Actual Problems of Osteoporosis and Osteopenia in Mountainous Regions of the Kyrgyz Republic

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Abstract: The aim of the study was to analyse the incidence of osteoporosis in mountainous regions of Kyrgyzstan, with special emphasis on the study of the influence of altitude on the incidence rate, as well as the identification of factors contributing to its development. For statistical analysis, aimed at assessing the relationship between altitude and the incidence of the disease, the Pearson correlation coefficient was applied. The survey reviewed data from five studies covering regions from altitudes ranging from 779 to 2,420 m above sea level. The incidence varied by region, gender and age group. The results showed no significant association between altitude and incidence of osteoporosis, but a trend towards lower prevalence was observed in high altitude areas, probably due to climatic conditions, physical activity and lifestyle. In addition to altitude, the study looked at other potential factors influencing the development of osteoporosis, including air pollution ($PM_{2.5}$, NO_2, NO_X), vitamin D levels and calcium intake. The results of the analysis of osteopenia showed that its incidence and frequency varied depending on age groups and region. In particular, in mountainous areas of Kyrgyzstan, there was a higher prevalence of osteopenia among older people, with the highest rates in urban and foothill regions. The practical significance lies in developing recommendations for osteoporosis prevention in mountainous Kyrgyzstan, improving diagnosis, treatment accessibility, and raising awareness of risk factors.

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Introduction

Osteopenia is a condition where bone density is reduced, but not to the level seen in osteoporosis. It is considered a precursor to osteoporosis, indicating an increased risk of developing the disease. The key difference is that osteoporosis leads to significant bone weakness, increasing the risk of fractures, while osteopenia is less severe and does not necessarily result in fractures. Osteoporosis is a systemic disease characterised by a decrease in bone mineral density (BMD) and impaired bone microstructure, resulting in increased fragility and fracture risk. Osteoporosis is not only a medical but also a socio-economic problem, contributing to the disability of the elderly population and increasing the burden on the health care system (Kashikova et al., 2024). The incidence of osteoporosis remains understudied in high mountainous areas, where chronic hypoxia, fluctuations in solar insolation and dietary patterns can significantly affect mineral metabolism. The absence of a national register, fragmented data, and limited access to diagnosis and prevention necessitate a comprehensive analysis of the impact of altitude on the prevalence of the disease in mountainous areas of Kyrgyzstan.

Bone tissue is constantly renewed through a remodelling process that is regulated by the balance between bone resorption by osteoclasts and bone formation by osteoblasts (Rowe et al., 2023; Latka et al., 2025). In osteoporosis, this balance is disturbed towards increased resorption or insufficient new bone formation. Osteoclast hyperactivity – increased bone resorption under the influence of parathyroid hormone, along with activation of receptor for nuclear factor kappa-B ligand and decreased osteoprotegerin levels. Osteoblast insufficiency – decreased differentiation and activity of osteoblasts due to hormone deficiency (estrogens, testosterone), vitamin D deficiency and chronic inflammation (Whitaker Elam, 2024).

Osteoporotic fractures are expected to increase by 68% by 2040 (Lewiecki et al., 2019). Femur fractures are considered one of the most dangerous among other fractures. About half of patients with this injury lose the ability to move independently, and mortality in women in the first year after fracture is 12–24%, compared to 33% in men (Zaheer and LeBoff, 2022). These findings support the importance of osteoporosis prevention and awareness of fracture risks in different age groups, especially among women over 70 years of age.

Primary osteoporosis is associated with aging and declining gender hormones, which deteriorates bone microstructure, decreases bone density, and increases fracture risk. Secondary osteoporosis is due to other diseases or their treatment (glucocorticoids [GCs], anti-epileptic drugs) and is more common in men (Lisiecka, 2024a, b). Predisposing factors include hyperparathyroidism, anorexia, malabsorption, hyperthyroidism, renal failure, Cushing's syndrome, prolonged immobility, secondary amenorrhoea, low weight, excessive exercise and hormone therapy. The risk increases with age, low weight, smoking, neurological disorders, early menopause, physical inactivity and after fractures (Lewiecki, 2024; Fathi, 2025). Patients with limited mobility, such as after spinal cord injuries, are particularly vulnerable (Porter and Varacallo, 2023).

There are many studies on osteoporosis that cover different aspects of the disease and risk factors, including the effects of altitude hypoxia, chronic diseases and genetic features. As a possible preventive approach of bone mass reduction Hao et al. (2023) proposed the application of pulsed electromagnetic fields (PEMF) to promote osteoblast activation and improve bone structure in rats exposed to hypobaric hypoxia.

The dynamics of fibrinogen during Ilizarov osteosynthesis was studied by Djumabekov et al. (2024). It was found that the fibrinogen level increases in high altitude conditions, indicating hypercoagulation and suppression of fibrinolysis. On day 21, the fibrinogen level reached 8.1 ± 0.3 g/l, which requires special attention during surgeries in such conditions. Among 395 people aged 50 years and above living in Madhesh region (Nepal), high risk of osteoporosis was found in 22.3% of participants. This risk was more common in women and underweight individuals. Chaudhary et al. (2024) also found that inadequate calcium intake was associated with an increased risk of osteoporosis.

