



## Prevalence of osteoporosis among residents living at different altitudes in Kyrgyzstan

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**Abstract.** Osteoporosis is a substantial health problem among people, which highlights the importance of studying its prevalence in different geographical regions. The study aimed to assess the prevalence of osteoporosis among population living at different altitudes in Kyrgyz Republic. The study included patients from three regions of Kyrgyz Republic. Baseline data were collected from populations of Bishkek (760 m) (Chui Region), Naryn (2,020 m) (Naryn Region) and Karakol (1,650 m) (Issyk-Kul Region) between July 2022 and August 2024. To assess differences in incidence of osteoporosis among populations living at different altitudes and with different characteristics, authors used chi-square test and rank sum test. A total of 2,300 people participated in study, including 850 lowland residents (Bishkek, 760 m above sea level), 750 residents of mid-mountain region (Karakol, 1,760 m above sea level) and 700 residents of high-mountain region (Naryn, 2,020 m above sea level). Prevalence of osteopenia in mid-altitude and high-altitude regions was 33.7% and 25.2%, respectively, while prevalence of osteoporosis varied significantly: 22.3% in mid-altitude areas compared to 14.9% in high-altitude areas ( $p < 0.002$ ). Further analysis revealed statistically significant differences in prevalence of osteopenia and osteoporosis among women ( $p < 0.05$ ), elderly people ( $p < 0.05$ ), as well as among underweight individuals ( $p < 0.01$ ), normal weight individuals ( $p < 0.05$ ) and obese individuals ( $p < 0.03$ ). With increasing height, prevalence of osteoporosis decreased in all groups, while prevalence of osteopenia decreased among women and in various body mass index categories, but increased among young and elderly people. This study demonstrates that higher altitudes are associated with a lower prevalence of osteopenia and osteoporosis, especially among women and middle-aged and elderly people

**Keywords:** osteoporosis; ageing; prevalence; altitude above sea level; Kyrgyzstan

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## Introduction

Osteoporosis is a common metabolic and non-infectious disease of the skeleton. This condition is characterised by a decrease in bone mass and accelerated destruction of bone microstructure [1]. As a result, bones become fragile and more prone to fractures. This disease often goes unnoticed until fractures occur, which can potentially lead to serious secondary health complications or even death [2]. Osteoporosis affects one in three women and one in five men over the age of fifty [1]. Approximately 200 million people worldwide suffer from osteoporosis, which is responsible for about 9 million fractures occurring worldwide each year [3].

Osteoporosis, characterised by a decrease in bone density and weakening of bone structure, imposes a significant social and economic burden, primarily due to fractures [1]. Globally, osteoporosis remains one of the most serious health threats: a new osteoporotic fracture is recorded every three seconds. Approximately half of women and one in five men over the age of 50 have experienced such a fracture at least once [2]. In addition, the first osteoporotic fracture rarely remains the only one: the probability of new fractures in such patients is 50% [3]. According to research, 20% to 24% of patients with hip fractures die within the first year after the injury, and among the survivors, a significant proportion face a long recovery period accompanied by chronic pain, depressive disorders and a significant reduction in quality of life [3-5]. In 2019, the direct economic costs associated with osteoporotic fractures in European Union countries reached 56.9 billion EUR, highlighting the scale of the problem for the healthcare system and society. If these costs are calculated as double the GDP per capita, the cost of quality-adjusted life years (QALY) lost in 2019 amounted to 112.9 billion EUR [6]. However, early intervention and adequate treatment of osteoporotic fractures can significantly reduce the probability of future fractures [7-9]. Therefore, obtaining information about the prevalence and characteristics of osteoporosis in a specific region is crucial. This creates the conditions for raising awareness among the population, healthcare professionals and decision-makers, contributing to the development of early screening programmes, diagnosis and effective treatment.

Future trends are alarming: it is estimated that by 2035, the number of osteoporotic fractures in critical areas – the wrist, spine and hip – could reach almost 4.83 million cases, and by 2050, this number is projected to rise to approximately 5.99 million [10,11]. However, given the geographical complexity and diversity of Kyrgyzstan's territory – from mountain ranges and hills to plains and desert areas – accurately assessing the prevalence of osteoporosis remains a substantial challenge. This problem is further exacerbated by the fact that existing studies have surveyed only about 5,000 people, which significantly limits the ability to draw

representative conclusions about the prevalence of osteoporosis across the country [11].

