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Two Techniques for Measuring Locomotion Impact Forces During Zero G

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Two Techniques for Measuring Locomotion Impact Forces During Zero G

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Introduction

A primary intent of treadmill exercise during space flight is to provide an axial load on the skeletal system and overload the skeletal muscles responsible for locomotion. To achieve these exercise effects, astronauts must adjust the treadmill restraint system to replicate one-g vertical forces (F_z) during spaceflight treadmill exercise. The current flight treadmill design lacks instrumentation capable of measuring dynamic-induced loads, thus preventing the quantification of locomotion F_z and accurate restraint adjustment. Therefore, the purpose of this study was to compare two methods of measuring dynamic F_z-induced loads while running on an instrumented, prototype treadmill in a zero-g environment.

Methods

For this study a motorized Whitmore MKII prototype treadmill was used. This treadmill was instrumented with load cells and mated with a Kistler force plate (Model Z). This configuration permitted the investigators to compare locomotion F_z recorded by the treadmill/force plate system simultaneously.

Four male subjects, ages 28-35, weighing 160 to 220 pounds, participated in this study. All subjects were required to pass a screening examination similar to an Air Force Class III physical and met National Aeronautics and Space Administration (NASA) standards for physiological training. Subjects also performed maximal treadmill stress tests prior to the study. Testing followed guidelines established by the NASA Johnson Space Center Human Research Policies and Procedures Committee.

The Whitmore MKII treadmill was instrumented with six 200-pound beam load cells (Superior, Model AW 802-200#), which were mounted directly under the tread roller bearings to measure F_z, and hard mounted to the floor of the NASA's KC-135 aircraft. During the KC-135 flights, 20-25 seconds of three-dimensional zero g was achieved by flying parabolic maneuvers. Subjects completed 10 parabolas, running at 6 mph, restrained to the treadmill with a harness adjusted to replicate each individual's one-g body weight. One-g replication was verified by Kistler load cells (Model 9301A) which were placed in series with the harness anchor lines.

For control measurements, the above-described treadmill was hard mounted to the floor of NASA's Anthropometry and Biomechanics Laboratory. Control subjects completed a 20-25 second run in one g at 6 mph.

The frequency response of an instrumented treadmill system is an important value to document in order to verify accurate F_z measures. A Ling Dynamic Systems electromagnetic vibrator/shaker (Model V411) and a H. M. Wilson Co. power amplifier (Model HMV 301), suitably configured, were utilized to input variable frequency forces to the surface of the treadmill. These measurements also were taken in NASA's Biomechanics Laboratory with the treadmill/force plate system.

Data from the treadmill/force plate system were sampled at 250 Hz and stored on an Ariel APAS computerized data acquisition/reduction system.

Results

The first resonant frequency of the treadmill/force plate system occurred at 20 Hz as measured by both techniques. These results demonstrated a flat frequency response to well above the 3 Hz expected for running at 6 mph (Figure 1). Even more relevant, when the treadmill/force plate system was statically loaded with a 185-pound subject, a first resonant frequency of 35 Hz for the treadmill load cells and 40 Hz for the force plate were recorded (Figure 2).

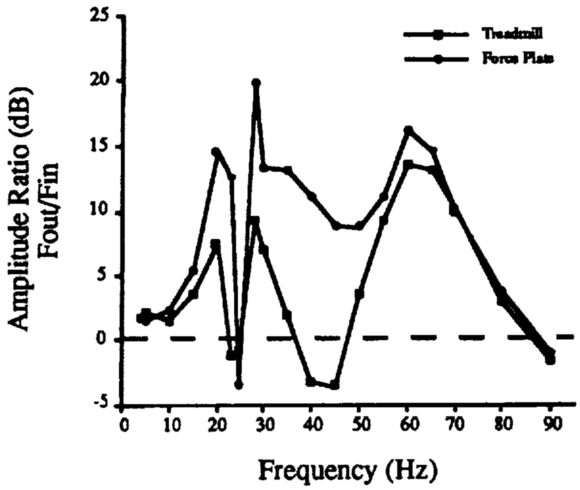

Figure-1 Frequency response of an unloaded, instrumented treadmill mated with a force plate (one g).