Among residents of lowland Kyrgyzstan (Bishkek), reduced BMD was more common in patients with chronic obstructive pulmonary disease (COPD) and long-term glucocorticoid use (Asanbaeva et al., 2023). BMD was measured using dual-energy X-ray absorptiometry (DXA). Multiple logistic analysis revealed that COPD and GC intake were the most significant risk factors for osteoporosis.

In a study by Zhanybek Kyzy et al. (2023) studied bone composition in 800 Kyrgyz children of both genders aged 4–7 years. Anthropometric and bioimpedance analyses revealed individual variability in bone component content. In boys aged 4–7 years this indicator ranged from 3.24 to 6.02 kg, in girls – from 3.04 to 6.02 kg. The highest values of the bone component were observed in children with muscular somatotype, and the minimum values were observed in children with asthenoid and thoracic somatotypes. Boys of 4 and 7 years of age had higher values than girls of the same age.

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The studies included in this analysis were selected based on their relevance to the research topic, sample size, geographical coverage, and diagnostic methods. Relevance was ensured by focusing on studies specifically addressing osteoporosis and osteopenia in the Kyrgyz Republic and mountainous regions. Sample size was considered to ensure statistical robustness, with studies that included substantial participant numbers being prioritized. Geographical coverage was taken into account to provide a representative understanding of osteoporosis prevalence across different regions, including both mountainous and foothill areas. Diagnostic methods, such as ultrasound densitometry, were evaluated for consistency and reliability in measuring bone density. These criteria ensured that only studies with high methodological quality and pertinent data were included in the analysis.

This study will help to fill the lack of epidemiological data in the population of the Kyrgyz Republic, improve diagnosis, prevention and accessibility of treatment, and may become the basis for the development of national strategies to combat osteoporosis. The aim of this study was to assess the prevalence of osteoporosis in mountainous regions of the Kyrgyz Republic, to determine its relationship with altitude and to identify the key factors influencing the development of this disease. The tasks of the study included systematisation and analysis of data on the incidence of osteoporosis in mountainous regions of Kyrgyzstan, as well as comparison of the prevalence of the disease in different age and gender groups.

Material and Methods

For statistical analysis, data on the prevalence of osteoporosis in mountainous regions of the Kyrgyz Republic were collected on the basis of scientific publications and materials found in international databases. This approach allowed a comprehensive study of the influence of various factors on the development of osteoporosis. In addition, the study reviewed the literature on the peculiarities of mineral metabolism and bone tissue metabolism in people living in mountainous areas. Special attention was paid to the works devoted to the prevalence of osteoporosis and osteopenia among the population of Kyrgyzstan.

The studies of Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022) were considered. These studies examined various factors influencing the development of osteoporosis, including air pollution, vitamin D levels, and calcium intake, which may have an indirect effect on the incidence of the disease. The study analysed the general altitude ranges of the regions involved, with high-altitude areas ranging from 1,800 meters to over 3,000 meters above sea level, and lowland areas at approximately 800 meters. The altitude data were sourced from TessaDEM (2025, https://topographic-map.com).

To analyse the incidence of osteoporosis in mountainous areas of Kyrgyzstan, data were selected for regions with different altitudes: highland areas (Karakol city, located at an altitude of 1,801 meters; Naryn city, located at an altitude of 2,420 meters; At-Bashi village, located at 2,150 meters) and foothill areas (Bishkek city, at 848 meters; Osh city, at 1,068 meters; Jalal-Abad city, at 779 meters). The study period covers the years from 2019 to 2025. Data were analysed in different age groups: 18–39 years, 40–59 years, and 60 years and older.

For statistical processing of the data, the Pearson correlation coefficient was used to measure the degree of linear relationship between the altitude of the location of the region and the prevalence of osteoporosis. The correlation coefficient ranges from –1 (complete negative relationship) to +1 (complete positive relationship). Values close to 0 indicate no significant relationship between the variables. This method provided a way to objectively assess whether there was an association between terrain elevation and the incidence of osteoporosis, and to determine the influence of other factors such as age and gender.

The correlation coefficient was calculated separately for each age category, taking into account the incidence of osteoporosis and the altitude of the region. The association between altitude of the area and the prevalence of osteoporosis for men and women was also assessed to account for differences in the number of participants by sex in the studies.

Microsoft Excel software with the CORREL function was used to calculate the Pearson correlation coefficient, which allowed for an automated calculation of the linear relationship between variables. Regional heights and prevalence of osteoporosis in different age groups were entered into Tables, which allowed the calculation of correlation coefficients for each group separately. Additionally, the correlation between age, gender and incidence was analysed, which helped to identify groups at increased risk of osteoporosis.

