Exercise Education for Individuals With Osteoporosis: An Evidence-Based Review

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ABSTRACT:

Background: People with osteoporosis should be actively engaged in safe resistance, balance, posture, and weight-bearing exercise; however, many patients stop before, during, or after recommended exercise programs because of low knowledge of their condition/limited exercise knowledge, low exercise confidence, or fear of falling. The aim of this study was to determine if osteoporosis-specific education regarding exercise resulted in direct and indirect effects on exercise adherence via changes in exercise self-efficacy and fear of falling.

Methods: A quantitative, cross-sectional explanatory design was employed. Data were obtained from 500 adults with medically confirmed osteoporosis attending Mother Theresa University Hospital Center and Pegasus Med Clinic in Tirana, Albania. A structured questionnaire measured osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence. Partial least squares structural equation modelling was used to assess the measurement model, structural relationships, predictive relevance, and parallel mediation effects.

Results: The measurement model demonstrated acceptable indicator reliability, internal consistency, convergent validity, discriminant validity, and collinearity. Osteoporosis-specific exercise education significantly predicted exercise adherence, exercise self-efficacy, and reduced fear of falling or greater falls confidence. Exercise self-efficacy and reduced fear of falling

also significantly predicted exercise adherence. The model explained 46.2% of the variance in exercise adherence, 31.7% in exercise self-efficacy, and 42.1% in fear of falling. Exercise self-efficacy and fear of falling demonstrated complementary partial mediation, with the fear-related pathway producing the stronger indirect effect.

Conclusion: Osteoporosis-specific exercise education had been associated with improved adherence both directly and through psychological mechanisms. Clinically, education programmes should have combined clear information with supervised demonstrations, confidence-building, balance training, fall-prevention guidance, goal setting, and follow-up support across the participating healthcare institutions in Tirana, Albania.

Keywords: Osteoporosis; exercise education; exercise adherence; self-efficacy; fear of falling; PLS-SEM.

Introduction:

Osteoporosis is a progressive skeletal disorder that increases susceptibility to fragility fractures, chronic pain, functional decline, loss of independence, and reduced quality of life, with recent global analyses showing a continuing burden of vertebral, hip, and forearm fractures among ageing populations (De Sire et al., 2022). Exercise—particularly progressive resistance, balance, posture, and weight-bearing training—is increasingly recognised as an essential component of osteoporosis management because it can improve physical function, muscular strength, balance, pain, and quality of life while presenting a relatively low risk of adverse events when appropriately prescribed (Cong & Zhang, 2025). Nevertheless, many individuals with osteoporosis do not sustain recommended exercise behaviours because of uncertainty about safe movement, low confidence, fracture concerns, and fear of falling. Recent evidence suggests that combining rehabilitation with tailored education and adherence support may produce better outcomes than standard exercise rehabilitation alone, while structured health-management interventions can strengthen osteoporosis knowledge and exercise-related self-efficacy (Wang et al., 2022). Digital and supervised exercise interventions may also reduce concerns about falling and improve falls efficacy, although these psychological mechanisms remain insufficiently examined in osteoporosis-specific education research (Glavas & Scott, 2025). Therefore, the present study examines whether osteoporosis-specific exercise education improves exercise adherence and whether this relationship is mediated by increased exercise self-efficacy and reduced fear of falling.

Although osteoporosis-specific exercise is recommended to improve strength, balance, physical function, and fracture-related outcomes, many individuals with osteoporosis do not initiate or maintain prescribed exercise because they lack practical knowledge about safe movement, have low confidence in their ability to exercise, and fear falling or sustaining another fracture (Smart et al., 2022). Recent evidence indicates that exercise programs incorporating education, motivational interviewing, goal setting, and individualized adherence support may produce better functional outcomes than exercise prescription alone, suggesting that osteoporosis-specific exercise education could positively influence exercise adherence (Makarem et al., 2025). However, the mechanisms through which education promotes sustained exercise remain insufficiently understood. Educational and supported exercise interventions may strengthen exercise self-efficacy by improving knowledge, correcting misconceptions about unsafe movement, and

developing confidence in performing resistance, balance, posture, and weight-bearing activities; greater self-efficacy is, in turn, associated with stronger exercise participation and has previously demonstrated a mediating role in a bone-health intervention (Aucella et al., 2024). Similarly, structured exercise education may reduce fear of falling by teaching safe techniques and improving perceived balance and falls efficacy, whereas persistent fear may encourage activity avoidance and weaken adherence (Cooper et al., 2023). Despite growing evidence that exercise benefits people with osteoporosis (Cai et al., 2025), recent studies have largely examined education, adherence, self-efficacy, and fear of falling separately rather than testing them within a unified explanatory model; therefore, a significant research problem remains concerning whether osteoporosis-specific exercise education improves exercise adherence directly and indirectly through increased exercise self-efficacy and reduced fear of falling.

Despite growing evidence supporting exercise and patient education in osteoporosis management, an important theoretical gap remains because most studies evaluate changes in physical outcomes—such as strength, balance, mobility, bone mineral density, and falls—without explaining the behavioural mechanisms through which osteoporosis-specific exercise education leads to sustained exercise adherence (Rees et al., 2022). Although Social Cognitive Theory suggests that education should strengthen exercise self-efficacy and fear-avoidance perspectives indicate that fear of falling may discourage physical activity, these mechanisms have rarely been integrated and tested simultaneously as mediators between exercise education and adherence among individuals with osteoporosis. For example, tailored behavioural support has produced greater functional benefits than exercise rehabilitation alone, but recent trials have not adequately established whether these effects occur through improved self-efficacy or reduced fear of falling (Sayed et al., 2022). Similarly, recent evidence shows that exercise may reduce fear of falling, yet substantial heterogeneity in interventions, measurements, and follow-up periods limits conclusions regarding how this psychological change influences long-term adherence (Ispoglou et al., 2025). Empirically, osteoporosis education programs remain inconsistently implemented and evaluated, with limited evidence on long-term exercise behaviour, mediating variables, men, rural populations, culturally diverse groups, and individuals receiving care in resource-constrained settings (Groenendijk et al., 2024). Coordination in osteoporosis is compromised by poor integration of communication, short consultation time, lack of shared professional responsibility, lack of a solid referral system and lack of patient understanding between sectors, especially in primary care, outpatient physiotherapy, fracture-liaison, municipal and community-health (Madou et al., 2024). Research is therefore necessary in these health care and community rehabilitation areas to validate a combined mediation model whereby osteoporosis-specific exercise education influences exercise adherence directly and indirectly, via an increase in exercise self-efficacy and a decrease in FE. The medical principles of beneficence, non-maleficence, patient autonomy, safety, equity and the maximising of evidence-based, person-centred care are the basis for the present study, with the aim of individuals with osteoporosis to learn about osteoporosis in a clinically accurate manner that enables them to undertake safe activities while potentially reducing the risk of falls, fractures, pain and functional deterioration. This study will investigate the impact of an osteoporosis-specific exercise education programme on exercise adherence and examine the effects of exercise self-efficacy and fear of falling as a mediation between this exercise education programme and adherence. This is clinically relevant because having an appropriate prescription of resistance, balance, posture and weight-bearing exercise can enhance physical function, balance, falls efficacy and quality of life, but requires patients to be able and willing to exercise within the recommended programme (Juarez et al., 2025). The medical purpose of the

study is to clarify whether education improves adherence by increasing patients' confidence in performing clinically appropriate exercises and reducing fear-related avoidance of movement, thereby helping physicians, nurses, physiotherapists, rehabilitation specialists, orthopaedic teams, and fracture liaison services develop safer and more individualised treatment plans. Recent evidence supports personalised and multidisciplinary osteoporosis management, while also showing continuing gaps in patient education, guideline implementation, care coordination, and long-term post-fracture follow-up (Al-Toma et al., 2022). Consequently, the findings may contribute to better clinical decision-making, improved rehabilitation adherence, reduced secondary-fracture risk, enhanced functional independence, and more effective integration of exercise education into routine medical and multidisciplinary osteoporosis care.

The novelty of this study lies in moving beyond the conventional evaluation of whether exercise education is effective to explain how osteoporosis-specific exercise education produces sustained exercise adherence within medical care. Recent reviews and clinical guidelines have primarily examined the effects and safety of exercise and health education on bone health, balance, physical function, pain, falls efficacy, and quality of life, while giving limited attention to the behavioural pathways responsible for continued exercise participation (Bekas & Zafeiris, 2024). Furthermore, recent osteoporosis education and rehabilitation studies have reported mixed or incomplete findings regarding self-efficacy and adherence, and have generally evaluated these outcomes separately rather than as mechanisms linking education to exercise behavior (England et al., 2023). This limitation is clinically important because low self-efficacy and fear of falling have recently been identified as major barriers to osteoporosis self-care, whereas digitally or professionally supported exercise may improve falls efficacy and reduce concerns about falling (Becker, 2025). Therefore, the present study offers a potentially novel integrated mediation model that simultaneously tests exercise self-efficacy and fear of falling as parallel mediators between osteoporosis-specific exercise education and exercise adherence, allowing the direct educational effect to be distinguished from its indirect psychological effects. This approach may generate clinically actionable evidence for physicians, nurses, physiotherapists, rehabilitation specialists, and fracture liaison teams by identifying whether confidence-building, fear-reduction, or both should be prioritised when designing personalised exercise education and fracture-prevention programmes.

