



REVIEW PAPER

Dariusz Wolski ^{1,2(ABDF)}, Joanna Michalik ^{3(AFG)}, Marek Bieńko ^{2(AFG)},
Radosław P. Radzki ^{2(AFG)}

Effects of obesity on health condition with an emphasis on bone tissues disorders

¹ Department of Animal Anatomy and Histology, Faculty of Veterinary Medicine,
University of Life Sciences in Lublin, Lublin, Poland

² Department of Animal Physiology, Faculty of Veterinary Medicine,
University of Life Sciences in Lublin, Lublin, Poland

³ Department of Oncology and Environmental Health, Faculty of Nursing and Health Sciences,
Medical University of Lublin, Lublin, Poland

ABSTRACT

Introduction. Obesity is today one of the most dangerous and the fastest growing civilization diseases in the world. The number of overweight or obese people is continually increasing. Obesity is defined as abnormal fat accumulation in an organism that may cause health impairment. Obesity may be conducive to an increased risk increase for occurrence of cardiovascular diseases as well as stroke, some types of cancer, endocrinal disorders, osteoarthritis and other bone disorders. Some studies have demonstrated that high body mass index (BMI) is protective against the development of osteoporosis and osteoporotic fractures in men and women. In slim people with a lower BMI than normal, weight loss is associated with low bone mineral density (BMD). On the other hand, obesity in childhood may lead to fragility fractures and may lead to early development of osteoporosis in adulthood. Currently, we have numerous methods for measurement of obesity such as dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), total body electrical conductivity (TOBEC) as well as magnetic resonance imaging (MRI) and computed tomography (CT). These methods are useful for diagnosing obesity and bone tissue disorders such as osteopenia with sarcopenia or osteoporosis, in particular in perimenopausal women and men after andropause. **Aim of the study.** The purpose of the study was review the literature on obesity and bone tissue disorders and their interrelations.

Material and method. Analysis of literature.

Keywords. fat tissue, bone, obesity, osteosarcopenic obesity, osteoporosis

Corresponding author: Dariusz Wolski, e-mail: dariusz.wolski@up.lublin.pl

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Introduction

The World Health Organization (WHO) published alarming data showing a continual increase in the number of overweight or obese people. In recent years, the prevalence and corresponding ratio of obese people increased significantly. In 2008, about 35% of adults were overweight and 10% of males and 14% of females of the world population were obese.¹ The percentages increased after eight years and in 2016, 39% of people suffered from overweight, 11% of males and 15% of females suffered from obesity worldwide.²

Obesity is a state of excess storage of body fat resulting from a chronic imbalance between energy intake and energy consumption as well as a lack of physical activity. This is also a complex condition causing more serious health problems affecting virtually any age and all socioeconomic groups. In the pathogenesis of obesity, main roles are played by genetic and environmental factors, as well as social and cultural factors and the hormonal state of the organism. The results of epidemiologic studies are very upsetting. Over the last few years, a progressive decline of the age threshold of subjects with these disorders has been observed; the problem of excessive body mass increasingly embodies the adolescent population. The results of relevant published studies are inconsistent. Some of them showed a protective role of body fat for skeletal health, whereas others point out a negative effect of adiposity on bone mineral density (BMD) and bone turnover. Obesity can also increase the risk for occurrence of type 2 diabetes, cardiovascular diseases as well as stroke, some types of cancer, endocrinal disorders, osteoarthritis, and premature death worldwide.^{2,3,4,5}