According to available sources, the influence of natural factors on bone tissue metabolism is described inconsistently, and research results remain ambiguous. For example, oxygen concentration is a key factor influencing bone tissue metabolism, with hypoxia being a significant cause of osteoporosis in high-altitude areas [12]. Conversely, sufficient sunlight satisfies the vitamin D requirements of most people, while vitamin D deficiency is one of the main causes of osteoporosis [13]. This was confirmed by a study [14] which demonstrated that animals raised in warm climates develop longer limbs than animals raised in colder conditions.

Screening studies for osteoporosis have been actively conducted in the Kyrgyz Republic [15,16], indicating growing attention to this problem. These studies included women and men of different age groups, including the elderly and senior citizens. However, the prevalence of osteoporosis at different altitudes in Kyrgyzstan remains insufficiently studied. Determination of these patterns is crucial for the development of effective regional strategies for the prevention and treatment of osteoporosis. The study aimed to investigate the prevalence of osteopenic syndrome and osteoporosis among the population living at different altitudes (highlands and lowlands) in Kyrgyzstan.

## Materials and Methods

Participants were recruited as part of practical healthcare assistance provided at joint Family Medicine Centres in Bishkek (Chu Province), Karakol (Issyk-Kul Province) and Naryn (Naryn Province). Residents of three regions of Kyrgyzstan participated in study, collecting data from communities that differed in both geography and ethnic composition. Study, which began in July 2022, completed its baseline data collection in August 2024. A total of 2,300 people participated in study, including 850 residents of lowlands (Bishkek, 760 m above sea level), 750 residents of midlands (Karakol, 1,760 m above sea level) and 700 residents of highlands (Naryn, 2,020 m above sea level). Inclusion criteria: 1) age 20 years and older, 2) permanent residence, and 3) for non-local residents – residence in area for at least six months with no intention to move within next five years. Exclusion criterion was the absence of bone mineral density measurements.

Measurements. Data collected included basic demographic information, body measurements, and bone mineral density (BMD) assessment. To collect basic information, name, gender, age, and unique identification number of each participant were recorded. Body measurements included height and weight, which were used to calculate body mass index (BMI). Bone status was assessed using quantitative ultrasound scanning (QUS), which uses ultrasound waves to assess bone mineral

density and structure and can detect osteopenia and osteoporosis, especially in peripheral areas (heel, wrist, forearm). This study used a portable ultrasound device from South Korean manufacturer OsteoSys – SON-OST-3000 (OsteoSys Co., Ltd, Seoul, Korea).

To avoid errors in study results, daily quality control checks were conducted using a standard phantom following manufacturer's protocol before data collection after turning on equipment. All measurements were performed by one researcher during one working day at the same temperature in study room. Right calcaneus was selected for study. Ethical review. Conducted following requirements of World Medical Association [17]. Study was approved by Bioethics

Committee of the Kyrgyz State Medical Academy named after I.K. Akhunbaev (approval protocol No. 11 of 2023). Each participant provided informed consent. Statistical analysis. Percentages were used to describe categorical variables. Chi-square  $R \times C$  criterion was used to assess statistical significance of differences between participant characteristics. A value of  $p < 0.05$  was considered statistically significant. All statistical analyses were performed using SPSS software version 29.0.

## Results and Discussion

General characteristics of the patients are presented in Table 1.

**Table 1.** General characteristics of patients

Characteristics	Study population – residents of different heights, n = 2,300			Total, n (%)
	Lowlands, n = 900	Mid-mountain range, n = 750	Highlands, n = 650	
Distribution by gender				
Males, n (%)	382 (42.4)	330 (44.0)	253 (38.9)	965 (42.0)
Females, n (%)	518 (57.6)	420 (56.0)	397 (61.1)	1,335 (58.0)
Distribution by age (years)				
18-44 years, n (%)	273 (30.3)	205 (27.3)	172 (26.5)	650 (28.3)
45-59 years, n (%)	287 (31.9)	237 (31.6)	220 (33.8)	744 (32.3)
60 years and older, n (%)	340 (37.8)	308 (41.1)	258 (39.7)	906 (39.4)
Total, n (%)	900 (39.1)	750 (32.6)	650 (28.3)	2,300
Distribution by body mass index (kg/m <sup>2</sup> )				
<18.5, n (%)	72 (8.0)	60 (8.0)	76 (11.7)	208 (9.0)
18.5-23.9, n (%)	360 (40.0)	311 (41.5)	282 (43.4)	953 (41.4)
24.0-27.9, n (%)	325 (36.1)	246 (32.8)	203 (31.2)	774 (33.7)
≥28.0, n (%)	143 (15.9)	133 (17.7)	89 (13.7)	365 (15.9)
Total, n (%)	900 (39.1)	750 (32.6)	650 (28.3)	2,300 (100)