The statistical significance of the results was assessed using GraphPad software's online calculator (P Value Calculator, 2025, https://www.graphpad.com/quickcalcs/pvalue1/), with the level of significance taken as $p<0.05$. This provided a strict statistical control and ensured the reliability of the findings. Using these methods, a more accurate and scientifically valid result was obtained to assess the effect of terrain

elevation on the prevalence of osteoporosis. Due to the limited availability of accurate elevation data for individual localities, average elevation values were used for the analyses. This could introduce errors into the data, especially in areas with pronounced elevation differences, which was also taken into account when interpreting the results obtained.

Results and Discussion

Review of osteoporosis research in the population of the Kyrgyz Republic

There is limited information on the incidence of osteoporosis in the Kyrgyz Republic. Based on the conducted work, five scientific studies on the prevalence of osteoporosis and osteopenia in the population of Kyrgyzstan were identified. Of these, studies by Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022) provided data on the regional affiliation of the studied groups (Table 1).

Karakol city (Issyk-Kul region), Naryn city (Naryn region) and At-Bashi villages (Naryn region), which are located in the higher mountainous areas of the country, can be attributed to the region with mountainous terrain. Foothill areas include Bishkek (Chui region), Osh and Jalal-Abad, which are located at the junction of mountains and lower areas.

Analyses of bone tissue status in mountainous regions of the Kyrgyz Republic have shown that the incidence of osteoporosis is lower in

Table 1: Research data on the prevalence of osteoporosis in mountainous regions of the Kyrgyz Republic

Author and date of the study	Tagaev (2022)	Tagaev et al. (2021)	Imanalieva (2020)	Imanalieva et al. (2019)	Mamatov et al. (2020)
Number of subjects	n=1,700	n=1,200	n=475	n=729	n=1,200
Age groups	60–74, 75–90 years	18–39, 40–59, >60 years	18–39, 40–59, >60 years	18–39, 40–59, >60 years	18–39, 40–59, 60–79 years
Gender (women/men, %)	51.8/48.2	51.7/48.3	61.3/38.7	64.9/35.1	57.6/42.4
Diagnostic method	ultrasound densitometry (heel bone)	ultrasound densitometry (heel bone)	ultrasound densitometry	ultrasound densitometry	ultrasound densitometry
Survey region	among patients of family medicine centres in Kyrgyzstan	Osh, Jalal-Abad	Karakol (Issyk-Kul region), as well as Naryn city and At-Bashi village (Naryn region)	Bishkek	Bishkek (Chui region), Karakol (Issyk-Kul region) and Naryn (Naryn region). Senior age groups – Chui region
Frequency of osteopenia (%)	60–74 – 43.5%, 75–90 – 36.5%, ≥60 years – 40.4%	Osh: 18–39 – 26%, 40–59 – 42.5%, >60 – 52.5%; Jalal-Abad: 18–39 – 25.5%, 40–59 – 44.6%, >60 – 60.7%	Karakol: 18–39 – 34.6%, 40–59 – 50.4%, >60 – 57.1%; Naryn and At-Bashi village: 18–39 – 30.3%, 40–59 – 54.8%, >60 – 77.4%	18–39 – 34.3%, 40–59 – 60%, >60 – 47.3%	18–39 – 38.9%, 40–59 – 60.2%, 60–79 – 50.2%
Frequency of osteoporosis (%)	60–74 – 31.1%, 75–90 – 45.5%, ≥60 years – 37.7%	Osh: 18–39 – 9%, 40–59 – 16.7%, >60 – 23.1%; Jalal-Abad: 18–39 – 6%, 40–59 – 21.2%, >60 – 28.7%	Karakol: 18–39 – 0.7%, 40–59 – 8%, >60 – 19.1%; Naryn and At-Bashi village: 18–39 – 1.1%, 40–59 – 7.1%, >60 – 9.7%	18–39 – 0.2%, 40–59 – 9.2%, >60 – 34.9%	18–39 – 5.5%, 40–59 – 8.9%, 60–79 – 40.3%
Range of overall osteoporosis prevalence (%)	18–39 years: 25.5–38.9 40–59 years: 42.5–60.2 ≥60 years: 40.4–77.4				
Range of overall osteoporosis prevalence (%)	18–39 years: 0.2–9 40–59 years: 7.1–21.2 ≥60 years: 9.7–34.9				

Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022)

