



Bone Adaptation in Adult Women Is Related to Loading Dose: A 12-Month Randomized Controlled Trial

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ABSTRACT

Although strong evidence exists that certain activities can increase bone density and structure in people, it is unclear what specific mechanical factors govern the response. This is important because understanding the effect of mechanical signals on bone could contribute to more effective rehabilitation prevention methods and efficient clinical trial design. The degree to which strain rate and magnitude govern bone adaptation in humans has never been prospectively tested. Here, we studied the effects of a voluntary upper extremity computer loading task in healthy adult women during a 12-month prospective period. A total of 162 women (age 21 to 60 years) participated in one of four experiments (2 low ($n = 24$) and high ($n = 24$) strain magnitudes or 20 low ($n = 20$) and high ($n = 20$) strain rate). Control ($n = 18$) no intervention. Strains were captured using subject-specific finite element models. Total cyclic work recorded digitally. The primary outcome was change in areal bone mineral density (aBMD) measured with DXA. Secondary outcomes were assessed with high-resolution pQCT (HR-pQCT) at the distal radius. Daily- to participants completed the intervention, and interim data were analyzed for 77 participants. Daily-related to improved connectivity and higher recorded loading dose, both the low strain rate and high strain rate groups had significant 12-month increases in areal bone mineral density (aBMD) change in control ($+0.3 \pm 1.7\%$, low strain rate; $2.7 \pm 2.1\%$, high strain rate; $3.4 \pm 1.7\%$, high strain rate) and other measures. Loading dose was significantly associated to 12-month change in areal bone mineral density (aBMD), cortical thickness, and mean radius size (HR-pQCT). Participants who generated most bone completed, on average, 1.88 loading hours of mean strain $175 \mu\epsilon$ at 1470 g/s. We conclude that signals related to strain magnitude, rate, and number of loading loads contribute to bone adaptation in healthy adult women, but only require a small amount of volume to induce changes. © 2020 The Authors. Journal of Bone and Mineral Research published by Wiley-Liss, Inc. for American Society for Bone and Mineral Research.

KEY WORDS: computer; bone structure; and mechanical dose; pQCT; clinical; trials; exercise

Introduction

Exercise-based interventions have long been considered a viable option for preventing and enhancing bone strength^{1,2} because bone adapts to load made to habitual mechanical loading environments. Individuals who play sports and lead very active lifestyles, off-site health, and, in turn, results have been observed to have better bone mechanical properties than those who do not.^{3,4} Clinical trials have shown that high impact activities such as jumping and hopping can improve bone density in

young children^{5,6} and young adults^{7,8} and maintain bone density in older adults.^{9,10} However, although the evidence is strong that certain activities can increase bone density and structure in some individuals, it is not clear what specific mechanical factors govern the response. Furthermore, these factors interact with individual physiology to create a variable response, which is not well understood.

Based on this loading model, demonstrated that mechanical signals related to strain rate^{11,12} and magnitude^{13,14} regulate bone adaptation. There is no consensus on which specific

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Additional Supporting Information may be found in the online version of this article.

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