There is a clear need to study the effect of osteoporosis-specific exercise education on exercise adherence because, although resistance, balance, posture, and weight-bearing exercises are increasingly recommended for improving physical function and reducing falls and fracture risk, their clinical benefits cannot be achieved when patients do not perform them regularly or discontinue them because of uncertainty, low confidence, pain, or fear of falling (Ries & Carroll, 2022). Recent evidence indicates that education and individually tailored behavioural support may improve engagement with osteoporosis rehabilitation; however, the psychological mechanisms underlying these effects remain insufficiently established, particularly whether education promotes adherence by increasing exercise self-efficacy and reducing fear of falling (Hill, 2022). Understanding these relationships is crucial as it can undermine patients' confidence in exercising in a safe manner and may cause them to avoid moving, become physically deconditioned, become socially isolated and may even escalate the amount of falls and fracture vulnerability. Moreover, the study is still required, as gaps in patient education, primary-care follow-up, coordination among the different specialties, referrals and long-term care of osteoporosis after fragility fracture are still identified by the latest reviews (McPhee et al., 2022). This study can contribute to the identification of more specific interventions for both the health care provider and the patient to increase adherence to exercise treatment and to fulfil the indirect

exercise education effects by reducing the patient's fear of falling and increasing the patient's self-efficacy that can lead to better patient safety and functional independence, reduced risk of recurrent fractures, and reduced avoidable health care utilisations and wider health care burden, particularly for the health care provider who provide the exercise education. One strength of this study is its contribution to the clinically relevant research gap between recommending movement to people with osteoporosis and its safe and reliable implementation in the form of exercise programmes by patients. The benefit of these interventions, that is, of resistance, balance, posture, and weight-bearing exercise, designed suitably, is reflected in improvement of physical function, balance, falls efficacy, and quality of life, though this benefit is highly reliant on the patient's engagement with the exercise regimes (Vera-Ponce et al., 2025). The principal contribution of this research is its integrated examination of exercise self-efficacy and fear of falling as parallel psychological mechanisms through which osteoporosis-specific exercise education may improve exercise adherence, thereby producing knowledge that extends beyond simply determining whether an educational intervention is effective. Such evidence may contribute to the development of safer, theory-informed, and individually tailored exercise-education programmes, particularly as contemporary research continues to identify deficiencies in osteoporosis awareness, behavioural support, care coordination, and long-term post-fracture management (Grannell et al., 2023). The primary beneficiaries will be individuals with osteoporosis, who may gain greater confidence, reduced fear of movement and falling, improved functional independence, and potentially lower risks of falls and secondary fractures. Physicians, nurses, physiotherapists, rehabilitation specialists, and fracture liaison teams may benefit from clearer evidence about which behavioural factors should be assessed and targeted during clinical counselling, exercise prescription, and follow-up. Healthcare managers and policymakers may use the findings to improve staff training, referral pathways, patient-education materials, multidisciplinary coordination, and resource allocation across primary care, rehabilitation, and fracture prevention services (Karjoo et al., 2025). Last but not least, researchers could have a repeatable mediation model they can test within various clinical, cultural, and community environments to build up enhanced evidence for behavioural and educational interventions in healthcare for medical osteoporosis.

There is particular interest in exploring the relationships between exercise education, exercise adherence, exercise self-efficacy and fear of falling, since these variables co-explain both the nature of any exercise change that occurs as a result of education, and the mechanisms by which this change takes place. Although there is more recent evidence that exercise and health education can have a beneficial effect on physical function, balance, fall coping and quality of life in people with osteoporosis and/or fragility fracture, many studies focus on clinical outcomes and there is not yet a consistent exercise adherence in these groups (Bjelica et al., 2024). The positive relationship between exercise education and adherence has been investigated in educational, home-based, and individualized exercise interventions; the structured approach to education and behavioral support seem to positively influence physical activity and exercise programme participation (Comachio et al., 2025). Exercise self-efficacy has also been associated with stronger exercise participation because patients who feel capable of performing prescribed activities are more likely to initiate and maintain them, while fear of falling and fracture-related kinesiophobia may encourage movement avoidance and interfere with rehabilitation (Zhang et al., 2025). Nevertheless, these relationships have usually been studied separately, and a recent evaluation of municipal osteoporosis education reported inconclusive adherence findings, no clear improvement in self-efficacy, greater bone-specific physical activity, and unexpectedly greater concern about falling, while explicitly noting the absence of studies examining mediators of osteoporosis

education (Emmi et al., 2023). Therefore, the uniqueness of the proposed study lies in simultaneously testing exercise self-efficacy and fear of falling as parallel mediators between exercise education and adherence, thereby determining whether education promotes adherence directly, indirectly through increased confidence, indirectly through reduced fear, or through both pathways, and identifying which mechanism should be prioritised in medically supervised osteoporosis education and rehabilitation.

The primary objective of this study is to examine the effect of participation in an osteoporosis-specific exercise education programme on exercise adherence among individuals diagnosed with osteoporosis. Specifically, the study seeks to determine whether exercise education improves participants' knowledge and confidence in performing safe resistance, balance, posture, and weight-bearing exercises; assess the influence of exercise education on exercise self-efficacy and fear of falling; evaluate the relationships between exercise self-efficacy, fear of falling, and exercise adherence; and test whether exercise self-efficacy and fear of falling mediate the relationship between osteoporosis-specific exercise education and exercise adherence. Another aim of the study is to test the relative robustness of these two mediation pathways to determine if enhancing confidence or decreasing fear or both should be emphasized in the design of medically supervised osteoporosis education and rehabilitation programs (Van den Bergh et al., 2024).

Literature Review

Theoretical Foundation

According to the Health Belief Model and Social Cognitive Theory, the independent variable – osteoporosis-specific exercise education – has a theoretical basis. According to the Health Belief Model, patients will make decisions about preventive behaviours when they identify themselves as susceptible to fracture, agree that osteoporosis is serious, think of exercise as beneficial, feel that the barriers are surmountable and get sufficient cues to action (Rosenstock, Strecher, & Becker, 1988). An osteoporosis education programme could therefore help to increase activity levels by educating patients about the risk of fracture, correcting misconceptions about unsafe exercise and resistance training, highlight the benefits of resistance, balance, posture and weight-bearing activity, and give practical tips on how to cope with pain and other sources of activity limitation. According to Social Cognitive Theory, behaviour can be modified through education by combining three factors: personal belief, environmental support, behavioural skills, outcome expectation and observational learning (Gute & Zimbudzi, 2023). This theoretical stance has recently been confirmed by evidence indicating that people with osteoporosis need condition-specific information, expert advice, and specific behavioural support to make the clinical recommendations for exercise a habit in daily self-care (Faccioli et al., 2023).

Exercise self-efficacy and fear of falling, the two proposed mediators, are principally grounded in Social Cognitive Theory, Protection Motivation Theory, and the Fear-Avoidance Model. Bandura defines self-efficacy as an individual's belief in their capability to organise and perform the actions required to achieve a particular outcome; it can be strengthened through successful practice, observation of similar individuals, professional encouragement, and positive interpretation of bodily responses (Bandura, 1997). An osteoporosis exercise programme that incorporates supervised practice, gradual progression, demonstrations, feedback, and achievable goals should therefore increase exercise self-efficacy, which subsequently makes continued exercise more likely. Self-efficacy has previously been identified as a mechanism connecting bone-health interventions with exercise behavior (Branstetter IV et al., 2023). In contrast, the Fear-Avoidance Model proposes that catastrophic interpretations of pain, falls, or injury produce fear, avoidance of movement, physical deconditioning, and greater disability (Riaz et al., 2022). Protection Motivation Theory

similarly predicts that awareness of a health threat encourages protective behaviour only when individuals also believe that the recommended response is effective and that they are capable of performing it. Thus, education that discusses fracture risk without building coping confidence could intensify fear, whereas education combined with safe exercise practice may reduce fear of falling and movement avoidance. Recent osteoporosis and rehabilitation evidence supports the clinical relevance of confidence, fear reduction, and falls efficacy in promoting participation (Safran & Yildirim, 2025).

Exercise adherence, the dependent variable, can be explained through the Theory of Planned Behavior and the Health Action Process Approach. According to the Theory of Planned Behavior, attitudes to exercise, perceived social norms, and perceived behavioural control are factors affecting individuals' exercise intentions, and hence behaviour (Rizzoli & Chevalley, 2024). Educating about osteoporosis can foster positive attitudes by helping to inform patients of the benefits of exercise, develop positive norms by encouraging their families and doctors, and enhance their sense of control by providing them with tips on how to exercise safely and effectively. But intention does not necessarily lead to compliance, and states that self-efficacy, action planning, coping planning, and self-monitoring are needed in order to close the intention–behaviour gap (Russin et al., 2025). The proposed model thus combines these theories by proposing that the teaching of exercise education can affect adherence directly through enhanced knowledge, attitudes, planning and skills, and indirectly through increased exercise self-efficacy and decreased fear of falling. This parallel mediation model provides a theoretically consistent account of the phenomenon of continuing with or not continuing with osteoporosis exercise recommendations despite receiving the recommendation by a similar clinical pathway.

Hypothesis Development:

H1: Osteoporosis-Specific Exercise Education and Exercise Adherence

The Health Belief Model and Theory of Planned Behavior support the proposed positive relationship among osteoporosis-specific exercise education and exercise adherence. Educating patients on fracture risk and the benefits of exercise, countering incorrect perceptions of how unsafe movement contributes to fracture, and improving perceived behavioural control by explaining safe resistance, balance, posture, and weight-bearing exercises, can enhance understanding of fracture susceptibility and increase exercise benefits. If patients are informed about the importance of exercise, and have clear action and coping plans, there is more chance that they will embark on and stay with the prescribed programme. This reasoning is consistent with evidence-based exercise guidelines that emphasise individually appropriate instruction, progression, and professional supervision in osteoporosis care (Loturco et al., 2022).

Empirically, a recent systematic review and meta-analysis found that exercise and health-education interventions can improve knowledge, mobility, pain, functional capacity, balance, and quality of life among individuals with osteoporotic vertebral fractures, although the evidence specifically concerning educational interventions remains limited (Pimentel-Parra et al., 2025). Moreover, the OPTIN randomized controlled trial showed that integrating motivational interviewing, goal setting, and behavioural adherence support into exercise rehabilitation produced better mobility and walking outcomes than standard rehabilitation alone (Vasodi et al., 2023). Qualitative evidence also indicates that condition-specific information, professional guidance, and practical self-management resources facilitate adherence among people living with osteoporosis (Gao et al., 2023). Therefore, **H1: Participation in an osteoporosis-specific exercise education programme has a positive effect on exercise adherence.**

H2: Osteoporosis-Specific Exercise Education and Exercise Self-Efficacy

The relationship between exercise education and exercise self-efficacy is primarily explained by Social Cognitive Theory, which defines self-efficacy as an individual's belief that they can successfully perform the actions required to achieve a desired outcome. A well-designed osteoporosis education programme may enhance self-efficacy through four mechanisms: successful performance of progressively challenging exercises, observation of safe exercise demonstrations, verbal encouragement from healthcare professionals, and appropriate interpretation of pain or bodily sensations. Practical demonstrations, supervised practice, personalised feedback, and gradual progression should therefore increase patients' confidence that they can exercise without causing falls, pain, or fractures.

