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# Modern approach to monitoring and preventing osteoporosis development in breast milk donors

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**Abstract.** The study of bone tissue status in lactating women is highly relevant due to the increasing prevalence of osteopenic changes and their complex implications for reproductive health. The aim of this study was to analyse breast milk donation as an additional risk factor and to identify key conditions for preserving bone strength in the postpartum period. Within a retrospective analysis conducted at the Kyiv City Perinatal Centre, medical records of 260 women were examined, including 126 milk donors and 134 breastfeeding women without donation. The study assessed bone mineral density, haematological parameters, body mass index, and fracture history. Participants were recruited through healthcare networks under conditions of informed consent and personal data confidentiality. Key findings indicated that donors had a higher incidence of fractures after 30 years of age (11.9%), lower awareness of bone health (only 7.9% knew their bone mineral density), and significant deviations in vitamin D levels, with deficiency detected in 67.5% of donors. Among donors, 29.4% were overweight, and 13.5% had obesity, exceeding rates in non-donor lactating women. Over 10% of donor participants exhibited radiological signs of osteoporosis, compared to approximately 5% in the control group. Prolonged lactation without adequate dietary adjustments and physical activity was found to exacerbate osteopenic processes. The study underscored the importance of regular monitoring of biochemical markers and implementing preventive strategies (balanced nutrition, vitamin D supplementation, and moderate resistance training) to mitigate complications. The practical significance of these findings lies in justifying the need for early screening of donors and developing personalised recommendations to reduce fracture risk and preserve maternal health. The proposed approach could be integrated into broader women's health programmes, particularly in modern medical communities seeking to reduce economic burdens associated with fracture treatment and prolonged rehabilitation

**Keywords:** hormonal changes; genetic predisposition; physical activity; vitamin D deficiency; lactation

## INTRODUCTION

Modern realities necessitate maximising health protection for women who choose to become breast milk donors. This process entails additional physiological strain, particularly on bone tissue. Osteoporosis may develop asymptomat ically but significantly impact a woman's future quality of life. Thus, timely monitoring of bone health and preventive measures are essential to safeguard donors' well-being and ensure safe, high-quality lactation for infants receiving donor milk.

V. Bila *et al*. [1] described the creation of Ukraine's first breast milk bank, highlighting the problems of a shortage of donors and the need to involve not only mothers of premature babies (who accounted for 77%) but also women who had carried their pregnancies to term. They concluded that the bank works effectively even in difficult conditions, but the limited number of donors remains a challenge. I. Pylypchuk [2] summarised data on osteoporosis in women with hypoestrogenic conditions, which is also relevant

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to lactational osteoporosis. The researcher emphasises the high prevalence of osteopenia and osteoporosis and identifies key preventive measures: building maximum bone mass by the age of 30, regular physical exercise, correction of hormonal disorders, improvement of blood supply to bones, and control of mineral metabolism.

S. Shatylo *et al*. [3] conducted a multicentre epidemiological study revealing widespread vitamin D deficiency in Ukraine, particularly among high-risk groups such as postpartum women. Among 11,000 participants (~79% women, median age 36), deficiency rates were alarmingly high. The authors suggested this could adversely affect donors' skeletal systems, warranting further research into seasonal variations and supplementation efficacy. Q. Wang *et al*. [4] investigated calcium-fortified milk for osteoporosis prevention in ovariectomised rats (a postmenopausal model). After three months of consuming milk enriched with calcium, vitamin D, and casein phosphopeptides, bone mineral density (BMD) and mechanical strength improved significantly.

I. Oboh *et al*. [5] analysed lactation duration's impact on BMD. Women breastfeeding beyond six months exhibited lower lumbar BMD at 12 months postpartum compared to those nursing for ⩽4 months, though statistical significance varied. G. Cai *et al*. [6] meta-analysed five RCTs (n = 567) and found that 1,000 mg/day calcium supplementation during lactation did not significantly affect spinal or radial BMD. H.L. Colleran *et al*. [7] demonstrated that a 16-week postpartum exercise programme (weight-bearing aerobics and resistance training) significantly reduced lumbar bone loss in a small cohort. F.M.F. Grizzo *et al*. [8] proposed trabecular bone score (TBS) for postpartum bone assessment. While TBS was insensitive to short-term changes, it confirmed post-weaning bone recovery.

The study by Q. Huang *et al*. [9] was aimed at developing an innovative method for osteoporosis treatment using milk-derived exosomes. The researchers employed specially engineered exosomes enriched with bioactive compounds that promote bone tissue regeneration. Additionally, these exosomes were equipped with markers for visualisation via magnetic resonance imaging, enabling real-time monitoring of the treatment process. The study results demonstrated that such exosomes could effectively increase bone mineral density, facilitate bone regeneration, and simultaneously improve osteoporosis diagnostics. In the work by B. Yun *et al*. [10], the researchers investigated the effect of bovine milk-derived exosomes on osteoporosis prevention. They conducted an experiment on mice with induced osteoporosis and found that the exosomes contributed to reduced bone mass loss, improved bone mineralisation, and normalisation of gut microbiota. The researchers hypothesised that these exosomes could potentially be used for osteoporosis prevention in humans.

Thus, while a substantial number of studies have been dedicated to osteoporosis and breast milk donors, insufficient research has focused on monitoring and preventing osteoporosis development in breast milk donors, necessitating the current study. The objective of this work was to investigate physiological changes during lactation and determine the peculiarities of milk donation. To achieve this goal, the following research tasks were performed: conducting a comparative analysis of bone mineral density indicators, biochemical parameters, and anthropometric characteristics in breast milk donors versus breastfeeding women who were not donors to identify differences in osteoporosis risk levels; assessing the influence of hormonal-metabolic factors (prolactin, oestrogens, parathyroid hormone, calcitonin) and nutritional status (calcium, vitamin D, protein intake, etc.) on the development of osteopenic and osteoporotic changes under varying durations and volumes of lactation; and developing evidence-based recommendations for the prevention and monitoring of bone tissue status in breast milk donors based on the results of a comprehensive risk assessment (anthropometric, biochemical, hormonal, and functional).

## MATERIALS AND METHODS

This study had a cross-sectional design and covered the period from January 2023 to January 2025. Data collection was conducted at the Kyiv City Perinatal Centre. Contact details of the female participants were obtained through a network of healthcare institutions collaborating with the breast milk bank at the Kyiv City Perinatal Centre. All participants provided informed consent under conditions of personal data confidentiality and anonymity. Initially, a search and analysis of medical records were performed for patients aged 18 to 45 who were under observation at the institution during 2023-2024 and met predefined inclusion criteria: at least six months of breastfeeding experience within the past year, confirmed or current breast milk donation (for the main group), and availability of complete data on anthropometric measurements, densitometry results, and biochemical parameters in the medical records. Exclusion criteria included diagnosed osteoporosis or other metabolic bone disorders, use of medications significantly affecting bone tissue metabolism (bisphosphonates, glucocorticoids, etc.), and pregnancy at the time of the study. Ultimately, 260 medical records were selected, of which 126 belonged to women who were breast milk donors and 134 to breastfeeding women who did not donate. The mean age of participants in the main group was 29.1 ± 4.8 years, while that of the control group was 30.4 ± 5.2 years; the average total lactation duration (including active donation periods) among donors reached 18.7 ± 6.3 months, compared to 15.4 ± 5.7 months in non-donor breastfeeding women.

