AN IMPROVED EXERCISE COUNTERMEASURE TO PROVIDE ENHANCED VERTICAL IMPACT LOADS IN LOW GRAVITY

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INTRODUCTION

Chronic exposure to microgravity causes a variety of physiological changes within the human body. The loss of bone mineral is one change that adversely affects the bio-mechanical integrity of the musculoskeletal system. To successfully accomplish long-term human space exploration, an effective countermeasure must be devised to minimize this effect (Baldwin, *et al*., 1996). We investigated the use of applied horizontal aiding forces (AHF) as a possible countermeasure against bone mineral loss.

Impact loading rates of bone from normal daily activity is correlated with the retention of bone mineral density (Cavanagh, *et al*., 1992; Lanyon and Rubin, 1984). Current countermeasures use elastic cords to apply a downward force to the shoulders and hips of a running astronaut to simulate Earth-like forces. This method, however, causes discomfort due to the high downward forces (McCrory, *et al*., 1996) and results in unsatisfactory forces generated against the ground (Boda, *et al*., 1998).

We previously saw that externally-applied, horizontal aiding forces caused vertical impact peaks generated against the ground to increase when running at Earth's gravity (Chang & Kram, 1999). We hypothesized that impact forces generated against the ground during running would increase with AHF even at simulated reduced gravity.

PROCEDURES

Four male subjects (27 ± 7 yr., 69.6 ± 8.3 kg, mean ± SD) gave their informed consent to run normally at 3 m/s on a force-measuring treadmill (Kram, *et al*., 1998) and at simulated gravity levels of 0.25, 0.38, and 0.50G (where G is 9.81 m/s^2). We simulated reduced gravity by pulling up on the subject's torso via a harness attached to a series of stretched latex springs. Applied horizontal aiding forces (AHF) were produced in a similar manner via a belt worn about the waist (Chang & Kram, 1999). For each gravity level, an AHF of 0%, 10%, 15%, and 20% of the gravity-specific body weight was applied. The order of trials at each gravity level was randomized. Vertical ground reaction force data were sampled at 1kHz and low-pass filtered (100 Hz cutoff).

We compared the vertical impact peaks generated on the ground at each condition to those for running at 1G with no AHF (control). We used a repeated measures ANOVA with a criteria of $p < 0.05$ and Tukey's HSD post-hoc test to compare across conditions. Impact peaks were deemed "desirable" if they met or exceeded impact peaks measured for normal running at 1G.

RESULTS AND DISCUSSION

Running normally at 1G, subjects generated impact peaks of 1.6x body weight at 1G (BW). Impact peaks increased with AHF at each gravity level (Fig. 1). With a 20% AHF, subjects produced desirable impact peaks at all gravity levels. At 20% AHF, impact peaks were 2.2x BW at 0.50G (a 32% increase above the 1G control). Impact peaks increased with gravity for each level of AHF (Fig.1).

Vertical impact force peaks generated on the ground during running increased with horizontal aiding forces and, with sufficient AHF, actually surpassed those experienced normally at 1G.

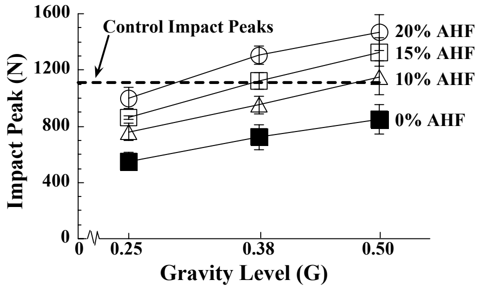

Figure 1: Vertical force impact peaks for different AHF at each gravity level. Dashed line indicates mean impact peak at 1G with no AHF (control). Data are mean ± SE.

Although the actively generated peak forces decreased with gravity (A), passive impact peaks (I) were highly sensitive to AHF and increased with AHF despite decreases in the active vertical force peak (Fig.2).

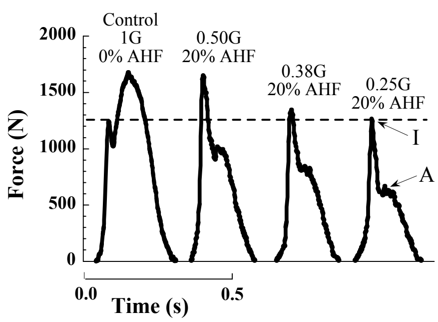

Figure 2: Typical vertical ground reaction forces at four gravity levels. Dashed line indicates impact peak for control condition. I is passive impact peak; A is active peak.

Our previous research has shown that both vertical and horizontal components of the forces generated on the ground during running are tightly coupled (Chang, *et al*., 1998). When one component of force is altered, people adjust their gait such that the other component changes in proportion.

Adding horizontal aiding forces to proposed exercise countermeasures (i.e. motorized treadmill running with simulated partial gravity) would improve impact loading on the musculoskeletal system. This technique would likely be a more effective countermeasure against the bone mineral loss from chronic exposure to weightlessness. This method can provide desirable impact loads and can do so at a much lower partial gravity level, which may provide a more comfortable alternative to currently used countermeasures.

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