Obesity in childhood can lead to fragility fractures and result in the early development of osteoporosis in adulthood. On the other hand, in postmenopausal obese women, the increase of BMD compared to slim women has been reported. Fat tissue, as the largest endocrine organ, secretes numerous adipokines such as the hormones leptin, adipokine visfatin, and cytokines (e. g. IL-1, IL-6, TNF- α) and their direct osteotropic effect is still under discussion. Moreover, adipokines affect bone tissue indirectly, by the controlling the action of other hormones, playing a key role in bone physiology (GH-IGF-I and 1.25 (OH)2D3). Additionally, an obese person has higher levels of serum estrogen and parathyroid hormone (PTH) and lower 25-hydroxyvitamin D (25OHD), sex hormone - binding globulin and lower 1.25 dihydroxyvitamin D₃; all of them have an important osteotropic effect. Obesity is also associated with higher levels of pancreatic hormones such as amylin and insulin which have anabolic properties in relation to bone.^{6,7}

Diagnostics of obesity

Body mass index (BMI) is a simple index of weight for a given height that is commonly used to classify overweight and obesity in adults. It is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m²). The WHO definition is: a BMI greater than or equal to 25 is overweight and a BMI greater than or equal to 30 is obesity.³

According to the proposed classification, overweight occurs when the value of BMI is in the range 25.0 – 29.9 compared with the norm 18.5 – 24.9. When its value increases over 30.0, it indicates obesity which can be classified and attributed in corresponding degrees. First degree obesity (I degree) is characterized by a BMI value in the range 30.0 - 34.9, II degree in the range 35.0 - 39.9 and the highest III degree obesity is indicated by a body mass value equal or larger than 40.0.^{1,2} Due to a large risk of error, other methods of obesity qualification have been proposed. At present, the most popular is the method based on the location of the largest amount of fat tissue in the organism. Using this method, central obesity also called ventral there is distinguished where the waist measurement is taken into account. However, the waist measurement values are differentiated according to race. Therefore, three subpopulations (American, European and Asian) are distinguished for comparison. The second type is hip and thigh obesity where the measure of obesity degree is hip and thigh circumference. It is assumed that the ratio obtained from the measurement of waist, hips, and thigh circumference after some calculations should not exceed 0.8 in woman and 0.9 in men. Special attention should be paid to the fact that the above methods can be applied for adults but not to children and youth during growth and development and differences in the metabolism of young and mature individuals. The composition of the body in children differs significantly from that in adults when the growth is ceases. An error is often made in diagnostics of obesity when children and youth are examined using the methods attributed to adults. Such a type of classification is allowed for youth in some cases when growth can be assumed to be nearly complete. Published centile charts can be used for diagnosis of obesity in children and youth.^{1,3,8}

Currently, numerous methods of measurement of obesity such as dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), total body electrical conductivity (TOBEC) as well as magnetic resonance imaging (MRI) and computed tomography (CT) are applied.⁹ Dual-energy X-ray absorptiometry (DXA), the measurement of the transmission of X-rays through the body at high and low energies, is a means of measuring bone mineral density (BMD). The additional capability of DXA to differentiate between bone mineral, fat tissue, and lean tissue has contributed to its

emergence as a popular tool to assess body composition. The DXA method allows determining such parameters as percentage of total fat content (Total Fat %), percentage ratio of fat tissue content in relation to soft tissue (Soft Tissue Fat %) and percentage ratio between the total skeleton BMC and the fat-free mass of the body (%TBMC/FFM).^{10,11} The bioelectrical impedance analysis (BIA) is a method of assessing body composition, the measurement of body fat in relation to lean body mass. This non-invasive test simply involves the placement of two electrodes on a person's right hand and right foot. The flow of the current is affected by the amount of water in the body. The device measures how this signal is impeded through different types of tissue. Tissues that contain large amounts of fluid and electrolytes, such as blood, have high conductivity, but fat and bone slow the signal down. As BIA determines the resistance to the flow of the current as it passes through the body, it provides estimates of body water from which body fat is calculated using selected equations.^{12,13} The total body electrical conductivity (TOBEC) was introduced as a rapid, safe, and noninvasive method suitable for the estimation of fat-free mass. The instrument (TOBEC) operates on the principle that organisms placed in an electromagnetic field perturb the field to a degree that depends on the amount and volume of distribution of electrolytes.¹⁴ Magnetic-resonance imaging (MRI) is a research technique that exploits the magnetic properties of certain atomic nuclei. It determines physical and chemical properties of atoms or the molecules in which they are contained. This phenomenon of nuclear magnetic resonance can provide detailed information about the structure, dynamics, reaction state, and chemical environment of molecules. Magnetic-resonance imaging is used in human adults and children to obtain measures of total body fat mass (FM) with high precision. Magnetic-resonance imaging and computed tomography scanning provide accurate data on adipose tissue distribution, but remain limited to the specialist use and are unsuitable for the routine clinical application. Additionally, CT involves exposure to high levels of radiation.^{15,16,17}