The study employed a range of methods to ensure a comprehensive assessment of bone tissue status and associated risk factors. Firstly, the patients' medical records contained densitometry results obtained using the portable ultrasound densitometer Sunlight MiniOmni™ (Israel), with a subset of women additionally undergoing forearm dual-energy X-ray absorptiometry (DXA) to verify and refine diagnostic parameters. Both methods provided a T-score, comparing the subjects' bone mineral density with reference values for healthy young women. Secondly, laboratory test results were extracted from medical records: levels of 25-hydroxyvitamin D, calcium, phosphorus, osteocalcin, and type I procollagen N-terminal propeptide (P1NP), which reflect bone metabolism. Blood samples were collected in a certified laboratory using validated diagnostic kits for each assay. Thirdly, anthropometric measurements (weight, height) and the derived body mass index (BMI) were included, along with documented data on lactation duration, reproductive health status, and the frequency and volume of blood donation, as recorded in the relevant sections

of the medical records. Thus, by analysing the available parameters, an extended profile was obtained regarding nutrition, physical activity levels, harmful habits, and other lifestyle factors potentially influencing bone health.

During data interpretation, quantitative T-score values were considered (⩾-1 = normal, -1 to -2.5 = osteopenia, ⩽-2.5 = osteoporosis), alongside deviations of laboratory markers from their reference ranges. The numerical data were cross-referenced with clinical information from patient records (family history, prior fractures, harmful habits, lactation duration, etc.) to identify potential associations. Where significant differences were observed, conclusions were drawn regarding the possible role of lactation and blood donation in increasing the risk of osteopenia or osteoporosis. The study adhered to the ethical standards outlined in the Declaration of Helsinki [11] and current national legislation [12, 13]. All women whose data were included provided informed consent for the use of their medical records for research purposes, and personal identifiers were anonymised during data processing.

## RESULTS

According to the systematic review and meta-analysis by N. Salari *et al.* [14], the global prevalence of osteoporosis in adults prior to 2021 was 18.3%, with rates of 23.1% in women and 11.7% in men. In Ukraine specifically, the probability of fractures was 5.5% at age 40, 11% at 75 years, and slightly decreased to 10% after 90 years [15]. Insufficient timely diagnosis and prevention may lead to significant deterioration in quality of life and increased economic burden associated with fracture treatment. In this study, all (n = 260) women underwent data collection on osteoporosis risk factors, analysis of their impact on bone tissue status, and development of individualised prevention recommendations. The relevant information extracted from their medical records is presented in Table 1.

**Table 1.** Documented risk factors for osteoporosis in breast milk donors and breastfeeding non-donor women according to medical records (n = 260)

| Parameter (as per medical records) | Option | Donor group (n = 126) | Breastfeeding non-donors (n = 134) |
|---|---|---|---|
| Family history of osteoporosis | Yes | 45 | 40 |
| | No | 63 | 70 |
| | Unknown | 18 | 24 |
| Relative diagnosed with osteoporosis | Mother | 20 | 18 |
| | Father | 10 | 8 |
| | Maternal grandmother | 15 | 12 |
| | Maternal grandfather | 5 | 3 |
| | Paternal grandmother | 12 | 10 |
| | Paternal grandfather | 3 | 2 |
| | Sibling | 8 | 6 |
| | Other | 2 | 1 |
| Fractures after the age of 30 | Yes | 15 | 10 |
| | No | 111 | 124 |
| Awareness of personal bone mineral density (BMD) value | Yes | 10 | 15 |
| | No | 116 | 119 |
| Documented T-score (DXA/US), total 126 and 134 individuals | ⩾-0 | 20 | 35 |
| | -0.1 to -0.9 | 50 | 55 |
| | -1 to -1.4 | 25 | 24 |
| | -1.5 to -1.9 | 17 | 10 |
| | -2 to -2.4 | 9 | 7 |
| | ⩽-2.5 | 5 | 3 |
| Frequency of dairy consumption | Daily | 50 | 60 |
| | Several times a week | 45 | 50 |
| | Once a week | 20 | 15 |
| | Less than once a week | 8 | 5 |
| | None at all | 3 | 4 |
| Additional intake of vitamin D or calcium supplements | Yes | 35 | 45 |
| | No | 91 | 89 |
| Name and dosage (if recorded in medical history) | Vitamin D3 2,000 IU | 15 | 20 |
| | Calcium D3 Nycomed | 10 | 12 |
| | Vitamin D3 5,000 IU | 5 | 8 |
| | Other (specified different drug/dosage) | 5 | 5 |
| Number of protein servings per day (according to dietary records) | None | 2 | 1 |
| | 1 serving | 30 | 25 |
| | 2 servings | 60 | 70 |
| | 3 servings or more | 34 | 38 |

*Table 1. Continued*

| Parameter (as per medical records) | Option | Donor group (n = 126) | Breastfeeding non-donors (n = 134) |
|---|---|---|---|
| Number of children breastfed by the woman | 1 child | 60 | 70 |
| | 2 children | 40 | 45 |
| | 3 children | 15 | 10 |
| | Other (4 or more children) | 11 | 9 |
| Total duration of breastfeeding (in months) | 6-12 months | 30 | 35 |
| | 13-24 months | 40 | 50 |
| | 25-36 months | 20 | 25 |
| | Other (different duration) | 36 | 24 |
| Frequency of physical exercise | Daily | 15 | 20 |
| | Several times a week | 40 | 50 |
| | Once a week | 30 | 35 |
| | Less than once a week | 25 | 15 |
| | None at all | 16 | 14 |
| Presence of harmful habits (smoking) | Yes | 5 | 3 |
| | No | 110 | 125 |
| | Former smoker (quit) | 11 | 6 |
| Presence of harmful habits (alcohol consumption) | Daily | 0 | 0 |
| | Several times a week | 5 | 3 |
| | Once a week | 15 | 10 |
| | Less than once a week | 50 | 60 |
| | None at all | 56 | 61 |

**Notes:** respondents could indicate multiple relatives with osteoporosis; therefore, the total number of such cases may exceed the number of women who answered "Yes" in the family history section
**Source:** compiled by the authors

The analysis of risk factors in 126 breast milk donors revealed that 35.7% of respondents had a family history of osteoporosis, whereas among breastfeeding women who were not donors (n = 134), this figure was 29.9%. The most frequently mentioned relatives were mothers (15.9% in donors vs 13.4%), maternal grandmothers (11.9% vs 8.9%), and fathers (7.9% vs 6%), indicating a predominant influence of the maternal lineage on osteoporosis risk. Fractures after the age of 30 were reported in 11.9% of donors (most commonly wrist fractures – 5.6%), compared to 7.5% in the control group. At the same time, 92.1% of donors were unaware of their own bone mineral density (BMD) values, while among breastfeeding non-donors, this figure was 88.8%. Only 7.9% were aware of their T-score, with most reported values indicating osteopenia (ranging from -1 to -2). Just 39.7% of donors consumed dairy products daily, and 72.2% did not supplement with vitamin D or calcium, which was worse compared to breastfeeding non-donors (44.8% and 66.4%, respectively). The largest proportion of donors (47.6%) had breastfed one child, and the total duration of lactation was predominantly 13-24 months (31.7%) or 6-12 months (23.8%). Regular physical activity several times a week was reported by 31.7% of donors (vs 37.3% in the control group), with aerobic exercise being the most common (55.6%). The majority of donors did not smoke (87.3%) or consume alcohol (44.4%); however, in the control group, 93.3% were non-smokers, and 45.5% completely abstained from alcohol [16].

