THEORETICAL ANALYSIS OF IMPACT LOADS INDUCED WITH A NOVEL EXERCISE DEVICE

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INTRODUCTION

In a weightless environment, astronauts bear little or no weight on their legs and as a consequence, (i) major muscle groups experience atrophy and (ii) regions such as the calcaneus, hip and lumbar vertebrae lose up to 20% bone mineral density during long-duration missions. The benefits of exercising the cardiovascular and musculoskeletal systems are widely accepted on Earth. Such studies have also indicated that a relatively small number of appropriate weight-loading cycles may be sufficient to stimulate bone deposition.

A key factor that must be taken into account when designing exercise devices for astronauts is the size and mass of the device. For a potential manned mission to Mars, a small exercise machine is essential, due to the need for room for other supplies.

METHODS

For this study, a dynamic analysis of an exercise device was performed in Matlab. The device itself (Figure 1) was one that met the following criteria:

- It had to be small enough to fit in an area of one half of a mid-deck locker (43.2 cm x 30 cm x 20 cm).
- It had to provide both resistive and dynamic forces.
- No force could be imparted to the actual space craft.

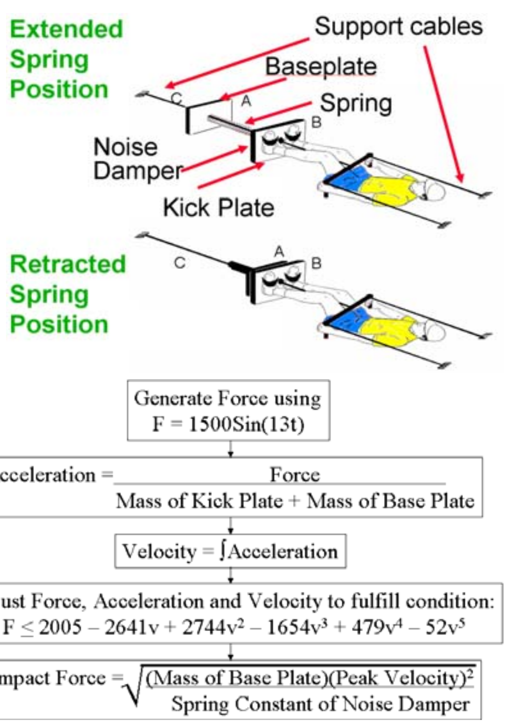

Figure 1. Schematic representation of the exercise concept (top) and the process for determining impact forces (bottom)

RESULTS AND DISCUSSION

The model used to predict forces under the feet was initially based on a spring-mass system. However, in this kind of model, it is theoretically possible to get non-physiological leg velocities and pushoff forces. For this reason, the applied force model was modified to obey the force vs. leg extension speed described by Vandenvoort (1984) which requires that , for a foot velocity "v", the applied force must be less than or equal to $2005 - 2641v + 2744v^2 - 1654v^3 + 479v^4 - 52v^5$. Peak applied forces of 1500 N and a push-off duration of 0.4 seconds were based on work done by Vrikotte (1991) who collected data for subjects jumping in 1G and in simulated zero-gravity.

This study showed that with a total applied force of 1500 N, the proposed exercise device would have an impact force of approximately 2500 N under each foot. The mass of the base plate had little effect (Figure 2).

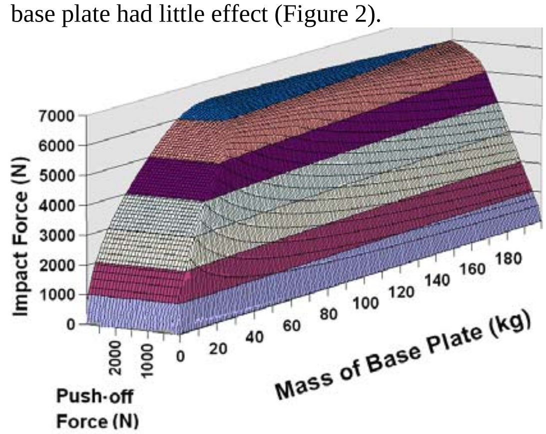

Figure 2. Dependence of Impact Force on (i) mass of base plate, and (ii) magnitude of push-off forces.

CONCLUSIONS

The theoretical analysis performed in this study showed that an exercise device that fits in half of a mid-deck locker can, when deployed in orbit, allow astronauts to exercise their leg muscles and experience both resistive and impact forces. The latter can achieve levels of 2,500 N.

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