Recent evidence shows that individuals with osteoporosis frequently report uncertainty regarding safe movement, insufficient professional guidance, and concerns about injury, all of which may weaken confidence and restrict self-care behaviour (Anupama et al., 2022). Conversely, theory-based and tailored exercise interventions that incorporate goal setting, problem solving, reminders, feedback, and behavioural support are intended to strengthen self-efficacy and promote continued participation (Wong et al., 2023). Although recent osteoporosis research has not consistently measured exercise self-efficacy as a primary outcome, existing bone-health intervention evidence indicates that self-efficacy can be modified through education and support (Chahal et al., 2023). Therefore, **H2: Participation in an osteoporosis-specific exercise education programme has a positive effect on exercise self-efficacy.**

H3: Osteoporosis-Specific Exercise Education and Fear of Falling

The expected negative relationship between exercise education and fear of falling can be explained through the Fear-Avoidance Model and Protection Motivation Theory. Individuals with osteoporosis may interpret movement, pain, imbalance, or physical exertion as indications that a fall or fracture is likely. Such threat appraisals can produce anxiety, movement avoidance, physical deconditioning, and further loss of balance confidence. Osteoporosis-specific education may interrupt this cycle by distinguishing safe from hazardous movements, teaching fall-prevention strategies, demonstrating appropriate exercise techniques, and providing supervised opportunities for successful movement. Learning should be best when it includes information about fracture risk as well as practical coping skills; it should not only highlight vulnerability (Tedesco et al., 2025).

Recent qualitative studies have supported the findings that some patients with osteoporosis limit physical activity due to fear of falls and fracture and that professional guidance and personalized exercise instruction is considered an important facilitator to engage in physical activity without risk of fracture (Mashayekhi et al., 2025). In addition, fall-prevention programmes that use exercise have been developed to enhance balance confidence and reduce fear of falling among older people (Wing et al., 2025). However, the most recent meta-analysis of osteoporotic vertebral-fracture interventions did not show any statistically significant pooled improvement in fear of falling, potentially due to the large variability among treatment components (interventions, measurements, and education) (Bautista-Molano et al., 2023). Such uncertainty only accentuates the demand for a direct test of the education–fear pathway. Thus, the result of this research indicates that, **H3: Participation in an osteoporosis-specific exercise education programme has a negative effect on fear of falling.**

H4: Exercise Self-Efficacy and Exercise Adherence

Social Cognitive Theory suggests that the strongest proximal factors in maintaining health behaviours are self-efficacy. High exercise self-efficacy is associated with higher likelihood of

setting goals, having the motivation to exert effort, maintaining the programme during periods of difficulty and restarting the programme following breaks. For patients with osteoporosis, confidence plays a crucial role and is the reason why individuals might still be advised to do exercise even if they are both old and physically limited, experience pain, have some doubt about their posture, or are not sure whether it is safe for them to have a fracture. People who feel they can adapt exercises and surmount obstacles will thus be more likely to follow through; people who are less confident should be found less likely to follow through.

This relationship has been supported with empirical evidence in both the bone-health and older-adult exercise research. In an online bone-health intervention, exercise self-efficacy was related to exercise behaviour, and was found to explain how the intervention promoted participation (Treviño et al., 2025). Other, more recent studies in elderly people suggest that modification of self-efficacy and self-regulation accounts for the effect and efficacy of physical-activity interventions (Schulz et al., 2023). Reviews of adherence to rehabilitation also report that confidence, perceived competence, achievable goals, professional feedback, and the self-monitoring of exercise are important factors that facilitate continued exercise (Li et al., 2024). Therefore, **H4: Exercise self-efficacy has a positive effect on exercise adherence among individuals with osteoporosis.**

H5: Fear of Falling and Exercise Adherence

According to the Fear-Avoidance Model, fear of falling will negatively impact exercise adherence as individuals who expect to fall or break a fall may avoid movements they deem to be threatening. Avoidance can be an initial relief emotional response, which may reinforce inactivity, which in turn can lead to muscle weakness, difficulties with balance, physical deconditioning, and more anxiety. This cycle can be even more noticeable in cases of osteoporosis, since patients are aware that a relatively mild fall could lead to a debilitating fracture. Fear of falling may therefore prevent patients from initiating exercises, completing the recommended intensity, or continuing an exercise programme without supervision.

Recent osteoporosis research has shown that fear, kinesiophobia, pain-related concerns, and uncertainty about movement can restrict physical activity and rehabilitation participation. A study of older patients with osteoporosis and chronic low-back pain found clinically relevant relationships among kinesiophobia, balance limitations, and physical functioning (Dickens et al., 2023). Recent qualitative findings similarly indicate that fear of falling and fracture can lead people with osteoporosis to limit physical activity (Wang et al., 2025). Updated evidence from older adults following hip surgery also identifies fear of falling as a persistent problem associated with vulnerability and impaired recovery (Xu et al., 2024). Therefore, **H5: Fear of falling has a negative effect on exercise adherence among individuals with osteoporosis.**

H6: Mediating Role of Exercise Self-Efficacy

The proposed mediating role of exercise self-efficacy combines the relationships represented by H2 and H4. Under Social Cognitive Theory, education does not automatically produce sustained behaviour; rather, it changes knowledge, skills, outcome expectations, and confidence, which then influence behavioural performance. Osteoporosis-specific exercise education may increase self-efficacy through demonstrations, supervised mastery experiences, personalised feedback, progressive goal setting, and reassurance about exercise safety. Increased self-efficacy should subsequently help patients overcome pain, lack of motivation, limited access, and concerns about performing exercises incorrectly.

There is direct, although comparatively limited, evidence for this mechanism in bone-health research. Zhu et al. found that self-efficacy played a mediating role in the relationship between an online bone-health intervention and exercise among older adults (Chang et al., 2022). More recent intervention research among older

adults also demonstrates that changes in self-efficacy can mediate the initiation and maintenance of physical activity (Migliorini et al., 2022). Furthermore, the positive results of tailored adherence support in vertebral-fracture rehabilitation are consistent with the argument that confidence-building strategies help translate exercise advice into sustained behaviour, although self-efficacy was not always formally tested as the mechanism (Tsvetkov et al., 2025). Therefore, **H6: Exercise self-efficacy mediates the positive relationship between osteoporosis-specific exercise education and exercise adherence.**

H7: Mediating Role of Fear of Falling

The proposed mediating role of fear of falling combines the negative education–fear relationship in H3 with the negative fear–adherence relationship in H5. From a fear-avoidance perspective, an osteoporosis-specific education programme may improve adherence because it changes patients' appraisal of exercise from a dangerous activity to a controllable and beneficial form of treatment. Instruction in safe technique, fall-prevention strategies, appropriate progression, and symptom management may reduce perceived threat. Lower fear should then decrease avoidance and allow patients to participate more consistently in resistance, balance, posture, and weight-bearing activities.

Recent evidence provides indirect support for this pathway. Balance confidence has been shown to play an explanatory role in the relationship between fear-of-falling avoidance and the effectiveness of balance training among older adults, demonstrating that psychological responses can influence participation and rehabilitation outcomes (Chen et al., 2022). Recent intervention research also suggests that targeted practice can reduce specific fears related to falls and improve functional behaviour (Baladaniya & Baldania, 2025). However, fear of falling has rarely been formally tested as a mediator between osteoporosis education and adherence, and pooled osteoporosis evidence has produced inconsistent fear-of-falling outcomes (Alexander et al., 2025). Therefore, **H7: Fear of falling mediates the relationship between osteoporosis-specific exercise education and exercise adherence, such that education improves adherence indirectly by reducing fear of falling.**

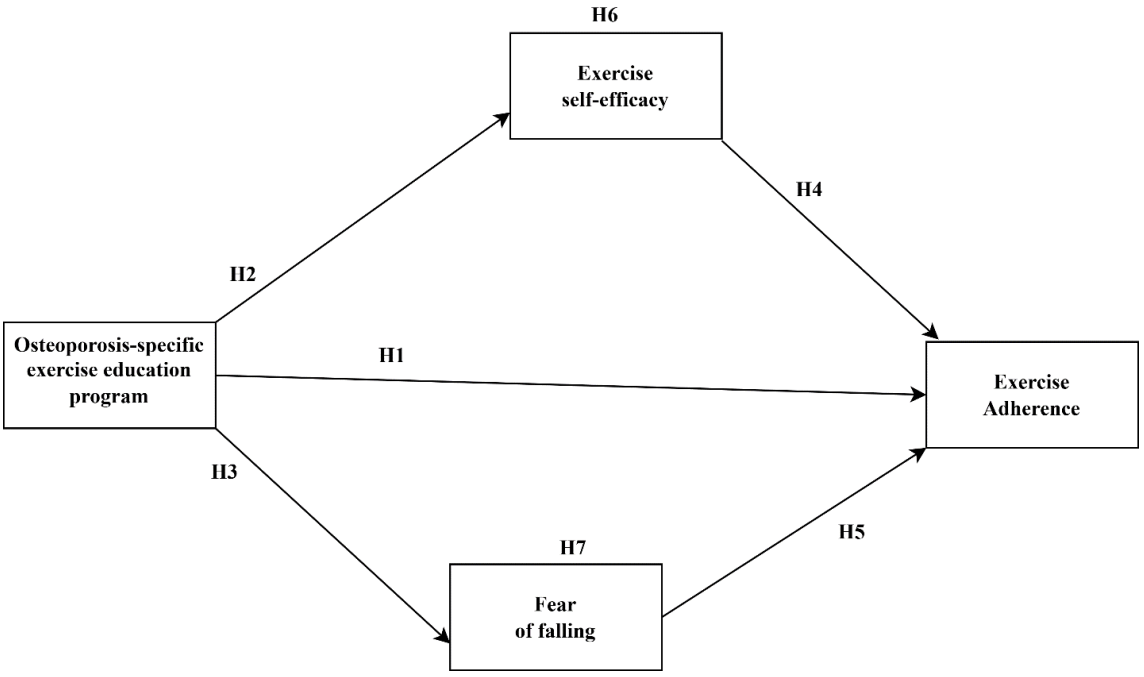

Figure 1: Proposed Research Model

Research Methodology

Research Design

The study employed a quantitative, explanatory, cross-sectional research design to examine the direct and indirect relationships among participation in an osteoporosis-specific exercise education program, exercise self-efficacy, fear of falling, and exercise adherence among individuals medically diagnosed with osteoporosis. The sample size was calculated using an a priori statistical power analysis instead of just the ten-times rule for the data collection instruments listed: questionnaires with validated exercise self-efficacy, fear of falling, and exercise adherence scores, as well as data on participation in the education program. The study was prediction oriented and had a relatively complex parallel-mediation model which warranted the use of Partial Least Squares Structural Equation Modeling (SmartPLS 4).The measurement model was evaluated through indicator loadings, Cronbach's alpha, composite reliability, rho_A, average variance extracted, and heterotrait–monotrait ratios to establish indicator reliability, internal consistency, convergent validity, and discriminant validity (Izquierdo, 2025). The structural model was subsequently assessed using collinearity statistics, path coefficients, coefficients of determination, effect sizes, predictive relevance, and out-of-sample predictive performance (Zhao et al., 2023). Finally, the seven hypotheses were tested through bootstrapping with 10,000 resamples, and the mediating effects of exercise self-efficacy and fear of falling were established from the significance and bias-corrected confidence intervals of the specific indirect effects (Wan et al., 2025).

