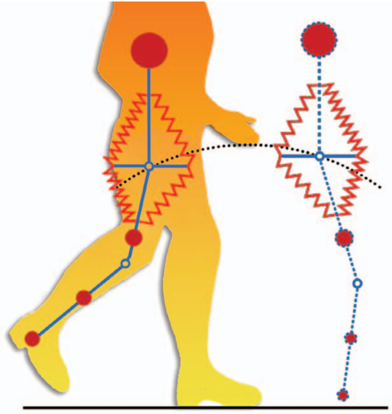
Walk With Elastic Fascia

Use the Springs In Your Step!

Adjo Zorn, Ph.D.   Kai Hodeck, Ph.D.

Seen from the eyes of other species, human beings have a very strange style of walking. In each step, the stance leg is stiff, as if it were made of wood. This design makes the upper body move up and down, causing scientists to compare the human gait with the slightly ridiculous motions of a rolling egg or a square wheel.[1] The whole body is permanently held in a very unstable position. The swing leg has a heavy club foot, which has to be flung around and stopped with every step. It has to reach its final position with high precision, or the walker will start to stumble.



A skillful walker can make a few adjustments to his or her gait and actually move forward with very little muscle use.

Without the example of the human prototype, no engineer in his right mind would dare suggest such an absurd design for the purpose of locomotion. In 1967, British anthropologist John Napier wrote, "Human walking is a unique activity, during which the body, step by step, teeters on the edge of catastrophe."[2] Human walking seems to be simple because, somehow, everyone learns it in childhood, but ever since we developed computer simulations of human gait, we have admired it almost as much as circus artistry.

Humans are known to be a very enduring species. We developed in a very poor and arid environment and were forced to carry lots of heavy things around: children, food, firewood, water, weapons. And we made it! Humans have managed to survive for an unimaginably long time and outdo all competitors.

Human gait is surely a kind of an enigma, but you probably think this enigma was solved long ago, and your trusted doctor learned everything about this subject when he was studying medicine. In fact, many researchers in the field of gait analysis seem certain that the whole picture is quite clear and only the details need to be clarified.

However, the two authors of this chapter – being physicists, Rolfers®, and movement freaks all in one – have serious doubts about the generally accepted concept of human walking, and we would like to provide a completely new suggestion as to how it really works.

In the following pages, we will analyze current theories regarding human gait in its basic form – on a flat surface – and suggest a new concept regarding gait. Whereas human walking is traditionally seen as driven by muscle activity, we will show that this need not be the case. A skillful walker can make a few adjustments to his gait and actually move forward with very little muscle use. We call this gait style "swingwalking," because each of the limbs, as well as the upper body, move freely – much like a child swings. The actual work is done by tendons and fascia. This new concept explains several features of human posture that are unique among the animal kingdom.

The Awkward, Yet Ingenious Human Gait

Imagine observing a walking human from the side (Fig. 1). Recognize that walking on the straight stance leg means a continuous up-down motion of the body. We are so used to it that we have a hard time noticing it at all (unless you view the very short video clip swingwalker.net/up-and-down.avi ,-) You probably don't need to be a physicist to know that repetitively moving weight up and down is hard work. Nowadays, people like to torture themselves with such movements in order to burn as much fat as possible. For our ancestors living in a poor and arid environment, however, extra movement to burn fat hardly made sense.

Obviously, there must be a hidden trick in human walking that allows us to avoid most of the work. We would like to understand this trick better than we do at the moment. One might argue that saving energy is nonsense for most of us, being in danger of getting fat and ill due to too much food and too little physical work. We would answer that our structure was built for the purpose of saving energy, and now we are doomed to use it that way, unless we want to become as unnatural as a rabbit living in a tree or a bird living in a hole.

The first explanation of how energy is conserved while walking came in the year 1836 from two famous brothers: Wilhelm and Ernst Weber.[3] One was a physicist – magnetism is still measured in Webers today – and the other a physiologist. Both were citizens of Prussia, a nation that had been deeply humiliated by the indecently quick-marching armies of Napoleon 30 years earlier. These brothers suggested that the swing leg, with the heavy foot, along with each arm, acts like a simple pendulum, and pendulums are well-known for moving weight up and down without much effort.

