Ground/Foot Impacts: Measurement, Attenuation, and Consequences

TIMOTHY R. DERRICK[1] and JOHN A. MERCER[2]

[1]*Department of Health and Human Performance, Iowa State University, Ames, IA; and* [2]*Department of Kinesiology, University of Nevada, Las Vegas, NV*

Ground/foot impact duration is typically less than 50 ms (5). During this brief period of time the shoe midsole is compressed, biological materials such as the calcaneal fat pad, ligaments, cartilage, and bone are deformed, and the muscle-tendon complexes of lower extremity joints are stretched. This is essentially a passive process because the duration is too short to actively respond to the impact. The most direct measure of the impact would be a recording of the forces in the responsive tissues. However, this would involve invasive instrumentation of these tissues or extensive modeling techniques. At present few studies of this nature have been attempted. Most research involving humans has examined either the external ground reaction forces or the resulting accelerations of the body segments in an attempt to gauge the magnitude of the impact. Neither method is perfect in all circumstances. Ground reaction forces are influenced by the entire mass of the body rather than the segments that are impacted, and the impact conditions that are studied are restricted because the foot must land on a force platform. Accelerometers are more versatile with regard to the impact conditions that can be evaluated and they are able to measure a more localized effect of the impact, but soft tissue movement relative to the bone can influence the resulting peak accelerations. Multiple accelerometers can be placed on the body so that the attenuation of the impact can be calculated between segments.

To assess the influence of impacts on the health of the human body the conditions under which impacts increase or decrease must be known. It is clear that changing the external and internal environments of an athlete can alter the kinematics and the magnitude of the impacts. Some of the environmental influences examined in this symposium include shoe hardness, surface stiffness, surface smoothness, running duration, grade, stride length, fatigue, light intensity, grass length, and knee flexion angle at contact. These influences can affect the impact by changing the foot/ground impact velocity, the stiffness of the impacting bodies, or they can cause altered body geometry during contact, which will also affect the impact magnitude. The kinematic adjustments that may take place during these altered environmental states are not necessarily an attempt to reduce impacts. Another possible criterion in the selection of optimal kinematics is the need to minimize metabolic costs and this may conflict with the need to minimize impacts.

The effect that impacts have on our body varies according to the magnitude of the impacts, the number of impacts, and the frequency of impact bouts. Threshold levels exist that define the lower limit of impacts that are adequate to maintain tissue health and the upper limit of impacts beyond which can lead to overstressed tissue (2). It is likely that anatomical variation changes these thresholds so that some people are predisposed to overuse injuries.

The series of articles presented here is compiled from a symposium presented by the authors on impacts during the 2002 American College of Sports Medicine annual conference. The purpose of this symposium was to consolidate information concerning the measurement of impacts, the methods of attenuating impacts, and the consequences of repeated impacts on the body. In the first article, Dr. Timothy Derrick from Iowa State University will present information on impact forces and accelerations as well as adjustments made to changing environmental conditions (1). Dr. Elizabeth Hardin and Dr. Anton van den Bogert, both from the Cleveland Clinic, and Dr. Joseph Hamill from the University of Massachusetts Amherst will discuss kinematic adaptations to midsole hardness, surface stiffness, and running duration (3). Finally, Dr. Alan Hreljac from California State University Sacramento will present information on the relationship between the impact phenomenon and running overuse injuries (4).

In summary, it is hoped that this symposium will spur new research into the area of impacts in the human body. Research needs to be accomplished that will help relate the forces and accelerations that are easily measured to the internal forces that can cause injury or stimulate improved

Address for correspondence: Timothy R. Derrick, 235 Forker Building, Department of Health and Human Performance, Iowa State University, Ames, IA, 50011; E-mail: tderrick@iastate.edu.
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bone structure. We also need to continue to establish the characteristics of impacts and impact bouts that will define the thresholds of injury and bone adaptation. Only then can recommendations be made regarding the dose of impacts that can be beneficial or detrimental to human health.

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