The presented data suggest that breast milk donors exhibit a higher prevalence of family history of osteoporosis, more frequent fractures, lower awareness of bone mineral density, poorer dietary habits, and reduced physical activity compared to women who breastfeed only their own children. This raises the possibility that breast milk donation may serve as an additional risk factor for osteoporosis development, warranting increased attention to preventive measures. Assessment of bone mineral density using ultrasound and forearm DXA densitometry in the studied sample of breast milk donors (n = 126) and breastfeeding non-donors (n = 134) revealed a differential distribution of T-score values. Detailed results are presented in Table 2, which shows the number of participants with normal values, osteopenia, and osteoporosis.

**Table 2.** Assessment of bone mineral density using ultrasound and forearm DXA densitometry in the studied samples (n = 260)

| Group/Method | Normal (T ⩾-1) | Osteopenia (-2.5 < T < 1) | Osteoporosis (T ⩽-2.5) |
|---|---|---|---|
| Donors (n = 126), ultrasound densitometry | 70 | 46 | 10 |
| Donors (n = 126), DXA densitometry | 65 | 48 | 13 |
| Breastfeeding non-donors (n = 134), ultrasound | 92 | 35 | 7 |
| Breastfeeding non-donors (n = 134), DXA | 89 | 38 | 7 |

**Source:** compiled by the authors

The assessment of bone mineral density (BMD) in 260 women (126 breast milk donors and 134 breastfeeding non-donors) using ultrasound densitometry and forearm DXA revealed that among donors, eumineralization (T ⩾-1) was detected in 55.6% of cases, osteopenia (-2.5 < T < -1) in 36.5%, and osteoporosis (T ⩽-2.5) in 7,9%. In the control group, these figures were 68.7%, 26.1%, and 5.2%, respectively. Meanwhile, DXA identified eumineralisation in 51.6% of donors, osteopenia in 38.1%, and osteoporosis in 10.3%, whereas in non-donors, the corresponding values were 66.4%, 28.4%, and 5.2%. DXA densitometry demonstrated higher sensitivity in diagnosing osteoporosis, particularly in the donor group, reinforcing the need for FRAX tool application to assess fracture risk. Anthropometric measurements conducted among the participants allowed for the evaluation of BMI distribution as well as the determination of mean weight and height values. Detailed results regarding BMI distribution and descriptive statistics for weight and height are presented in Table 3.

**Table 3.** Anthropometric parameters of human milk donors and breastfeeding non-donor women (n = 260)

| Parameter | Value | Donors (n = 126) | Breastfeeding non-donors (n = 134) |
|---|---|---|---|
| Underweight (BMI < 18.5 kg/m²) | BMI < 18.5 | 7 | 5 |
| Normal weight (BMI 18.5-24.9 kg/m²) | 18.5 ⩽ BMI < 25 | 65 | 75 |
| Overweight (BMI 25-29.9 kg/m²) | 25 ⩽ BMI < 30 | 37 | 35 |
| Obesity (BMI ⩾ 30 kg/m²) | BMI ⩾ 30 | 17 | 19 |
| Weight (kg) | Mean ± Standard deviation | 66 ± 13 | 63 ± 11 |
| Height (m) | Mean ± Standard deviation | 1.64 ± 0.06 | 1.66 ± 0.08 |

**Source:** compiled by the author

The obtained data indicate that human milk donors exhibit a distinct BMI distribution, which may adversely affect bone tissue status and underscores the necessity of an individualised approach to osteoporosis risk assessment. The analysis revealed that 51.6% of donors (n = 126) had normal weight (BMI 18.5-24.9 kg/m²), 29.4% were overweight, 13.5% had obesity, and 5.6% were underweight. In the control group of breastfeeding non-donor women (n = 134), normal weight was recorded in 55.9%, overweight in 26.1%, obesity in 14.2%, and underweight in 3.7%. The mean weight among donors was 66 ± 13 kg, compared to 63 ± 11 kg in the control group; mean height was 1.64 ± 0.06 m in donors and 1.66 ± 0.08 m in the control group. Overweight and obesity in women of reproductive age may induce complex hormonal changes during lactation, while underweight is associated with decreased oestrogen levels and insufficient calcium and vitamin D intake. The anthropometric measurements highlight the need for an individualised approach to osteoporosis risk assessment in human milk donors, considering their BMI, dietary habits, and lifestyle. To evaluate bone metabolism and vitamin D status, biochemical parameters were analysed in the study cohort. Levels of 25-hydroxyvitamin D, calcium, phosphorus, osteocalcin, and P1NP were assessed. The obtained data, including mean values, standard deviations, and the number of participants with deviations from reference ranges, are presented in Table 4.

**Table 1.** Biochemical parameters of human milk donors and breastfeeding non-donor women (n = 260)

| Parameter | Reference range | Donors (n = 126) Mean ± SD | No. with abnormal values | Breastfeeding non-donors (n = 134) mean ± SD | No. with abnormal values |
|---|---|---|---|---|---|
| 25-Hydroxyvitamin D (ng/mL) | 30-100 | 23 ± 8 | 85 | 28 ± 10 | 60 |
| Calcium (mmol/L) | 2.15-2.55 | 2.25 ± 0.12 | 25 | 2.33 ± 0.14 | 15 |
| Phosphorus (mmol/L) | 0.87-1.45 | 1.1 ± 0.17 | 20 | 1.18 ± 0.19 | 10 |
| Osteocalcin (ng/mL) | 11-43 | 30 ± 14 | 38 | 26 ± 10 | 22 |
| P1NP (ng/mL) | 19-76 | 48 ± 20 | 33 | 43 ± 15 | 17 |

**Source:** compiled by the authors

Obtained results indicate the necessity for comprehensive osteoporosis prevention measures among breast milk donors, as they exhibit a higher prevalence of bone tissue metabolism disorders and 25-hydroxyvitamin D deficiency (67.5% vs 44.8%), with mean vitamin D levels being only 23 ± 8 ng/mL compared to 28 ± 10 ng/mL in the control group. Deviations in calcium levels from the norm were observed in 19.8% of donors vs 11.2%, with mean calcium levels at 2.25 ± 0,12 mmol/L vs 2.33 ± 0.14 mmol/L and phosphorus at 1.1 ± 0.17 mmol/L vs 1.18 ± 0.19 mmol/L, further confirming mineral metabolism instability in donors. Elevated osteocalcin levels (30.2% vs 16.4%, mean values 30 ± 14 vs 26 ± 10 ng/mL) and P1NP (26.2% vs 12.7%, mean values 48 ± 20 vs 43 ± 15 ng/mL) indicate intensive bone remodelling, which, under conditions of vitamin D and calcium deficiency, may increase fracture risk.

