Literature Review
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Obesity and bone health: key 2020–2022 highlights and implications

Abstract

Sound bone health is crucial for life affirming activities, but is bone physiology impacted in the face of excess body weight? Since fractures and osteoporosis are on the rise, is obesity a risk factor for, as well as a possible negative albeit remediable correlate of bone health in the older adult? To examine this premise the PUBMED and GOOGLE SCHOLAR data bases were sourced for relevant data published between January 1 2020 and November 1 2022 in an effort to capture post COVID-19 possible research observations on the topic. These data bases show while a pervasive idea has been that obesity may be beneficial in some respects to bone mineral density attributes and impart fracture protection, several current publications tend to portray a negative impact of obesity on bone health via multiple proposed mechanisms. However, the research points to a strong need for continued research as well as clinical vigilance of vulnerable individuals both young and old in a period where obesity rates in all age groups appear to be on the rise, along with cases of bone fragility and osteoarthritis that can both foster high morbidity and mortality rates and possibly more challenging weight issues in the face of painful fractures or joint derangement.

Keywords: adiposity, bone, bone mineral density, fat cells, fractures, obesity, osteoporosis, prevention

Volume 12 Issue 5 - 2022

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Received: November 03, 2022 | **Published:** November 14, 2022

Background

Bone fractures, as well as diseases that affect bone such as osteoporosis and osteoarthritis, among others, are enormous challenges that prevail in most aging populations and that are associated with high morbidity and mortality rates[1,2] and frequently prevail in the presence of obesity, despite beliefs to the contrary.[3] Indeed, while excess weight may impact bone mineral density favorably, bone fractures and the multiple attributes of bone destruction may still be occurring silently in sizeable numbers of older adults as well as youth categorized as being obese. This unwanted and highly disabling health situation may be occurring according to some owing to the greater risk of an overweight person as far as the risk of acquiring one or more chronic health conditions, such as type 2 diabetes is concerned, along with chronic pain, depression, poor cardiovascular health, and possible resultant suboptimal motivation to exercise that may weaken their ability to protect their bones from excess mechanical forces as well as altering bone health metabolic status and physiology directly, with possible dire consequences.[4]

This situation, when viewed in both the short term and the long-term, and in the face of an increasingly older society, as well as a highly obese society, is thus not only likely to prove highly deleterious in multiple ways to the goal of attaining a healthy aging state for all in the United States and elsewhere in the future if obesity bone impacts are ignored or understated, but may have enormous life changing personal repercussions and social costs. Moreover, ignoring this topic in the belief having a large body size protects bone, rather than exposes it to damage, is also inconsistent with reality, and especially with cost containment themes being stressed by policy makers and others. Of specific concern is that efforts to mitigate obesity, not only often fail even if attempted, but may be attempted too late in the case of its impact on bone fragility for example. In addition, the myth that overweight older adults or youth are protected against fractures or bone loading alterations, rather than at risk for injury and resultant functional challenges, and are thus not routinely screened for their bone health status or questioned about their health behaviors such as calcium intake levels, may result in a lack of any effort to mitigate this possible substantive health impacting factor in this respect.

This current article focuses on examining what is being observed and concluded as regards the possible linkage of obesity to late life bone health status as well as in early life. It examines if a case can be made for arguing against blanket acceptance that obesity protects an older adult from sustaining one or more bone fractures, especially at the hip, along with possible bone micro fractures that underpin painful osteoarthritis. Since the risk factors for adult obesity of diet and physical activity are well studied, as is the link between obesity and cardiovascular diseases, this overview specifically elected to examine its association with bone health and any implications this might have for advancing healthy aging in light of the limited emphasis on this possible salient health threat. The time period 2020-2022 was chosen as the main focus, as it was felt this body of works may reflect some updated issues that have emerged in the post COVID-19 realm or that must be more carefully attended to than was previously acknowledged, for example if health services are delayed or unavailable, while selected COVID mobility restrictions may have jeopardized both weight as well as overall health status of many inadvertently.

