Measurement of Ground Contact Time in Elite Distance Runners: Utilization of Accelerometer Technology

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(Note: A copy of the Power Point slides will be distributed in NPEP meeting in Las Vegas, and also placed on-line at www.iub.edu/~hplabs

Introduction / Purpose

Most elite distance runners take, on average, between 180 and 200 foot strikes per minute of racing. Over the course of a 10,000m race, elite males will take approximately 5100 steps, and elite females approximately 5800 steps. In the simplest analysis, reducing ground contact time by just a few thousandths of a second, while maintaining ground force application, could have a significant effect on race time and performance.

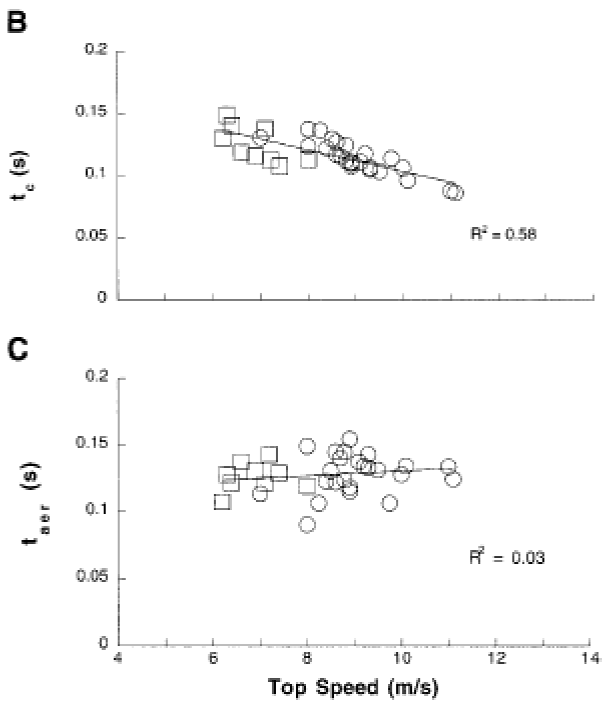
For the distance events, closing speed in the final 400m has been identified as one of the primary critical zones for racing success. Reducing ground contact time could have a significant positive effect for the critical zone as 1) reducing ground contact time could directly impact finishing speed in distance events, and 2) mechanical interventions reducing ground contact time during the bulk of the distance race could leave the athlete in a better "physiological state" going into the final 400m.

The primary limitation in determining the ultimate effect of ground contact time in distance race performance is the difficulty in obtaining accurate measures in a real world setting. As a result, it is unknown if our nation's best distance runners have reduced ground contact times compared to "average elites" or world class athletes from other nations. Similarly, it is not known if training interventions can lead to reduced ground contact time, and if so, if it comes at a neutral metabolic cost making it positive for performance.

Recent advances in accelerometer technology make precise measurements of ground contact time obtainable in a portable, real world manner. Using accelerometers, measurements of ground contact time can now be made not only in the controlled environment of the laboratory, but also on the track in training and racing situations, allowing coaches, athletes, and sports scientists to gain valuable information that can have a direct impact on the critical zone for distance events. This proposal outlines an introductory set of measurements designed to document ground contact times in elite distance runners a) as a function of pace, b) in response to the fatigue of workouts, c) in actual racing situations, and d) after training interventions.