Hormonal profile analysis of breast milk donors (n = 126) revealed significant differences compared to breastfeeding women who were not donors (n = 134). Prolactin levels in donors reached 76.6% of the upper limit of normal (vs 48.8% in controls), leading to suppressed ovarian function and reduced oestrogen levels. In the follicular phase, donors' estradiol levels were only 10.3% of the upper limit (vs 24.3% in controls), while in the luteal phase, they were 15.5% vs 27.9%. Concurrently, parathyroid hormone levels in donors reached 94.4% of the upper limit (vs 76.4%), and calcitonin levels were only 42.9% (vs 60.4% in controls), exacerbating bone resorption.

Prolonged lactation (over 12 months) and milk donation may lead to sustained reductions in bone mineral density due to hypoestrogenism and calcium depletion. The most significant bone loss occurs during the first 6 months of lactation, after which the rate of decline slows, and post-lactation, gradual bone mass recovery typically occurs. However, with lactation and donation exceeding 18-24 months, irreversible bone structural changes may arise. These findings suggest an elevated osteoporosis risk among breast milk donors, necessitating further research and preventive strategies accounting for hormonal status and lactation duration.

Comprehensive prevention and correction of bone tissue disorders during lactation require consideration of individual metabolic characteristics, breastfeeding duration, and milk donation volume. Prolonged lactation increases the demand for mineral resources, primarily calcium, potentially reducing bone mineral density. Additional milk donation exacerbates this process due to accelerated loss of bone-essential micronutrients and proteins. With adequate loss compensation and post-lactation hormonal recovery, bone mass often restores; however, prolonged and intensive breastfeeding may worsen osteopenic changes. Thus, guideline development must involve individual risk factor assessment and integrated approaches to nutrition, diagnostics, monitoring, and physical activity.

A balanced diet, accounting for optimal quantitative and qualitative characteristics of micro- and macronutrients, is fundamental for maintaining bone tissue throughout the entire lactation period. In women with an average duration of breastfeeding (6-12 months), the requirements for calcium and vitamin D typically align with generally accepted norms: 1,000-1,300 mg of calcium and 600-800 IU of vitamin D per day, provided that plasma 25(OH) D (25-hydroxyvitamin D) levels remain within ⩾30 ng/mL. If breastfeeding extends beyond one year – particularly under conditions of regular breast milk donation (>2-3 L per week) – it is advisable to adjust the diet by increasing daily calcium intake to 1,300-1,500 mg and, if necessary, consider higher doses of vitamin D (1,000-2,000 IU), guided by laboratory monitoring results (e.g., in cases of 25(OH) D < 20 ng/mL, a temporary increase to 4,000 IU per day may be warranted). Magnesium, which plays a role in regulating bone tissue metabolic pathways, should be maintained within a range of 300-400 mg per day; serum magnesium levels are recommended to remain no lower than 0,8 mmol/L. Optimal protein intake typically amounts to approximately 1.2-1.5 g/kg of body weight, as lactogenesis requires increased protein support. In cases of low BMI (<18.5 kg/m2), it may sometimes be appropriate to raise this amount to 1.6-1.8 g/kg.

The diet should ideally include sufficient high-quality proteins of both animal and plant origin (meat, fish, legumes, nuts), as well as an adequate intake of calcium-rich foods: dairy products (cheese, kefir, yogurt), leafy green vegetables, cabbage, sesame seeds, and almonds. Vitamin D is partially synthesised under ultraviolet exposure; however, during autumn and winter or in cases of insufficient regular sunlight exposure, supplementation in doses determined by 25(OH)D analysis is recommended (monitoring should be conducted every 3-4 months in cases of pronounced deficiency). In the event of vitamin K insufficiency – which is involved in the synthesis of proteins required for calcium fixation in bone tissue – it is advisable to increase the consumption of green vegetables and consider specialised supplementation (particularly vitamin K2 in doses of 100-200 μg/day), especially when densitometric parameters indicate progressive declines in mineral density.

Regular diagnostic assessment and monitoring of bone tissue status are essential. Initial screening is recommended at the onset of breastfeeding (or during the planning stage of donation) to evaluate baseline mineral density. The most informative method is considered to be DXA (dual-energy X-ray absorptiometry), which quantifies bone mineral density in high-risk fracture zones (lumbar spine, femoral neck). A T-score between -1 and -2.5 indicates osteopenia, reflecting moderate bone mineral density reduction, while a T-score ⩽-2.5 signifies osteoporosis. In women with prolonged lactation (over 12 months) and in donors providing large volumes of milk (cumulatively exceeding 15-20 L per month), repeat DXA scans are recommended every 6-12 months, depending on the severity of prior changes and fracture risk levels. If DXA is unavailable, ultrasound densitometry (forearm) may serve as a screening method; however, if abnormalities are detected, DXA should be supplemented for more precise bone status assessment. Biochemical markers of bone formation and resorption (osteocalcin, P1NP, β-CrossLaps), as well as serum levels of calcium, phosphorus, magnesium, and 25(OH)D, should ideally be evaluated every 6-8 months during prolonged lactation and every 3-4 months in cases of osteopenia or osteoporosis. If 25(OH)D levels are <20 ng/mL, targeted correction (up to 4,000 IU of vitamin D3 per day under calcium level and renal function monitoring) is advisable.

Physical activity is a key factor in the prevention of osteopenic changes and osteoporotic fractures. Weight-bearing exercise (strength training, free weights or machine-based exercises, bodyweight exercises) promotes osteoblast activation and increases bone mass. It is recommended to engage in at least 150 minutes per week of moderate-intensity aerobic exercise (e.g., brisk walking or light jogging at 60-70% of maximum heart rate) and incorporate 2-3 strength training sessions per week, each lasting 30-40 minutes, with a working weight of approximately 40-60% of 1RM (one-repetition maximum). The average Rating of Perceived Exertion should be maintained at 12-14 (on the 6-20 scale), avoiding excessive strain that may be detrimental to lactating mothers with insufficient recovery. For breastfeeding women, an individualised approach is applied, considering their fitness level, postpartum musculoskeletal changes, and general well-being. Consultation with a physical rehabilitation specialist or sports medicine expert can help tailor the programme to the individual's condition.

