

EFFECTS OF FREQUENCY AND AMPLITUDE ON OSTEOBLAST-LIKE CELL VIABILITY AND METABOLISM UNDER VIBRATIONAL LOADING

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ABSTRACT

Abstract: Whole-body vibration (WBV) is a recognized occupational hazard contributing to soft tissue and skeletal injuries, particularly in professions involving heavy machinery or off-road transport. While the impact of WBV on soft tissue has been previously explored, less is known about its effects on bone cells at the microscopic level. This study investigates the cellular response to vibration in SAOS-2 human osteosarcoma cells, a model for osteoblastic activity, using in vitro assays to identify potentially harmful vibration parameters. Cells were subjected to four vibration conditions varying in frequency (10 Hz and 90 Hz) and amplitude (0.5 and 1.5 times the force of gravity). Cell viability was assessed using Trypan Blue staining for membrane integrity and the XTT assay for mitochondrial metabolic activity. Results revealed that 90 Hz at 0.5g significantly increased metabolic activity compared to controls, suggesting a potentially stimulatory effect. In contrast, 10 Hz at 1.5g resulted in the most severe reduction in both viability and metabolic function, indicating detrimental effects likely due to resonance-related mechanical stress. Intermediate conditions produced moderate responses. These findings underscore the frequency- and magnitude-dependent nature of WBV effects on osteoblastic cells and emphasize the importance of tailoring occupational exposure limits and therapeutic vibration protocols. The study highlights the need for further investigation into cellular-level mechanisms and long-term responses to vibration, potentially through computational modeling or molecular pathway analysis.

Keywords: whole body vibration, osteoblasts, cell viability, in vitro, spine health, vibration therapy

INTRODUCTION

Whole-body vibration (WBV) exposure is a common occupational hazard and has been directly linked to both soft tissue and skeletal injuries [1]. Individuals regularly operating heavy machinery, off-road vehicles, or aircraft, such as military personnel, farmers, and construction workers, are at increased risk of WBV-related injury [2], [3]. Spine-related injuries are among the most prevalent outcomes of WBV exposure, contributing significantly to lower back pain that impacts individual well-being and workplace productivity, affecting both employees and employers [4], [5].

Previous investigations have examined the effects of vibrational forces on soft tissue cell models. However, the impact of WBV on skeletal tissue, especially the spine's delicate vertebral structures, is less well understood. Repeated vibrational exposure can compromise vertebral integrity and endplate structure [6], [7], [8]. Damage to these areas risks exposing intervertebral disks to blood due to disruption of the highly vascularized lamellar bone, which may trigger chondrocyte apoptosis [9]. Exposure of chondrocytes to vascular components has been linked to calcification of intervertebral disks, a key contributor to spinal pain and degeneration [10], [11], [12]. Calcification of intervertebral disks not only increases the risk of spinal cord injury but also diminishes mobility and long-term musculoskeletal health.