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IDEA EXCHANGE

The Biomechanics of Running

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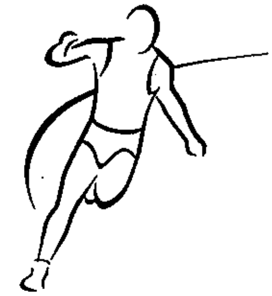
Physics 11

The following pages outline an interesting way to present a practical application of Hooke's law in Physics 11. The attached research paper is used to establishing the importance of elastic properties of the Achilles tendon during a sprinters stride. A simple wood, spring, and hinge model of the ankle joint can be made to further demonstrate this. Using their imaginations and Hooke's Law, students are then asked to test classroom springs, elastics, and other materials for their suitability as an Achilles tendon replacement.

The Biomechanics of Running



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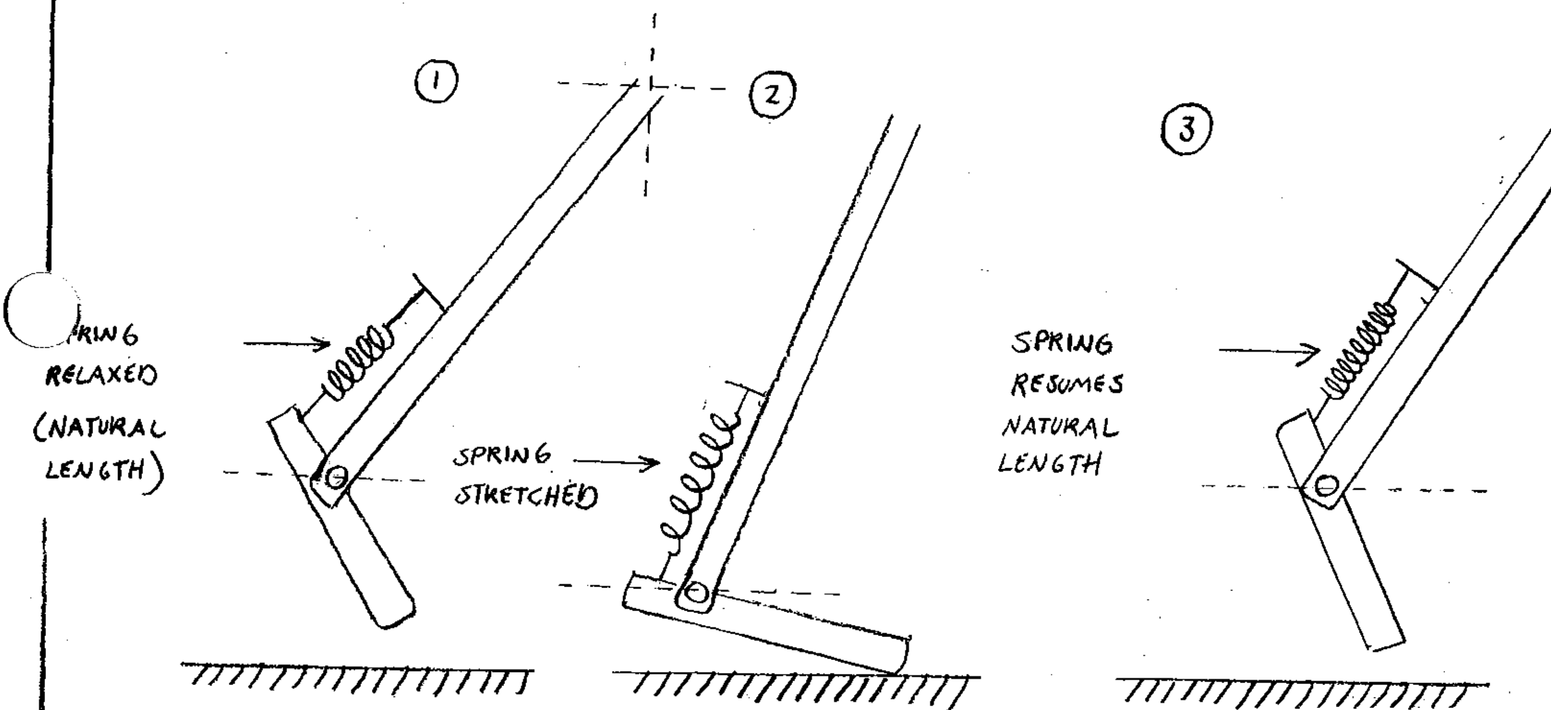
As indicated in the research paper by Tom F. Novacheck the Achilles tendon is an important component of a human's ability to run. Novacheck explains that tendons act like springs which help to propel a human forward during a running motion.