**Source:** compiled by the authors

Following Table 1, the distribution was observed in the group of residents surveyed. In terms of altitude, 900 participants (39.1%) lived in lowland areas, namely residents of the city of Bishkek (760 m above sea level); 750 (32.6%) lived in mid-altitude areas, residents of the city of Karakol (1,760 m above sea level) and 650 (28.3%) lived in high-altitude areas, residents of the city of Naryn and the village of At-Bashi (2,020 and 2,060 m above sea level). The age distribution showed that 650 people (28.3%) were classified as young, 744 (32.3%) as middle-aged, and 906 people (39.4%) as elderly and old. Lastly, the study population was also classified according to body mass index (BMI). Most of the study participants were

classified as having a normal body weight (953 people or 41.4%), followed by those who were overweight (774 people or 33.7%). There were 365 obese individuals (15.9%), and the smallest group consisted of underweight or low-weight individuals, numbering only 208 (9.0%). The data obtained from ultrasound densitometry were analysed as follows. According to the proposed diagnostic criteria for osteoporosis, which are based on a decrease in bone mineral density, A T-score of -1.0 and above indicates normal BMD values; a T-score of -1.0 to -2.5 was considered “osteopenic syndrome”; and finally, a T-score of -2.5 and below in the presence of one or more fractures was considered osteoporosis.

**Table 2.** Differences in the incidence of osteoporosis among populations living at different altitudes in Kyrgyzstan

Variables	Lowlands, n = 900			Mid-mountain range, n = 750			Highlands, n = 650			P
	Norm	Osteopenia	Osteoporosis	Norm	Osteopenia	Osteoporosis	Norm	Osteopenia	Osteoporosis	
Total	337 (37.4%)	329 (36.6%)	234 (26.0%)	330 (44.0%)	253 (33.7%)	167 (22.3%)	389 (59.8%)	164 (25.2%)	97 (14.9%)	$p < 0.05$
Gender										
Male	204 (66.5%)	120 (31.4%)	58 (15.2%)	173 (52.4%)	120 (36.4%)	37 (11.2%)	203 (80.2%)	34 (13.5%)	16 (6.3%)	$p < 0.002$
Female	133 (25.7%)	209 (40.3%)	176 (34.0%)	157 (37.4%)	133 (31.6%)	130 (31.0%)	186 (46.9%)	130 (32.7%)	81 (20.4%)	
Age (years)										
18-44	156 (57.1%)	70 (25.6%)	47 (17.2%)	113 (55.1%)	60 (29.3%)	32 (15.6%)	119 (69.2%)	40 (23.3%)	13 (7.5%)	$p < 0.05$
45-59	110 (38.3%)	105 (36.6%)	72 (25.1%)	107 (45.1%)	81 (34.2%)	49 (20.7%)	125 (56.8%)	69 (31.3%)	26 (11.8%)	$p < 0.05$
≥60	71 (20.9%)	154 (45.3%)	115 (33.8%)	110 (35.7%)	112 (36.4%)	86 (27.9%)	145 (56.2%)	55 (21.3%)	58 (22.5%)	$p < 0.05$
BMI (kg/m <sup>2</sup> )										
<18.5	31 (43.1%)	22 (30.5%)	19 (26.4%)	29 (48.3%)	18 (30.0%)	13 (21.7%)	47 (61.8%)	24 (31.6%)	5 (5.6%)	$p < 0.05$
18.5-23.9	128 (35.6%)	145 (31.9%)	87 (24.2%)	120 (38.6%)	117 (37.6%)	74 (23.8%)	169 (59.9%)	74 (26.2%)	39 (13.8%)	$p < 0.05$
24.0-27.9	118 (36.3%)	109 (33.5%)	98 (30.2%)	121 (49.2%)	77 (31.3%)	48 (29.2%)	122 (60.1%)	38 (18.7%)	43 (21.2%)	$p < 0.05$
≥28.0	60 (42.0%)	53 (37.1%)	30 (20.9%)	60 (45.1%)	41 (30.8%)	32 (24.1%)	51 (57.3%)	28 (31.5%)	10 (11.2%)	$p < 0.05$