Individual adjustments to recommendations depend on the degree of bone mineral density (BMD) loss. In cases of osteopenia (T-score between -1 and -2.5), it is usually sufficient to enhance dietary intake of calcium, vitamin D, magnesium, and protein, alongside introducing regular physical activity with an emphasis on weight-bearing exercises and moderate impact loading (jogging or brisk walking). Additional calcium supplementation (1,000-1,200 mg/day of elemental calcium) combined with

vitamin D (depending on 25(OH)D levels) is considered a preventive measure to stabilise bone tissue. In cases of low physical activity or insufficient sun exposure, more careful vitamin D correction with possible dose adjustment is required. A BMI <18.5 kg/m$^2$ or >30 kg/m$^2$ increases the risk of metabolic and hormonal disturbances, which may worsen bone health, necessitating careful dietary and exercise modifications in these cases.

In the presence of osteoporotic changes (T-score ⩽-2.5), standard measures may be insufficient. Further diagnostic evaluation is recommended to exclude secondary causes of osteoporosis, including assessment of parathyroid hormone, calcitonin, and estradiol levels, as well as consultation with an endocrinologist or other relevant specialist. Where indicated, specific pharmacological agents (bisphosphonates, denosumab, selective estrogen receptor modulators) may be prescribed; however, most of these have restrictions during active lactation. Therefore, in cases of severe osteoporosis requiring continued breastfeeding, alternative correction strategies (e.g., high-dose vitamin D and calcium supplementation, enhanced diet, specialised physical therapy programmes) should be considered. After cessation of lactation, all available medical treatment strategies may be implemented in consultation with a physician.

The duration of breastfeeding should be guided by health status and bone density indicators. In cases of early osteopenia, prolonged lactation (beyond 12-18 months) necessitates more frequent densitometry, careful hormonal monitoring, and active dietary adjustments, including revised vitamin D and calcium dosages. Concurrently, practical considerations (e.g., daily routine management, work-rest balance) may be decisive in shaping individualised recommendations. With a proactive approach to diagnosis and prevention, the risk of persistent osteoporotic changes is significantly reduced, even with prolonged breastfeeding or intensive milk donation.

According to current research, evaluating biochemical markers (25(OH)D <20 ng/mL, osteocalcin >43 ng/mL, P1NP > 76 ng/mL) alongside DXA results (T-score below -1.5) improves the reliability of bone health risk assessment. Women with prolonged lactation and early signs of bone deterioration (T-score between -1 and -2) should undergo biennial screening and continued monitoring post-weaning, as bone mineral density recovery may take several months to a year or longer. For women with shorter lactation periods (<6 months) or no additional milk donation, annual monitoring is typically sufficient unless other significant risk factors are present (e.g., family history of osteoporosis, BMI <18.5 kg/m$^2$, physical inactivity). Moderate but consistent physical activity, correction of nutritional deficiencies, and biomarker monitoring contribute to bone structure stabilisation and, under favourable conditions, restoration.

Thus, for the comprehensive prevention and correction of osteopenic and osteoporotic changes during lactation, it is recommended to maintain a balanced diet that accounts for increased requirements of calcium, vitamins D and K, magnesium, and protein, incorporate regular physical activity (primarily weight-bearing and aerobic exercises within 150-180 minutes per week), conduct screening and dynamic monitoring of bone tissue status (densitometry, blood tests), rationally plan the duration of breastfeeding and milk donation, and implement additional corrective measures if osteopenia or osteoporosis is detected. This strategy helps preserve adequate bone quality and reduces the risk of fractures in the postpartum period and in the future.

## DISCUSSION

The study demonstrated that breast milk donors have a higher incidence of osteopenia and osteoporosis compared to breastfeeding women who are not donors. It was found that 38.1% of donors exhibit osteopenia according to DXA densitometry, while 10.3% have osteoporosis, whereas in the group of breastfeeding non-donors, these figures are 28.4% and 5.2%, respectively. Biochemical analysis revealed significantly lower levels of 25-hydroxyvitamin D (23 ± 8 ng/mL in donors vs 28 ± 10 ng/mL in the control group), which may be one of the contributing factors to the increased osteoporosis risk. Hormonal status analysis confirmed elevated prolactin and reduced estradiol levels in donors, which may also influence bone metabolism.

According to the study by M. Aghaei *et al*. [17], pregnancy- and lactation-associated osteoporosis is a rare but potentially serious condition that may lead to fractures in postpartum women. The study documented three clinical cases of women who experienced significant bone mineral density loss and vertebral fractures following childbirth and during lactation. It was found that two of the three patients had vitamin D deficiency, and their bone mineral density (T-score) in the lumbar spine ranged from -3.1 to -3.6, substantially exceeding typical osteopenia thresholds. The difference between this study and the current findings lies in the fact that M. Aghaei *et al.* focused on lactation-associated osteoporosis as a rare syndrome, whereas the present study examines breast milk donation as a potential systemic risk factor with a gradual impact on bone mineral density. This may indicate the necessity of expanded screening and early detection of mineral density abnormalities in breastfeeding women before clinical symptoms or fractures manifest.

The current study provided a detailed account of how prolonged lactation and breast milk donation may lead to temporary depletion of bone mineral density. It highlighted that during lactation, hypoestrogenemia and significant calcium expenditure for milk production can result in reduced bone mass in women, increasing the risk of osteopenia and osteoporosis. The data underscore the need for regular monitoring of bone tissue status (e.g., via densitometry) in milk donors and the implementation of measures for rapid bone density recovery after lactation cessation. In another study by M. Fukushima *et al*. [18], international findings on pregnancy- and lactation-associated osteoporosis were summarised. A meta-analysis of eight studies indicated that approximately 5% of women in the first year postpartum had spinal osteoporosis, while up to 12% exhibited femoral neck osteoporosis. Pregnancy and breastfeeding significantly increased fracture risk in these women, aligning with the current study's data on the adverse effects of lactation on bone. The meta-analysis authors emphasised the necessity of a standardised approach to bone status assessment in the postpartum period for timely detection and management of osteoporotic

changes. Thus, the results of M. Fukushima *et al*. support the conclusions of the present study that lactation may cause substantial bone mass loss, and variations in osteoporosis incidence may stem from differences in sample characteristics and preventive measures. Notably, milk donors are typically under medical supervision and receive recommendations, which may reduce the actual prevalence of osteoporotic lesions compared to the general population represented in the meta-analysis.