Imagine you are a biomechanical engineer who has been asked to replace a runner's severed Achilles tendon with an alloy spring. To match the spring constant of the Achilles tendon you must find a spring that has a spring constant of 75N/m.* You have found 5 suitable springs from a surgical catalog and now you must test the spring constant of each to see if any are a good match.

Using the experimental method outlined by your instructor. Create a F vs. ΔL graph for your spring and determine its spring constant. Answer any lab questions in and hand in a <u>formal lab report</u> of your findings.

**an accurate spring constant for the Achilles tendon would be closer to 100N/mm.*

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Review Paper

The biomechanics of running

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Abstract

This review article summarizes the current literature regarding the analysis of running gait. It is compared to walking and sprinting. The current state of knowledge is presented as it fits in the context of the history of analysis of movement. The characteristics of the gait cycle and its relationship to potential and kinetic energy interactions are reviewed. The timing of electromyographic activity is provided. Kinematic and kinetic data (including center of pressure measurements, raw force plate data, joint moments, and joint powers) and the impact of changes in velocity on these findings is presented. The status of shoewear literature, alterations in movement strategies, the role of biarticular muscles, and the springlike function of tendons are addressed. This type of information can provide insight into injury mechanisms and training strategies. © 1998 Elsevier Science B.V.

Keywords: Running; Biomechanics; Kinematics; Kinetics; Electromyography; Energy; Injury

1. Introduction/history

To avoid the misconception that the analysis of running is a new area of interest, one need only examine the art of Grecian vases and consider the writings of Aristotle, 'Further, the forces of that which causes movement and of that which remains still must be made equal... For just as the pusher pushes, so the pusher is pushed—i.e. with similar force' [1]. Leonardo da Vinci's interest in accuracy in painting in the 15th and 16th centuries increased focus on human movement and was followed by Newton's proclamation of his three laws in the 17th century. In 1836, the Weber brothers (Wilhelm and Eduard) set the agenda for future research with the most detailed treatise on walking and running gait to date. They listed 150 hypotheses including that the limb can act as a pendulum. More sophisticated tools were needed than were currently available to test them. Etienne Jules Marey (1830–1904) was a prolific pioneer of instrumentation. He was among the first to employ photography and use it as a true photogrammetric tool. He also designed and built the first serious force platform. The reader is referred to Cavanagh's historical review [2] for further insight into the contributions and historical significance of the works of Braune, Fischer, Muybridge, Hill, Fenn, Elftman, and Hubbard.

The explosion of interest in running has prompted a comparable explosion of research and assessment. This has been potentiated by technical advances including faster cameras and marker systems which eliminate the need to hand digitize frame after frame of video. The growth of this field has been spurred by the vast growth in participation in distance running in the late 1960's and early 1970's. Approximately 30 million Americans run for recreation or competition. The rate of injury is significant. Each year between 1/4 and 1/2 of runners will sustain an injury that is severe enough to cause a change in practice or performance [3,4]. This may lead the runner to seek consultation, alter training, or use medication.

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IMPORTANT INFO ON REVERSE SIDE

Because of this difference, the body completely alters the methods it uses to maintain energy efficiency. Large fluctuations in total energy going into and out of the system would be disadvantageous regardless of the pace of movement. Efficiency in walking is maintained by the effective interchange between potential and kinetic energy. They are out of phase. In running, because the two are in phase, this is not possible. Instead, efficiency is primarily maintained in two ways [16,31,39].

1. The storage and later return of elastic potential energy by the stretch of elastic structures (especially tendons);
2. The transfer of energy from one body segment to another by two joint muscles such as the rectus femoris and the hamstrings.

These two concepts will be addressed separately in the next two sections. These mechanisms do not occur without some cost of their own. It is the repetitive cycling of tendon stretch and recoil that is responsible for many of the chronic overuse syndromes in runners [7] (see subsequent 'injuries' section).