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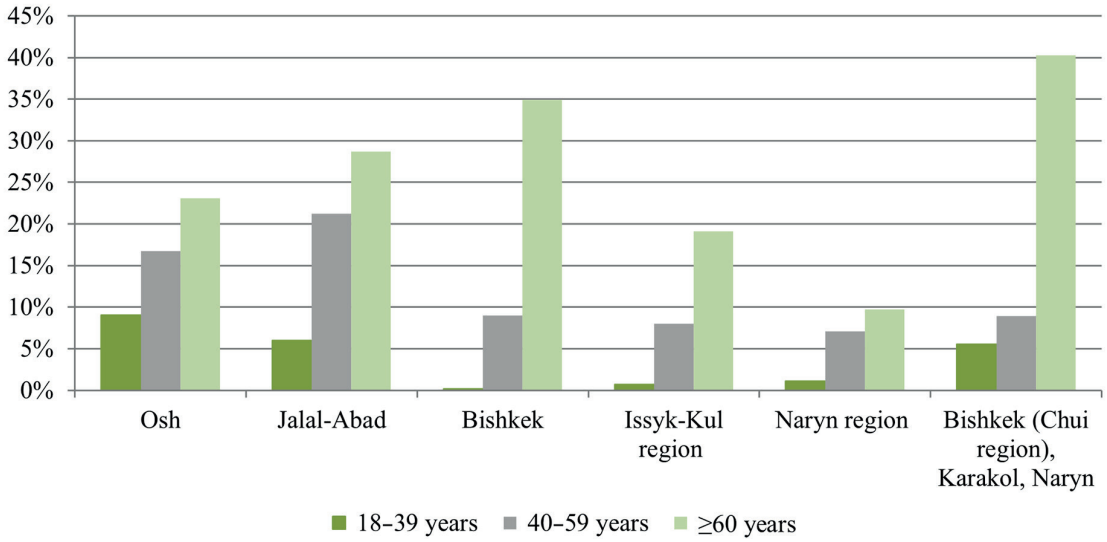

Figure 1: Frequency of osteoporosis in different regions of Kyrgyzstan by age groups.
Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022).

high-mountainous regions, such as Naryn and Issyk-Kul, which may be due to compensatory mechanisms caused by living in high-mountainous conditions (Figure 1).

The Issyk-Kul region is located in a mountainous area at an altitude of 2,471 metres (TessaDEM, 2025) and had the lowest incidence of osteoporosis among younger age groups. Among people older than ≥60 years of age, a relatively low incidence of the disease was recorded here compared to the foothill regions. This may indicate favourable climatic conditions, such as clean mountain air and sufficient sunlight, as well as lifestyle characteristics, including increased physical activity in these regions.

The Naryn city, located at an altitude of 2,420 meters (TessaDEM, 2025), which is part of the Naryn region (with an overall altitude of more than 3,060 meters), is characterised by low levels of osteoporosis among all age groups, especially the elderly. This may be due to the harsher climatic conditions, which may have favoured active physical activity in the daily lives of local residents, as well as possible environmental factors affecting health. At-Bashi village (Naryn region) is located at 2,150 metres above sea level (TessaDEM, 2025).

It is a high-altitude region, which makes it more susceptible to factors associated with osteoporosis risk, such as hypoxia and dietary patterns. Obviously, oxygen deficiency can significantly affect bone metabolism (Tulewicz-Marti et al., 2022). Studies indicating the effect of altitude on bone health are found in the scientific literature, but the results may be contradictory. The climatic conditions of Kyrgyzstan may have an additional impact on bone tissue regeneration processes. Factors that influence the healing of bone defects in high-altitude conditions include compensatory mechanisms for blood supply, such as vasoconstriction and increased levels of erythropoietin (EPO) and haemoglobin (Logvynenko et al., 2025).

Research by Chen et al. (2022) indicates that high sympathetic nervous system activity inhibits osteoblasts and stimulates osteoclast formation. Local acid-base compensation is accompanied by a decrease in pH, which hinders osteoblast differentiation and promotes osteoclast activation. Systemic compensation, characterised by a decrease in PaO_2 and an increase in $PaCO_2$, leads to an increase in pH, which in turn suppresses the proliferation of bone marrow precursor cells. It's worth noting that high-altitude conditions in this study were defined as altitudes above 2,500–3,000 metres above sea level.

In bone tissue, oxygen deficiency causes a reduction in osteoblast differentiation and activity, while simultaneously stimulating the maturation and function of osteoclasts (Łątka et al., 2024). Hypoxic conditions are associated with decreased bone formation and impaired mineralisation of the osteoblast matrix, which is explained by the suppression of osteoblast differentiation, largely through the Runx2, Sox9, Wnt, and PI3K/Akt signalling pathways (Usategui-Martín et al., 2022). Exposure to simulated very high altitude (5,500 m) causes significant changes in the skeletons of rodents. After 4 and 12 weeks of exposure to hypobaric hypoxia, Brent (2022) observed a 13–14% reduction in bone mineral density. This also supports the idea that oxygen deficiency is one of the factors that can trigger osteoporosis.

