perform behaviours linked to successful osteoporosis treatment in everyday life. This helped to confirm the theoretical approach that attitude leading to change in behavior was related to people's beliefs that they can do recommended behaviors. Chintham et al. (2025) highlighted the significance of self-efficacy, patient beliefs and patient-centered understanding in the self-care and medication-taking of osteoporosis.

The study also built on the social support theory by finding that providing the effects of health-literacy-tailored education messages on osteoporosis knowledge and self-efficacy was more effective when combined with a strong sense of social support than when it was provided alone, while there was no significant strengthening effect when health-literacy-tailored education messages and social support were combined. This finding suggested that the social support could be a rather learning experience and a belief builder than a behavior triggering experience. This confirmed that

theoretically, social support can help them understand, remember and “believe” the information about osteoporosis; however other barriers related to the cost of the medicines, potential side effects and difficulty of follow-up and complexity may also be factor in their adherence to the behavior. The interpretation was consistent with recent studies which suggested that knowledge, self-efficacy, social support, access to health care facilities and communication with the health care provider were related to adherence to osteoporosis (Jianu et al., 2024).

Practical implications

In conclusion, the study suggests that health professionals, osteoporosis clinics, primary care units, and fracture liaison services develop and offer osteoporosis education programs targeting the different health literacy levels of individuals. During the following area, education should be provided in simple language in a repetitive fashion, with the use of visual materials, teach-back methods and practical examples: Medication use, Calcium and Vitamin D nutrition, Physical activity, Fall prevention, and follow-up. The study revealed that the delivery of information was not a sufficient approach to patient education as knowledge and self-efficacy were significantly increased, instead healthcare practitioners and professionals should prioritise the understanding and application of patient's self-management practices for osteoporosis. This was confirmed by van Oostwaard et al. (2024) who pointed to the importance of patient education, digital education tools, exercises guidance and health education in osteoporosis management.

More broadly, they indicated the necessity to implement measures to improve confidence and provide support - as they also more strongly influenced the maintenance of treatment and behaviour to avoid fracture than knowledge did. Healthcare providers should educate individuals to not only understand how to use medications but, also education around side effects of medications, how they can carry out activities safely, how to avoid falling at home,

understanding how to communicate with a healthcare provider and how to continue to receive ongoing health care treatment when things are challenging. This may be done through individual counselling, goal setting, reminding of supports and encouragement to motivate, and post-monitoring. These strategies were similar to those identified in a recent study in which patients' feeling of empowerment to manage treatment and prevention behavioral practices was positively correlated with changes in these behaviors as well as benefits for osteoporosis health related outcomes (Ward et al., 2024).

Additionally, the researchers recommended that family members/caregivers, peers, and health care providers be involved in osteoporosis education as it also optimizes the effect of osteoporosis education on knowledge and self-efficacy. Depending on the case, it may be possible to engage family/caregiver in their patients treatment which could increase the chances of the patient remembering to take medications, understanding health information, attending appointments, exercising and practicing fall-prevention behaviors. But, social support did not significantly moderate the mediation effect of education on adherence behavior, suggesting that healthcare managers should not solely rely on social support. Rather, it should be provided in conjunction with input from a structured follow-up mechanism, medication counselling, affordable and coordinated fracture prevention medications, and support services/counselling. Duque et al. (2022) reinforced this implication, when they talked about the need for harmonised care, social support and responsiveness of the health care system in order to achieve better long-term outcomes of osteoporosis.

All in all, the study gave conclusive evidence towards addressing osteoporosis using confidence, literacy and support as a means for its care. Future research might have implications for patient education protocols, staff training programs, fracture liaison service pathways, digital self-management tools and follow-up systems that increase adherence to treatment

and decrease preventable fracture risk among osteoporosis patients that could be used by healthcare managers and policymakers.

Conclusion

Because both good adherence with osteoporosis therapy and good fracture prevention practices are difficult to achieve in patients, the authors were interested in exploring this in this study. Study was designed based on the concept of it's difficult for the patients who don't have clear health information, osteoporosis knowledge, self-efficacy and supportive care conditions to maintain the same conditions in order to use up the medicines and follow-up care, osteoporosis dietary and exercise regimen, fall prevention, etc. The direct and indirect relationships between health literacy–enriched patient education regarding osteoporosis and increased knowledge about osteoporosis and osteoporosis self-efficacy were examined, with a secondary goal of examining if adding social support created greater relations between health literacy and increased knowledge of osteoporosis and osteoporosis self-efficacy, and increased adherence to care, and fracture-prevention behaviors, as wells.

The results indicated that treatment adherence and fracture prevention behaviors were significantly enhanced with health-literacy–tailored patient education in persons with osteoporosis. It also had positive impact on knowledge about osteoporosis and osteoporosis self-efficacy that were significant. Both knowledge about osteoporosis and self-efficacy had a significant impact on adherence and fracture prevention behaviour, the latter being more powerful influence. The findings of the mediation revealed partial mediation of patient education with adherence outcomes by the level of knowledge about osteoporosis and SE of managing osteoporosis, indicating that patient education also impacts adherence outcomes by raising patient's self-efficacy to deal with osteoporosis. These contrast with recent reports indicating that health literacy about osteoporosis, education, osteoporosis knowledge and self-efficacy and attitude and

values toward patient-centered counseling were significant variables to support a better self-management and adherence in people with osteoporosis.