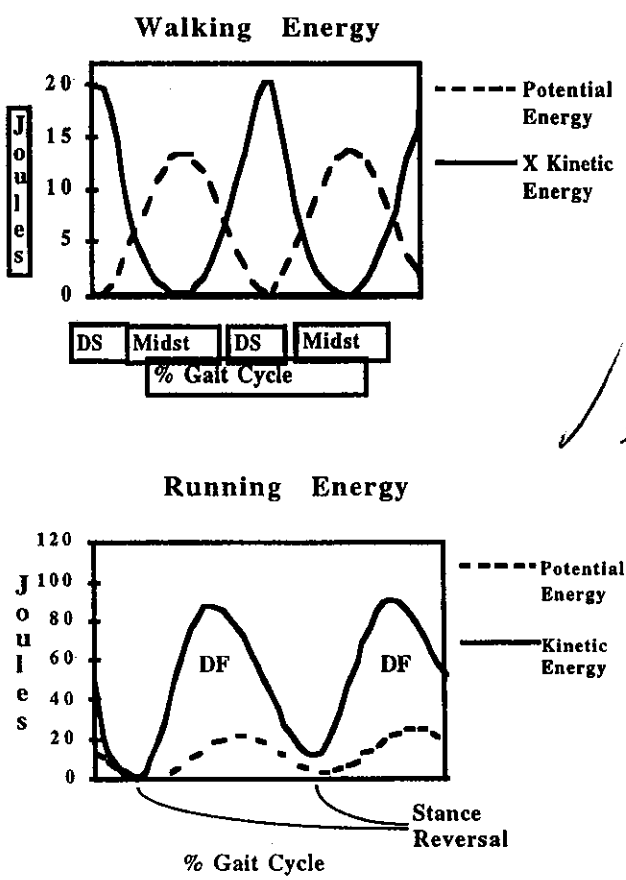

Fig. 11. The relationship between potential and kinetic energy in walking and running. The relationship between potential and kinetic energy is one of the crucial differences between walking and running. In walking, they are out of phase. In running, they are in phase.

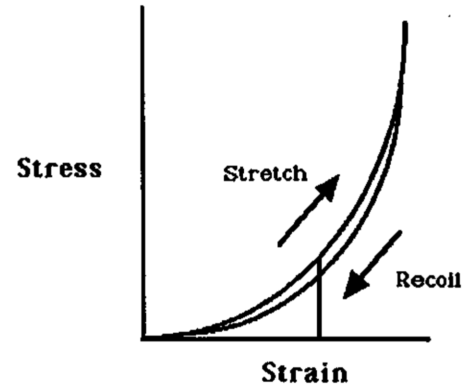

Fig. 12. Hysteresis curve for tendon. Tendons efficiently recoil in a springlike fashion returning approximately 95% of the energy stored when stretched. For any given amount of stretch (strain), the difference in stress is dissipated as heat.

During running, potential and kinetic energy peak in midswing. As the center of mass falls toward the ground, potential energy is lost. As the foot contacts the ground, kinetic energy is lost. Much of the lost potential and kinetic energy is converted into elastic potential energy and stored in the muscles, tendons, and ligaments (see later section on the tendon as the musculotendinous spring). During the generation phase, the center of mass accelerates upward and both potential and kinetic energy increase. Energy for this movement is supplied by the active contraction of the muscles and the release of the elastic potential energy stored in the ligaments and tendons. The storage of energy in the elastic structures of the lower extremities thus plays a more important role in running and sprinting than in walking.

7. Tendons as springs

As mentioned above, each of these musculotendinous units absorbs power by stretching (eccentric) just before they shorten (concentric) to generate power. Recent animal studies have indicated that the changes in the length of the muscle belly itself are relatively minimal [46]. Instead, they function as tensioners of the musculotendinous springs, their tendons. Most of the change in length comes from the stretch and recoil of their respective tendons. Therefore, most of the work is done by the tendons. An excellent source for information on this topic is provided by McMahon [47].

Tendons are, in fact, excellent biological springs (Fig. 12). In this way, we should begin to think of tendons as springs and muscles as the tensioners of the springs. The analogy of a runner to a person on a pogo stick [21] starts to make even more sense! If we consider the Achilles' tendon, for example, we can begin to understand the way that it stretches during the first portion