**Note:**  $p < 0.05$  – reliable when comparing highland values with midland and lowland values

**Source:** compiled by the authors

Following Table 2, out of the total number of people examined, osteopenia was diagnosed in 746 (32.4%) people, and osteoporosis in 498 people (21.7%). The remaining 1,056 (45.9%) had normal bone mineral density. Within the same altitude zones, there were significant differences in the incidence of osteoporosis depending on gender and age ( $p < 0.001$ ). Among lowland residents, osteopenic syndrome was detected in 329 (36.6%) people, including 209 (40.3%) women and 120 (31.4%) men; osteoporosis was detected in 34.0% of women and 15.2% of men. In the mid-altitude region, osteopenia affected 31.6% of women compared to 36.4% of men, while osteoporosis was present in 31.0% of women and 11.2% of men. In high-altitude areas, osteopenia was observed in 32.7% of women and 13.5% of men, while osteoporosis affected 20.4% of women versus 6.3% of men.

Following Table 2, in the group of young people, the values of normal bone density and osteopenia did not show a statistically significant difference among residents of lowlands (57.1% and 25.6%), mid-altitude areas (55.1% and 29.3%) and high-altitude areas (69.2% and 23.3%). However, when comparing osteoporosis values, it was found that people permanently residing in high altitude areas had significantly lower values (7.5% versus 15.6% and 17.2%) than residents of mid-altitude and low-altitude areas. With increasing age, the prevalence of both osteopenia and osteoporosis increased. Thus, the prevalence of osteopenia in lowland areas increased with age from 25.6% to 45.3% ( $p < 0.05$ ), in the mid-mountain region – from 29.3% to 36.4% ( $p < 0.05$ ), and in the high-mountain region – from 23.3% to 31.3% ( $p < 0.05$ ). The prevalence of osteoporosis also increases: in lowland areas from 17.2% to 33.8% ( $p < 0.05$ ), in mid-mountain areas from 15.6% to 27.9% ( $p < 0.05$ ) and in high-mountain areas from 7.5% to 22.5% ( $p < 0.05$ ).

The study found statistically significant differences in the prevalence of osteoporosis depending on BMI category. Thus, among participants with an BMI  $< 18.5$  kg/m<sup>2</sup>, the prevalence of normal bone density, osteopenia, and osteoporosis in lowland conditions was 43.1%, 30.5%, and 26.4%, respectively ( $p < 0.05$ ); in mid-altitude conditions – 48.3%, 30.0% and 21.7%, respectively ( $p < 0.05$ ), in high-altitude conditions – 61.8%, 31.6% and 5.6%, respectively ( $p < 0.05$ ). For individuals with a BMI  $\geq 28.0$  kg/m<sup>2</sup>, the corresponding prevalence rates in lowland conditions were 42.0%, 37.1% and 20.9%, respectively ( $p < 0.05$ ), in mid-altitude conditions – 45.1%, 30.8% and 24.1%, respectively ( $p < 0.05$ ), and in high-altitude conditions – 57.3%, 31.5% and 11.2%, respectively ( $p < 0.05$ ). Concerning osteoporosis, the prevalence of osteoporosis among residents of high-altitude areas in the group of people with a low BMI  $< 18.5$  kg/m<sup>2</sup> was 5.6%, with a normal BMI of 18.5-23.9 kg/m<sup>2</sup> – 13.8%, with an overweight BMI of 24.0-27.9 kg/m<sup>2</sup> – 21.2%, and with an obese BMI  $\geq 28.0$  kg/m<sup>2</sup> – 11.2%. In other words, osteoporosis rates remain statistically lower among people living in high-altitude areas than among those living in low- and mid-altitude areas.

