RUNNING TO MARS: A BIOMECHANICAL ADVENTURE

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INTRODUCTION

The opportunity to present the James Hay Memorial Award lecture is a significant honor for my colleagues and me and a particularly meaningful one for me, given my long association with Jim. I first met him in 1972 when, as the architect of the American Society of Biomechanics, he came to Penn State University to formulate a constitution for the fledgling society. In many interactions with Jim over 30 years of subsequent friendship , I developed a deep respect for his integrity, energy, intellect, and his life-long passion to bring science to sports.

The title of this talk clearly needs some explanation. In the presentation, I intend to trace some of the work of my research group in the biomechanics of running and to show how this has influenced the subsequent direction of my career and that of my students. Even though our research team is no longer active in the field of sport biomechanics, this area has informed our current interests, which are focused on bone loss during long-duration space travel and on foot disease in diabetes. My goal is not only to present some of the research that has been conducted, but also to communicate to the younger members of the Society the metaphor of a career in science as an adventure, where each new destination enables a multitude of other possible pathways. I also hope to show the critical contributions that graduate theses and dissertations make to the scientific literature.

BIOMECHANICS OF RUNNING

An enduring issue in locomotion studies is the relationship between the mechanics and energetics of running. Studies of male and female elite distance runners indicated that "economy" is not a clear determinant of success (Cavanagh et al., 1977; Williams et al., 1987). Defining the "efficiency" of human movement has proven an elusive goal (Cavanagh and Kram, 1985; Williams and Cavanagh, 1987; van Ingen Schenau and Cavanagh, 1990). Estimates are highly dependent on methodological approaches, such as the ever-present issue of optimal filtering. Prolonged eccentric muscle action, in downhill running for example, produces delayed onset soreness and a slowly increasing oxygen uptake that remains unexplained (Dick and Cavanagh, 1987).

New insights into the role of the arms in running were provided by Hinrichs et al. (1987), and the limits of motion analysis were explored by Lafortune et al. (1992) in a study that involved inserting intra-cortical pins in the bones of the knee joint. This led to significant insight into action of the normal knee joint, which was extended to pathological subjects, using similar techniques, by McClay et al. (1991). The motion capture capability in our laboratory was also applied in studies of older individuals during standing and stair climbing (Simoneau et al., 1991; Startzell et al., 2000), including the elucidation of postural instability secondary to peripheral neuropathy (Simoneau et al., 1994).

FOOTWEAR AND FOOT DISEASE

Studies of ground reaction forces (Cavanagh and Lafortune, 1980) and moments (Holden and Cavanagh, 1991) were accompanied by work on running shoes (Cavanagh, 1980), including an early "computer shoe" that interfaced with an Apple IIe computer (Cavanagh, 1988). The advent of devices to measure plantar pressure distribution (Hennig et al., 1982) opened new doors to the study of the foot complications of diabetes (Schaff and Cavanagh, 1990), which has since become a major focus of my laboratory's work (Cavanagh et al, 2005).

BONE LOSS IN SPACE

Running in space as a countermeasure to adverse musculoskeletal and cardiovascular changes was pioneered by the astronaut-physician William Thornton, who designed a treadmill for use on the space shuttle. Our own work in space started when Dr. Thornton asked us to analyze film of crew members using this device on the Shuttle (Thornton et al., 1997). We subsequently performed an in-flight evaluation of the current International Space Station (ISS) treadmill (McCrory et al., 1999). A simulator for zero-gravity locomotion was constructed in our laboratory (Davis et al., 1996) and used to demonstrate that subjects could run with a gravity replacement system that applied full body weight loading (McCrory et al., 2002). This work culminated in a recent experiment on the ISS implicating decrements in daily load to changes in lumbar and femoral bone mass.

SUMMARY

Early studies in the biomechanics and energetics of distance running have informed much of the subsequent research of our group and have led to new opportunities to gain insight from biomechanical approaches to the study of space flight and diabetic foot disease.

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