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# TYPE 1 DIABETES AND BONE HEALTH: ROLE OF REDUCED BONE DENSITY AND FRACTURE RISK

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**ABSTRACT**
Type 1 diabetes mellitus (T1DM) is an autoimmune disease that affects not only glycemic control but also bone remodeling, leading to reduced bone mineral density (BMD) and increased fracture risk. The aim of this study was to investigate the relationship between T1DM and bone health, focusing on reduced BMD and fracture risk. Methods included a systematic review of the scientific literature from the last 10 years in the Pub Med, Scopus and Web of Science databases with the keywords: diabetes type 1, bone fractures, BMD, prevention and accessible full text of the scientific reports from which this review was prepared. The results of the systematic review indicate that the duration of the disease, impaired insulin and calcium metabolism, as well as chronic hyperglycemia contribute to impaired osteogenesis and increased risk of fractures. The most susceptible to fractures in type 1 diabetes are the bones of the femoral neck and lumbar spine. The accompanying complications, such as diabetic retinopathy, neuropathy and hypoglycemic episodes, increase the risk of falls and fractures. Conclusion: optimal blood glucose control, adequate calcium and vitamin D intake, physical activity and regular monitoring of BMD can minimize subsequent fracture risks and prevent bone health.

**Keywords**: type 1 diabetes mellitus, bone fractures, bone density, prevention

## INTRODUCTION

Type 1 diabetes mellitus (T1DM) is a chronic autoimmune disease characterized by destruction of pancreatic beta cells and absolute insulin deficiency (1). Despite advances in treatment and improved glycemic control, T1DM remains a chronic condition with a wide range of long-term complications. Although clinical focus has traditionally been on glycemic control and the prevention of vascular and neurological complications, increasing evidence is pointing to an underappreciated but clinically significant consequence: bone damage. The growing knowledge of diabetic osteopenia is laying the foundations for new paradigms in the care of patients with diabetes from early childhood. A key indicator of skeletal bone strength and a major predictor of fracture risk is bone mineral density (BMD).

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Numerous clinical and epidemiological studies have shown that BMD is significantly reduced in patients with T1DM (2) compared with the healthy population, especially in the case of long duration of the disease, poor glycemic control and the presence of complications (2-4). This impairment begins during puberty and persists throughout the life span, and is associated with the failure of bone mass to reach its optimal peak, especially in children with poor glycemic control (5). Reduced BMD is not only a consequence of excess insulin, which plays the role of an anabolic hormone for bones, but also the result of a complex network of metabolic and hormonal disorders. The risk of hip and lumbar spine fractures is up to six times higher in T1DM than in patients without diabetes or those with type 2 diabetes. Data indicate that hip fractures are more common at a young age, but the consequences during this period are also more serious. Patients with T1DM have prolonged hospital stays after trauma, are at increased risk of cardiovascular

complications (6), infections (7), and increased mortality (8).

In addition to insulin deficiency, chronic hyperglycemia has a negative effect on bone strength, leading to the accumulation of advanced glycation end products (AGEs) in the bone matrix. These molecules damage the collagen structure and disrupt the microarchitecture of bone, which compromises its strength (9). In addition, AGEs alter the functions of osteoblasts and osteoclasts, thereby disrupting the normal balance between bone formation and resorption (10).

Another key factor is the deficiency of insulin-like growth factor 1 (IGF-1), which is often observed in diabetics and plays an important role in osteoblast differentiation and bone remodeling (11). In addition, calcium malabsorption and vitamin D deficiency, characteristic of the diabetic state, further contribute to bone loss and impaired mineralization (12).

Of particular concern is that patients with type 1 diabetes may develop subclinical osteopenia as early as childhood and adolescence, which prevents them from reaching optimal peak bone mass, a critical factor in maintaining a healthy skeleton throughout life (13). This condition, combined with the increased propensity to fall in the presence of diabetic complications such as neuropathy and retinopathy, significantly increases the incidence of low-energy fractures in this population (14). Thus, even minor trauma can lead to serious orthopedic consequences in patients with type 1 diabetes.

Systematic screening for bone density in patients with type 1 diabetes – using methods such as dual-energy X-ray absorptiometry (DXA) – is necessary, especially in adolescence, in postmenopausal women, or in patients with a long history of diabetes. Early diagnosis of osteopenia or osteoporosis allows for preventive measures, including adequate vitamin D and calcium supplementation, individualized physical activity, and optimization of glycemic control (15).

It is also important to consider the psychosocial aspect of the risk of fractures and T1DM, which is associated with a prolonged period of immobilization, which makes blood sugar control difficult and increases the risk of additional complications, including hypoglycemia and infections (16).