Unfortunately, this turned out to be wrong. G.B. Duchenne was a French physiologist who became famous as the first person to stimulate single muscles with electricity to find out what they do. (As an aside, Duchenne is to be blamed for a crime with the most serious consequences – he brought the term "iliopsoas" into general use because he could not reach the psoas with his electrodes.) Duchenne observed victims of polio in the 1860s. In people whose walking was disabled by polio, he noted that the only muscles really indispensable for walking were the hip flexors, because without the hip flexors, the swing leg could not move forward enough to be at the right position for the next step.[4]

After World War II, there was a lot of money spent for prosthetic research in the United States, and gait analysis experienced a real boost. "Six determinants" of gait were found, and all of them were presumed to help save energy in walking. In a 2007 issue of ***Human Movement Science***, Dr. Arthur D. Kuo, a professor of mechanical and biomedical engineering at the University of Michigan, states: "The six determinants of gait have practically been accepted as fact for 50 years, appearing in major clinical and scientific textbooks, without being subjected to experimental testing."[5] Meanwhile, several experiments were done, and not one of the six determinants was found to provide a significant contribution to saving energy.

Another concept, the "inverted pendulum," is more widely accepted.

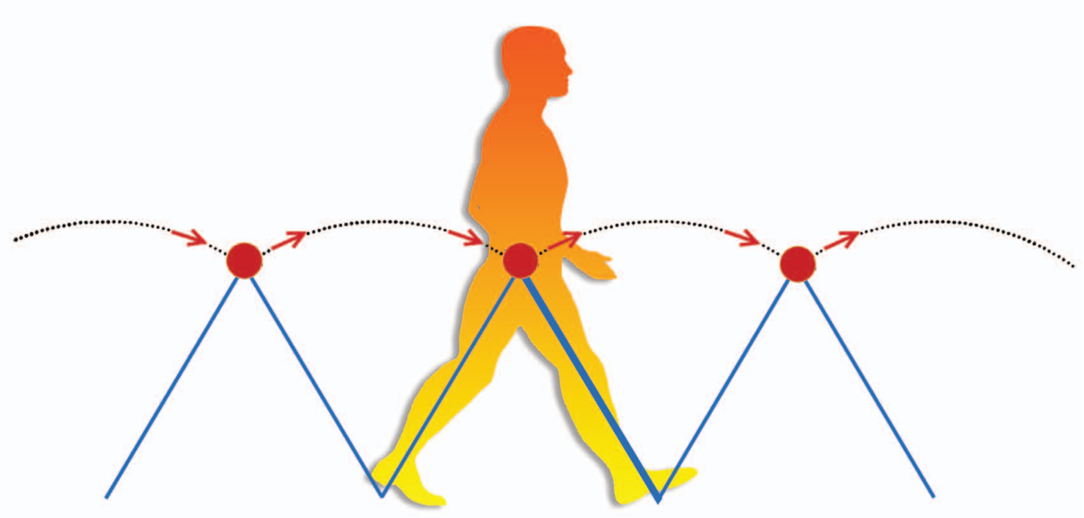


Figure 1: The stance leg as an inverted pendulum

The Inverted Pendulum Model

In this section, we will discuss and bring into doubt the generally accepted theories of human gait.

In the 1960s, Italian researcher Giovanni Cavagna became famous for his correct prediction that the first astronauts on the moon would not walk, but hop. He explored human walking and running by examining how each limb gains and loses kinetic energy. His conclusions laid the basis for what became a kind of dogma in gait analysis: In running, energy is saved by elastic storage, as in a bouncing ball, while in walking, energy is saved by the action of a rigid "inverted pendulum," and elasticity is not involved.

The concept is quite convincing. In a normal suspended pendulum, such as a child's swing, the energy is saved in a similar way – losing speed and gaining height while moving up, then gaining speed and losing height while moving down. In physical terms, the energy of speed (kinetic energy) and the energy of height (potential energy) are transformed into one another, back and forth. The twin forces related to mass, gravity and inertia, keep this process running. The inverted pendulum seems to do the exact same thing: It converts kinetic into potential energy, and vice versa, transferring the kinetic energy from one step into the next.

This transference of energy explains the energy-efficient, stiff-leg walking of human beings.

But does it really? We think not.

First: The inverted pendulum is not a pendulum at all. It does not oscillate. If left alone, it simply crashes to the ground. At the end of one step, the velocity of the mass points in the wrong direction – downward instead of upward – and a considerable amount of energy is needed to redirect the movement (Fig. 2). When a walker breaks the fall of the body and accelerates it upward again, the vertical component of the velocity is reversed. Only the horizontal component of the velocity can be taken into the next step – this is the saved energy.

Second: The actual movement of a walking human body is significantly different from the inverted pendulum model. In reality, the center of the body mass is not attached at the top of the leg, but instead is located somewhere in the middle of the upper body (Figs. 3 and 4).