Thus, the analysis revealed significant differences in the prevalence of osteoporosis depending on gender (significantly higher among women,  $p < 0.05$ ), altitude above sea level (the prevalence of osteoporosis decreases with increasing altitude,  $p < 0.001$ ), and age (the older the person, the higher the prevalence of osteoporosis). Depending on BMI values, osteoporosis was less frequently detected in overweight ( $p < 0.001$ ) or obese ( $p < 0.001$ ) individuals. There were also significant differences in the frequency of osteoporosis among men ( $p < 0.05$ ) living at different altitudes in Kyrgyzstan. A range of studies is being conducted in the Kyrgyz Republic that

focus on specific categories of patients. According to [15], the prevalence of osteoporosis in different age groups was 3% in the 20-29 age group, 5% in the 30-39 age group, 10% in the 40-49 age group, 15% in the 50-59 age group, 19% in the 60-69 age group, 23% in the 70-79 age group, and 31% in the 80+ age group. At the same time, a study of the prevalence of osteoporosis in older age groups [16] showed that in the first age group (40-59 years), osteoporosis was 23.4%, in the second group aged 60-74 years, 38.6%, and in the third group aged 75-90 years, 51.2%. The results indicate a high prevalence of osteoporosis with age, especially in women. Screening studies on the prevalence of osteoporosis among residents living at different altitudes in the Kyrgyz Republic were continued.

The main results of the study show that the prevalence of osteopenia and osteoporosis decreases with increasing altitude above sea level. At all altitudes, women consistently had higher rates of osteopenia and osteoporosis than men, with both conditions becoming more prevalent with age. In addition, people who were underweight in high-altitude regions had lower rates of osteoporosis compared to other body mass index categories. Stratified analysis further showed that the prevalence of osteoporosis was lower among women, older people, and all body mass index categories in mid-altitude regions. However, in the highest mountainous areas, osteoporosis showed a further decrease among women and in all individual body mass categories, while osteopenia, on the contrary, was elevated in the group of people with underweight and overweight body mass index.

The overall prevalence of osteoporosis in this study was 21.1% in total across three different altitude zones in Kyrgyzstan. Notably, the prevalence in mid-altitude areas was 22.3%, which is significantly lower than the values for residents living in lowland areas. With increasing altitude, the prevalence of osteoporosis studied in this work was 14.9%, which is significantly lower than both the mid-altitude and low-altitude levels. This study highlights significant differences in the prevalence of osteoporosis among people living at different altitudes in Kyrgyzstan. In the following discussion, potential factors contributing to the lower prevalence of osteoporosis in high-altitude areas, including natural environmental conditions, lifestyle factors, and genetic factors, were addressed. For example, longer exposure to sunlight and better air quality in high-altitude regions are key factors contributing to the lower prevalence of osteoporosis [18].

The human body synthesises vitamin D endogenously, whereby 7-dehydrocholesterol in the skin is converted into vitamin D<sub>3</sub> under the influence of ultraviolet (UV) radiation from sunlight. Factors such as season, duration of sunlight exposure, latitude, and use of sunscreen can affect vitamin D synthesis. Longer exposure to sunlight in high-altitude regions is a natural

advantage in reducing the risk of osteoporosis. Environmental pollution may also be a critical factor influencing the prevalence of osteoporosis [18,19]. Studies have shown that environmental pollutants such as particulate matter (PM), nitrogen oxides (NO<sub>x</sub>, NO<sub>2</sub>), carbon monoxide, polychlorinated biphenyls (PCBs), phthalates, bisphenols, and heavy metals can negatively affect bone health through various mechanisms. These pollutants can disrupt hormonal balance, cause systemic inflammation, impair calcium metabolism, and interfere with the differentiation, proliferation, and function of bone cells, ultimately increasing the risk of skeletal diseases, including osteoporosis [19].

