MUSCULOSKELETAL OUTCOMES FROM CHRONIC HIGH-SPEED HIGH-IMPACT RESISTANCE EXERCISE

OR

WE HAVE A DEXA SCANNER AND SOME COLLEGE STUDENTS. LET'S COMBINE THEM AND SEE WHAT HAPPENS.

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L Bai, EA Selimovic, TB Symons, Daunis M, Bayers T, LJ Vargas
Problem addressed
Solution proposed
Results
Conclusions and further studies
PROBLEM ADDRESSED

There are four steps in this pathway that can be targeted:
- Osteoid progenitor cells
- Osteoclast inhibition (bisphosphonates, RANKL inhibitors)
- Osteoblast formation (recombinant PTH given in a burst)
- Osteocyte differentiation (surgical intervention)
1. Peptide-bound crosslinks (N-terminal or C-terminal products of collagen degradation, ICTP)
2. Pyridinium crosslinks (pyridinoline, deoxypyridinoline)
3. Hydroxyproline
4. Calcium
During a repetition, muscles spend more time in eccentric action (lengthening) than concentric action.

In a standard eccentric action (springing back), energy is lost as heat proportional to how fast the muscle "jumps back". This means that total work imparted to the muscle can be controlled by adjusting the time a muscle is lengthening.
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**Legend:**
- ISS Required
- SS Required
- Milestone Requires SS
- SS Mission Milestone
- ISS Mission Milestone
- Anticipated Milestone Shift
- High Likelihood
- Low Likelihood
- Seasonal Milestone
- Mission Milestone
- COTS
- Ground-based Milestone
- High Likelihood by Consequence
- Low Likelihood by Consequence
- Optimized
- Inadequate Data

**End ISS**

**HRP CB-Approved**

7/28/2016

PP0219 baseline
SOLUTION PROPOSED: OPTIMIZED INERTIAL EXERCISE

ARED requires 100 watts of continuous and 200 watts peak maximum power. The Load Range is 10-600 lbs on Bar and 5-150 lbs on Cable; stroke Range – 0-30 inches on bar and 0-52 inches on cable. Lift bar must accommodate hand spacing up to 51 inches; platform must accommodate foot spacing up to 47 inches. Able to deliver constant load within 10% over entire stroke and load range; eccentric load must be at least 90% concentric load for load 50-600 lbs; eccentric load must be at least 80% concentric load for load 10-50 lbs.
• Our objective examines musculoskeletal adaptations to chronic exercise done on the Inertial Exercise Trainer (Impulse Technologies; Newnan GA), a novel strength-training device that permits high-speed high-impact repetitions.

• We hypothesize a chronic training program on the Inertial Exercise Trainer will yield significant changes to dependent variables related to musculoskeletal physiology and performance.

• This gravity-independent device uses inertial exercise to artificially lengthen the amount of eccentric time as well as cause “microfractures” to bone.

• The machine can autoregulate its safety: if a participant cannot handle a certain load or speed, the machine will not operate well.
METHODS

Our sample was based on a power analysis conducted prior to data collection. Ten subjects would offer > 90% power to detect a 15% change from our training sessions with a two-factor repeated-measures design with leg and time as within-subjects factors. Thus our sample (n = 13) meets these power and change thresholds for our PT and TTPT analyses.

13 healthy subjects completed 30 workouts on the Inertial Exercise Trainer that targeted the lower-body weight-bearing musculoskeleton.

Only a subject’s left leg performed the workouts; their right leg served as untreated controls.

Before and after the workouts subjects underwent:

- Isokinetic strength testing of the knee & ankle extensors of both legs
- Lower body DEXA scans targeting the hip, knee & ankle regions of both legs
- Blood draws to assess changes in bone-specific alkaline phosphatase & C-terminal telopeptides of type I collagen

Subjects averaged ~3 workouts per week. They completed their workouts in ~10 weeks.

Workouts entailed a bilateral 5-minute warm-up on a cycle ergometer, followed by three 60-second sets each of the knee extension, hip extension & ankle extension exercises. They were done with 3.4 kg of added resistance to the weight sled, which was unchanged across the ~10 week training intervention.

Subjects provided three 3-day food logs coinciding with completion of their 10\(^{th}\), 20\(^{th}\) & 28\(^{th}\) workouts. Food logs were used to quantify kilocalorie, protein & Ca\(^{++}\) intakes.
RESULTS: TOTAL WORK AND PEAK FORCE

Total work: How much work is transferred to the muscle

Peak force: How much force is transferred to the bone
• 2 x 2 ANCOVAs, w/ repeated measures on both IV & scan area as a covariate, showed calcaneal BMD & BMC significantly increased from Inertial Exercise Training

• T-tests revealed Inertial Exercise Training led to a significant decline in type I collagen C-terminal telopeptides, a marker of bone resorption
The high-speed high-impact repetitions common to our study likely evoked high tensile & compressive forces in muscles & bones respectively.

High-speed high-impact workouts led to two-way interactions for several peak torque measurements, in which strength increased in the left, but not the right, legs of our subjects.

Devoid of significant changes in dietary Ca$^{+2}$ intake, current increases in left calcaneal BMD & BMC values may be the result of significant declines in C-terminal telopeptide values, a marker of bone resorption.

The Inertial Exercise Trainer impart resistance to users without the typical requirement of gravity. Thus this exercise device/technology has promise as in-flight countermeasures hardware to ameliorate the losses incurred by the lower-body weight-bearing musculoskeleton.
FURTHER STUDIES

- **Ground based** – Persistence, strength of bone, and use in osteoporosis. Long term retention of bone mass is key.

- **Flight based** – Logistics and direct observation in an osteoblast-inhibiting environment.

- **Earth applications** – osteoporosis, debility, physical therapy, athletics