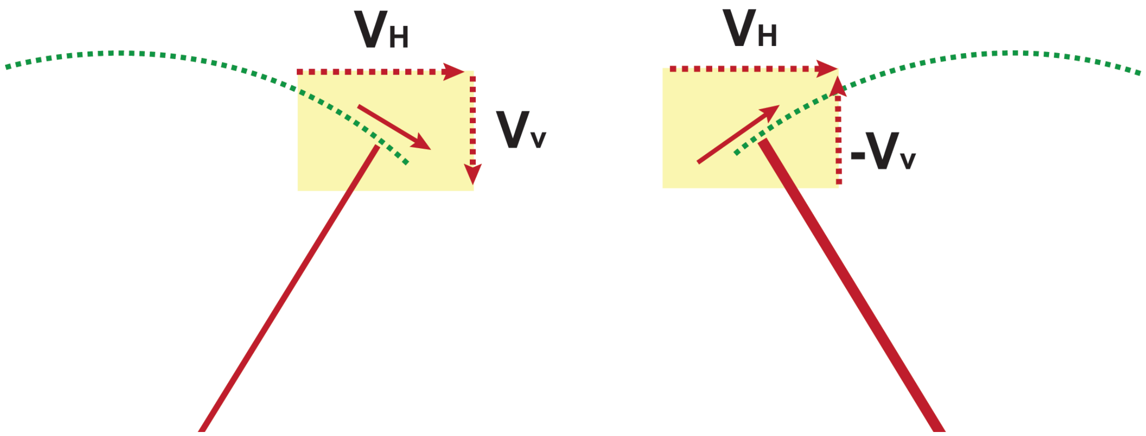


Figure 2: The direction of the velocity at the end of one step

The Inverted Pendulum Model

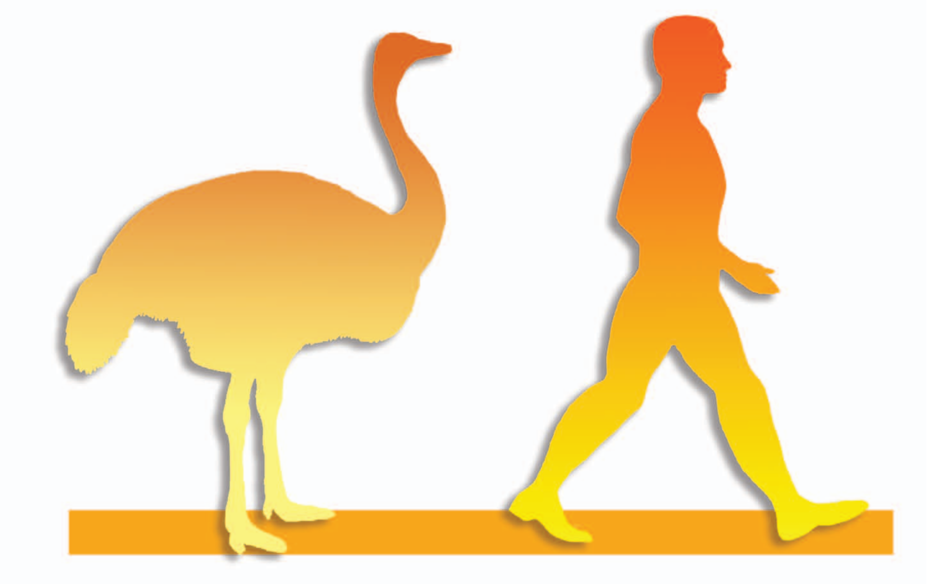


Figure 3: Mass distribution (moment of inertia) above the hip joint in ostrich and man. The greater the dark region, the more weight has to be balanced. The position of the center of mass in an ostrich fits the inverted pendulum concept better than the position in man. However, ostriches don't walk with a straight stance leg.[6]