When studying differences in the prevalence of osteoporosis, it is necessary to consider both lifestyle and genetic factors. The differences in lifestyle between these groups are noticeable: highlanders traditionally lead a nomadic lifestyle, their diet is rich in dairy products and meat, they prefer tea with milk, and their consumption of fruit and vegetables is limited due to a lack of resources. In contrast, the diet in lowland areas is more varied and characterised by abundant consumption of vegetables and fruit, but small amounts of meat. The prevalence of osteoporosis is directly related to the consumption of various nutrients, including vitamin D, calcium, vegetables, fruits, legumes, nuts, dairy products, soy protein, and eggs [20,21]. Therefore, it is necessary to study the dietary characteristics of the population of high-altitude areas, quantitatively assess their nutritional components, and study the composition of their diet, which may help prevent osteoporosis in order to develop appropriate preventive measures. Physical activity may be central in the development of osteoporosis. It is known that the population of high-altitude areas leads a physically active lifestyle, which may affect the prevalence of osteoporosis and requires an evidence base. Genetic studies are substantial in the analysis of the prevalence of osteoporosis, as they demonstrate the role of genetics in the prevalence of the disease [22].

The study showed that the prevalence of osteoporosis in both women and men in low-altitude areas is higher than in women and men in high-altitude areas. This suggests that growth-related factors, including increased exposure to sunlight and dietary adjustments, along with other modifiable factors, may reduce the risk of osteoporosis. This finding should help in the development of a targeted strategy for the prevention of osteoporosis in Kyrgyzstan. In addition, it is essential for future studies to investigate the reasons for differences in the prevalence of osteoporosis depending on height and gender. However, the study showed that people with different body mass indices living at different altitudes have different prevalence rates of osteopenia and osteoporosis. This suggests that different body mass index categories may also be substantial in the prevention of osteoporosis.

## Conclusions

Study demonstrated that residence at high altitudes above sea level is associated with a lower prevalence of osteopenia and osteoporosis, particularly among women and older individuals. Findings highlight the need to develop regional strategies for prevention of osteoporosis. A notable feature of study is analysis of differences in prevalence of osteoporosis among different demographic groups living at different altitudes in Kyrgyzstan, a topic that has been understudied. This provides relevant information for development of future intervention strategies. However, a major limitation of this study is lack of an in-depth analysis of factors influencing differences in osteoporosis prevalence among

these altitude groups. Addressing this gap will be a key focus for future research.

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## Conflict of Interest

None.

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## Кыргызстанда ар түрдүү бийиктикте жашаган тургундардын арасындагы остеопороздун таралышы

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**Аннотация.** Остеопороз коомдук саламаттыкты сактоонун олуттуу көйгөйү болуп саналат, бул анын ар кандай географиялык аймактарда таралышын изилдөөнүн маанилүүлүгүн баса белгилейт. Бул изилдөөнүн максаты Кыргыз Республикасында ар кандай бийиктикте жашаган калк арасында остеопороздун таралышын баалоо болгон. Изилдөөгө Кыргыз Республикасынын үч аймагынан келген бейтаптар катышкан. Баштапкы маалыматтар 2022-жылдын июль айынан 2024-жылдын август айына чейин Бишкек (760 м) (Чүй облусу), Нарын (2020 м) (Нарын облусу) жана Каракол (1 650 м) (Ысык-Көл облусу) шаарларынын тургундарынан чогултулган. Ар кандай бийиктикте жана ар кандай мүнөздөмөлөрдө жашаган калктын арасында остеопороздун пайда болуу көрсөткүчтөрүндөгү айырмачылыктарды баалоо үчүн биз хи-квадрат тестин жана рангдык сумма тестин колдондук. Изилдөөгө жалпысынан 2300 адам катышкан, анын ичинде төмөнкү тоолуу аймактардын (Бишкек, деңиз деңгээлинен 760 м бийиктикте) 850 тургуну, орто тоолуу аймактардын (Каракол, деңиз деңгээлинен 1760 м бийиктикте) 750 тургуну жана бийик тоолуу аймактардын (Нарын, деңиз деңгээлинен 2020 м бийиктикте) 700 тургуну болгон. Орто тоолуу жана бийик тоолуу аймактарда остеопениянын таралышы тиешелүүлүгүнө жараша 33,7 % жана 25,2 % түзгөн, ал эми остеопороздун таралышы бир топ айырмаланган: орто тоолуу аймактарда 22,3 %, ал эми бийик тоолуу аймактарда 14,9 % ( $p < 0,002$ ). Андан ары талдоо аялдардын ( $p < 0,05$ ), улгайган адамдардын ( $p < 0,05$ ) жана салмагы жетишсиз