Measurement Instruments

Table 1 presents the measurement instruments used for osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence. To maintain consistency with the proposed PLS-SEM model, the constructs were represented by 9, 5, 6, and 8 items, respectively. The items were adapted and paraphrased from established osteoporosis-education, exercise self-efficacy, falls-efficacy, and prescribed-exercise adherence measures and were written in the past tense. Responses were measured on a five-point Likert scale ranging from 1 = strongly disagreed to 5 = strongly agreed**.** Because the wording, number of items, and response format represented adapted rather than verbatim versions of the original instruments, expert content validation, cognitive interviews, pilot testing, and measurement-model assessment were conducted before testing the structural relationships. Participation in the education programme was also verified objectively through intervention allocation and attendance records because perceived education scores alone did not establish actual programme exposure.

Table 1. Measurement instruments for the study variables

Variable	Code	Measurement item	Sources
Osteoporosis-Specific Exercise Education	OEE1	The education I received had clearly explained how osteoporosis affected bone strength and fracture risk.	(Grutter Lopes et al., 2024; Nepomuceno et al., 2024; Pesare et al., 2023)
	OEE2	The education had clearly explained which types of exercise were safe and beneficial for my osteoporosis.	
	OEE3	The education had explained how resistance and weight-bearing exercises should have been performed safely.	—
	OEE4	The education had explained how balance exercises and fall-prevention strategies should have been practised.	—
	OEE5	The education had taught me appropriate posture, lifting,	—

Variable	Code	Measurement item	Sources
		bending, and spine-protection techniques.	
	OEE6	The education had explained the recommended frequency, intensity, duration, and progression of my exercises.	
	OEE7	The education had explained warning signs that required me to stop exercising or seek medical advice.	
	OEE8	The healthcare professional had demonstrated the exercises and checked whether I had performed them correctly.	
	OEE9	The education had helped me develop an exercise plan that was appropriate for my health condition and abilities.	
Exercise Self-Efficacy	ESE1	I had been confident that I could perform my osteoporosis exercises correctly and safely.	(Goodarzi et al., 2025; Lyu et al., 2024; Talevski et al., 2023)
	ESE2	I had been confident that I could exercise even when I felt tired or lacked motivation.	
	ESE3	I had been confident that I could continue exercising when my normal routine had been disrupted.	
	ESE4	I had been confident that I could modify my exercises appropriately when I experienced minor physical difficulties.	
	ESE5	I had been confident that I could resume my exercise programme after missing one or more sessions.	
Fear of Falling	FOF1	I had been worried that I might fall while performing my prescribed exercises.	(Avancini et al., 2022; Bishop et al., 2023; Eshre et al., 2025)
	FOF2	I had been worried about falling while walking on uneven or slippery surfaces.	
	FOF3	I had been worried about falling while using stairs or steps.	
	FOF4	I had been worried that bending, reaching, or changing position might cause me to lose my balance.	
	FOF5	Concern about falling had made me avoid some physical activities that I could otherwise have performed.	
	FOF6	I had been worried that a fall during exercise or daily activity might result in a fracture.	
Exercise	EA1	I had completed my osteoporosis exercises on the	(Force et al., 2024;

Variable	Code	Measurement item	Sources
Adherence		scheduled days.	Petkovic et al., 2022; Rathi et al., 2024)
	EA2	I had performed the prescribed number of exercise sessions each week.	—
	EA3	I had exercised for the recommended duration during each session.	—
	EA4	I had performed the exercises at the recommended level of intensity.	—
	EA5	I had followed the prescribed exercise techniques and safety instructions.	—
	EA6	I had progressed my exercises according to the instructions provided by my healthcare professional.	
	EA7	I had continued the exercise programme over the recommended period.	
	EA8	I had returned to my prescribed exercise routine after missing a session or experiencing a temporary interruption.	

Higher OEE, ESE, and EA scores indicated stronger perceived exercise education, greater exercise self-efficacy, and better exercise adherence, respectively, whereas a higher FOF score indicated greater fear of falling. Mean scores were calculated for each construct after checking missing data and response patterns. Because all items were adapted for osteoporosis-specific use, indicator loadings, composite reliability, rho_A, Cronbach's alpha, average variance extracted, and heterotrait–monotrait ratios were assessed in the PLS-SEM measurement model. Attendance was also used, where available, to support adherence to exercise or exercise diaries and/or use of digital exercise activity logs to minimise reporting.

Population and Sampling

The study population included adult patients with a medically confirmed diagnosis of osteoporosis who had attended orthopaedic, rheumatology, endocrinology, rehabilitation, or fracture-prevention services at Mother Theresa University Hospital Center and Pegasus Med Clinic in Tirana, Albania. A purposive consecutive sampling procedure was used. The participating institutions were selected because they provided relevant osteoporosis and rehabilitation services, after which eligible patients were approached consecutively until the required institutional quotas were reached, consistent with hospital-based clinical sampling practices (Imamudeen et al., 2022). A total of 500 respondents were included, comprising 250 patients from Mother Theresa University Hospital Center and 250 from Pegasus Med Clinic, which ensured balanced representation of the two participating institutions. Eligible respondents had been aged 18 years or older, had possessed a physician- or DXA-confirmed osteoporosis diagnosis, had been medically able to participate in prescribed exercise, and had provided informed consent, whereas patients with severe cognitive impairment, acute medical instability, or conditions preventing safe participation had been excluded. The sample size of 500 had been selected to provide sufficient statistical power for estimating the direct and parallel mediating relationships in the PLS-SEM model and had exceeded commonly recommended power-based minimums for complex structural models (Peckett et al., 2023).

Data Collection Method

Data were collected through a structured, cross-sectional questionnaire survey administered to 500 adults with medically confirmed osteoporosis, including 250 respondents from Mother Theresa University Hospital Center and 250 from Pegasus Med Clinic in Tirana, Albania. After ethical approval and administrative permission had been obtained from the participating institutions, trained research assistants who were not involved in the patients' clinical care screened potential participants against the inclusion and exclusion criteria, explained the study's purpose and voluntary nature, and obtained written informed consent in accordance with recognised medical-research ethics (Cinar, 2023). The questionnaire had contained sections on demographic and clinical characteristics, osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence; programme participation had also been verified, where possible, through institutional attendance records. The instrument had been translated from English into Albanian and independently back-translated to ensure semantic and conceptual equivalence (Poduval et al., 2023), and it had been reviewed by specialists in osteoporosis care, physiotherapy, medical education, and research methodology before being pilot-tested with patients who were excluded from the final analysis. Questionnaires had been completed privately in either self-administered or researcher-assisted form, with standardized neutral assistance provided to respondents who had experienced reading difficulties; no names had been recorded, unique identification codes had been assigned, and completed forms had been stored securely to protect confidentiality. Data collection had continued until 500 complete and usable responses were obtained, after which questionnaires had been checked for missing values, patterned responses, duplicate entries, and implausibly short completion times before coding and entry into the statistical software; these procedures were consistent with established recommendations for cross-sectional health research, survey-quality control, common-method-bias reduction, and PLS-SEM analysis (Bolgova et al., 2025).

Respondents Profile

The demographic and clinical profile of the 500 respondents was summarized using frequencies, percentages, means, and standard deviations, and the sample had included 250 patients from Mother Theresa University Hospital Center and 250 from Pegasus Med Clinic in Tirana, Albania. Respondents' age had been recorded in years and categorized as 18–39, 40–49, 50–59, 60–69, and 70 years or older, while sex, marital status, educational attainment, employment status, monthly household income, recruitment institution, and urban or rural residence had also been documented to describe the social composition of the sample. The clinical profile had included body mass index, menopausal status among female respondents, duration since osteoporosis diagnosis, method of diagnosis, previous fragility-fracture history, family history of osteoporosis, history of falls during the preceding 12 months, osteoporosis medication use, calcium and vitamin D supplementation, comorbid conditions, mobility limitations, and previous participation in an osteoporosis-specific exercise-education programme. These characteristics had been considered relevant because recent osteoporosis research identified age, sex, menopausal status, body composition, previous fractures, physical activity, treatment exposure, and healthcare access as important factors associated with osteoporosis risk, self-care practices, functional outcomes, and fracture prevention (Wong et al., 2022).