The study also revealed that the level of social support reinforced the links found between health-literacy adapted education and osteoporosis knowledge and osteoporosis self-efficacy; and between an education and adherence/fracture-prevention behaviors, but did not find significant reinforcing with the latter link. This indicates that social support helped patients grasp and accept the information regarding osteoporosis and gave them greater confidence, but other barriers dealing with availability of treatment medications, side effects of drugs, quality of follow-up, access to health care and need for greater complexity and cost of the treatment also played a role in adherence to treatment. This finding aligns with studies targeting barriers to osteoporosis preventive behaviors with a focus on social support, adherence behavior, chronicity of the disease, and availability of health care systems.

The study as an idea was a contribution to the literature on self-management of osteoporosis that integrated Health Literate Care Model, Health Belief Model, Social Cognitive Theory and Social Support Theory in a single aspect of the study. It showed both cognitively and psychologically being literate strengthen adherence tasks particularly in terms of knowledge and sense of self-efficacy. Practically, the findings suggested that the hospital and/or health centre-based education programs should include the use of basic and easily understood language, "teach back" methods, visual aids, repeated counseling, engagement of care partner/family, and the use of confidence-building techniques. These strategies can help improve patients' knowledge of osteoporosis, confidence in their ability to effectively treat osteoporosis, and mitigate risk for fractures.

The Study has made contributions however there were certain limitations. Due to the cross sectional nature of the study it was not possible

to draw cause effect conclusions related to the findings and the self-reported information provided on the questionnaires may have resulted in recall or social desirability bias. However, the study was limited to osteoporosis patients that were available and willing to participate and this may limit the generalizability to all osteoporosis populations. To assess causal effects, future studies will need to utilize longitudinal study or use an experimental study; objective measures of adherence such as medication record notes from the pharmacist or patients using clinical follow-up data would be useful additions to future studies; and support from the healthcare system, provider communication, digital health education and medication beliefs would be added factors to examine in future research examining adherence. In summary, the study demonstrated that providing health-literacy-tailored patient education on osteoporosis was an effective way to improve adherence to the treatment of osteoporosis and behaviour in prevention of fractures, particularly when increasing knowledge and boosting self-efficacy and providing an enabling care environment.

Limitations

Some limitations or potential strengths and weaknesses should be considered when using the results of this study in practice. Study design, which was a cross sectional study was utilized, did not allow causal relationship between the factors each other such as; adherence to treatment/fracture-prevention behavior with health-literacy-tailored osteoporosis patient education, osteoporosis knowledge, osteoporosis self-efficacy, and social support to be established. Second, data was collected on the basis of self-reported questionnaires, which may have led to a recall bias, a response bias, and social desirability bias especially in terms of the treatment adherence or fracture-prevention behavior. Similar restrictions have been reported in the recent studies on osteoporosis and health-behaviour that used cross-sectional and consecutive design and focused on self-reported data (Gregson et al., 2025). Third, results of this study may not be generalizable to patients in

other healthcare practices, rural populations, newly diagnosed patients or severe disability following fracture due to only having available and willing patients with osteoporosis. Additionally, the study focused on only two mediators (osteoporosis knowledge, osteoporosis SE) and one moderator (social support) and did not include other factors that could impact outcomes or factors that may contribute to osteoporosis treatment but were not measured, including the costs of medication, their side effects, patient-provider communication, comorbidities, access to digital health, and receiving a follow-up appointment within the healthcare system. Treatment adherence and fracture-prevention behaviour, however, were reported in terms of perceived as opposed to clinical (e.g. pharmacy recorded adherence) or type of behaviour (e.g. fall occurrence), bone mineral density change, respectively.

Future Research Directions

There is a need for ongoing research to see whether patients' fracture-prevention behavior and/or their health behavior that foster such outcomes, over the life of the program, improve with the addition of health-literacy-tailored education; as well as to confirm that health-literacy-tailored education improves treatment adherence with time. Longitudinal and experimental or randomized trials are suggested. Objective measures of adherence should also be used, as should be clinical outcomes like prescription refill information, access to appointments, bone mineral density reports, record of falls or whether/when fractures occurred, to improve the validity of the findings. Further investigation of other mediators and moderators such as beliefs regarding medication, perceived fracture risk, fear of side effects, financial restrictions, communication with health care providers, digital health literacy, comorbidities, and fracture liaison services, could also be examined in future studies. Further research should involve the investigation of various kinds of social support on their own because they seem to be better predictors of direct relationship between

knowledge and adherence to the educational tasks as well as between individual and family education. Recommendations for future research should also include a comparison of the different educational approaches used, such as face-to-face, electronic, education based on chatbots, and education based on the family, to explore the effectiveness of each approach, given the importance of digital and structured

education and self-management of osteoporosis in recent years (Chandran et al., 2023). In conclusion, future research needs to be undertaken in a variety of cultural, rural and healthcare-system settings for the sake of generalizability and identification of educational interventions that work best with different groups of osteoporosis patients.

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