Table 2: Data for calculating the correlation coefficient by age groups

Region	Height (m)	Frequency of osteoporosis in the group		
		18–39 (%)	40–59 (%)	>60 (%)
Osh	1,068	9.0	16.7	23.1
Jalal-Abad	779	6.0	21.2	28.7
Bishkek	848	0.2	9.2	34.9
Karakol	1,801	0.7	8.0	19.1
Naryn and At-Bashi villages	2,420	1.1	7.1	9.7
Bishkek	848	5.5	8.9	40.3
Karakol	1,801	5.5	8.9	40.3
Naryn	2,420	5.5	8.9	40.3

Note: the repeated cities in Table (Bishkek, Karakol and Naryn) are due to the fact that the study by Mamatov et al. (2020) presented one common indicator for all three cities. Therefore, the same data are shown for these cities. Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022)

Therefore, altitude above sea level can have varying effects on bone tissue health. While the hypoxia that occurs at extremely high altitudes contributes to a decrease in bone mineral density, other factors predisposing to osteoporosis may be at play in relatively lower mountainous regions (Tulewicz-Marti et al., 2023; Logvynenko and Bursova, 2024). This is supported by epidemiological data from the Osh and Jalal-Abad regions (average altitude of Osh is around 1,068 metres, Jalal-Abad is approximately 779 metres) (TessaDEM, 2025), where the prevalence of the disease among people over 40 is higher than in high-altitude areas. The city of Bishkek, located at an altitude of about 848 metres (TessaDEM, 2025), is characterised by a high level of osteoporosis (34.9%) among people over 60. This may be related not only to altitude but also to the characteristics of urban lifestyles, diet, levels of physical activity, and other factors typical of large cities.

Literature data indicates that anthropogenic stress in densely populated urbanised areas leads to a significant increase in the concentrations of nitrogen dioxide (NO_2), nitrogen oxides (NO_X), and fine particulate matter ($PM_{2.5}$), which is due to emissions from road transport, industrial facilities, and slow dispersion rates of pollutants due to specific urban aerodynamics (Wang et al., 2022; Bikis, 2023). Air pollution increases the risk of osteoporosis and fractures.

Polluted air amplified the influence of genetic factors on the development of osteoporosis (Yu et al., 2023). The frequency of osteoporosis in the mountainous regions of Kyrgyzstan is lower, which may be related to adaptation mechanisms to high-altitude conditions, physical activity, and environmental factors, whereas in urban and pre-mountainous areas, the incidence is higher due to air pollution, a sedentary lifestyle, and other urban risks.

Relation of altitude to the incidence of osteoporosis

The results of the study indicate that there is no association between height and the incidence of osteoporosis in the age groups considered. The obtained correlation coefficient value for the 18 to 39-year group is close to zero (–0.255), indicating a very weak negative association between height and osteoporosis incidence in this age group. The p-value of 0.545 significantly exceeds the standard threshold of statistical significance of 0.05, indicating that this association is insignificant. Thus, it can be concluded that there is no statistically significant relationship between height and incidence of osteoporosis in the age group of 18–39 years (Table 2). For 40–59 years, the correlation coefficient was –0.581 indicating a moderately significant negative relationship between height and incidence of osteoporosis.

However, the p-value of 0.132 also does not reach the level of statistical significance, which means that this relationship is also not statistically significant. That is, although the correlation coefficient indicates some decrease in the incidence of osteoporosis with increasing altitude, this relationship is not statistically supported. The correlation coefficient for the population over 60 years of age also indicates a weak negative relationship between height and osteoporosis incidence (–0.273). However, the p-value of 0.513 is significantly higher than 0.05, which also indicates that there is no statistically significant relationship between these variables in the older age group.

Analysis of the data obtained did not reveal a statistically significant correlation between altitude and the incidence of osteoporosis in the studied age groups. However, other studies emphasise the possible influence of altitude on bone metabolism. For example, a cohort study by Zuo et al. (2022)

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Table 3: Data for calculating the correlation coefficient for men and women

Region	Height (m)	Men	Women
Jalal-Abad, Osh	923	13.1	22.3
Bishkek	848	19.3	19.6
Bishkek	848	12.8	15.5
Karakol	1,801	12.8	15.5
Naryn	2,420	12.8	15.5

Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022)

showed that living at high altitudes can negatively affect bone mineral density, increasing the risk of osteoporosis. The authors found an inverse relationship between altitude and quantitative ultrasound index of the heel bone (QUI) and also examined the influence of gut microbiota, including *Catenibacterium*, on bone health.

Short-chain fatty acid (SCFA) concentrations, associated with a lower risk of osteoporosis, were higher in residents of lowland regions. Other data indicate an association of higher altitude with better BMD scores in women with no physical activity habits (Takeda et al., 2015). These findings emphasise possible mechanisms of bone adaptation to high altitude conditions and provide a basis for further research on prevention.

The imbalance in gender representation across the studies can significantly affect the overall conclusions, especially since osteoporosis is more prevalent in women. In particular, women are more predisposed to the disease due to factors such as hormonal changes during menopause, which accelerate bone density loss. The differences in the proportions of men and women in the studies can introduce variability that may confound the relationship between altitude and osteoporosis prevalence.

For instance, in Table 3, the proportions of men and women vary considerably between regions. In some cases, such as in the Jalal-Abad and Osh regions, the proportion of women is significantly higher (22.3%) than men (13.1%), which could skew the results, as the higher female representation could amplify the observed prevalence of osteoporosis. Conversely, regions like Bishkek and Naryn show more balanced or even male-dominated proportions, which may yield different findings. Since four studies (Imanalieva et al., 2019; Mamatov et al., 2020; Tagaev et al., 2021; Tagaev, 2022) report data on osteoporosis separately for men and women, but the works by Mamatov et al. (2020) and Tagaev et al. (2021) provide generalized data for cities without specifying the level of morbidity, this inconsistency complicates the interpretation of results. The varying gender proportions in these studies might therefore obscure the true impact of altitude on osteoporosis, particularly if the risk factor for women is not adequately accounted for.