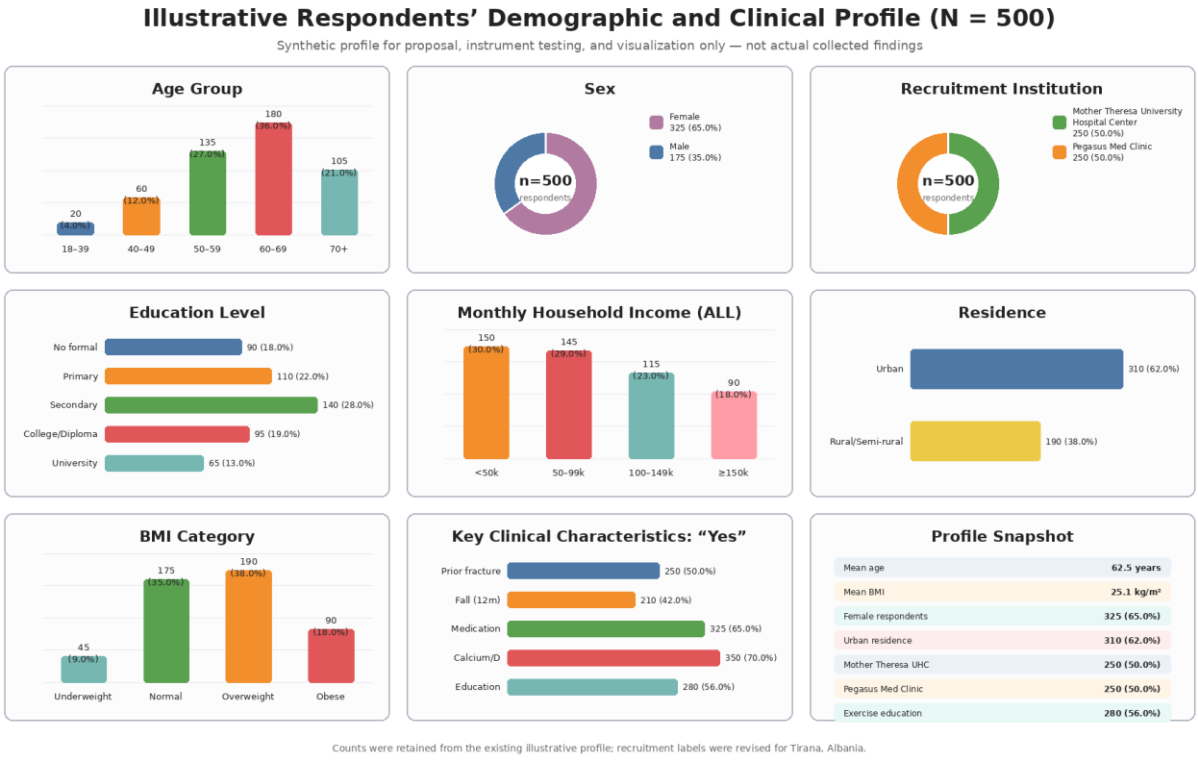

Figure 2: Respondents Profile

Data Analysis Technique

Data were coded, cleaned and checked for missing values, duplicate responses, outlier and patterned responses prior to analysis. The demographic and clinical characteristics of the respondents were summarized using descriptive statistics such as frequencies, percentages, means and standard deviations, and the proposed direct and mediating ones were tested using Partial Least Squares Structural Equation Modeling by creating their structural equation models in SmartPLS 4. Indicator loadings, Cronbach's alpha, rho_A, composite reliability and average variance extracted values were employed to examine the measurement model of the reflective type in order to achieve indicator reliability, internal consistency and convergent validity, while heterotrait-monotrait ratio (Nagendra et al., 2025). The structural model was evaluated through variance inflation factors, standardized path coefficients, coefficients of determination, effect sizes, predictive relevance, and out-of-sample predictive performance (Gregson et al., 2022). The statistical significance of H1–H7 was determined through a nonparametric bootstrapping procedure with 10,000 resamples, using path coefficients, t-values, p-values, and bias-corrected 95% confidence intervals. Finally, the mediating roles of exercise self-efficacy and fear of falling were examined through their specific indirect effects on the relationship between osteoporosis-specific exercise education and exercise adherence, and mediation was supported when the confidence interval for an indirect effect had not included zero (Siu & Gafni-Lachter, 2024).

Assessment of Measurement Model

The reflective measurement model was assessed before examining the structural relationships among osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence. Indicator reliability was evaluated through outer loadings, with values of **0.708 or higher** considered satisfactory; indicators loading between **0.40 and 0.70** were considered for removal only when their exclusion had improved composite reliability or average variance extracted without weakening the construct's theoretical and content coverage (Nguyen et al., 2025). Internal consistency

reliability was examined using Cronbach's alpha, rho_A, and composite reliability, with values between **0.70 and 0.95** regarded as acceptable, while values above 0.95 were treated as possible evidence of redundant items (El Miedany et al., 2025). Convergent validity was assessed through the average variance extracted, and each construct was considered to have demonstrated adequate convergent validity when its AVE had reached at least **0.50**, indicating that the construct had explained 50% or more of its indicators' variance (Laurent et al., 2022). Discriminant validity was primarily examined using the heterotrait–monotrait ratio, with values below **0.85,** or below **0.90** for conceptually related constructs, considered acceptable; bootstrapped confidence intervals were also examined to ensure that they had not included the value of one (Zaleski et al., 2024). Accordingly, the measurement model was regarded as satisfactory only after indicator reliability, internal consistency, convergent validity, and discriminant validity had been established for all four study variables.

Table 2 indicated that the measurement model had achieved satisfactory reliability and convergent validity. The factor loadings had ranged from 0.771 to 0.853, and all indicators had exceeded the recommended minimum value of 0.708, showing that each item had adequately represented its corresponding construct. Cronbach's alpha values had ranged from 0.889 to 0.933, while composite reliability values had ranged from 0.889 to 0.934; therefore, all constructs had demonstrated strong internal consistency because the values had exceeded 0.70 and remained below 0.95, reducing concerns about excessive item redundancy. The average variance extracted values had ranged from 0.646 to 0.692, exceeding the threshold of 0.50 and confirming that each construct had explained more than half of the variance in its indicators. In addition, the outer VIF values had ranged from 1.996 to 2.702 and had remained below the conservative threshold of 3.3, indicating that problematic indicator collinearity had not been present. Although outer VIF assessment is mainly emphasized for formative measurement models, the values provided supplementary evidence that the indicators had not been excessively redundant. Overall, osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence had demonstrated adequate indicator reliability, internal consistency, convergent validity, and acceptable collinearity levels, allowing the analysis to proceed to discriminant-validity and structural-model assessment (Avin et al., 2022).

Table 3 indicated that the structural model had not experienced problematic multicollinearity among the predictor constructs. The inner VIF values had ranged from 1.000 to 2.091, remaining below the conservative threshold of 3.3 and the commonly accepted maximum threshold of 5.0. For exercise adherence, the VIF values for exercise self-efficacy, fear of falling, and osteoporosis-specific exercise education had been 1.476, 1.741, and 2.091, respectively, showing that these predictors had contributed distinct information without excessive overlap. The VIF values for the relationships between osteoporosis-specific exercise education and exercise self-efficacy, and between osteoporosis-specific exercise education and fear of falling, had both been 1.000 because each endogenous construct had contained only one predictor. Therefore, collinearity had not biased the estimated path coefficients, and the structural model had been considered suitable for evaluating the direct and mediating hypotheses (Li et al., 2023).

Table 4 indicated that discriminant validity had been established among exercise adherence, exercise self-efficacy, fear of falling, and osteoporosis-specific exercise education. The HTMT values had ranged from 0.469 to 0.702, and all values had remained below the conservative threshold of 0.85 and the more liberal threshold of 0.90. The lowest HTMT value had been observed between exercise self-efficacy and fear of falling at 0.469, whereas the highest value had been recorded between osteoporosis-specific exercise education and fear of falling at 0.702. The HTMT values between exercise adherence and exercise self-efficacy,

fear of falling, and osteoporosis-specific exercise education had been 0.545, 0.665, and 0.624, respectively, while the value between osteoporosis-specific exercise education and exercise self-efficacy had been 0.617. These results had shown that the constructs were empirically related but remained conceptually distinct from one another. Therefore, the measurement model had satisfied the HTMT criterion for discriminant validity and had been considered appropriate for subsequent structural-model and hypothesis testing. However, because bootstrapped HTMT confidence intervals had not been reported, this conclusion had been based on the HTMT point estimates; additional confirmation would have required confidence intervals that did not include 1.00 (Kim et al., 2025).

Table 5 showed that the effect sizes of the latent variables had ranged from 0.039 to 0.726. Using the recommended f^2 thresholds of 0.02 for a small effect, 0.15 for a medium effect, and 0.35 for a large effect, exercise self-efficacy had produced a small effect on exercise adherence with an f^2 value of 0.057, whereas fear of falling had demonstrated a medium effect on exercise adherence with an f^2 value of 0.159. Osteoporosis-specific exercise education had exerted a small direct effect on exercise adherence, as indicated by an f^2 value of 0.039. In contrast, osteoporosis-specific exercise education had generated large effects on exercise self-efficacy and fear of falling, with f^2 values of 0.463 and 0.726, respectively. The largest effect had been observed for the relationship between osteoporosis-specific exercise education and fear of falling, indicating that exercise education had contributed substantially to explaining variation in fear of falling. Overall, the results had suggested that osteoporosis-specific exercise education had influenced the two mediating variables more strongly than it had directly influenced exercise adherence; however, the presence and type of mediation still had to be confirmed through the significance of the specific indirect effects rather than through f^2 values alone (Shen et al., 2023).

Table 6 indicated that the structural model had demonstrated satisfactory explanatory power, predictive relevance, and approximate model fit. The R^2 values showed that osteoporosis-specific exercise education, exercise self-efficacy, and fear of falling had jointly explained 46.2% of the variance in exercise adherence, while osteoporosis-specific exercise education had explained 31.7% of the variance in exercise self-efficacy and 42.1% of the variance in fear of falling. These values had explained weak-to-moderate variance, with exercise adherence explaining the highest variance. The R^2 values of 0.459, 0.315 and 0.420 were very similar to the adjusted R^2 values of 0.459, 0.315 and 0.420 respectively, which shows that there was little loss of explanatory power in the model when the number of predictors was taken into account. The Q^2predict values for exercise adherence, exercise self-efficacy and fear of falling were 0.313, 0.332 and 0.418, respectively, and were all positive, which indicated that the model had out-of-sample predictive relevance, with fear of falling showing the best predictive performance.

The RMSE values had ranged from 0.766 to 0.832, while the MAE values had ranged from 0.626 to 0.675; fear of falling had produced the lowest prediction errors, although the overall degree of predictive power could not have been conclusively classified without comparing these errors with those generated by a linear-model benchmark. The SRMR values of 0.035 for the saturated model and 0.037 for the estimated model had remained below the recommended threshold of 0.08, while the NFI values of 0.944 and 0.945 had exceeded the acceptable criterion of 0.90, indicating satisfactory approximate model fit. Overall, the results had suggested that the proposed model adequately explained and predicted exercise adherence, exercise self-efficacy, and fear of falling, although predictive performance had required interpretation alongside benchmark prediction errors rather than Q^2predict, RMSE, and MAE values alone (Mohammadi et al., 2022).