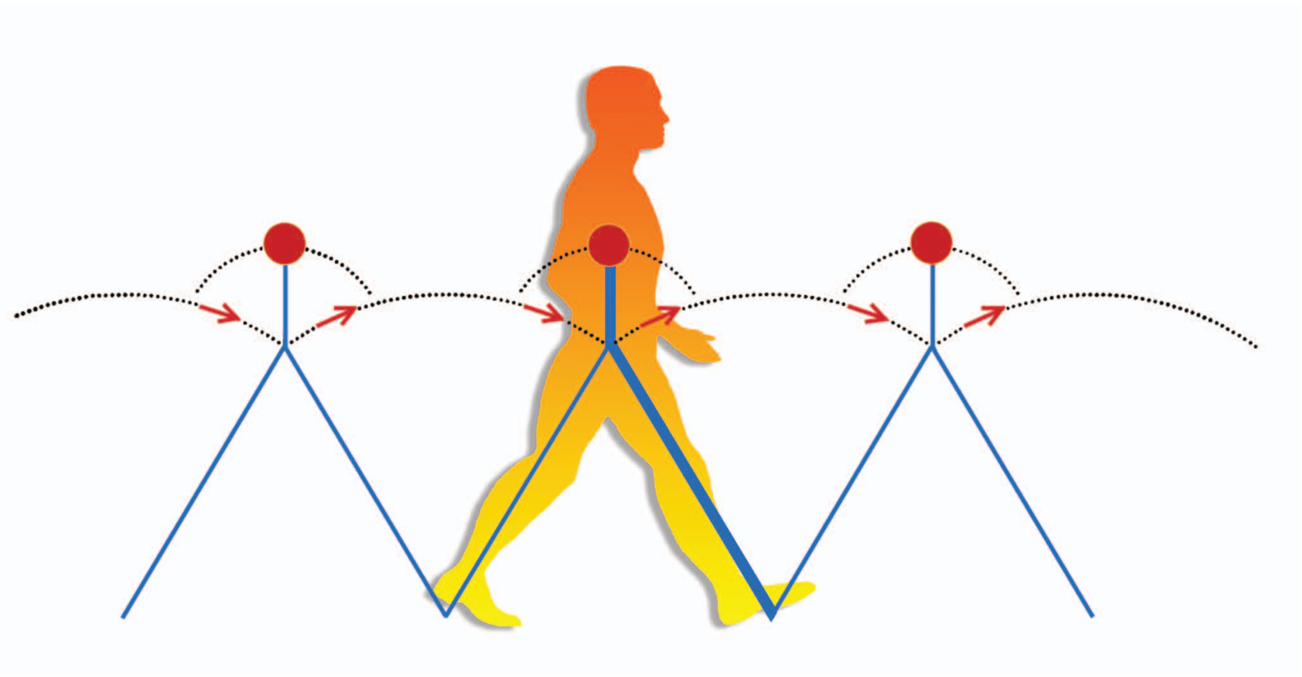


Figure 4: The stance leg and the upper body in a human actually build a pair of inverted pendulums.

This design conforms to a model of an inverted pendulum with a second inverted pendulum on top of it.[7] In contrast to the single inverted pendulum, this structure is by no means able to transform kinetic energy into potential energy in the expected manner.

We explored the behavior of this structure with the help of a computer simulation. This is what happens:

At the beginning of the step, the lower inverted pendulum moves up and slows down, as expected. The upper inverted pendulum starts with perfect balance but soon gets into trouble. Its mass tries to maintain speed while its base slows down. As a result, the upper inverted pendulum starts to fall forward, as if stumbling. This fall quickly accelerates. Once it has reached a real oblique angle, it starts to get in the way of the lower inverted pendulum and effectively blocks its movement. Before long, both inverted pendulums unavoidably crash into the ground (Fig. 5).

The pendulums' fall can be avoided if something slows down the upper mass and accelerates it again, in good synchronicity with the lower inverted pendulum. This accelerating and decelerating conformance with the lower inverted pendulum costs lots of energy.

As a result, our computations show that the inverted pendulum can only save approximately one quarter of all the energy in one step to use in the next step. This is not very effective. Fortunately, by taking into consideration the elastic properties of fascia, we can suggest a simple improvement to the inverted pendulum concept, which solves the above problems.