In particular, this report investigates the recent evidence base broadly, rather than addressing any specific issue in order to raise awareness and broaden the possible opportunities for heightened preventive actions against obesity. Some pertinent literature that emerged prior to COVID-19 is presented if this points to having future research or clinical implications or both. The review does not examine some of the other leading causes of bone impairments in older or younger adults and does not examine studies in depth for their possible flaws or shortcomings. It was assumed that recent peer reviewed studies as housed in PUBMED, PubMed Central, and GOOGLE SCHOLAR data bases using the key words: *bone health and adiposity/obesity* would provide salient and valid points of interest as of January 2020-November 1, 2022. The term obesity was used to denote any degree of excess body weight that could prove injurious to both a younger as well as an older person. The term bone

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health referred to the ability of the skeleton to withstand stress, and provide for pain free functional independence and optimal mobility and stability functions.

Results

Among the numerous publications posted on bone these commonly show that under optimal health conditions, bone comprises an essential component of the skeleton, along with solid support for the body, while fostering mobility, and protecting vital organs. In terms of the specific theme of bone health and its association with obesity, a topic studied since at least 1945 with a total of 12, 312 related PUBMED publication listings, this topic is still of interest as indicated by the 2020-2022 set of 2731 listings as of January 2020-November 1, 2022 on this issue, albeit with diverse conclusions.

The reason for this appears to be that while it is agreed bone tissue houses important minerals and ions that can be released or stored in a controlled manner to provide constant concentrations in body fluids as required, bone is also a relatively dynamic organ that undergoes significant turnover compared to other organs in the body and is a tissue that may be affected negatively by multiple factors, and possibly by obesity. As well, obesity and osteoporosis, a disease that is associated with bone loss and fracture risk, are studied in particular quite frequently, because both common conditions are associated with high rates of morbidity and mortality, especially in older adults. There is also increasing evidence that the relationship between obesity and bone may not be as protective against fractures as previously believed,[5] because bone homeostasis in general may be altered in multiple ways that can impair bone integrity and bone remodeling.[6] It also appears that obesity in the form of visceral fat in particular, appears to harm bones even in the infant–juvenile phases of development, possibly raising the risk of incurring osteopenia/osteoporosis in adulthood as well as later life.[7]

Thus, even if it is accepted that the presence of any excess body weight can help to build bone, there are several pathways whereby excess weight can yet pose an unanticipated bone fracture or bone damage risk at all ages. This is due in part to a possible obesity associated array of adverse inflammatory impacts on bone genes and bone cell physiology, as well as having diverse negative metabolic influences,[8] for example in cases with type 2 diabetes who are obese.[9]

Piñar-Gutierrez et al.,[10] recount that the recent scientific evidence that has emerged and that shows an increased risk of fractures among patients with obesity who have an especially high degree of visceral adiposity must be seen to contradict the former belief that the obese patient is more protected against fractures than normal weight or underweight cases. One reason for this may be that muscles are commonly infiltrated by fat in those who are overweight and thus these persons may have less bone protection from muscle if they are perturbed and the faller fails to generate the necessary degree of well timed and sufficient muscle reflex responses designed to prevent this, along with age related muscle mass losses, in general. Moreover, those who also suffer from obesity associated multiple inflammatory responses, may show possible related impacts of a vitamin D deficiency, chronic repetitive joint injury that can cause osteopenia and enhanced bone resorption and bone loss.[11] In addition, it appears multiple obesogenic-associated metabolic disturbances not only impact bone homeostasis, but can affect bone quality detrimentally over time because the obese person may be less mobile or inclined to move than normal weight similar age individuals. They may thus exhibit various degrees of bone fragility, that progressively impact bone cellular processes as well as various body systems, as well as contributing to alterations in local bone homeostasis and systemic metabolism[7] and metabolic disorders,[12] especially if undetected.[13]

