Introduction

Bone has a natural tendency to adapt to mechanical loading. The type of loading that bone is most receptive to is dynamic. Depending on the magnitude and duration of the load applied to the bone, modifications in its structure occur. Bone mineral content, bone mineral density and bone structure all contribute to bone’s overall strength in witholding the load without failure. A thermostat mechanism controls this phenomenon within the bone structure. Numerous sensors, which detect interstitial fluid flow over the lacunar – canalicular porosity in bone, either send a signal to build bone or to remove it. The major sensors within the bone are the osteocytes. When loading on the bone surpasses 1000 microstrains osteocytes give signal to osteoblasts, cells responsible for bone formation, to build new bone. Conversely, if the loading on the bone falls under 200 microstrains, osteocytes send a signal to osteoclasts to remove bone. If the loading on the bones is between 200 and 1000 microstrains, equilibrium occurs, where no bone is made or removed. As a reference, most bones fracture at 25,000 microstrains. Under normal conditions this thermostat regulates overall bone strength and structure.

Estrogen is responsible for maintaining proper homeostasis of bone mineral content and bone mineral density, which controls bone’s strength. Under this homeostasis bone formation equals bone removal. No mineral content is lost, without it being replaced. Thus, bone remains strong

Biomechanics/ Mechanisms/Explanation

Estrogen has a tendency to lower the strain threshold, under which bone is made. Thus, lower loading yields bone formation. In addition to this function, estrogen increases the mechanosensitivity of bone to mechanical strain. As research shows, osteocytes tend to detect strain better within the environment where estrogen is present. Under lower estrogen levels, mechanosensitivity of bone decreases, bone mineral content is decreased, consequently bone decreases in strength.

This decreased level of estrogen and its subsequent effect on the bones is evident in women who undergo menopause. This state of low estrogen levels and inevitable weakening of the bone leads to osteoporosis, a brittle bone disease. Osteoporosis causes bone to be less stiff and tough. Ultimate strength is reduced, yield strength is also compromised. In combination these factors decrease the tolerance of the load, and thus, injuries occur.

Application

Decreased estrogen levels and reduced mechanosensitivity should be considered when writing exercise prescription to pre – menopausal women and post – menopausal women experiencing symptoms or have osteoporosis already. Since bones respond well to dynamic loading, it should be implemented as much as possible into their daily lives. Since there is a limit to how much bones can respond to a single bout of exercise, significant consideration should go into prescription of exercise and the mode. Short, frequent bouts of dynamic exercise tend to be the best for of exercise when the goal is to build bone. Since estrogen levels have a significant effect on bone formation, bone should be acquired at the time when estrogen levels are more abundant in females – the pre menarche period. At that time, research shows that bones are most receptive. Building bone at an early level will later on in life offset osteoporosis. Thus, school based programs should be administered to battle osteoporosis at a later part of a woman’s life.
Summary

Sensing mechanical strain is a part of thermostatic mechanism of bone mineral regulation. Mechanosensitivity of bone cells is directly proportional to the estrogen levels in the system. As estrogen levels decrease, as in women who experience menopause, mechanosensitivity decreases proportionally. With diminishing levels of estrogen and mechanosensitivity, there is a rise in the strain threshold. The set point of the thermostat is raised higher. In addition to the increased strain threshold, decreased level of estrogen increases osteoclastic activity, thus, removal of bone is greater than the formation of bone – thus causing bone loss. Decreased in bone mineral content and bone mineral density decreases bone’s ability to respond normally to loading. The tolerance is decreases, thus, injury is likely to occur at loads of smaller magnitude. This decrease of estrogen puts post – menopausal women in high risk of developing osteoporosis. Knowing this, preventive action must be administered early on in life before estrogen levels decrease, as in menopause. Young women, pre- menopausal women and post menopausal women should be encouraged to participate in dynamic exercise programs to facilitate bone formation, consequently deter osteoporosis.

References