Obesity development and bone tissue

Accessible methods for measuring obesity and control of its treatment allow determining contents of an individual fraction of fat tissue in the organism. Due to close relations between the fat tissue and the bone tissue as well as metabolic interactions between them, location and content of fat in the organism should be taken into account. The largest reservoir is the subcutaneous fat tissue whose contribution can be up to 70%, constituting the largest reserve of energy in the organism due to the ready acquisition of fatty acids which can be used in metabolic transformations.^{4,6,8} The second fraction

with respect to the amount is the visceral fat tissue and its content does not change greatly during the individual life as in the case of subcutaneous fat tissue but its contribution is sexually differentiated. This constitutes about 20% of the total fat content in men's body and 8% in women. Thus the visceral fat tissue is a source of triglyceride as well as LDL cholesterol contributing largely to the development of atherosclerosis and adipocytokines taking a direct part in bone tissue metabolism. The remaining contribution comes from the fat tissue dispersed throughout the organism as intermuscular fat surrounding the nervous tissue or articulations.^{18,19}

As follows from published studies, an increase in the fatty tissue content and growing obesity result in hormonal economy disorders with respect to estrogen and androgen sex hormones. Their role in bone metabolism is enormous as they stimulate osteoblasts to synthesize many factors responsible for intensification of bone formation and inhibit synthesis as well as release proresorption factors. The function of estrogens consists in inhibition of bone tissue resorption. In turn, androgens have the function of stimulating bone formation.^{20,21} Central obesity in men causes loss of endocrine equilibrium reducing the level of testosterone and proteins binding it. The favorable effect of testosterone results in stronger lipolysis in the visceral fat tissue and reduces capture of lipids in the blood. A different character of obesity effect is observed in women where obesity is accompanied by a decrease in sex hormone binding proteins which leads to the increase of estradiol in blood.²¹ Therefore, in menopausal women that are overweight or have first-degree obesity, the fat tissue possessing protective properties against osteoporosis or related fractures seems to be advantageous. Moreover, it was shown that the loss of body mass during the menopausal period and a BMI below the norm leads to a decrease of BMC and BMD of the whole bone system and also a decrease the mechanical properties of bone.^{22,23}

Fat tissue and osteopenia with sarcopenia

Besides the positive effects of the increased content of the fat tissue and muscle mass, obesity can affect the bone tissue negatively. Osteosarcopenic obesity (OSO) is a description with discrimination of the bone tissue quality which was defined recently. This condition is characteristic of postmenopausal women where, with reduction of bone mineral density (BMD), there is an observed decrease in the muscle mass and strength with an increased content of body fat typical of obesity.²⁴ Unfortunately, when it is necessary to bear a larger body mass, muscle strength can be reduced. In this disease, there is observed a larger content of fat tissue which results in movement restrictions and difficulties with locomotive faculty thus enhancing the risk of falling down and fractures.²⁵ As follows from the investigations of

BMD of thigh and neck bone diminishes with fat tissue contribution exceeding 33% but in the case of BMD of lumbar vertebra it exceeds 38%.²⁶ Also, proinflammatory cytokines produced by fat tissue (above-mentioned IL-1, IL-6, TNF- α) affect OSO development as they intensify the bone loss process changing the architecture of the bone tissue and increasing risk of fracture.