Rationale / Need

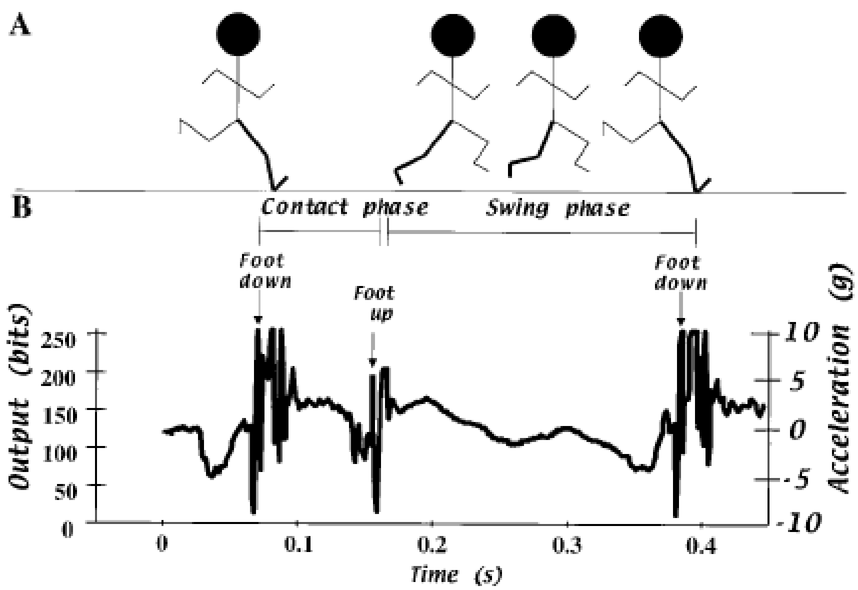
Faster top running speeds are achieved primarily by greater ground forces and reduced ground contact time, not by simply moving the legs faster in the air. Note in the graph below, generated from a study of sprint athletes using data from a force plate, that as the athletes run faster (from left to right on the X-axis), ground contact time (t_c in graph B) is significantly reduced. Also note in graph C that aerial time (t_{aer}) remains essentially unchanged as speed increases.



At any <u>common speed</u>, elite runners spend less time in contact with the ground and take longer strides compared to average runners or untrained individuals. The reduced ground contact time in elite runners is accomplished primarily by generating greater ground reaction forces. However, for the elite distance runner who is looking to expend energy physiologically in a rationed manner during the course of a race, generating greater ground reaction forces may increase speed but at the expense of premature fatigue. Alternatively, altering mechanical components (such as negative foot acceleration at foot strike, foot strike position / toe dorsiflexion) or increasing muscle / tendon elasticity through pre-stretching or selective muscle activation just prior to ground contact could shorten ground contact time in a way that is "metabolically neutral." To date, measures of ground contact times in elite distance runners have not been reliably obtained. Therefore, we do not know of our nation's best distance runners have naturally shorter ground contact times, or if a training intervention could lead to shorter ground contact times and improved performances.

Previously, to measure ground contact time, the use of force plates was mandated. While force plates provide accurate data, their use in simulating the real conditions of running on the track are limited by their fixed location. While a few laboratories have been successful in imbedding force plates beneath a treadmill belt, these set ups are very uncommon and very expensive. It has also been argued that the mechanics of running on a treadmill may be markedly different than running on a track, and it is difficult to simulate a race or workout situation on a treadmill.

Accelerometers are relatively new devices which allows for very precise measurements of motion. Recently, accelerometer technology has advanced significantly, making these devices small, light, and portable enough to be placed upon the top of a shoe to measure force due to motion. These accelerometers have no wires and can either store data in internal memory or transmit data wirelessly to a computer, allowing for measurements to be taken on a track in a real competitive or workout situation. The sampling rates of these devices can exceed 100 Hz, allowing for sensitivity to measure ground contact time while running accurately to the nearest thousandth of a second. As an example, note the output data (graph below) from an accelerometer placed on top of a runner's foot. By examining accelerometer output in the vertical plane (Z-axis), we can easily determine the exact time point of initial ground contact and toe-off.



Additionally the same data from the accelerometer can be used to calculate swing time (i.e. flight time), stride frequency, and (if distance covered is known) stride length. Some devices have three separate accelerometers mounted on each movement axis within the same device unit. These tri-axial accelerometers can be attached to the lumbar spine on the lower back, and can be used to measure vertical and side motion, which hold the potential for determining changes in economy as an athlete fatigues.

In terms of application of ground contact times to our understanding of the critical zone for the distance events, the power of accelerometers are their portability. We now have a measurement technique that can accurately measure ground contact time during workouts and races, with essentially no affect on the athlete.

Methodology

For this project, we have selected the G-link wireless accelerometer by Microstrain. This device is ideal, as it is:

--small (2.25 in x 1.75 in x 1 in)
--portable (onboard lithium battery can measure for up to 8 hours before re-charge is needed)
--wireless (data is transferred wirelessly, either in real time or after the experiment is complete)
--light (46 grams or 1.6 ounces)
--fast sampling and high sensitivity (as fast and sensitive as 0.0005 sec)
--high memory (holds up to 150 minutes of data when sampling at 100 Hz)

A picture of the G-link accelerometer is below. (Note, the graphic should appear in this document close to real size, and the wireless antenna can be removed if necessary).

