Is prolonged sitting a risk factor for osteoporosis?

Alexandra Mavroeidi, *Senior Lecturer in Physical Activity for Health,* ***Lauren McMichan****, Teaching Fellow, University of Strathclyde, and* ***Dawn A Skelton****, Professor in Ageing and Health, Glasgow Caledonian University*

Introduction

In the UK, one in two women and one in five men over the age of 50 will experience an osteoporotic fragility fracture[1]. The combined lifetime risk for hip, forearm and vertebral fractures coming to clinical attention is around 40%, equivalent to the risk for cardiovascular disease[2]. Living with osteoporosis is challenging, with huge personal consequences for the individuals[3] and large economic consequences for the NHS[4]. Although some bone loss is a normal part of the ageing process, osteoporosis is not an inevitable disease of the old, with many risk factors for osteoporosis and osteoporotic fracture being modifiable[5]; immobility has long been recognised as such a risk factor. There is a plethora of studies investigating the beneficial effects of exercise/physical activity modalities and bone health; the majority of them concentrate on the high end of the physical activity continuum (i.e. the high intensity physical activity). For example, Stiles and colleagues[6] advocate that accumulating 1–2 min/day of high-intensity activity, equivalent to running in pre-menopausal women and slow jogging in post-menopausal women, would lead to improvements of bone health. However, in addition to this body of evidence, there is currently emerging data from the opposite end of the spectrum (inactivity/sedentary behaviour) to support the detrimental effects of such behaviours on bone. Everyday modern life lends itself for prolonged periods of immobility (such as long uninterrupted periods of sitting at work, transportation, leisure e.g. TV viewing). Data from cross-sectional and longitudinal studies suggest that such sedentary behaviours might have a detrimental effect on bone mineral density (BMD). There is also the suggestion that breaking up prolonged bouts of sedentary behaviour (by standing up) might also have beneficial effects on the skeleton but data on this are currently sparse.

Sedentary behaviour and health

Sedentary behaviour (SB), recently segregated from the term Physical Activity (PA), can be defined as 'any waking activity characterized by an energy expenditure ≤ 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture'[7]. High volumes of SB can be detrimental to health, after controlling for the role of moderate-vigorous physical activity (MVPA)[8,9]. Adults may meet the physical activity guidelines (of at least 150 minutes of MVPA per week[10]), but still be at risk due to their high levels of SB throughout the reminder of their day[9].

Adverse health consequences include higher risk of cardiovascular disease[11], diabetes mellitus[12], and reduced cognitive function[13]. The increasing evidence regarding the deleterious health effects of SB, led the UK's four Chief Medical Officers[10] (Figure 1) and the American Heart Association[14] making recommendations to reduce SB in addition to engaging in physical activity.

SBs are now ubiquitous in everyday life – during work (e.g. sitting in front of a computer), leisure (e.g. watching TV) and transportation (e.g. driving). National surveys reveal that adults spend on average 6-8 hours/day sitting increasing to 8-10 hours in older age[15,16].

Sedentary behaviour and bone health: proposed biological mechanism

It has been postulated that SBs might also have an adverse effect on bone health[17,18] and thus be a risk factor for osteoporosis. It has been hypothesised that regular and sustained SB exposure, leading to diminished postural variation, might affect bone physiology in a similar way to that observed in extreme cases of immobilisations (e.g. bed rest studies), but this remains to be tested.

The effect of complete immobilisation (e.g. total bed rest for 12 weeks) on bone metabolism is pretty severe and can lead to 3-5% decrease in bone mineral density, equivalent to about a decade of normal ageing bone loss[19,20]. The bone mass loss is mostly pronounced in the cortical section of the epiphyses[21]. At the metabolic level this seems to result from an imbalance of bone resorption and formation, described by a rapid increase in collagen breakdown products without any or with marginal changes in markers of bone formation.

In everyday life, long periods of immobility such as the ones seen in complete bed rest are rare; however modern lifestyles are increasingly leading to excessive exposure to long periods of time spent sitting. While not as extreme as bed rest, these SBs involve prolonged periods of unloading of the lower limbs and diminished postural variation.

Figure 1: Infographic of UK Chief Medical Officers' Physical Activity Guidelines 2019 including distinct section on sedentary behaviour

Evidence from cross-sectional and longitudinal studies

A number of studies mainly in children and adolescents have been conducted in this area and a recent systematic review explored the effects of SB on bone health in children, adolescents and young adults[22]. It was concluded that there is a negative association between SB and bone health in children in the lower extremities, and that one less hour of sedentary time mimics the positive effect of 18 minutes of moderate-vigorous physical activity (MVPA), however, these findings were based on a small number of studies.