Hsu et al.,[14] found that the risks of an individual acquiring osteoporosis, osteopenia, or nonspine fractures was significantly higher for subjects with a higher percentage of body fat independent of body weight, physical activity, and age. As such it appeared that having a high fat mass could impose a negative effect on bone mass that is different from that of normal weight-bearing. Other research has revealed that even though rats appeared to show beneficial improvements in bone mineral density in response to the presence of excess body mass in an osteoporosis model,[15] Turcotte et al.,[16] confirmed obesity does appear to induce apparent beneficial increases in the bone mineral density of overweight human subjects, along with an enhancement of their bone micro architecture and bone strength. On the other hand, Lopez-Gomez et al.,[17] found postmenopausal women who were deemed obese tended to show lower levels of bone formation markers than those who were deemed to be of a healthy weight. In addition, other data indicate that bone quality in the obese case may not be sufficient to successfully avert a fragility fracture because other factors are involved.[16] For example, a role for low bone density in increasing fracture risk in obese children and adolescents cannot be discounted due the possible inflammatory impact of excess fat, along with a high risk of developing severe co-morbid health conditions, and possible neurodegenerative disruptions that play a role in bone health.[18] Bone as well as various body systems may also serve as a 'fat-depot' in this regard and may mediate a range of obesity associated low-grade inflammatory responses that may not only alter the expression of multiple life affirming cellular processes and molecules but those that affect bone metabolism directly, and that can result in its attrition.[19]

Fintini et al.,[18] recently highlighted the finding that excess adiposity in childhood may not only impact bone development adversely, with the possible later consequence of bone frailty, but may explain a number of prior reports indicating an increased rate of extremity fractures among children categorized as being in the obese range. At the same time, this unpredictable set of events occurs even though ample evidence suggests their bone mineral content is higher than that observed in their normal weight peers. One explanation here is that since adipocytes and bone cells known as osteoblasts are derived from the same stem cell source, the presence of obesity may foster more adipocyte differentiation than osteoblast differentiation. These increased numbers of bone adipocytes are found to release a number of pro-inflammatory and immunomodulatory molecules that up-regulate formation and activation of osteoclasts, a bone cell that removes excess bone, thus favoring bone fragility. As well, the persistent impact of excess body weight, while possibly favoring bone mineral increases, may yet exceed the overall mechanical threshold of the bone, especially in females[20] if other obesity associated health conditions prevail that heighten fracture risk.[20,21]

Rinonaploi et al.,[22] who recently reviewed this issue concluded that despite the fact that an increase in body weight may induce a higher than normal bone mineral density, the risk of sustaining a fracture is higher in the obese individual than predicted. This greater risk of fracture in the obese subject may involve an array of complex metabolic factors as well as an increased falls risk. As well, age and diabetes type 2 factors, having a lower than desirable vitamin D intake due to sedentary and nutritional practices, may confer an increased risk of non vertebral fractures among obese women with type 2 diabetes.[21]

A strictly weightbearing explanation for some fractures must however be ruled out, because as observed by Franchesci et al.,[23]

Citation: Marks R. Obesity and bone health: key 2020–2022 highlights and implications. *Adv Obes Weight Manag Control.* 2022;12(5):148–152.
DOI: 10.15406/aowmc.2022.12.00378

forearm fractures in children and adolescents are often associated with the presence of an increased body mass index, but this bone site is non-weight-bearing and results of 12 key studies showed overweight children typically had normal or increased volumetric levels of bone mineral density and an inconsistent finding of an associated higher fat-to-lean mass ratio, and findings bone size and bone strength were not lower than those of their normal weight peers. However, it was concluded that the local higher fat-to-lean mass ratio in the muscles of the forearm may yield a mismatch between the prevailing bone strength and the load experienced by the distal forearm during a fall, thus resulting in increased forearm fracture risk.

A 2017 review put forth the idea that has since been somewhat upheld. That is, mechanisms whereby obesity adversely affect bone health are quite complex and may include multiple factors, such as an alteration of bone-regulating hormones, inflammation, oxidative stress, and other biochemical factors that collectively affect bone cell metabolism.[24] As a result, it appears the positive impact of the presence of excess body weight on bone mineral density cannot necessarily counteract the multiple detrimental effects of obesity on bone quality,[25] especially among women and blacks[26] and adults with abdominal obesity.[27]