The present study has identified vitamin D deficiency as one of the key risk factors for osteoporosis in breastfeeding mothers. The issue lies in the fact that insufficient 25(OH) D levels in lactating women reduce intestinal calcium absorption and impair bone tissue remodelling, accelerating bone mass loss. The study provided data on vitamin D levels in breastfeeding mothers, demonstrating that a significant proportion of women exhibit insufficiency or deficiency of this vitamin postpartum, which correlates with alterations in bone turnover markers. For prevention, correction of the deficiency is proposed – either through dietary enrichment with cholecalciferol or supplemental vitamin D intake. The significance of this aspect is supported by the study by X. Chen *et al.* [19], which revealed that among postmenopausal women with osteopenia/osteoporosis, over 47% had vitamin D deficiency (25(OH)D levels <20 ng/mL), while approximately 34% exhibited insufficiency. Low 25(OH)D levels were associated with elevated parathyroid hormone and bone resorption markers, as well as reduced bone mineral density (BMD) values. In the osteoporosis group, higher vitamin D levels significantly correlated with greater BMD in the femoral neck and hip joint. Thus, the findings of X. Chen *et al.* demonstrated a causal relationship between vitamin D hypovitaminosis and bone deterioration. The current study aligns with these conclusions: although the participants differ in age, the biological role of vitamin D in maintaining bone homeostasis is similar. Potential discrepancies concern the degree of impact – in postmenopausal women, prolonged vitamin D deficiency manifests as more pronounced osteoporosis, whereas in breastfeeding mothers, short-term deficiency may be compensated more rapidly if corrected in a timely manner. This underscores the importance of monitoring 25(OH)D levels and early intervention, as reflected in the study's recommendations.

The present study emphasised the role of nutrition in breastfeeding mothers as a critical component of osteoporosis prevention. The identified issue was insufficient intake of key nutrients for bone health – primarily calcium and high-quality proteins – which could hinder bone mass recovery during and after lactation. The study elaborates that lactation increases calcium demand: if maternal diet does not provide sufficient intake (≈1,000-1,200 mg Ca/day), the body mobilises calcium from bones for milk secretion, thereby weakening the skeletal system. Similarly, the study highlighted the role of dietary protein: amino acids are essential for collagen matrix synthesis in bones, and protein deprivation may delay bone tissue remineralisation. As a preventive measure, a balanced diet rich in dairy products (as a calcium source) and protein were recommended, or supplementation if dietary intake is inadequate. These findings are consistent with the review by G. Kędzia *et al*. [20], which analysed recent data on protein intake and bone health. According to G. Kędzia *et al*., adequate calcium and vitamin D intake are fundamental for maintaining bone mass, yet without sufficient protein, bone loss occurs significantly faster. Protein constitutes approximately 50% of bone volume and one-third of its mass, influencing collagen formation and hormonal regulation, particularly by stimulating IGF-1 synthesis, which promotes bone formation. Thus, dietary protein is considered an equally critical factor in bone nutrition alongside calcium. The review also noted that protein excess per se does not harm bones in healthy individuals: potential adverse effects (increased calcium excretion) are observed only in patients with renal insufficiency. Therefore, for most individuals, a high-protein diet – provided calcium intake is sufficient – is either safe or even beneficial for bone health. Compared to the current study, G. Kędzia *et al*. expanded the focus on the protein component, whereas the present study prioritises calcium (given its evident depletion during lactation). These differing approaches are not contradictory but complementary: a comprehensive osteoporosis prevention strategy for breastfeeding mothers should include both optimal calcium provision and adequate dietary protein – consistent with both sources.

The present study examined the issue of hypodynamia in breastfeeding women as a risk factor for accelerated bone mass loss. Due to postpartum fatigue and the demands of infant care, many lactating women may reduce their physical activity levels, which adversely affects bone remodelling (the absence of sufficient mechanical loading diminishes the stimulus for bone formation). The study concluded that regular physical activity, particularly weight-bearing exercises (walking, running, resistance training), is an essential component of osteoporosis prevention in this group. Early resumption of physical activity postpartum (accounting for health status) is recommended, as it promotes both bone strengthening and improved overall metabolism. The efficacy of this approach is supported by the results of a large prospective study by Y. Yue *et al*. [21]. In this study, which followed 24,700 elderly individuals for approximately three years, it was found that moderate daily physical activity significantly reduces the incidence of osteoporosis. Specifically, individuals who walked outdoors for more than 30 minutes per day had a 17% lower risk of developing osteoporosis compared to sedentary individuals (hazard ratio HR ≈ 0.83), while those who walked more than 60 minutes daily experienced a 40% risk reduction (HR ≈ 0.6). The authors emphasised a dose-dependent protective effect: longer walking durations correlate with a lower likelihood of osteoporosis. This association was observed across all subgroups, though it was most pronounced in individuals without a high genetic predisposition. Thus, the study by Y. Yue *et al.* confirmed a fundamental thesis shared with the present research: physical activity is a simple and effective means of preventing bone mass loss. Although Y. Yue *et al*. assessed an elderly population, the principle of mechanical bone stimulation is universal and applies equally to younger women. Differences may lie only in the type of recommended activity: walking suffices for older individuals, whereas more intensive exercises may be advisable for younger breastfeeding women (provided no contraindications exist). Ultimately, both studies highlighted that maintaining an adequate level of physical activity promotes bone density recovery and reduces osteoporosis risk.

The present study also identified a correlation between anthropometric characteristics of lactating women and their bone health status. The issue is framed as follows: women with low BMI or insufficient body weight during lactation may be more vulnerable to bone mass loss. It is noted that lean donors, particularly those who experienced rapid postpartum weight loss, exhibit lower bone mineral density (BMD). A possible mechanism involves a combination of factors: reduced mechanical load on the skeleton, lower nutrient and oestrogen reserves in adipose tissue, and intense metabolic demands of lactation amid limited physiological reserves. Conversely, women with higher BMI (within normal or moderately elevated ranges) may have some protection against osteoporosis due to greater skeletal loading and higher levels of leptin and oestrogens derived from adipose tissue.

These findings are corroborated by a large-scale study by C.T. Chiu *et al*. [22], which analysed data from ~14,000 Taiwanese individuals and established a strong association between body weight and bone density: higher BMI was statistically linked to greater BMD and lower osteoporosis risk. Crucially, low body weight emerged as an independent predictor of osteoporosis progression. In the underweight subgroup, osteoporosis incidence was significantly higher than in those with normal BMI. Conversely, the authors identified a BMI range of ~23-24.9 kg/m$^2$ as optimal for fracture prevention; below this threshold, osteoporosis risk progressively increased. These results align with the conclusions of the present study: maintaining a healthy body weight is a modifiable factor that can reduce the likelihood of bone density loss. Minor discrepancies may arise from the fact that postpartum women experience dynamic weight fluctuations (physiological weight loss after pregnancy is possible, as is weight gain due to excessive caloric intake). The data from C.T. Chiu *et al.* indicate that rapid weight loss (>5-10% in a short period) adversely affects bones – a critical consideration when advising lactating women: excessive postpartum weight loss is detrimental to skeletal health. Overall, both studies confirm that anthropometric indicators (primarily BMI) are interrelated with bone mineral density, and maintaining body weight within the normal range is a key component of osteoporosis prevention in breastfeeding women. Prolonged breastfeeding increases calcium demand, which may lead to reduced maternal BMD. The present study underscores the importance of monitoring bone mass in donors and preventing osteoporosis through timely osteopenia diagnosis and corrective measures (dietary adjustments, calcium and vitamin D supplementation, etc.).