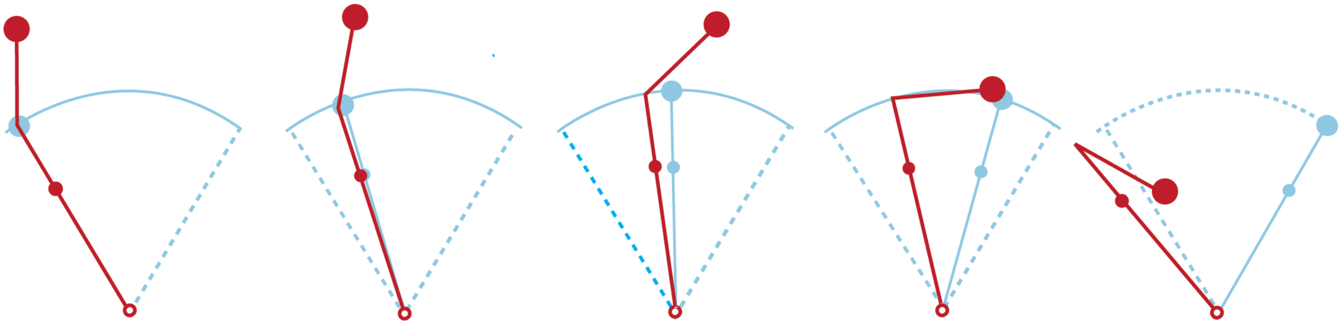


Figure 5: This is a comparison of movement of the inverted pendulum and the double inverted pendulum, starting with the same initial conditions.

Elastic Fascia

In this section, we will question generally accepted views about the nature of the most common tissue in the human body.

We daresay there is a lot of confusion in the medical world regarding the nomenclature and characteristics of tight connective tissue. This confusion can, unfortunately, lead to confusion in discussions regarding how tendons, fascia, and the like work together during human walking. Therefore, before we proceed further, we would like to clarify a few foundational concepts.

First: We would like to clear up the misconception regarding the elastic properties of collagen and elastin. If a person thinks steel is hard and rubber is elastic, we have to remind him, "what cannot bend will break." He does not realize that steel is strong because it is elastically yielding. The yielding motion is so small that it escapes observation. Early anatomists were of the same sort, and their erroneous thinking is still alive today.

Henry Gray's classic 1918 publication *Anatomy of the Human Body* states, "Tendons are devoid of elasticity." These early anatomists distinguished between "elastin" and "collagen" fibers in the connective tissue. *Colla* is the Greek word for glue and a misleading denotation. Today, the elasticity of collagenous tissue is demonstrated beyond any doubt, not only by hopping kangaroos, but also in laboratories showing the properties of tendons, ligaments, and fascia in various mammals. (see also page 368 in this book)

The difference between elastin and collagen is not about being more or less elastic – both are of the elastic kind – but rather that elastin and collagen have different quantities of elastic stiffness.

However, many of the most respectable physiologists still write about "elastic and collagenous fibers," implicitly suggesting that collagen fibers are not elastic. They should at least use the correct - though still unfortunate - term "elastin and collagen fibers." Even worse, practitioners of both conventional and complementary medicine often speak blithely about "non-elastic collagen." Next time a person tells you how non-elastic collagen is, you might want to show him Christopher Anderson's video, featuring the projection of chameleon tongues.[8]

The difference between elastin and collagen is not about being ***more or less*** elastic – both are of the elastic kind – but rather that elastin and collagen have different quantities of elastic stiffness. (Young's modulus is used to quantify the stiffness of an elastic material.) Collagen is approximately 100 times stiffer than elastin, meaning it can store the same amount of energy while stretching only one-hundredth the amount. A 1957 text written by Henry Bull, a professor of physiological chemistry, states: "Since collagen fibers are not much extensible, their elastic properties, so far as biology is concerned, are of limited interest."[9] In our opinion, this statement is nonsense.

The high stiffness is essential for the locomotion system of the human body. You don't want your plantar fascia stretched one hundred times more than it is when receiving the body's weight, do you? The stiff collagen can take a lot of force and store a lot of energy while changing its shape just a little. The source of the misunderstanding is the wonderfully unobtrusive nature way in which collagenous tissue does its job. Collagen is to the body what steel is to technology, and both are the most used materials for the purpose of stability in their respective fields. If you still have any doubts about that, you can try building a suspension bridge with rubber ropes.

It is no wonder that the collagenous tissue of animals was also the preferred material in pre-industrial technology, when elastic material with great stiffness was needed for things like catapults, arch-bow strings, tennis rackets, violins, drum skins, parts of the Zeppelin, and even for condoms.

Second: The general nomenclature we have for high-tensile, elastic, collagenous tissues rarely indicates accurately their biomechanical function. There are tendons, aponeuroses, fasciae, ligaments, retinaculae, septa, membrana, joint capsules, and many others. However, the sharp distinctions made among these collagenous tissues stem from the dissection of corpses, so there is a lack of understanding about their common function. In fact, the only clear borders between them are those made by the anatomist's knife.