According to Rikkonen et al.,[28] the presence of obesity is associated with the earlier than expected rate of sustaining a hip fracture injury as well as a higher post fracture mortality rate. Those women who were obese and had a low bone mineral density appeared to have the highest risk of hip fracture if they were younger than 75 years of age, but this effect waned after that. However, patients with an excess body mass appeared to be at a higher risk of developing complications following a femoral fracture along with poorer clinical outcomes than those with a healthy body mass.[29] Some of these observations may stem from what is measured as well as how, plus observations that dynapenic abdominal obesity, denoting weak muscles, is related to a heightened risk for falling among older adults,[30] as is obesity assessed by body mass index and waist circumference in older Chinese cases who might sustain falls.[31] Importantly, if a fracture injury occurs, the presence of obesity tends to hamper repair[32] and may disrupt bone morphology via inflammatory and other mechanisms[33,34] as identified in a laboratory study by Stephen et al.,[35] and may be especially accentuated in those categorized as being morbidly obese.[36] As concluded by Crivelli et al.,[37] when these findings are viewed concurrently, they tend to suggest that both visceral and subcutaneous fat may be detrimental for bone health in pre- and postmenopausal women, and that severe obesity may increase the risk of vertebral fractures, even in young women.

Moreover, Copes et al.,[38] note that the belief that obesity confers protection against bone fractures may yet be challenged if other conditions affecting people with obesity, such as type 2 diabetes and chronic kidney disease that can cause bone loss, poor bone quality and increased risk of hip and spine fractures are overlooked. Unsurprisingly, given the parallel epidemics of obesity and diabetes, among others, Molina et al.,[39] noted that there appears to be an increasing number of obese patients presenting to orthopedic departments and that may represent alterations in two broad mechanisms: biomechanical and metabolic mechanisms that cause damage to both the bone itself and/or the surrounding soft tissue and its structures.

Gkastaris et al.,[2] conclude the interaction between obesity and bone metabolism even though complex and not fully understood to date must take note of the possible effects of obesity on skeletal strength that might be site-dependent and lead to bone fractures for mechanical reasons as well as possible increases in bone marrow adipogenesis,[40] as well as mechanisms attributable to subcutaneous fat, as might occur in metabolic diseases.[41] As per Palermo et al.,[40] in light of the exponentially growing obesity rate in recent years, its overall increase in youth since COVID-19 emerged, and the increased life expectancy of many older adults no matter where they reside, this topic is of major current import and warrants further study.

Discussion

Obesity, hip fractures and others, osteoarthritis, osteopenia, and osteoporosis have become major global health problems over the last decades and their prevalence in an aging society is increasing, rather than decreasing. The interaction between obesity and bone metabolism is thus of considerable interest and has been studied for many decades, but remains poorly understood and non conclusive. This mini review that attempted to examine current bone adiposity interactions that may be harmful was indeed very confusing. Even if research design variations are discounted, and the focus was only on recent articles, the current papers that were retrieved largely differ with respect to the extent obesity either builds bone mass or fosters bone attrition and fractures. For example Bland et al.,[42] in 2022 concluded that whereas the measure of total body adiposity, abdominal subcutaneous adipose tissue, and visceral adipose tissue were all significantly associated with bone mineral density in both men and women, the strength and direction of this association was not a given but dependent on the subjects sex, body mass index classification, and menopausal status (women).

Yet Chen et al.,[43] conclude that sarcopenic obesity, defined by visceral adiposity is associated with the risk of osteoporotic vertebral fracture. Moreover, low skeletal muscle index, low muscle strength and visceral adiposity are independently associated with osteoporotic fractures, whereas rather than having a muscular related explanation, perhaps excess weight asserts a mechanical signal that induces inflammatory responses that underpin joint fragility that lead to bone destruction.[44]

Luo et al.,[45] suggest that a larger waist circumference, but not body mass index may increase the fracture risk in men, but in women, neither measure affects the risk. Yet, they also found trunk fat mass, visceral adipose tissue mass, and limb fat mass were negatively associated with vertebral body bone mineral density and geometry and strength in men and women, but not necessarily fracture risk. Other research shows that obesity (and specifically, accumulated visceral fat) harms bones at least in the infant–juvenile phases of development, thereby possibly increasing the risk for osteopenia/osteoporosis in adults and the elderly in later life.[7] Moreover, even though historically, obesity was thought to be protective against osteoporosis, several studies have challenged this belief.[46] Indeed, several recent studies have begun to reveal an interactive role for mechanical, biochemical and hormonal mechanisms to explain the association between adipose tissue and its interaction with bone and that obesity impacts on mechanical loading may induce bone changes attributable to obesity associated with a low-grade systemic inflammatory presence that is probably harmful to the bone, at least in some cases. Finally, visceral abdominal fat may exert different actions to the bone compared with the subcutaneous fat, which needs to be studied further.[2]