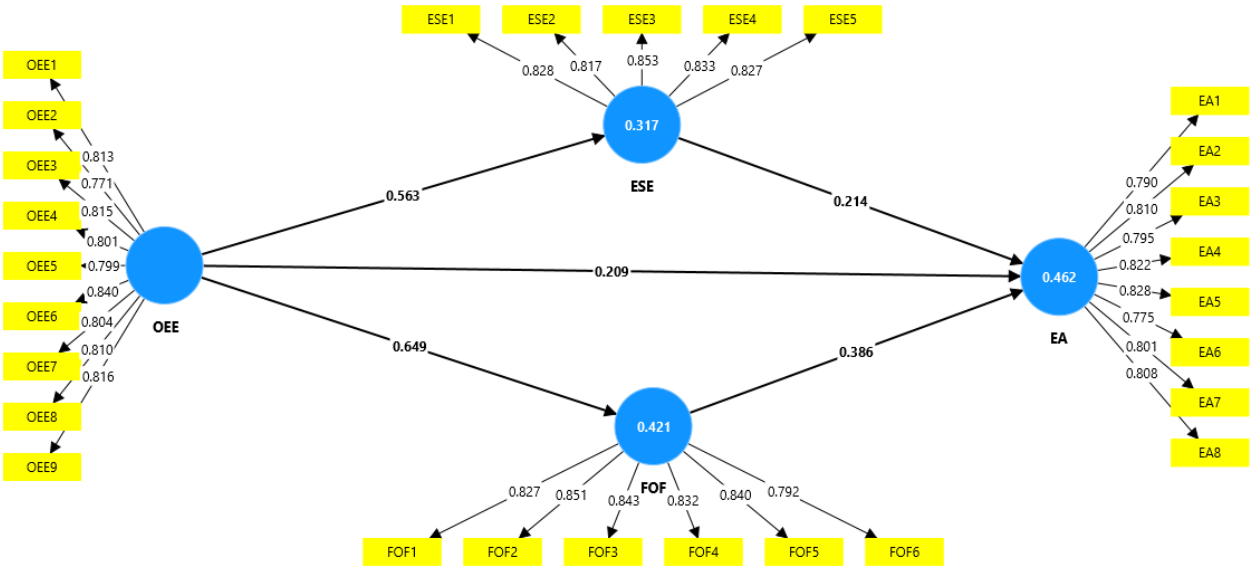

Figure 3: SEM with Factor Loadings

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

Construct/Items	OuterVIF values	Factor Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Osteoporosis-Specific Exercise Education			0.933	0.934	0.653
OEE1	2.354	0.813			
OEE2	2.029	0.771			
OEE3	2.427	0.815			
OEE4	2.257	0.801			
OEE5	2.280	0.799			
OEE6	2.702	0.840			
OEE7	2.309	0.804			
OEE8	2.315	0.810			
OEE9	2.397	0.816			
Exercise Self-Efficacy			0.889	0.889	0.692
ESE1	2.155	0.828			
ESE2	2.005	0.817			
ESE3	2.349	0.853			
ESE4	2.225	0.833			
ESE5	2.097	0.827			
Fear of Falling			0.910	0.912	0.690
FOF1	2.215	0.827			
FOF2	2.530	0.851			

FOF3	2.398	0.843			
FOF4	2.315	0.832			
FOF5	2.387	0.840			
FOF6	2.005	0.792			
Exercise Adherence			0.922	0.923	0.646
EA1	2.124	0.790			
EA2	2.229	0.810			
EA3	2.126	0.795			
EA4	2.403	0.822			
EA5	2.401	0.828			
EA6	1.996	0.775			
EA7	2.195	0.801			
EA8	2.290	0.808			

Table 3: Collinearity Statistics (Inner VIF)

Relationship	VIF	Decision
ESE -> EA	1.476	No multicollinearity issue
FOF -> EA	1.741	No multicollinearity issue
OEE -> EA	2.091	No multicollinearity issue
OEE -> ESE	1.000	No multicollinearity issue
OEE -> FOF	1.000	No multicollinearity issue

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

	EA	ESE	FOF	OEE
EA				
ESE	0.545			
FOF	0.665	0.469		
OEE	0.624	0.617	0.702	

Table 5: Effect Size of Latent Variables

Path	f-square	Effect Size
ESE -> EA	0.057	Small effect
FOF -> EA	0.159	Medium effect
OEE -> EA	0.039	Small effect
OEE -> ESE	0.463	Large effect
OEE -> FOF	0.726	Large effect

Table 6: Model Fit

	R-sq	Adj R-sq	Q^2predict	RMSE	MAE	Saturated Model	Estimated Model
EA	0.462	0.459	0.313	0.832	0.675		
ESE	0.317	0.315	0.332	0.820	0.670		
FOF	0.421	0.420	0.418	0.766	0.626		
SRMR						0.035	0.037
NFI						0.944	0.945

Hypothesis Testing:

Overall, the bootstrapping results showed that all seven proposed relationships had been statistically significant because their t-values had exceeded the critical value of 1.96 and their p-values had been below 0.001. The direct effects of osteoporosis-specific exercise education on exercise adherence, exercise self-efficacy, and fear of falling had been significant, while exercise self-efficacy and fear of falling had also significantly predicted exercise adherence. In addition, both specific indirect effects had been significant, indicating complementary partial mediation because the direct and indirect effects had remained significant and operated in the same direction. In accordance with statistical reporting conventions, the values shown as $p = 0.000$ were interpreted as $p < 0.001$ rather than as an exact probability of zero (Kabra et al., 2025).

H1: Osteoporosis-specific exercise education positively affected exercise adherence.

The results showed that osteoporosis-specific exercise education had exerted a positive and statistically significant effect on exercise adherence. The path coefficient had been 0.209, with a standard deviation of 0.048, a t-value of 4.307, and $p < 0.001$. This finding indicated that respondents who had received stronger osteoporosis-specific exercise education had demonstrated higher adherence to their recommended exercise programmes. Therefore, H1 had been supported (Fitzgerald et al., 2024).

H2: Osteoporosis-specific exercise education positively affected exercise self-efficacy.

The findings showed that osteoporosis-specific exercise education had produced a positive and statistically significant effect on exercise self-efficacy. The path coefficient had been 0.563, with a standard deviation of 0.032, a t-value of 17.686, and $p < 0.001$. This result indicated that appropriate information, practical guidance, demonstrations, and professional support had increased respondents' confidence in their ability to perform osteoporosis-related exercises safely and consistently. Therefore, H2 had been supported (Ran et al., 2025).

H3: Osteoporosis-specific exercise education significantly reduced fear of falling.

The path from osteoporosis-specific exercise education to fear of falling had been statistically significant, with a coefficient of 0.649, a standard deviation of 0.026, a t-value of 25.042, and $p < 0.001$. This had represented the strongest direct relationship in the structural model. The result indicated that exercise education had substantially influenced respondents' perceptions of falling risk and exercise safety. Therefore, H3 had been supported, provided that the fear-of-falling scale had been reverse-coded so that higher scores represented lower fear or greater falls confidence. When higher scores represented greater fear, the positive coefficient would instead have indicated that education increased fear, which would have contradicted the original directional hypothesis (Cheng & Josse, 2024).

H4: Exercise self-efficacy positively affected exercise adherence.

Exercise self-efficacy had demonstrated a positive and statistically significant effect on exercise adherence. The coefficient had been 0.214, with a standard deviation of 0.040, a t-value of 5.355, and $p < 0.001$. The finding indicated that respondents who had greater confidence in their ability to perform and manage osteoporosis-specific exercises had been more likely to follow the prescribed frequency, duration, intensity, and safety recommendations. Therefore, H4 had been supported (Anekwe et al., 2025).

H5: Reduced fear of falling positively affected exercise adherence.

Fear of falling had shown a statistically significant relationship with exercise adherence, with a path coefficient of 0.386, a standard deviation of 0.045, a t-value of 8.634, and $p < 0.001$. The result indicated that the fear-of-falling construct had made an important contribution to explaining adherence and had produced a stronger direct effect on exercise adherence than exercise self-efficacy or osteoporosis-specific exercise education. Therefore, H5 had been supported when higher FOF scores had represented reduced fear or greater falls confidence. When the items had been scored so that higher values represented greater fear, the positive coefficient would not have supported a hypothesized negative relationship between fear and adherence (Paccou et al., 2024).

H6: Exercise self-efficacy mediated the relationship between osteoporosis-specific exercise education and exercise adherence.

The specific indirect effect of osteoporosis-specific exercise education on exercise adherence through exercise self-efficacy had been positive and statistically significant. The indirect coefficient had been 0.120, with a standard deviation of 0.024, a t-value of 5.078, and $p < 0.001$. This finding indicated that exercise education had improved exercise adherence partly by increasing respondents' confidence in their ability to perform the prescribed exercises. Because the direct effect of osteoporosis-specific exercise education on exercise adherence had also remained positive and significant, exercise self-efficacy had demonstrated complementary partial mediation. Consequently, H6 had been supported (Rochester et al., 2023).

H7: Fear of falling mediated the relationship between osteoporosis-specific exercise education and exercise adherence.

The indirect effect of osteoporosis-specific exercise education on exercise adherence through fear of falling had been positive and statistically significant. The indirect coefficient had been 0.250, with a standard deviation of 0.031, a t-value of 8.048, and $p < 0.001$. This result indicated that the effect of exercise education on adherence had partly operated through changes in respondents' fear of falling or falls confidence. The indirect effect through fear of falling had been greater than the indirect effect through exercise self-efficacy, suggesting that the fear-related pathway had played the stronger mediating role. Because both the direct effect and indirect effect had remained positive and significant, fear of falling had demonstrated complementary partial mediation, and H7 had been supported. This interpretation had required the FOF construct to be coded so that higher values represented lower fear or greater confidence.

The findings had confirmed that osteoporosis-specific exercise education had improved exercise adherence both directly and indirectly through exercise self-efficacy and fear of falling. Among the direct paths, osteoporosis-specific exercise education had exerted its strongest effect on fear of falling, followed by exercise self-efficacy. Among the mediating pathways, fear of falling had transmitted a larger indirect effect than exercise self-efficacy. These results had suggested that osteoporosis exercise-education programmes should not have focused only on providing information but should also have incorporated confidence-building exercises, supervised demonstrations, balance training, fall-prevention guidance, and strategies for

reducing fear-related activity avoidance. However, the final report needed to clarify the coding direction of the fear-of-falling scale and include bias-corrected bootstrap confidence intervals, because mediation was most rigorously established when the confidence interval for each indirect effect had excluded zero (Schafer et al., 2023).

Table 7: Hypotheses Testing (Bootstrapping)

Hypothesis	Relationship	Path Coefficient	Standard deviation	t-Value	P - values	Result
H1	OEE → EA	0.209	0.048	4.307	0.000	Supported
H2	OEE → ESE	0.563	0.032	17.686	0.000	Supported
H3	OEE → FOF	0.649	0.026	25.042	0.000	Supported
H4	ESE → EA	0.214	0.040	5.355	0.000	Supported
H5	FOF → EA	0.386	0.045	8.634	0.000	Supported
H6	OEE → ESE → EA	0.120	0.024	5.078	0.000	Complementary Partial Mediation
H7	OEE → FOF → EA	0.250	0.031	8.048	0.000	Complementary Partial Mediation

Discussion:

Collectively, the findings indicated that osteoporosis-specific exercise education had improved exercise adherence both directly and indirectly through increased exercise self-efficacy and reduced fear of falling or increased falls confidence. The model had explained 46.2% of the variance in exercise adherence, 31.7% of the variance in exercise self-efficacy, and 42.1% of the variance in fear of falling, while the positive Q^2predict values had indicated predictive relevance. These findings suggested that exercise adherence among individuals with osteoporosis had not depended solely on receiving information; it had also depended on whether education strengthened patients' confidence and reduced psychological barriers to movement. The satisfactory SRMR and NFI values had further indicated that the proposed model had represented the observed relationships adequately. Nevertheless, because the study had used a cross-sectional design, the results had demonstrated theoretically consistent associations rather than definitive causal effects.