Two examples:

Aponeuroses are flattened tendons … Fasciae are aponeurotic laminae. – early anatomist Henry Gray[10]

'Fascia' may be an inappropriate classification for the lumbodorsal fascia because it blends medially with vertebral ligaments and forms aponeurotic attachments for the transversus abdominis and latissimus dorsi muscles, so might also be considered ligamentous or tendinous. – Priscilla Barker, physiotherapist[11]

This nomenclature often tempts biomechanical researchers to consider only tendons while ignoring fascia. Consequently, although it means taking quite a big step away from the established tradition, we would like to support the suggestion of Thomas Findley and Robert Schleip that the term "fascia" be used as a **group name** "for all kinds of high-tensile, collagenous tissues that have a function in the musculo-skeletal framework."[12]

We would like to support the suggestion of Thomas Findley and Robert Schleip that the term "fascia" be used as a group name "for all kinds of high-tensile, collagenous tissues that have a function in the musculo-skeletal framework."

This suggestion was made at the two international conferences on fascia research in 2007 and 2009. (Interestingly, although these conferences were each explicitly named "Fascia Research Congress," they featured topics on tendons, ligaments, and other tissues.) This naming suggestion was hotly debated because typical examples of tendons and fascia seem to show very different structures when observed under a microscope. Nevertheless, as we are concerned in this chapter with the ***biomechanical function*** of fascia, we will use the term fascia as a **group name**, as defined above, from here forward.

Third: We would like to address those practitioners of complementary medicine who claim to work only with the elite tissue "fascia," despising "mundane" muscles. For example, when one of the authors was sharing a practice with another Rolfer, he was not allowed to have dumbbells visibly lying around. By spurning muscle work, practitioners unintentionally make a distinction between tendons and fascia – causing them to work with only one and ignore the other. In addition, we feel such practitioners are missing a real understanding of the human body structure. There is not a single fascia in an awake body that is not exposed to a pull by certain muscles. In our opinion, fascia and muscles must skillfully work together in any accurate representation of the human body.

Muscle Springs

Previously, we called into question the necessity of a muscle-driven gait. In this section, we introduce the devices that can replace contracting muscles in propelling a walker forward.

In the 1940s, the first researchers who used electromyography (EMG) devices to explore muscle activity in walking people expressed their surprise about how much work was done in braking activities.[13] They found that the work to decelerate moving limbs was almost as much as the work needed to accelerate them. The researchers would have expected otherwise – that much more energy is used in forward propulsion.

During deceleration, the muscle that slows down the movement works "eccentrically" – the outer force stretches it while it tries to contract. (By the way, for physicists, the term "eccentric" is a little confusing – it means "without a general center." It developed historically from research on the heart muscle.) This fact stimulated a discussion among some of the founders of modern muscle physiology, such as A.V. Hill and Wallace Fenn, about whether the stretching of the muscles might actually be storing elastic energy in their tendons. It would have been an elegant trick to store the lost kinetic energy of the limb somewhere and recycle it for the next acceleration, like an electric train that is able to produce electric energy while braking. But finally, they came to the conclusion that holding the tendons tight would cost too much energy. In 1957, Fenn wrote: "The limbs do not 'bounce' from their tendons, and the body does not bounce from one step to another however 'elastic' the step may appear to be."[14]

Contrary to traditional opinions, elastic mechanisms do *play* a role in *walking*.

Instead, these physiologists suggested the existence of so-called "chemical springs," meaning muscles that produce chemical energy when they are contracting while elongating – like accumulators.[14,15] This theory seems to be the origin of the term "negative work" for the work done by eccentrically acting muscles.

As mentioned earlier in this chapter, Cavagna examined the kinetics of walking humans and confirmed the absence of bouncing movements. He came to the conclusion that, in human walking, energy is saved by the inverted pendulum, and contrary to running, the storage of elastic energy is not involved.[1] This conclusion was reinforced from a similar standpoint by R. McNeill Alexander, a professor in the department of biological sciences at the University of Leeds and the undoubted authority for all questions about the usage of elastic mechanisms for the locomotion of animals.[16]

We will demonstrate that Fenn, Cavagna, and Alexander were correct – there is not much bouncing. However, bouncing is not the only elastic thing fascia can do. Compare the freely bouncing movements of a ball bouncing back from the ground, a child jumping on a trampoline, or a hopping kangaroo with the controlled, constrained movements of catapults, crossbows, mechanical clocks, and grasshoppers.

