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The effects of frequency-dependent dynamic muscle stimulation on inhibition of trabecular bone loss in a disuse model

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Abstract

Clinical electrical muscle stimulation has been shown to alleviate muscle atrophy resulting from functional disuse, yet little is known about its effect on the skeleton. The objective of this study is to evaluate the potential of dynamic muscle stimulation on disused trabecular bone, and to investigate the importance of optimized stimulation frequency in the loading regimen. Fifty-six skeletally mature Sprague–Dawley rats were divided into seven groups for the 4-week experiment: baseline control, age-matched control, hindlimb suspended (HLS), and HLS with muscle stimulation at 1 Hz, 20 Hz, 50 Hz, and 100 Hz. Muscle stimulation was carried out for 10 min per day for 5 days per week, total of 4 weeks. The metaphyseal and epiphyseal trabecular regions of the distal femurs were analyzed with microcomputed tomography and histomorphometry methods. HLS alone for 4-week resulted in a significant amount of trabecular bone loss and structural deterioration. Muscle contraction at 1 Hz was not sufficient to inhibit trabecular bone loss and resulted in similar amount of loss to that of HLS alone. Bone quantity and structure were significantly improved by applying muscle stimulation at mid-frequency (20 Hz and 50 Hz). Dynamic stimulation at 50 Hz demonstrated the greatest preventive effect on the skeleton against functional disused alone animals (up to + 147% in bone volume fraction,

+ 38% in trabecular number and − 36% in trabecular separation). Histomorphometric analysis showed that the stimulation, regardless of its frequency, did not have an effect on the bone formation indices, such as mineral apposition rate and bone formation rate. Overall, the data demonstrated the potentials of frequency-dependent dynamic muscle contraction in regulating skeletal adaptive responses under disuse conditions. Dynamic muscle stimulation, with a specific regimen, may be beneficial to future orthopedic research in developing a countermeasure for disuse osteopenia and osteoporosis.

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Keywords

Electrical muscle stimulation; Bone fluid flow; Loading frequency; Bone adaptation; Functional disuse; Osteopenia; Skeletal adaptation

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