In older adults, early cross sectional studies showed that the risk of osteoporotic fracture doubled in post-menopausal women who reported over 4 hours of daily sitting[23]. This could however have been explained by frailer women, who would be more likely to experience osteoporotic fracture, having a tendency to sit more. More recently, work with data from the NHANES study revealed that in a large representative sample of adult women (age range: 23-90 years), habitual sitting time was associated with lower femoral bone mineral density regardless of age, menopausal status and presence of other risk factors such as alcohol intake or smoking[18]. Remarkably, this association was still present in women who engaged in exercise and regular physical activity, with an effect size commensurate with that of tobacco consumption, suggesting that too much habitual sitting in daily life might be an important risk factor for bone health.

More recent findings by Rodriguez-Gomez et al. found that the associations between the movement patterns and BMD seem to be gender specific. When they analysed 871 older (mean age 76.8 ± 5.0 years) people's data from the Toledo Study in Healthy Aging, they found that there is positive effect of MVPA relative to other behaviours on bone mass in men. In women, however fracture risk was decreased through an increase in PA and a reduction in SB[24]. Increasing the number of breaks in SB was also positively associated with a higher BMD in both men and women.

A study by Onamele-Pearson et al. (2019) included 112 community dwelling OA aged between 57-89 years found that the number of breaks in SB was positively linked to a higher BMD at various sites in both men and women. The number of short duration SB breaks (≤5mins) in women appeared beneficial for BMD at sites such as ribs, upper and lower limbs. In men, MVPA appeared to have beneficial effects on BMD[25].

In addition to the above observational studies, some small studies have investigated the effects of regular standing on preventing bone loss that is pronounced in certain diseases and conditions. For example, one study showed that bone loss could be prevented after long term immobilisation due to spinal cord injury, with as little as 30 minutes of standing three times per week for 12 weeks[26]. More recently, a study of 44 community dwelling post-menopausal women aged ≥60 years old, found that reduced sedentary time and a great number of breaks in SB were significant predictors of osteopenia/osteoporosis at the femoral neck but not the lumbar spine[27]. A one-unit increase in daily sedentary time and a one unit increase in the number of daily breaks in SB decreased the odds of being classified as osteoporotic or osteopenic by 2% and 10% respectively.

Conclusion: future studies

To the best of the authors' knowledge, there are no large scale randomised controlled trial interventions in SB and bone health. The current cross-sectional evidence needs to be substantiated by controlled experimental data to ascertain how much prolonged sitting affects bone metabolism and the mechanisms likely to be involved. The Royal Osteoporosis Society is currently funding such a study, which is due to produce results to this effect in early 2020. This study aims to investigate the acute dynamics of bone metabolism during prolonged sitting, using data from controlled laboratory experiments. If this study identifies a significant effect of SB on bone metabolism then, as is now recommended in the case of type 2 diabetes[28], it may be that breaking up periods of prolonged sitting regularly could be a simple and cheap new lifestyle tool to prevent bone loss, particularly in older adults who are the most sedentary segment of society and have the highest prevalence of osteoporosis.

Key points:

1. Sedentary behaviour (SB) is any waking activity characterized by an energy expenditure ≤ 1.5 metabolic equivalents, while in a sitting, reclining, or lying posture. Examples include sitting in front of a computer, watching TV, and driving.
2. High volumes of SB can be detrimental to health (e.g. cardiovascular disease, diabetes mellitus).
3. It is possible that regular and sustained SB exposure, leading to diminished postural variation, might affect bone physiology in a similar way to that observed in extreme cases of immobilisations (e.g. bed rest studies).
4. Observational studies report negative associations between SB and bone health, but these appear to be gender specific and results are not unanimous.
5. More experimental data is required to ascertain how much prolonged sitting affects bone metabolism and the mechanisms likely to be involved.

Declaration of interest

The authors declare that there is no conflict of interest.