Fintini et al.,[18] in discussing bone and the probable role of excess adiposity in childhood felt this may well affect bone development, and if unrelieved eventual bone frailty. Previous reports in support of this idea show an increased rate of extremity fractures in children with obesity. On the other hand, there is also contrasting evidence suggesting that bone mineral content is higher in obese children than in normal weight peers, thus other influences of obesity must be considered here, such as the finding that obesity drives the

differentiation of bone stem cells towards becoming adipocytes at the possible expense of osteoblast differentiation. Furthermore, these adipocytes in the bone marrow microenvironment are able to release a number of pro-inflammatory and immunomodulatory molecules that can up-regulate formation and activation of osteoclasts, thus favoring bone attrition and possible subsequent fragility. On the other hand, even if abdominal obesity raises the risk for a subsequent vertebral fracture after a primary fracture,[46] body adiposity represents a mechanical load, which is beneficial for bone accrual, but a role for diet, physical activity, and the hormonal milieu at puberty may play a pivotal role on bone development and maintenance as well as resistance to unexpected or excess joint loads. As well, according to Rinonapoli et al.,[22] metabolic factors and a possible increased risk of incurring falling may explain the presence of fractures among overweight youth and adults and in cases of sarcopenic obesity.

What the health status of the individual is may also impact what is observed. For example, in men, the combination of obesity and type 2 diabetes is associated with reduced bone turnover and poorer trabecular bone microarchitecture and bone strength compared to those who are obese but without type 2 diabetes, suggestive of worse bone disease.[47] Chain et al.,[48] further suggest that muscle strength losses or dynapenia, obesity, and their combination may affect bone density in a sex-dependent manner, in that the presence of dynapenia, and excess fat mass appears to exert a protective effect on bone density in women, but not in men. However, not all agree, and the obese subject can be found to have a have lower bone quality rather than a higher one, regardless of their obesity phenotype,[1] women who are in the normal weight range, but younger than post menopausal women may have low bone mineral density,[49] and although bone mineral density is found to be higher on average in obese young women, this may not be beneficial later in life in the face of any persistent vitamin D deficiency.[50]

Recommendations by Bialo et al.,[51] appear relevant here. These argue for improved efforts at early recognition and management of both underweight and overweight youth and the accompanying consequences on bone and mineral metabolism that are essential for the preservation of optimal skeletal health. Moreover, more attention to accepting that bone metabolism, bone turnover, and mineral content are altered in severe obesity[52] is indicated.[53] It also appears that while the skeleton can adapt to some degree relative to excess body weight, this does not preclude limits of this adaption to offset all mechanical loads imposed on the bone, especially in cases of extreme obesity.[54] To forge a better understanding of these possible clinically relevant body responses that may arise in the face of excess body weight, and prove detrimental rather than protective, but are currently non-conclusive, poorly understood, and somewhat disparate, carefully construed clinical studies that are prospective in nature, and that examine the bone impacts of varying categories of body weight in the realm of different age and health status groups as far as their possible implications for bone architecture, bone biology and biochemistry, as well as bone vascular and fat cell impacts are concerned are especially indicated. In addition, bone density attributes relative to body weight, a possible highly salient but overlooked bone health indicator in this regard surely warrants more careful study in its own right in diverse subject groups, and at different bone sites, as well as in the context of various health conditions associated with obesity, as well as in healthy controls across the lifespan.[55]

Conclusion

An updated overview of the bone obesity interactional research observations and implications leads us to conclude that an interactive negative role for obesity in mediating or moderating bone fracture risk, bone density, and bone integrity at all ages cannot be discounted.

It is further concluded that the parallel between diabetes, metabolic disease and bone, and a possible independent impact of excess weight on bone metabolism, as well as the ability to absorb load may explain the paradox of bone fractures in the face of obesity associated increases in bone density and should be studied further.

Acknowledgements

None.

Conflicts of interest

Author declared there is no conflict of interest.

Funding

None.

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Citation: Marks R. Obesity and bone health: key 2020–2022 highlights and implications. *Adv Obes Weight Manag Control.* 2022;12(5):148–152.
DOI: 10.15406/aowmc.2022.12.00378