Data analysis shows a negative correlation between altitude of the area and the incidence of osteoporosis in men (–0.428) and women (–0.577), but the association is statistically insignificant ($p>0.05$). This indicates that there is no clear relationship between region height and incidence of osteoporosis in the study sample. The results show similar values of correlation coefficient with the results of all 5 studies,

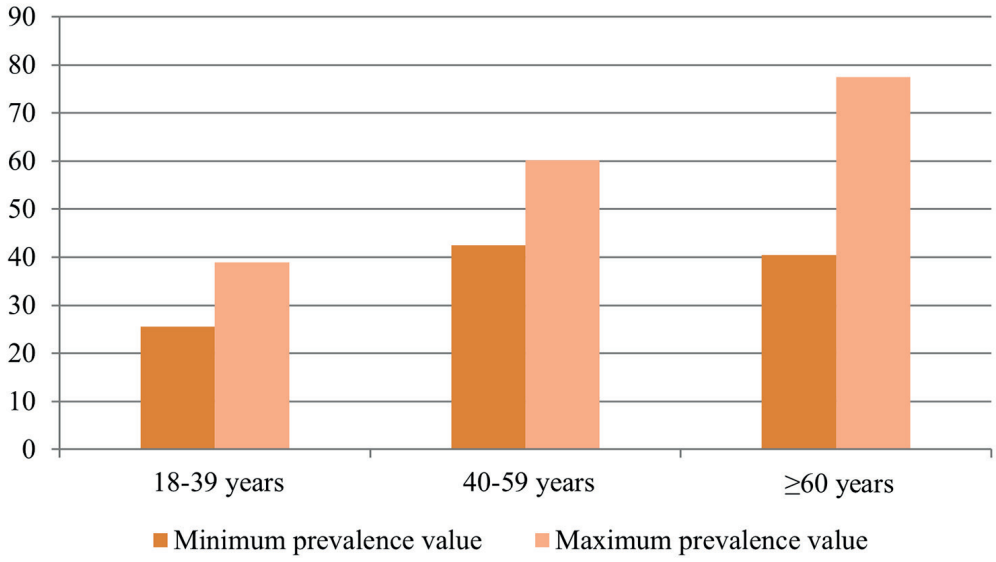

Figure 2: Range of osteopenia frequency values for each age group.
Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022).

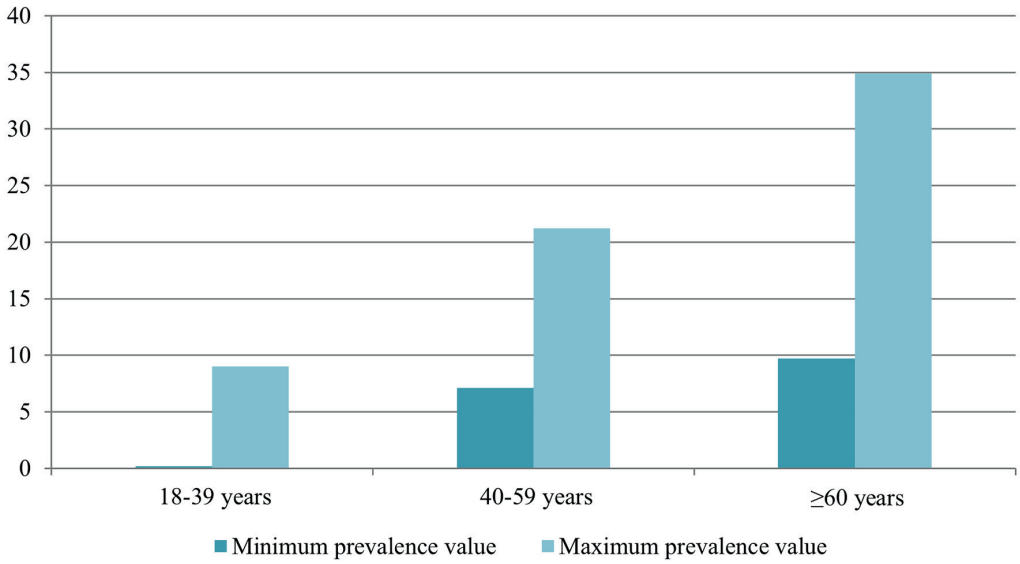

Figure 3: Variation in the incidence of osteoporosis among different age groups.
Source: compiled by the authors based on Imanalieva et al. (2019), Imanalieva (2020), Mamatov et al. (2020), Tagaev et al. (2021), Tagaev (2022).

indicating that the difference in gender ratio in these studies does not significantly affect the main results.