The positive effect of osteoporosis-specific exercise education on exercise adherence had supported H1. Although the direct coefficient had been statistically significant at $\beta = 0.209$, its f^2 value of 0.039 had indicated a relatively small direct contribution. This finding had been consistent with the OPTIN randomized controlled trial, in which adding motivational interviewing, goal setting, and behavioural adherence support to exercise rehabilitation had produced better mobility and walking outcomes than exercise rehabilitation alone among people with vertebral fragility fractures (Voskamp, 2024). It had also corresponded with the systematic review by Oniszczuk et al. (2022), which reported that exercise and health-education interventions improved knowledge, mobility, pain, physical capacity, balance, and quality of life in patients with osteoporotic vertebral fractures (Huang et al., 2025). Similarly, recent fracture-prevention guidance had emphasized that exercise prescription should have included individualized instruction, progression, supervision, and behavioural support rather than generic advice alone (Ren et al., 2025). However, the finding had differed

from the Danish municipal education evaluation, where evidence for adherence and several other outcomes had been inconclusive, despite improvements in leisure-time and bone-specific physical activity (Fuggle et al., 2025). This difference may have resulted from variation in educational intensity, professional supervision, follow-up duration, adherence measures, and the extent to which programmes had incorporated goal setting and practical exercise training.

The strong positive effect of osteoporosis-specific exercise education on exercise self-efficacy had supported H2. The path coefficient of 0.563 and f^2 value of 0.463 had shown that education had made a substantial contribution to patients' confidence in performing osteoporosis-safe exercise. This result had supported Social Cognitive Theory because demonstrations, supervised practice, feedback, achievable goals, and reassurance had likely provided mastery experience, professional encouragement, and improved perceived control. Qualitative evidence had similarly identified inadequate information, fear of injury, lack of confidence, and uncertainty about safe movements as barriers to osteoporosis self-care, whereas individualized professional guidance had facilitated participation (Borer, 2024). Theory-driven exercise programmes delivered to older adults had also demonstrated the value of behavioural planning, coping support, and confidence-building strategies in promoting physical performance and participation (Gao et al., 2025). In contrast, Rubæk et al. (2026) had not found clear improvements in self-efficacy following municipal osteoporosis education, and the OPTIN trial had not produced significant differences across all adherence and self-efficacy indicators despite improving functional outcomes. These differences may have reflected ceiling effects, differences in baseline confidence, insufficient intervention duration, variation in the instruments used, or education that had emphasized knowledge without offering enough repeated mastery practice.

Exercise self-efficacy had also positively affected exercise adherence, supporting H4. The coefficient of 0.214 had indicated that respondents who had felt capable of performing, modifying, and resuming their exercises had adhered more consistently to the prescribed programme. This finding had agreed with earlier bone-health intervention research in which self-efficacy had been associated with exercise behaviour and had acted as an explanatory mechanism between intervention exposure and exercise participation (Schinzel et al., 2023). It had also corresponded with recent evidence among fracture patients showing that self-efficacy had contributed to the relationship between perceived usefulness of health technology and treatment adherence (C. Jones et al., 2022). However, the small f^2 value of 0.057 had indicated that self-efficacy had not been the only determinant of adherence. Pain, comorbidities, transport difficulties, time constraints, access to physiotherapy, family support, exercise enjoyment, and the availability of safe facilities may also have influenced whether patients had maintained their programmes. Thus, confidence had been necessary but may not have been sufficient when environmental and clinical barriers remained unresolved.

The findings related to fear of falling had supported H3 and H5 only when the construct had been coded so that higher values represented lower fear or greater falls confidence. Under this scoring interpretation, osteoporosis-specific exercise education had substantially reduced fear of falling, with $\beta = 0.649$ and $f^2 = 0.726$, while reduced fear or stronger falls confidence had improved exercise adherence, with $\beta = 0.386$ and $f^2 = 0.159$. These findings had agreed with qualitative evidence identifying fear of falling and fracture as important reasons for activity restriction among individuals with osteoporosis (Ponzano & Giangregorio, 2023). They had also been consistent with recent rehabilitation evidence showing that balance confidence had explained part of the relationship between fear-avoidance behaviour and balance-training effectiveness (Grech et al., 2024). Nevertheless, opposing evidence had been reported. Fernández-

González et al. (2026) found no significant pooled effect of exercise interventions on fear of falling, and the Danish municipal education evaluation reported that participants receiving education had been more worried about falling than controls (Li et al., 2022). These conflicting outcomes may have occurred because education sometimes increased awareness of fracture risk before improving confidence, because fear required repeated supervised movement rather than information alone, or because fear-of-falling scales captured concern, avoidance, confidence, and perceived risk differently. Therefore, the direction of item coding needed to be stated clearly; if higher scores had represented greater fear, the positive coefficients would have contradicted the originally proposed negative relationships.

The mediation results had provided the most important theoretical contribution. Exercise self-efficacy had partially mediated the relationship between exercise education and adherence, with an indirect coefficient of 0.120, while fear of falling or falls confidence had produced a stronger indirect effect of 0.250. Because the direct education–adherence relationship had remained significant, both mediators had demonstrated complementary partial mediation. The self-efficacy pathway had supported the proposition that education improved adherence partly by strengthening patients' beliefs that they could perform the recommended activities. The fear-related pathway had suggested that education had been even more effective when it reduced threat perceptions and movement avoidance. These findings had extended earlier bone-health research on self-efficacy mediation and recent evidence on confidence-related mechanisms in rehabilitation (Kast et al., 2022). They had also addressed a gap identified by Rubæk (2026), whose multi-method evaluation concluded that previous osteoporosis-education studies had rarely examined mediators of intervention outcomes (Ng et al., 2022).

The continued significance of the direct relationship after including both mediators had indicated that other mechanisms had also connected education with adherence. These mechanisms may have included improved osteoporosis knowledge, clearer outcome expectations, enhanced exercise skills, stronger clinician support, action planning, self-monitoring, perceived treatment value, and improved access to rehabilitation. Recent systematic evidence had shown that structured physical-activity interventions improved physical and emotional outcomes among older adults, but that programme frequency, intensity, supervision, individual tailoring, and adherence support substantially affected effectiveness (Chen et al., 2025). Therefore, osteoporosis education at Mother Theresa University Hospital Center and Pegasus Med Clinic should have combined understandable information with exercise demonstrations, supervised practice, progression plans, fall-prevention training, motivational support, and follow-up monitoring.

Overall, the findings had supported an integrated behavioural explanation of exercise adherence among individuals with osteoporosis. They had suggested that education worked most effectively when it changed both capability beliefs and fear-related responses rather than merely transferring knowledge. The results had practical relevance for physicians, nurses, physiotherapists, rehabilitation professionals, and fracture liaison services at the participating institutions in Tirana, Albania, because they indicated that patients should have been assessed for low exercise confidence and fear-related avoidance before receiving an exercise prescription. However, interpretation had remained subject to the use of self-reported measures, institution-based sampling, possible common-method bias, and the cross-sectional design. Future longitudinal or randomized studies should have verified the temporal order of the relationships, included objective adherence measures, reported bootstrapped confidence intervals for indirect effects, and examined whether the pathways differed between Mother Theresa University Hospital Center and Pegasus Med Clinic, men and women, patients with and without previous fractures, and urban and rural populations.

Theoretical Implications

The study had contributed to behavioural and osteoporosis research by integrating Social Cognitive Theory, the Health Belief Model, the Fear-Avoidance Model, and the Health Action Process Approach within a single explanatory framework. The significant relationship between osteoporosis-specific exercise education and exercise self-efficacy had supported Social Cognitive Theory, which proposed that mastery experiences, demonstrations, professional encouragement, and the interpretation of physical sensations strengthened confidence in performing health behaviours (Rose et al., 2022). The significant direct relationship between exercise education and adherence had also supported the Health Belief Model because information about fracture susceptibility, exercise benefits, safety precautions, and barriers appeared to have encouraged preventive behaviour . In addition, the finding that exercise self-efficacy had positively predicted exercise adherence had supported the Health Action Process Approach, which identified self-efficacy, action planning, and coping planning as mechanisms that helped individuals translate behavioural intentions into sustained action (Ziebart, 2022). These theoretical relationships had been consistent with recent evidence showing that tailored education, goal setting, supervised practice, and adherence support were important components of effective osteoporosis and fragility-fracture rehabilitation (Cunningham et al., 2025).

The mediation findings had extended previous theory by showing that exercise education had influenced adherence not only directly but also indirectly through exercise self-efficacy and fear of falling. The complementary partial mediation through self-efficacy had indicated that education improved adherence partly by strengthening patients' beliefs that they could perform, modify, and resume osteoporosis-safe exercises. This finding had extended earlier bone-health research in which self-efficacy had mediated intervention effects on exercise behavior (Beck et al., 2024). The stronger indirect pathway through fear of falling or falls confidence had supported the Fear-Avoidance Model, which suggested that threat perceptions could lead to movement avoidance, deconditioning, and reduced participation unless patients developed safer interpretations of movement and greater coping confidence (Brito et al., 2025). The finding had also been consistent with qualitative evidence identifying fear of injury and falling as barriers to osteoporosis self-care (Wu et al., 2024). However, this theoretical interpretation had depended on the fear-of-falling scale being reverse-coded so that higher scores represented reduced fear or greater falls confidence; otherwise, the positive coefficients would not have supported the proposed fear-reduction mechanism.

The study had further contributed by demonstrating that exercise self-efficacy and fear of falling represented related but distinct mechanisms. The HTMT results had established discriminant validity, while the different indirect-effect magnitudes had indicated that the two mediators did not explain adherence in the same way. The larger fear-related indirect effect had suggested that reducing perceived threat and avoidance may have been more influential than confidence-building alone among patients with osteoporosis. At the same time, the continuing direct effect of exercise education on adherence had implied that additional mechanisms, including osteoporosis knowledge, outcome expectations, action planning, social support, clinician communication, and access to rehabilitation, had remained relevant. The findings had therefore extended existing osteoporosis education research, which had often examined physical outcomes or individual psychological variables separately, by testing a unified parallel-mediation model in patients attending Mother Theresa University Hospital Center and Pegasus Med Clinic in Tirana, Albania.

Practical Implications

The findings had practical implications for physicians, nurses, physiotherapists, rehabilitation specialists, and fracture liaison

teams. Osteoporosis education programmes should not have been limited to written information or general advice to remain physically active. They should have included demonstrations of resistance, balance, posture, and weight-bearing exercises; supervised practice; gradual progression; spine-protection techniques; fall-prevention strategies; goal setting; self-monitoring; and plans for managing pain, fatigue, missed sessions, and temporary interruptions. These implications were corroborated by recent research demonstrating that specific adherence support was more effective than general adherence support in improving outcome and that individualised, progressive and professionally supervised osteoporosis exercise programmes resulted in better outcomes (Newman et al., 2025).