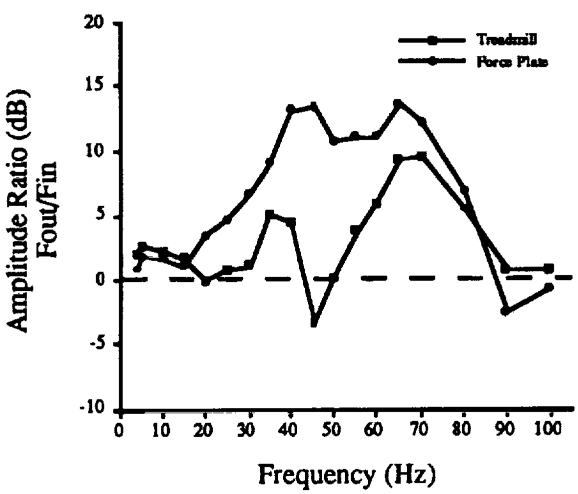

Figure-2 Frequency response of a loaded, instrumented treadmill mated with a force plate (one g).

Representative F_z data from the four subjects during one-g treadmill running appear in Figures 3 and 4. These data show that F_z recorded simultaneously by both measuring systems are comparable to within 5%.

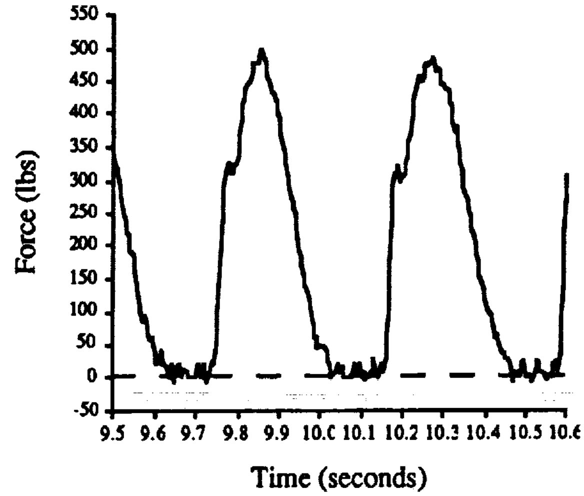

Figure-3 F_z at 6 mph in one g on a load-cell-instrumented treadmill.

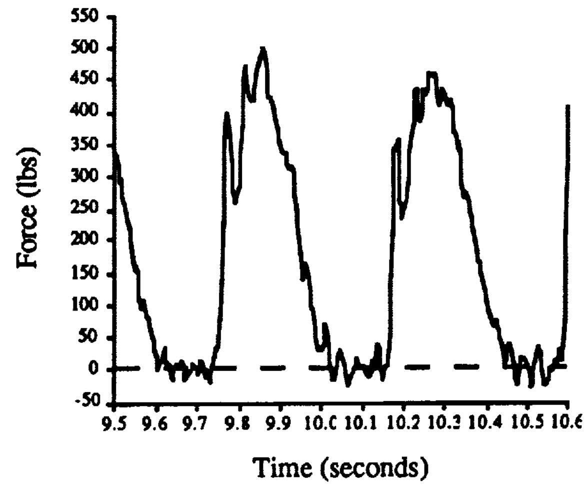

Figure-4 F_z at 6 mph in one g on a treadmill mated with a force plate.

Similarly, representative data produced by the four subjects while running in zero g are illustrated in Figures 5 and 6. These data also show that F_z measured by the two systems are comparable within 7%. All locomotion F_z data (zero g and one g) from this study compared to within 10%.

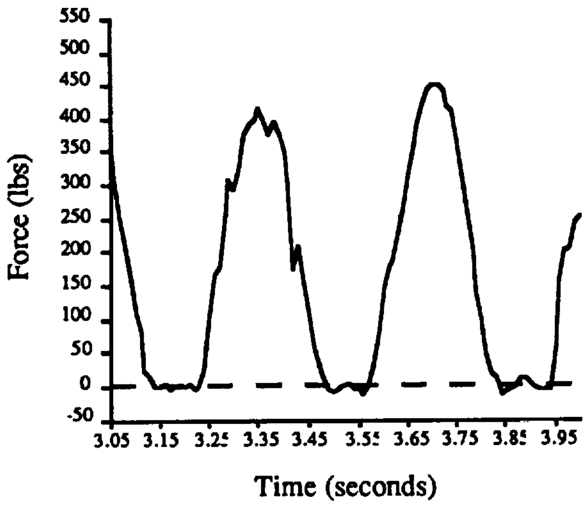

Figure-5 F_Z at 6 mph in one g on a load-cell-instrumented treadmill.

