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研究成果報告書

研究課題名

血中骨代謝マーカー変動予測に基づく骨量減少予防の個別化予測医療の実現

Realizing Personalized Predictive Medicine for Preventing Bone Loss Based on Predictions of Blood Bone Metabolism Marker Dynamics

研究期間

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Abstract

This study adopts a comprehensive approach that integrates mathematical modeling, experimental biology, and data analysis to advance the prevention and treatment of osteoporosis. The goal is to gain new insights into predicting and addressing bone loss.

First, a mathematical model was developed to describe the integrated dynamics of bone turnover markers and temporal changes in bone mass. Using detailed time-series data obtained from healthy mice and immobilization-induced osteoporosis model mice, the mechanisms underlying bone loss were elucidated. This analysis revealed that reduced mechanical stress increases RANKL production from osteocytes while decreasing the production of osteocalcin and P1NP, contributing to bone loss. Furthermore, new biomarkers indicative of bone mass and physical inactivity were identified, laying the foundation for improved prediction accuracy of osteoporosis tailored to individual physical conditions.

Next, research was conducted to develop exercise programs aimed at maintaining bone mass. Through experiments using mice and integrated analyses with human data, the daily exercise requirements to suppress bone loss were quantified. For healthy adults, a target of 8,000 steps per day was proposed, while 5,000 steps per day were suggested for healthy older individuals. These findings are expected to significantly contribute to the design of osteoporosis prevention strategies through exercise interventions.

Additionally, efforts were made toward developing bone formation-promoting drugs. Gene expression analyses using immobilization-induced model mice identified abnormalities in the cell cycle and mitochondrial dysfunction in osteocytes as key factors driving bone loss. Administration of the diabetes drug imeglimin, which improves mitochondrial function, successfully prevented bone loss caused by inactivity in mice, suggesting the potential for a novel osteoporosis treatment.

Building on these results, future efforts will focus on incorporating the findings on exercise requirements for mitigating bone loss into various domestic and international guidelines and public health policies. The validity of the newly identified biomarkers will be further tested to develop bone mass and inactivity assessment technologies that are simple to use in clinical settings. Simultaneously, leveraging data-driven approaches, this research will advance mathematical models and machine learning tools to explore applications in personalized medicine and preventive healthcare.