High rates of osteopenia (54.6%) and osteoporosis (9.6%) in postmenopausal Tibetan women were found by Zhong et al. (2023). The key risk factors were age, body mass index, height of residence and creatinine level. However, other findings were reported in a population in Sichuan Province, China, the incidence of osteopenia and osteoporosis decreased with increasing altitude, especially among women and middle-aged individuals (Yang et al., 2024). This study revealed an age-dependent prevalence of osteopenia and osteoporosis: their incidence increased in older age groups, confirming age as a key risk factor for the development of these conditions (Figures 2 and 3).

For osteoporosis, the correlation coefficient was 0.992, although the association was not statistically significant ($p=0.08$). The significant variation in the prevalence of osteoporosis (from 9.7 to 34.9 for the group over 60 years of age) may be due to differences in regional characteristics (Figure 3).

The relatively high rate of osteoporosis and osteopenia already at the age of 18–39 years (up to 38.9%) may indicate the presence of predisposing factors that require further study. This fact emphasises the need for early prevention and identification of factors contributing to bone mass loss, starting from childhood and adolescence. Optimal bone development in children and adolescents requires a balanced diet, physical activity and early correction of risk factors, including calcium deficiency and sedentary behaviour (Mora and Gilsanz, 2003; Berezenko et al., 2021). None of the five studies reviewed considered important determinants of osteoporosis such as nutrition, physical activity level and genetic factors. The lack of information on these indicators limits the possibility of comprehensive analyses and does not permit an assessment of their influence on the relationship between height and the incidence of osteoporosis.

Risk factors for osteoporosis in Kyrgyzstan: vitamin D, calcium and geographical features

Given the expected increase in the number of people with osteoporosis, the problem of vitamin D – 25(OH)D – deficiency becomes even more urgent, as this deficiency significantly affects bone health (Lewiecki et al., 2019). Vitamin D deficiency is a significant factor contributing to the deterioration of BMD, which is associated with impaired calcium metabolism and increased risk of osteoporosis.

According to Isupova and Isupov (2021), seasonal fluctuations of 25(OH)D levels have been detected in the blood serum of Kyrgyz residents. In spring its concentration is 41.7 ± 2.3 nmol/l (95% CI [confidence interval] 37.1–46.4), and in autumn – 50.0 ± 2.1 nmol/l (95% CI 45.9–54.2), indicating vitamin D deficiency. This confirms the need to develop comprehensive measures to prevent vitamin D deficiency at the national level.

Thus, despite the geographical location of the country and the duration of sunshine, vitamin D levels do not reach optimal health values. The representativeness of the sample for the entire population of Kyrgyzstan allows general conclusions to be drawn about the prevalence of vitamin D

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deficiency, but may smooth out regional differences. To identify specific factors affecting 25(OH)D levels in mountainous and lowland areas, additional stratification of the sample by geographical zone is required.

This approach will provide a more accurate identification of local characteristics that may influence vitamin D levels in Kyrgyzstan. Vitamin D deficiency remains a significant global problem with a high prevalence among populations in different regions and groups (Al-Maqtari e al., 2024). Despite some reduction in deficiency levels since 2010, it remains a serious health risk factor. According to Cui et al. (2023), women, high-latitude residents, and populations in low-income countries are particularly vulnerable to osteoporosis because hormonal changes, especially the decline in estrogen during menopause, accelerate bone loss in women, while high-latitude residents have limited sunlight exposure, reducing vitamin D synthesis essential for calcium absorption and bone mineralization. Populations in low-income countries are at higher risk due to limited access to healthcare, poor nutrition, and delayed diagnosis, all of which contribute to decreased bone density.

Altitude significantly affects the level of ultraviolet (UV) radiation reaching the earth's surface. The higher the terrain, the shorter the path that UV takes through the atmosphere, which favours more vitamin D synthesis in the skin (Antipikin et al., 2019). Wacker and Holick (2013) analysed vitamin D synthesis at different geographical locations: Agra (169 m), Kathmandu (1,400 m), and Everest base camp (5,300 m). Their results showed that pre-vitamin D formation was minimal in Agra in November, while at 5,300 m, it increased almost fivefold under the same latitudinal conditions. This emphasises the importance of considering altitude factors when investigating vitamin D levels in different regions, especially in high altitude areas.

Data on the frequency and amounts of dietary calcium intake among the Kyrgyz population, including milk and dairy products, are limited in the literature. Consumption of dairy products contributes to the bone health of the population, as milk is a major source of calcium and vitamins D and B12, which are essential for bone health (Ilesanmi-Oyelere and Kruger, 2020). Consumption of dairy products among children and adolescents in Kyrgyzstan remains insufficient: only 33.3% of respondents consume them daily, while 9.0% practically exclude them from their diet. In addition, less than a quarter of adolescents regularly include cheese and cottage cheese in their diets, which may reduce the intake of calcium and other important nutrients (Tolebaeva et al., 2021; Nabiyev et al., 2024). Dietary calcium and vitamin deficiencies are particularly critical for children and adolescents, as they can negatively affect bone development and predisposition to osteoporosis.