In short, the skeletal system should not be considered a "victim" only of age and hormonal changes – it is a dynamic structure, sensitive to metabolic disorders such as those characteristic of T1DM. Awareness of this fact and its integration into clinical practice can prevent serious debilitating complications and improve the quality of life in patients with type 1 diabetes.

This review aims to investigate the relationship between type 1 diabetes and bone health, focusing on reduced BMD, fracture risk, and potential strategies for early diagnosis and prevention of complications.

## MATERIAL AND METHODS

A systematic review of the scientific literature from the last 10 years was performed in the Pub Med, Scopus, and Web of Science databases using the keywords: diabetes type 1, bone fractures, BMD, prevention, and the full text of the scientific reports from which this review was prepared was available.

## RESULTS AND DISCUSSION

The global prevalence of diabetes continues to increase. According to the latest data from the International Diabetes Federation (IDF Diabetes Atlas 11th Edition), approximately 589 million people live with diabetes worldwide, or one in every 9 adults, and almost half of them are unaware of it. This number is projected to reach 643 million by 2030 and 853 million by 2050 (17).

Scientific data accumulated over the past decade confirm that patients with T1DM have significantly reduced bone mineral density (BMD) and an increased risk of fractures compared with healthy individuals (18).

Reduced BMD in patients with T1DM is observed already in childhood and adolescence - periods critical for reaching peak bone mass. A 2015 cohort study by Weber et al. found that in 36% of children and adolescents with T1DM, BMD was below the norm for age and increased the risk of fractures by more than 50% compared with the healthy population (19). Similar results were confirmed in a 2007 meta-analysis by Vestergaard, covering more than 20 studies, which showed a clear decrease in BMD

in patients with T1D compared with control groups (20).

Another factor that negatively affects BMD and increases the risk of fractures is poor glycemic control, as determined by glycated hemoglobin levels (HbA1c ≥ 7%) (21, 22). This reliable association was found and confirmed in a meta-analysis conducted in 2007 (23), as well as in a study among girls with T1D in childhood, in which a violation of the cortical and trabeculae bone structure was found in those with HbA1c > 8.5% (24).

Age as well as the duration of the disease significantly modify the impact of diabetes on bone health.

Reduced BMD and increased concentration of CTX (a marker of bone resorption) in the hip joints were also found in a study conducted among women of different age groups and T1DM, in the postmenopausal period, compared with healthy controls, which proves accelerated bone loss and the risk of fragility during this period (25).

High fracture risk is also observed in patients with long-term disease duration (10 years or more), a claim supported by the two-phase model proposed in a study by Ivers et al. (26) and in the Canadian Longevity Study conducted among 75 patients with a long-term history of T1DM (27).

Biomarker analysis results also confirm impaired bone metabolism in T1DM. Thrailkill et al. (2005) found reduced serum levels of osteocalcin and increased concentrations of bone resorption markers (e.g. CTx), indicating an imbalance between bone formation and bone loss. This is consistent with the hypothesis that chronic hyperglycemia and insulin deficiency inhibit osteoblast activity and promote bone fragility (28).

In addition to changes in BMD, T1DM is also associated with an increased number of low-energy fractures. In a population-based study conducted in Denmark, Dahl et al. (2013) reported that the risk of fracture in women was 92% higher than in healthy controls and twice as high as in men with T1DM (29).

Other studies have shown that glycemic control plays a key role in bone health. Patients with HbA1c >8% showed lower BMD and a higher incidence of fractures compared with those with better metabolic control, suggesting that optimal disease control may have a protective effect on the skeletal system (30).

An interesting approach is presented by the study by Morales-Palomo et al. (2023), which investigated the effect of physical activity on bone health in patients with T1DM. The authors found that moderate-to-high intensity programs can improve bone density and reduce levels of bone resorption markers, especially in frail patients (31).

Recently published data by Petrova et al. (2024) also confirm the need for an individualized therapeutic approach in patients with T1DM with regard to their skeletal health. The authors recommend regular monitoring of BMD, CTX and other biomarkers as part of routine clinical practice (32).

## CONCLUSION

T1DM has a significant impact on bone health, increasing the risk of reduced BMD and subsequent fractures. These changes develop early and often remain undiagnosed until clinical manifestations occur. Optimal blood glucose control, adequate calcium and vitamin D intake, physical activity, and regular bone density monitoring can minimize these risks and improve the quality of life of affected patients. Bone health assessment should be included as part of routine screening and overall disease management.

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