After modern, portable ultrasound devices became available, it was demonstrated that, contrary to traditional opinions, elastic mechanisms ***do*** play a role in walking.[17] Research led by Tetsuo Fukunaga, professor in the department of life science at the University of Tokyo, showed that the gastrocnemius muscle and the Achilles tendon actually function as a catapult. When the stance leg rolls over the ankle joint, the gastrocnemius muscle holds against the ankle, and its tendon is drawn by the falling body weight. Although the muscle maintains an almost constant length, its resisting force rises. This force is the same one that increasingly stretches the tendon. At the moment when the knee buckles, the tendon launches the new swing leg.

The stance leg must be straight in order to function properly. Otherwise, the Achilles spring could not be drawn and suddenly released – it acts as an *escapement* (a catch) device. Consequently, this design provides another explanation for the straight stance leg than the "inverted pendulum" model: Through the help of the stance leg, the falling body weight is

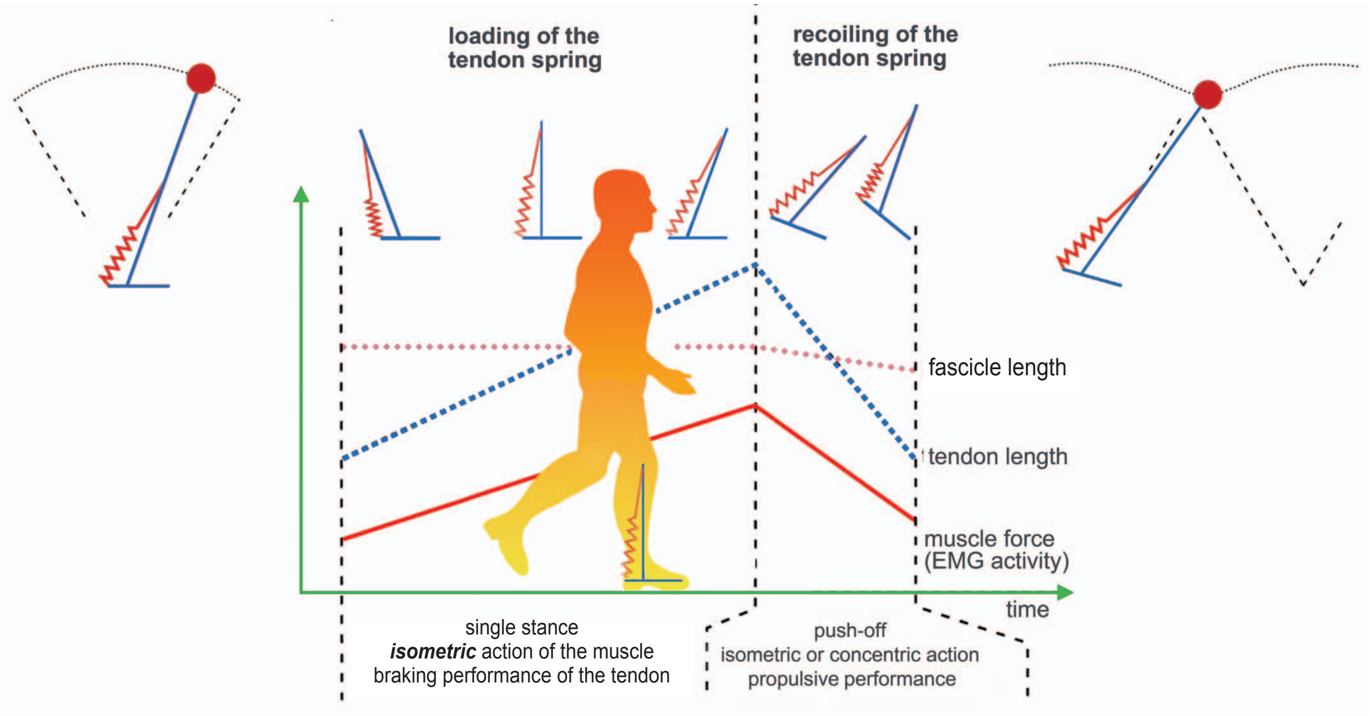


Figure 6: The gastrocnemius muscle and its fascia (aponeurosis) are shown here during single stance and push-off in walking, according to researcher Tetsuo Fukunaga.[17]

softly slowed down, and its energy is used to draw the Achilles tendon, like the string of a catapult (Fig. 6).

The most interesting point in this design is probably that the gastrocnemius muscle *fascicles* are working strictly isometrically. (Please note the difference from the common usage of the term "isometric," which means constant length of muscle and tendon together.) Like a Velcro strip, the fascicles get locked at a certain length, determined by neural control. Then, they maintain their length against increasing force. Therefore, the length change of the whole muscle is provided only by the stretching of the fascia spring. This stretching stores energy, which can be used later.