To better understand the influence of factors on bone health, it is important to consider the specific physiological state in mountainous regions, where living conditions can have a significant impact on mineral metabolism. In a study by Tashieva et al. (2024), 190 pregnant women from high mountainous regions of Kyrgyzstan (>2,500 m above sea level) and Osh city were examined. It was found that women living in the mountains for a long time have hypoestrogenaemia and compensatory hypocalcaemia, indicating an influence on the course of pregnancy and the process of childbirth. Animal experiments confirmed changes in bone tissue, indicating the development of osteopenia (Ilderbayev et al., 2021). Nutritional characteristics, including whey intake, have been found to influence calcium metabolism and hormonal status.

A significant decrease in bone mineral density in patients over 70 years of age was recorded by Amanalieva (2014). Women suffered from reduced BMD 2.8 times more often than men, especially those who underwent early menopause. More than 80% of patients were vitamin D deficient, and 93.7% with low levels of physical activity experienced a marked decrease in BMD. The greatest risk factor for osteoporosis was found to be low body mass index (BMI) and inadequate calcium intake (Nurgaziyev et al., 2024). These results emphasise the importance of monitoring calcium metabolism and hormonal status in women, especially those living in high altitude areas, as such changes may increase the risk of osteoporosis and fractures, including severe injuries like hip fractures.

Age and height increased the risk of major osteoporotic fractures, while weight had a protective effect in a study by Song et al. (2023). Clear differences by region in Canada in the incidence of low traumatic fractures, which did not always correlate with BMD, were found by Langsetmo et al. (2008). Fracture risk was found to be more dependent on complex factors including age, frequency of falls, previous fractures and vertebral deformity. This confirms that osteoporosis and its consequences are not only determined by BMD but also by other factors, emphasising the need for a multifactorial approach to risk assessment. According to a multifactorial analysis by Özmen et al. (2024), among postmenopausal women, the risk of osteoporosis was increased 2.46-fold in smokers, 3.78-fold in diabetic patients, and 6.23-fold in those with previous fractures. At the same time, increased BMI had a protective effect.

In Kyrgyzstan, osteoporosis is a growing problem associated with vitamin D deficiency and calcium deficiency in the diet. Seasonal variations in vitamin D and dietary patterns increase the risk of the disease. High altitude, hypoestrogenemia and hypocalcaemia in women also contribute to osteoporosis, which requires further attention. Age and level of physical activity play an important role in the development of the disease, emphasising the need for a comprehensive approach to prevention and treatment.

Thus, the presence of additional risk factors, such as high altitude, poses a challenge for the health care system to improve diagnosis and risk assessment of osteoporosis, as well as to develop recommendations for prevention aimed at reducing the incidence and preventing severe health consequences for the population.

A limitation of the study was the lack of data on individual regions, the small sample size, and the limited number of studies on the incidence of osteoporosis in Kyrgyzstan, which reduced the completeness of the information provided. The reviewed studies lacked information on the influence of nutrition, physical activity and genetic factors, which did not allow their role in the identified patterns to be taken into account. In two studies, gender was either not reported or was presented in a generalised form, which may have affected the accuracy of the results. The sample size should be increased to increase the power of the analyses. Expanding the geographical scope of the study to focus on the mechanisms of altitude exposure will provide more accurate, valid and meaningful data that will be important for the development of effective interventions to prevent and treat osteoporosis in the Kyrgyz Republic.

Conclusion

The review covers five scientific works investigating the prevalence of osteoporosis and osteopenia in Kyrgyzstan. The total number of study participants ranged from 475 to 1,700. In the age group 18–39 years, the incidence of osteopenia ranged from 25.5 to 38.9% and osteoporosis from 0.2 to 9%. For the 40–59 age group, these rates ranged from 42.5 to 60.2% for osteopenia and from 7.1 to 21.2% for osteoporosis. Over 60 years of age, the rates of osteopenia ranged from 40.4 to 77.4% and osteoporosis from 9.7 to 34.9%.

At the same time, studies demonstrated that in highland regions (Naryn and Issyk-Kul regions) the incidence of osteoporosis among the elderly is lower. In foothill regions such as Bishkek, Osh and Jalal-Abad, a higher incidence of osteoporosis was observed among people over 40 years of age. Age correlation with the prevalence of osteoporosis was found ($r=0.992$) but did not show statistical significance ($p=0.08$).

Analysis showed that the Pearson correlation coefficient between regional height and osteoporosis incidence was –0.255 (18–39 years), –0.581 (40–59 years) and –0.273 (≥60 years). The p-values obtained (0.545; 0.132; 0.513) did not reach statistical significance, indicating that there was no significant association between height and incidence of osteoporosis in the age groups studied. The study emphasises the importance of considering climatic and geographical factors in the prevalence of osteoporosis, noting that although altitude is not a major risk factor, it may have an indirect influence through environmental conditions and lifestyle.

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