References

1. van Staa TP, Dennison EM, Leufkens HG, Cooper C. Epidemiology of fractures in England and Wales. *Bone*. 2001;29(6):517-22.
2. Kanis JA. Diagnosis of osteoporosis and assessment of fracture risk. *Lancet*. 2002;359(9321):1929-36.
3. National Osteoporosis Society. Life with Osteoporosis: the untold story. 2014.
4. Lawrence TM, White CT, Wenn R, Moran CG. The current hospital costs of treating hip fractures. *Injury*. 2005;36(1):88-91; discussion 2.
5. Abrahamsen B, Brask-Lindemann D, Rubin KH, Schwarz P. A review of lifestyle, smoking and other modifiable risk factors for osteoporotic fractures. *Bonekey Rep*. 2014;3:574.
6. Stiles VH, Metcalf BS, Knapp KM, Rowlands AV. A small amount of precisely measured high-intensity habitual physical activity predicts bone health in pre- and post-menopausal women in UK Biobank. *Int J Epidemiol*. 2017;46(6):1847-56.
7. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75.
8. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab*. 2010;35(6):725-40.
9. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-32.
10. Department of Health and Social Care. UK Chief Medical Officers' Physical Activity Guidelines. Edinburgh 2019.
11. Chrysant SG, Chrysant GS. The Cardiovascular Consequences of Excess Sitting Time. *J Clin Hypertens* (Greenwich). 2015;17(7):528-31.
12. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *Jama*. 2003;289(14):1785-91.
13. Falck RS, Davis JC, Liu-Ambrose T. What is the association between sedentary behaviour and cognitive function? A systematic review. *Br J Sports* Med. 2017;51(10):800-11.
14. Endorsed by The Obesity S, Young DR, Hivert MF, Alhassan S, Camhi SM, Ferguson JF, et al. Sedentary Behavior and Cardiovascular Morbidity and Mortality: A Science Advisory From the American Heart Association. *Circulation*. 2016;134(13):e262-79.
15. The Scottish Executive Department of Health. The Scottish Health Survey 2015: A National Statistics Publication for Scotland. 2015.
16. Harvey JA, Chastin SF, Skelton DA. How Sedentary are Older People? A Systematic Review of the Amount of Sedentary Behavior. *J Aging Phys Act*. 2015;23(3):471-87.
17. Chastin SF, Mandrichenko O, Skelton DA. The frequency of osteogenic activities and the pattern of intermittence between periods of physical activity and sedentary behaviour affects bone mineral content: the cross-sectional NHANES study. *BMC Public Health*. 2014;14(1):4.
18. Chastin SF, Mandrichenko O, Helbostadt JL, Skelton DA. Associations between objectively-measured sedentary behaviour and physical activity with bone mineral density in adults and older adults, the NHANES study. *Bone*. 2014;64:254-62.
19. O'Flaherty EJ. Modeling normal aging bone loss, with consideration of bone loss in osteoporosis. *Toxicol Sci*. 2000;55(1):171-88.
20. LeBlanc AD, Spector ER, Evans HJ, Sibonga JD. Skeletal responses to space flight and the bed rest analog: a review. *J Musculoskelet Neuronal Interact*. 2007;7(1):33-47.
21. Rittweger J, Simunic B, Bilancio G, De Santo NG, Cirillo M, Biolo G, et al. Bone loss in the lower leg during 35 days of bed rest is predominantly from the cortical compartment. *Bone*. 2009;44(4):612-8.
22. Koedijk JB, van Rijswijk J, Oranje WA, van den Bergh JP, Bours SP, Savelberg HH, et al. Sedentary behaviour and bone health in children, adolescents and young adults: a systematic review. *Osteoporos Int*. 2017;28(9):2507-19.
23. Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, et al. Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. *N Engl J Med*. 1995;332(12):767-73.
24. Rodriguez-Gomez I, Manas A, Losa-Reyna J, Rodriguez-Manas L, Chastin SFM, Alegre LM, et al. Associations between sedentary time, physical activity and bone health among older people using compositional data analysis. *PLoS One*. 2018;13(10):e0206013.
25. Onambele-Pearson G, Wullems J, Doody C, Ryan D, Morse C, Degens H. Influence of Habitual Physical Behavior - Sleeping, Sedentarism, Physical Activity - On Bone Health in Community-Dwelling Older People. *Front Physiol*. 2019;10:408.
26. Ben M, Harvey L, Denis S, Glinsky J, Goehl G, Chee S, et al. Does 12 weeks of regular standing prevent loss of ankle mobility and bone mineral density in people with recent spinal cord injuries? *Aust J Physiother*. 2005;51(4):251-6.
27. Braun SI, Kim Y, Jetton AE, Kang M, Morgan DW. Sedentary Behavior, Physical Activity, and Bone Health in Postmenopausal Women. *J Aging Phys Act*. 2017;25(2):173-81.
28. Colberg SR, Sigal RJ, Yardley JE, Riddell MC, Dunstan DW, Dempsey PC, et al. Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care*. 2016;39(11):2065-79.