Defined OSO allows to estimate fracture risk in people which so far has not taken into account overweight patients. It was believed that one reason that obesity could protect against fractures is due to the larger loading of the skeleton which could stimulate bone formation.²⁷ Despite this, Zhao et al. showed that increased body mass cooperates negatively with the quality of bone tissue after determination of bone stimulation effect through mechanical loading by means of dynamic tests.²⁸ In turn, another factor which suggests a positive effect of obesity is the fact that the fatty lining can act as a buffer against the force acting on the bone tissue during the fall thus protecting against fracture. Moreover, it was demonstrated in many papers that increased body mass and BMI correlate with increased BMD and BMC and that a drop in body mass results in deterioration of bone tissue structure contributing to a larger number of fractures in people with a very small body mass.^{29,30}

Fat tissue and osteoporosis

Numerous literature reports are contradictory with regards to the effect of fat tissue and/or muscle tissue content on the development of osteoporosis. Lau et al. showed that intensification of bone tissue resorption through an increase of bone turnover in postmenopausal women leads to BMD reduction and lower body fat.³¹ In turn, Christensen et al. showed that with the increase of fat tissue content in an organism, some fluctuation in the BMD and BMC is observed compared to control group patients.³² The changes in the bone tissue with age depends on several factors connected with the fact that when the peak bone mass (PBM) resorption processes is reached and prevails over bone formation in postmenopausal women, they are predisposed to the occurrence of osteoporosis.³³ An increased body mass at BMI above 25kg/m² in elderly people exerts osteoprotective activity persons of lower BMD value which was demonstrated by the studies of Zhao et al.²⁸ A different character of changes was presented by Greco et al., who found lower BMD values of thigh bones in overweight people compared to those with proper BMI values²¹ which indicates that increased body mass is not indifferent as regards bone tissue metabolism. Moreover, in women who are postmenopausal overweight, studies with pQCT showed higher values of volumetric BMD of the tibia and brachial bones compared to the women of the same age with the regular body mass.³⁴

Besides the percentage content of fat tissue, that of muscle tissue is more and more often taken into account in diagnostics of obesity and bone disorders. Low muscle mass near to or during the menopausal period is correlated with lower values of BMD and the positive effects of increased body mass in counteracting osteoporosis depends mainly on increased muscle mass but not the percentage content of the fat tissue.^{35,36} Larger body mass in the elderly contributes to a smaller risk of osteoporotic growth by the increase in the mechanical loading of bones. The gain in long bone resistance results from intensification of osteosynthesis processes and inhibition of osteoblast apoptosis which contributes directly to BMD value growth³⁷ which is contrary to the studies by Zhao et al. who showed an opposite dependence.²⁸

The positive influence of adiposity on bone tissue can also be a consequence of increased mechanical loading of the skeleton. Body mass is directly associated with bone mineral density and a low body mass index (BMI) is an important risk factor for lower BMD in aged patients. Lean mass and fat mass are both independent determinants of bone mass. In postmenopausal women, low muscle mass is associated with low BMD, and positive effects of a higher body mass on bone occurs only when it is primarily composed of lean mass. In conclusions, the quality of bone tissue depends on numerous factors. The level of growth hormones, cytokines, vitamins as well as calcium intake and calcium absorption play the main role in maintaining of bone mineral density (BMD) and content (BMC). However, the role of fat tissue in the physiology of bone is still under consideration and further studies are necessary.^{28,34-36}

Conclusions

Given the divergence in the literature with regards to the effect of fat tissue, it is difficult to state its explicit influence on the organism including the bone system. Both obesity and undernutrition, quality and quantity of consumed nutritional components as well as lipid economy can have a modulating effect on the bone parameters. During the diagnostic of bone distemper, individual fractions of fat tissue and their percentage contribution in the organism should be taken into account. Moreover, the proportions between the fatty and muscle tissues should be considered in diagnostic of OSO or osteoporosis as both fat mass and lean mass play a key role in the development of these osteoporotic diseases.

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