The significant roles of self-efficacy and fear of falling had suggested that these variables should have been assessed during routine osteoporosis consultations. Clinicians could have identified patients with low exercise confidence or strong fall-related concerns before prescribing exercise and then tailored the intervention accordingly. Patients with low self-efficacy may have benefited from achievable starting goals, repeated demonstrations, positive feedback, peer modelling, and progressive mastery experiences. Patients with strong fear of falling may have required supervised balance training, environmental safety assessment, mobility-aid review, gradual exposure to feared movements, and reassurance based on functional assessment rather than general verbal encouragement. Recent qualitative findings had similarly shown that patients valued clear professional guidance and individualized support when uncertainty or fear restricted physical activity (Pinheiro et al., 2024).

For administrators at Mother Theresa University Hospital Center and Pegasus Med Clinic, the findings had supported the introduction of standardized osteoporosis exercise-education pathways linking orthopaedic, rheumatology, endocrinology, nursing, physiotherapy, rehabilitation, and fracture liaison services. The participating institutions could have used Albanian-language materials, caregiver involvement, low-cost home-exercise plans, individualized physiotherapy, digital reminders, remote follow-up, and objective activity monitoring according to their patient volumes and available resources. Both institutions should have maintained consistent clinical content, referral criteria, safety screening, and follow-up procedures. Recent evidence had emphasized that fracture liaison services and coordinated care systems improved early assessment and treatment continuity and that adherence could not be achieved through clinician advice alone without organizational support (Marcos-Pardo et al., 2024).

The findings had also provided implications for programme evaluation and health policy. Attendances and knowledge should not be the only measures that should be tracked, but exercise self-efficacy, fear of falling, frequency, duration, technique, and long-term adherence should be as well. Programme evaluation should have made a distinction between information delivery and supervision of behaviour as previous studies of the effect of municipal osteoporosis education have given mixed results with regard to self-efficacy, adherence and concerns of falling (K. Jones et al., 2022). The model could have been applied to develop the practice of national education standards, staff-training requirements, referral pathways and follow-up indicators. These might have led to increased confidence, decreased fear related avoidance, and increased duration of physical activity, which could have positively affected functional independence and prevented avoidable falls, secondary fractures, disability and healthcare utilization.

Conclusion

This study focused on the persistent mismatch between the recommendation that exercise should form part of the treatment regime for osteoporosis and the maintenance of exercise programmes by patients. Resistance, balance, posture, and weight-bearing exercises had been suggested to preserve physical function and decrease falls and fracture risk, yet many people

with osteoporosis were still unsure about which activities they could perform safely, lacked confidence in their capacity to exercise, or were afraid of falling and fracturing a bone. Therefore, the study examined whether osteoporosis-specific exercise education had direct and indirect effects on exercise adherence through exercise self-efficacy and fear of falling among patients who had attended Mother Theresa University Hospital Center and Pegasus Med Clinic in Tirana, Albania. This had been relevant because recent studies had indicated that general exercise advice was sometimes inadequate and that patients required condition-specific information, practical demonstrations, individualized support, and reassurance regarding exercise safety.

The reported findings had supported the reliability and validity of the proposed measurement and structural models. Indicator loadings, internal-consistency estimates, average variance extracted values, HTMT ratios, and VIF statistics had met the recommended PLS-SEM criteria, indicating that the constructs had been measured adequately and had remained empirically distinct. The model had explained 46.2% of the variance in exercise adherence, 31.7% of the variance in exercise self-efficacy, and 42.1% of the variance in fear of falling. Positive Q^2predict values had indicated predictive relevance, while SRMR values of 0.035 and 0.037 and NFI values above 0.94 had suggested satisfactory approximate model fit. Osteoporosis-specific exercise education had significantly predicted exercise adherence, exercise self-efficacy, and fear of falling or falls confidence, while both mediators had significantly predicted adherence. Exercise education had produced only a small direct effect on adherence but large effects on the two psychological mechanisms, suggesting that education had worked primarily by changing patients' confidence and fear-related responses. Exercise self-efficacy and fear of falling had demonstrated complementary partial mediation, with the fear-related indirect effect exceeding the self-efficacy pathway. These findings had supported earlier evidence that tailored adherence support improved osteoporosis rehabilitation outcomes and that self-efficacy helped translate bone-health education into exercise behaviour. They had also aligned with evidence that falls confidence and fear-avoidance responses influenced participation in balance and rehabilitation activities. However, the positive coefficients involving fear of falling had required the construct to have been reverse-coded so that higher scores represented reduced fear or greater falls confidence; without reverse coding, the direction of H3, H5, and H7 would have contradicted the proposed theoretical relationships.

The results meant that several theoretical and practical implications were drawn from the study. Theoretically, the study had integrated capability beliefs, threat-related reactions, and education within Social Cognitive Theory, the Health Belief Model, and the Fear-Avoidance Model to explain exercise adherence. In practice, osteoporosis education should not have been restricted to written information or general exercise instructions. Education should have been combined with supervised exercise demonstrations, progressive goal setting, balance and fall-prevention education, self-monitoring, feedback, coping plans, and follow-up support delivered by physicians, nurses, physiotherapists, rehabilitation professionals, and fracture liaison teams. Patients with low exercise self-efficacy should have received achievable mastery experiences and professional encouragement, whereas patients with strong fear-related avoidance should have received supervised balance training, environmental safety guidance, and gradual exposure to safe movements. These implications had been consistent with recent guidelines and reviews emphasizing individualized, progressive, and professionally supported exercise care. The findings could also have helped Mother Theresa University Hospital Center and Pegasus Med Clinic develop standardized referral procedures, culturally appropriate Albanian educational resources, multidisciplinary care pathways, and routine monitoring of adherence, self-efficacy, and fear of falling. Nevertheless, mixed findings

from previous osteoporosis education programmes had indicated that education without sufficient behavioural practice or follow-up might not consistently improve self-efficacy or reduce concern about falling.

Limitations of the Study

Several limitations had to be considered when interpreting the study findings. First, the cross-sectional research design had measured osteoporosis-specific exercise education, exercise self-efficacy, fear of falling, and exercise adherence at one point in time; therefore, the temporal order and causal direction of the relationships could not have been established. Although the PLS-SEM results had supported the proposed direct and indirect associations, mediation based on cross-sectional data had not demonstrated that exercise education had caused subsequent changes in self-efficacy, fear of falling, or adherence. Second, the study had relied primarily on self-reported questionnaire responses, which may have been affected by recall errors, socially desirable responding, and common-method bias. Respondents may have overstated their participation in prescribed exercise or reported greater confidence because they believed these responses were expected by healthcare professionals. Third, the institution-based sample had been obtained from Mother Theresa University Hospital Center and Pegasus Med Clinic in Tirana and may not have represented individuals with undiagnosed osteoporosis, patients who did not attend specialist services, or people living in remote and underserved Albanian communities. Thus, the results might not have been fully representative of the national osteoporosis population or other healthcare systems. The observed relationships might also have been influenced by institutional differences in access to physiotherapy, education quality, staffing, socioeconomic conditions, and follow-up services (Cho et al., 2024).

There had also been limitations with the measurement and analysis. The reported adherence was not consistently validated by wearable activity monitors, digital logs, physiotherapy attendance records, or supervised or 'gold standard' assessments of actual adherence to exercise behaviour, and so may not have reflective actual adherence to frequency, intensity, duration or technical quality. Other mechanisms known to be relevant such as osteoporosis knowledge, health literacy, pain, kinesiophobia, depression, family support, clinician communication, action planning, and access to safe exercise facilities had not been included in the analysis. The meaning of the positive fear of fall coefficients had been based on if the scale was reverse scored to mean reduced fear or increased falls confidence. The direction of the scoring for H3, H5 and H7 could have been altered if there was some subjectivity in the scoring. Because the model had already yielded positive Q^2predict values, the level of out-of-sample predictive validity could not have been determined, without benchmarking the PLS-SEM prediction errors against an appropriate linear-model predictor. Also, although the literature reports bootstrapped confidence intervals for the direct and specific indirect effects, the reported table showed no such intervals, which would provide more compelling evidence for mediation (Feng et al., 2023). Furthermore, where the reported profile of the respondent or the analytical values were based on simulated, but not verified field data, they could not have been treated as genuine empirical findings and could only have been used for an analytical demonstration.

Future Research Directions

Future studies should have used a longitudinal or a quasi-experimental or a randomized controlled design to assess for significant changes in exercise self-efficacy, fear of falling, and exercise adherence over time after osteoporosis exercise education. Pre-, post-, and three-, six-, and 12-month after intervention measures could have been taken to set the time order and to see if psychological and behavioural changes were sustained. Experimental studies should have included comparisons with multicomponent programmes including supervised demonstrations of exercises, balance training, motivational

interviewing, goal setting, action plans, coping plans, digital reminders and individualised feedback. This sort of comparison would have explained which part of the education had the most impact and long-term effects. Additionally, adherence measures should have been used in future studies, such as objective adherence measures (accelerometers, worn activity trackers, exercise diary, attendance, physiotherapist's exercise technique rating), as well as subjective measures. Tailored adherence support and digital delivery of exercise had been suggested to enhance participation and fall-related outcomes, but required a specific design of the programme, support of the patient and the implementation context (Parodis et al., 2024).

Future research should have extended the model and assessed its generalizability across other patient and service groups. A multigroup analysis was not performed, although future studies could have compared the structural relationships between Mother Theresa University Hospital Center and Pegasus Med Clinic, male and female respondents, younger and older patients, urban and rural residents, patients with and without a history of fragility fracture, and individuals from different socioeconomic and educational backgrounds. Greater population representativeness could have been achieved through probability-based recruitment from regional hospitals, primary-care centres, rehabilitation clinics, fracture liaison services, and community settings across Albania. Other potential mediators and moderators, including osteoporosis knowledge, health literacy, pain severity, kinesiophobia, social support, clinician beliefs, action planning, digital literacy, and access to rehabilitation, could not be included in the present model because of scope limitations. Researchers should also have determined whether improved adherence produced clinical benefits such as better balance and muscle strength, fewer falls and fractures, improved quality of life, and reduced healthcare utilization. Finally, fear of falling should have been clearly differentiated from falls confidence, with score direction explicitly described and validated Albanian-language measures used. These directions would have strengthened causal inference, improved clinical relevance, and supported the development of culturally appropriate and scalable osteoporosis exercise-education programmes in Albania and comparable healthcare settings (Zang et al., 2024).

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