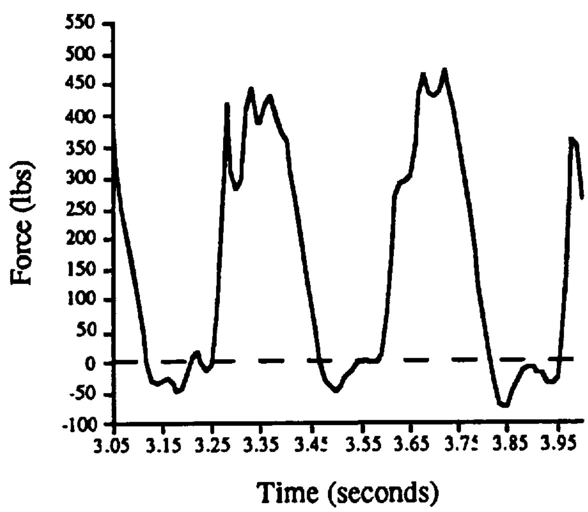

Figure-6 F_Z at 6 mph in zero g on a treadmill mated with a force plate.

Conclusion

Based on frequency responses determined from this study, both systems accurately measured predominant F_Z. A force plate properly mated with a treadmill was able to accurately measure the magnitude of F_Z as effectively as the load-cell-instrumented treadmill.

References

1. Alexander, R. Mechanics of walking and running. In: Reuland, H, D.N. Ghista, G. Rau (eds.). *Perspectives of Biomechanics*. London: Harwood Academic Press, 355-379, 1980.

2. Elam, R. Effects of motor unit potentiation and ground reaction force from treadmill exercise. Johnson Space Center Final Report N89-20069, 1988.

3. Frey, M.A. Considerations in prescribing preflight aerobic exercise for astronauts. *Aviat. Space Environ. Med.* 58:1014-1023, 1987.

4. Greenisen, M., M. Walton, P. Bishop, and W. Squires. Techniques for determination of impact forces during walking and running in a zero-g enviroment. NASA TP 3159, 1991.

5. He, J., R. Kram, and T.A. McMahon. Mechanics of running under simulated low gravity. *J. Appl. Physiol.* 71(3):863-870, 1991.

6. Kram, R. and A.J. Powell. A treadmill-mounted force platform. *J. Appl. Physiol.* 67:1692-1698, 1989.

7. Martin, M.A., M. Gagnon, and M.R. Pierson. Ground reaction forces and frontal plane hip, knee, and ankle angles during running on a treadmill. Proceedings of the International Society of Biomechanics Congress, p.201, 1987.

8. Schoutens, A., E. Laurent, and J.R. Poortmans. Effects of inactivity and exercise on bone. *Sports Med.* 7:71-81, 1989.

9. Spengler, D.M., E.R. Morey, D.R. Carter, R.T. Turner, and D.J. Baylink. Effect of space flight on bone strength. *Physiol.* 22:S75-76, 1979.

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13. ABSTRACT

A load-cell-instrumented treadmill mated to a Kistler force plate was used to investigate two methods of force measurement instrumentation during treadmill ambulation in zero g, created by parabolic flight on NASA's KC-135 aircraft. Current spaceflight treadmills do not have adequate instrumentation to determine the resultant foot impact force applied during restrained ambulation. Accurate measurement of foot-ground reaction forces is critical in attaining proper one-g loading, therefore ensuring proper musculoskeletal conditioning. Treadmill instrumentation and force plate measurements were compared for frequency response and linearity. Locomotion impact data were also collected under one-g laboratory settings and in Keplerian flight. The first resonant frequency for both techniques was found to be well above the primary frequency content of the locomotive forces. Peak impact forces measured by the two systems compared to within 10 percent.

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