We have designed a series of experiments to determine the ground contact time of elite distance runners. An important first step will be to generate baseline measures of ground contact time, both on the treadmill and on the track, at known speeds. Utilizing the treadmill at known speeds will also allow calculation of stride length, stride frequency, aerial time, and swing time.

Once the general ground contact time response has been well characterized, the second step will be to determine how ground contact time changes as a runner fatigues in a controlled workout protocol. Third, will be to measure how ground contact time changes over the course of a race. Finally, we will examine the efficacy of placing an accelerometer on the lumbar spine (lower back) in an effort to measure vertical and horizontal forces and their effect on running economy.

Once this data has been generated, our laboratory can work together with the Director of High Performance and Men's and Women's Development to determine what future measures and experiments should be completed to a) further our understanding of critical zone factors for the distance races, and b) best help our elite athletes prepare for international competitions.

For these initial characterization experiments, we can minimize expenses by testing athletes who are members of an elite post-collegiate training group in Bloomington. While not representing the top of the spectrum of U.S. distance performers, the group includes both male and female athletes – 12 of whom have a PR faster than the US Olympic Trials B qualifying standard in events ranging from the 800m to the 10,000m. This group of athletes should serve our needs well in generating initial data, without requiring expenses for travel. Additionally, less talented (slower) runners from the Indiana University team can be tested for comparison purposes.

Protocol #1

The first step in the process will be to get baseline measures of ground contact times at known speeds. This will be accomplished first in a laboratory setting by having athletes run on a treadmill at multiple speeds, ranging from slightly slower to slightly faster than race speeds. Following, athletes will perform a similar series of trials running on a Mondo surface outdoor track.

Protocol #2

The second set of experiments will involve measuring changes in ground contact time as the athlete fatigues over the course of a controlled workout. After an initial series of ground contact measures are obtained, the athlete will complete a standardized workout (either a set number of repetitions at a fixed speed, or a continuous workout at a fixed percentage of VO_2max).

Protocol #3

The final set of initial characterization experiments will involve measurements of ground contact time over the course of a competitive event. With accurate measurements of race splits, average velocity can be used to normalize ground contact time.

Protocol #4

The Bloomington post-collegiate group has an altitude training camp planned for Flagstaff, starting in mid-February immediately after USATF XC nationals. This presents a unique opportunity to measure ground contact time before and after altitude training. This data is important as many of our '08 team members will utilize altitude training as part of their peak performance plans, and often athletes feel a lack of "turnover" upon return to sea level. The real manifestation of altered mechanics or neuromuscular function after altitude training could be observed with our accelerometer protocols. Obtaining measures immediately upon return to sea level, and serially over the next several weeks at sea level, we can potentially help athletes determine the proper timing (from a mechanical sense) of when to come down from altitude prior to a key race.

Future experiments

Once the general ground contact time response has been well characterized, the results can help our research team and USATF plan appropriate future experiments. Potential future experiments include:

--changes in ground contact time after interventions, such as plyometrics, sprint drills, flexibility programs, etc.

--measurement of barrier flight times in the steeplechase (accelerometers provide a unique measurement technique to obtain these measurements accurately).

--measurement of ground contact times in our nation's top distance talent, for purposes of identifying specific athletes for whom interventions may be most productive in improving performance.

Critical Zone Application

A partial list of potential application of project results to the critical zone for endurance events:

1) Identification of ground contact times in our best distance runners.

--Can success in the critical zone be explained by shorter ground contact times?
--Do certain elites have significantly longer ground contact times than their peers, thus making possible mechanical interventions more likely to improve performance in the critical zone?

2) Changes in ground contact times in elites as the runner fatigues over the course of a race.

--Does a change in ground contact time with fatigue as the critical zone is approached affect finishing speed / performance inside the critical zone?
--Do changes in stride length, stride frequency, and aerial time also affect performance in the critical zone?
--Are some athletes better able to reduce ground contact time within the critical zone? What characteristics do they have that enable them to do so?
--If ground contact times get longer over the course of a race in our top distance runners, coaches/athletes can be informed and can look to modify training to overcome this change.

3) Changes in ground contact time after altitude training.

--Does ground contact time explain why many athletes feel neuromuscularly slower immediately after an altitude training camp?
--Can we identify the time course of ground contact time changes after an altitude camp, better helping elite athletes time altitude camps prior to key races?