The study by E.N. Lee *et al.* [23] synthesised data from 7 trials involving 3,813 postmenopausal women and found that prolonged lactation history was associated with an increased risk of osteoporosis. According to the meta-analysis, women who breastfed for the longest duration had nearly twice the odds of developing osteoporosis (OR ≈ 1.93) compared to those who breastfed for shorter periods. The authors concluded that extended lactation periods are associated with an elevated risk of osteoporosis. This aligns with the findings of the current study regarding bone mass loss during prolonged human milk donation. The difference lies in the fact that E.N. Lee *et al.* assessed long-term consequences (in postmenopausal women), whereas the present study focused on current monitoring of young lactating women. Potential reasons for discrepancies include population differences (a Korean cohort, differing dietary habits and genetics) and the possibility that bone loss – partially reversible after lactation cessation – may still have long-term effects on bone health decades later. This study reinforces the argument for monitoring bone status in women with prolonged breastfeeding periods (such as milk donors).

Pregnancy, and particularly lactation, induce temporary remodelling of maternal bone metabolism. In breast milk donors, this process may be more pronounced due to intensive and prolonged breastfeeding, necessitating measures to ensure full bone mass recovery and prevent osteoporosis. The review by E.M. Winter *et al*. [24] noted that physiological skeletal changes during pregnancy and lactation are typically reversible – maternal bone density generally recovers almost completely after lactation cessation. Moreover, long-term studies suggest potential minor localised benefits for future bone density in women who have undergone pregnancy and lactation. Thus, normal lactation does not lead to persistent osteoporosis – most women recover bone mass after weaning. These conclusions partially differ from the emphasis of the current study. While the present research highlighted the risk of osteoporosis and the need for preventive measures in donors (as a high-risk group due to extended lactation), the review by E.M. Winter *et al*. underscores the body's compensatory capacity. The discrepancy may arise because the review examines population averages and physiological norms, whereas women in milk donation programmes may breastfeed longer and more intensively than usual. This creates a scientific debate: on one hand, lactation is a natural, transient risk factor; on the other, in cases of exceptionally prolonged lactation (donation), closer monitoring of bone health is warranted – even if recovery occurs in most cases.

E.M. Kyle *et al*. [25] investigated the dynamics of bone mineral density during the first year postpartum in breastfeeding women compared to non-pregnant controls (USA, Nutrients). The study observed 18 lactating mothers from 4-6 months postpartum until 12 months, alongside 16 age-matched controls. The present study highlights potential bone mass deficits in milk donors and the need for osteoporosis prevention, whereas the results of E.M. Kyle *et al*. demonstrated that bone mineral density loss during the first year of lactation is moderate and reversible for most women. Both sources agree on the physiological bone loss during breastfeeding. They concur that early postpartum skeletal demineralisation occurs due to calcium mobilisation for lactation. However, the current study likely emphasises osteoporosis risk more, suggesting that without proper monitoring, donors may accumulate significant bone tissue loss. In contrast, E.M. Kyle *et al*. presented more optimistic findings: in the absence of other risk factors, lactation-induced osteopenia is transient and does not lead to fractures or severe osteoporosis within the first year postpartum. This difference may stem from variations in lactation duration and intensity. In E.M. Kyle's *et al*. study, many women ceased breastfeeding before 12 months, whereas milk donors often continue lactation longer and express substantial

volumes daily. Thus, donors may experience greater "calcium stress" than the average lactating mother. Another factor is vitamin D deficiency: if prevalent among donors, bone loss may be more pronounced. E.M. Kyle *et al*. did not report acute vitamin D deficiency in their participants (the study was conducted in the US with supplement access). Hence, differences in baseline vitamin D status and nutrition may explain why lactation only temporarily reduces bone mineral density in some cases but potentiates osteoporosis in others. Overall, E.M. Kyle's *et al*. work supports the thesis that monitoring bone density – even with minor changes – is critical: the authors propose tracking T-scores and remodelling markers to identify women with excessive bone loss promptly. This aligns with the current study's recommendations for regular diagnostics (e.g., densitometry) in breast milk donors.

E. Sümer *et al*. [26] conducted a large-scale retrospective study in Turkey, examining the association between the total duration of breastfeeding and bone health in 1,218 postmenopausal women. In addition to measuring bone mineral density (lumbar spine and femoral neck), serum 25(OH)D (vitamin D) levels were assessed. The mean age of participants was ~60 years; according to World Health Organization criteria, 41.3% had osteoporosis, while 42% exhibited osteopenia. The work of E. Sümer *et al.* directly supports the key hypothesis of the current study: prolonged lactation may have long-term adverse effects on a woman's bone health. This is particularly relevant for breast milk donors, who often breastfeed for longer than average. Both studies concur that, without preventive measures and nutrient supplementation, extended breastfeeding depletes maternal mineral reserves. The Turkish study also identified a link with vitamin D, aligning with the current study's assumption that vitamin D deficiency in donors may exacerbate osteoporosis. When 25(OH) D levels are low, calcium absorption is impaired, accelerating bone mass loss. Both E. Sümer *et al*. and the authors of the current approach recommend ensuring adequate vitamin D and calcium intake in long-term breastfeeding women. The studies differ in design: the Turkish study is a retrospective review of postmenopausal women, whereas the current research focuses on real-time active monitoring of donors. Nevertheless, the findings of E. Sümer *et al*. provide insight into a potential long-term outcome: women with a prolonged cumulative breastfeeding history (often donors, multiparous mothers, or those who breastfed a single child for an extended period) face a higher risk of osteoporotic fractures later in life. This evidence underscores the importance of preventive measures proposed in the current study. Specifically, regular bone density screening in such women would enable early detection of osteopenia before menopause, allowing timely intervention. Both sources also highlight the significance of modifiable factors, such as physical activity and body weight. The 2020 study found that higher body weight and an active lifestyle partially mitigate bone mineral density loss (improving femoral bone mineral density). This confirms that preventive strategies should encompass not only calcium and vitamin D supplementation but also lifestyle recommendations (balanced nutrition, moderate physical activity).

In the current study, the mean 25(OH)D level in breast milk donors was 23 ± 8 ng/mL, compared to 28 ± 10 ng/mL in the control group. The majority of donors (67.5%) had vitamin D deficiency, indicating insufficient intake. X. Ni & W. Xia's [27] study demonstrated that, under normal conditions, lactation alters mineral metabolism, enhancing intestinal calcium absorption while reducing renal excretion. Most women fully recover bone mass losses after lactation cessation; however, those with low baseline bone mass may develop osteoporosis and osteoporotic fractures. This reinforces the necessity of additional vitamin D and calcium intake, particularly for high-demand groups such as breast milk donors.

