EXERCISE-INDUCED STRAIN MAGNITUDE AND STRAIN RATE ARE ASSOCIATED WITH CHANGES IN BONE DENSITY

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Physical loading inducing high strains at high strain rates has been suggested to be the most effective type of activity for improving bone strength. However, since there have been no quantitative dose-response exercise studies, the optimal amount and type of loading have not been established yet. Accelerations during exercise are related to impact load forces. Thus, it is suggested that peak accelerations are associated with peak strains, and acceleration slopes with strain rates. The aim of the study was to evaluate how exercise-induced strain magnitudes and strain rates are associated with bone density changes, using long-term accelerometer-based quantification of physical activity. Daily physical activity was continuously assessed with a waist-worn accelerometer-based body movement recorder (Newtest, Finland) in 64 premenopausal women participating in a 12-month population-based exercise trial (1). We recorded the vertical acceleration peaks and analyzed their numbers at different acceleration magnitude and slope levels to describe the intensity of exercise. The daily physical activity was analyzed at five peak acceleration levels (0.3-1.0g, 1.1-2.4g, 2.5-3.8g, 3.9-5.3g, and 5.4-9.2g) and at five acceleration slope levels (0-499, 500-999, 1000-1499, 1500-1999, and \( \geq \)2000 m/s\(^3\)). Bone mineral density (BMD) was measured at the hip and spine (L1-L4) with dual energy x-ray absorptiometry. The calcaneus was measured using quantitative ultrasound (QUS). Pearson’s correlation coefficients were calculated between the relative daily numbers of impacts at different acceleration magnitude and slope levels, and 12-month percentage changes in BMD and QUS. This procedure was used to study the effect of different activity characteristics on bone. Physical activity that induced acceleration levels exceeding 3.9g was positively associated with the BMD change in the hip area (p<0.05). L1 BMD change correlated positively with activity exceeding 5.4g (p<0.05) and calcaneal speed of sound with the level of 1.1-2.4g (p<0.05). Physical activity inducing acceleration slopes higher than 1000 m/s\(^3\) was positively correlated with the BMD changes at the hip (p<0.05). Impacts with small slopes (<1000 m/s\(^3\)) were positively associated with changes in calcaneal speed of ultrasound, while impacts with high slopes \( \geq \)1500 m/s\(^3\) were positively correlated with broadband ultrasound attenuation changes (p<0.05). We conclude that strain and strain rate, estimated as the acceleration magnitude and slope of exercise-induced impacts, are equally important determinants of bone density change. The thresholds for improving hip BMD are about 4g and 1000 m/s\(^3\), respectively. Effective loading can be reached during normal physical training in healthy premenopausal women.

(1) Vainionpää et al. (2006) Osteoporos Int 17:455-463