The current study found that donors exhibit reduced muscle strength, poorer coordination, and an increased risk of falls (decreased hand dynamometry in 18% of cases, prolonged Timed Up and Go test duration in 12%). These effects may result from elevated energy expenditure and mineral depletion. D. Athonvarangkul & J. Wysolmerski's [28] study analysed the interaction mechanism between the hypothalamus, mammary gland, and bone tissue during lactation. Adaptive bone remodelling occurs, but prolonged lactation may reduce bone mass. This research also confirms that lactation affects muscle tone via hormonal changes, explaining the observed impairments in muscle strength and coordination.

The current study revealed that breast milk donors experience more pronounced bone mineral density reduction, potentially increasing postmenopausal osteoporosis risk. A. Sarantaki's [29] study examined the long-term impact of lactation on postmenopausal osteoporosis. Data across studies are conflicting: some suggest a protective effect of breastfeeding, while others indicate elevated bone mass loss risk. These discrepancies may stem from variations in lactation duration, vitamin D and calcium intake, and genetic predisposition.

The current study established that breast milk donors have an elevated risk of osteopenia and osteoporosis, necessitating tailored preventive and therapeutic strategies. Conversely, P. Anagnostis *et al*. [30] study evaluated the efficacy of various osteoporosis treatments in women with PLO. Calcium and vitamin D supplementation improved bone mineral density, but bisphosphonates and teriparatide were most effective. However, their use during lactation is restricted, highlighting the need for alternative prevention and treatment approaches.

Thus, studies indicated that breast milk donors are more likely to develop osteopenia and osteoporosis compared to breastfeeding women who are not donors, which is attributed to vitamin D deficiency, hypoestrogenaemia, elevated prolactin levels, and additional metabolic calcium expenditure during lactation. Several studies have described clinical cases of vertebral fractures in women with pregnancy- and lactation-associated osteoporosis, where the critical factor is hypovitaminosis D and insufficient dietary intake of protein and calcium. Meta-analyses confirm that prolonged lactation correlates with a significant reduction in bone mineral density and an increased risk of fractures in the postpartum period; however, most women exhibit gradual recovery of bone mass after cessation of breastfeeding. At the same time, milk donors demonstrated more pronounced bone tissue loss, likely due to longer and more intensive lactation, exacerbated by physical inactivity, low BMI, and other individual risk factors.

## CONCLUSIONS

The conducted study comprehensively demonstrated enhanced bone remodelling under conditions of prolonged lactation, which combines elevated prolactin levels with transient hypoestrogenaemia in breast milk donors. It was established that 35.7% of respondents had a familial predisposition to osteoporosis, while 11.9% had sustained fractures after the age of 30, underscoring the significant role of hereditary factors. Among donors, 34.1% were diagnosed with osteopenia, 7.9% with osteoporosis, whereas 57.9% exhibited normal densitometry values. Anthropometric analysis revealed that 27.8% of women were overweight, 12.7% were obese, and 4% were underweight, contributing to complex alterations in bone tissue metabolism. Additionally, 59.5% had 25(OH)D deficiency, 15.9% exhibited abnormal calcium levels, and 11.9% had phosphorus imbalances; 23.8% showed deviations in osteocalcin content, while 19.8% had altered P1NP levels, indicating varying bone matrix formation activity.

Assessment of dietary habits demonstrated insufficient intake of calcium-rich foods: 6.3% of women consumed dairy products less than once a week, and 2.4% avoided them entirely, potentially compromising calcium supply. The majority of donors (72.2%) did not supplement with vitamin D or calcium, whereas 27.8% used appropriate supplements. It was found that 31.7% of mothers breastfed for over a year, and 15.9% for over two years, which, combined with milk donation, may exacerbate mineral depletion. Only 11.9% of women engaged in regular daily physical activity, while 12.7% did not exercise at all. Among those aware of their bone status, 7.9% had a T-score between -1 and -2, signalling early osteopenic changes. The combination of these factors suggests that prolonged lactation, coupled with genetic predisposition, nutritional imbalances, and excess weight, increases the risk of structural bone damage.

Optimising dietary intake with adequate protein, calcium, and vitamin D, supplementing where necessary, and engaging in regular physical exercise reduce the likelihood of accelerated bone tissue depletion. Routine examinations using ultrasound or DXA densitometry and monitoring biochemical markers are also recommended for early detection of structural abnormalities. Simultaneously, attention should be paid to the post-lactation period, as bone mass recovery occurs during this phase and may be delayed in the presence of additional risk factors. A limitation of the study is the non-representative age and geographical distribution of the sample. Future research should focus on genetic screening of polymorphisms regulating bone metabolism to develop targeted preventive measures for high-risk osteoporosis groups.

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## CONFLICT OF INTEREST

None.

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# Сучасний підхід до моніторингу та профілактики розвитку остеопорозу у донорок грудного молока

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**Анотація.** Вивчення стану кісткової тканини жінок, які годують немовлят, є актуальним з огляду на зростаючу поширеність остеопенічних змін і складні наслідки для репродуктивного здоров'я. Метою дослідження було проаналізувати донорство грудного молока як додатковий фактор ризику та визначити ключові умови збереження міцності кісток у післяпологовий період. У межах ретроспективного аналізу, проведеного на базі комунального некомерційного підприємства «Перинатальний центр м. Києва», вивчено медичні записи 260 жінок, серед яких 126 були донорками молока, а 134 годували власних дітей без донорства. У процесі дослідження оцінювалися показники щільності кісткової тканини, кількісні параметри крові, індекс маси тіла та історія переломів. Контингент учасниць дослідження формувався через мережу лікувальних закладів за умови отримання інформованої згоди та забезпечення конфіденційності персональних даних. Основні результати засвідчили, що донорки частіше мали випадки переломів після 30 років (11,9 %), меншу обізнаність про стан кісток (7,9 % знали власний індекс маси тіла) та суттєві відхилення рівня вітаміну D, дефіцит якого фіксувався у 67,5 % жінок із цієї групи. Поміж донорок 29,4 % мали надлишкову вагу, а 13,5 % – ожиріння, що перевищувало аналогічні показники серед годувальниць без донорства. Понад 10 % учасниць-донорок продемонстрували рентгенологічні ознаки остеопорозу, тоді як у контрольній групі такі зміни охоплювали близько 5 %. Було виявлено, що триваліша лактація без належної корекції харчування й фізичної активності сприяє прогресуванню остеопенічних процесів. Доведено важливість регулярного моніторингу біохімічних маркерів та використання профілактичних стратегій (раціональне харчування, контроль надходження вітаміну D та помірні силові вправи) для запобігання ускладненням. Практична цінність результатів полягає в обґрунтуванні необхідності раннього обстеження донорок і формуванні індивідуальних рекомендацій, щоб знизити ризик переломів і зберегти здоров'я матері. Запропонований підхід може бути застосований у масштабніших програмах охорони здоров'я жінок, які годують немовлят. Це особливо важливо для сучасної медичної спільноти, яка прагне зменшити економічні витрати, пов'язані з лікуванням переломів та подовженою реабілітацією

**Ключові слова:** гормональні зміни; генетична схильність; фізична активність; дефіцит вітаміну D; лактація