It appears from this muscle feature that isometric action might be especially energy efficient. In addition, isometric contraction can be done in a slow manner and, therefore, anaerobically – which is of utmost importance for endurance walking. Indeed, the muscles in some invertebrates show that isometric action can come with almost zero energy costs – this way mussels can wrestle for hours against the force of pillaging starfish. Unfortunately, research on isometric contraction in humans at levels far below maximum force is surprisingly rare. The few results show high energy efficiency (Fig. 7).

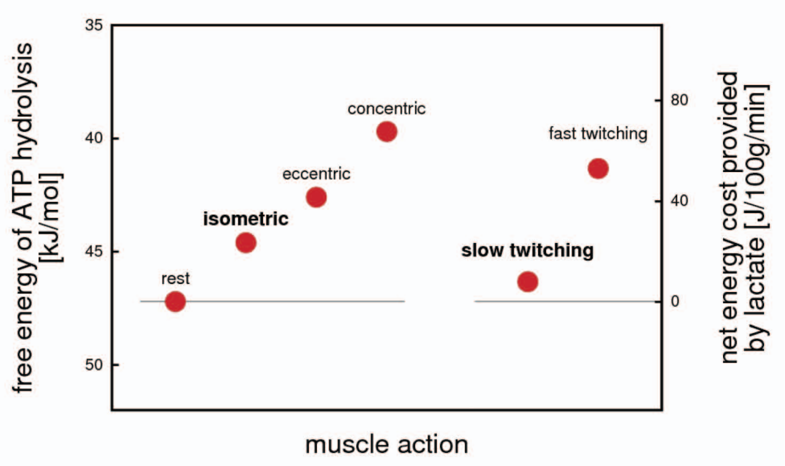


Figure 7: This shows the advantage of low-level isometric contraction. The left values reflect the energy efficiency of different contracting modes.[18] The right values show the energy consumption of slow and fast twitching muscles.[19]

Surveying the EMG results of men walking, we see that many muscles show an increasing EMG activity while they are lengthening and a decreasing activity while they are contracting. Increasing EMG activity indicates increasing muscle force and, therefore, increasing tendon stretch. Inevitably, some part – if not all – of the lengthening of the muscle tendon unit occurs elastically in the tendon. And *vice versa*: Decreasing EMG activity results in a recoiling tendon, and the energy is sent somewhere into the system, whether we like it or not. Just by contemplating the EMG results of human walking, we see no possibility of denying the involvement of elasticity in walking.

We would even like to go one step further and introduce the hypothesis that the above-mentioned Fukunaga mechanism is commonly used in human walking. Isometric action results in increasing EMG activity in the lengthening (braking) muscle, followed by decreasing activity in the shortening (accelerating) muscle. This pattern is what we see in the EMG recordings of many muscles during walking (Figs. 8-10). Although these findings do not provide evidence for pure isometric action, they should be worth considering and may very well merit more research.

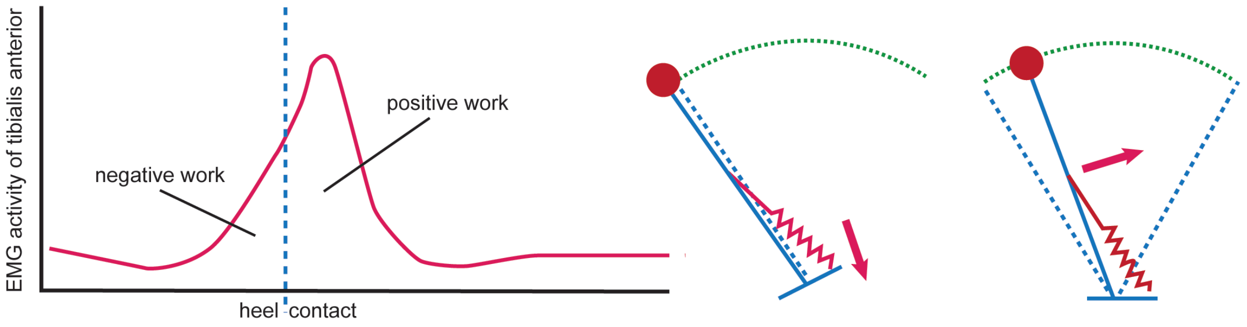


Figure 8: On the left, we see EMG activity of the tibialis anterior.[13] On the right, we assume the spring acts as a shock absorber to brake the fall of the body weight over the ankle joint, and with its recoil helps to lift up the upper body on the inverted pendulum.

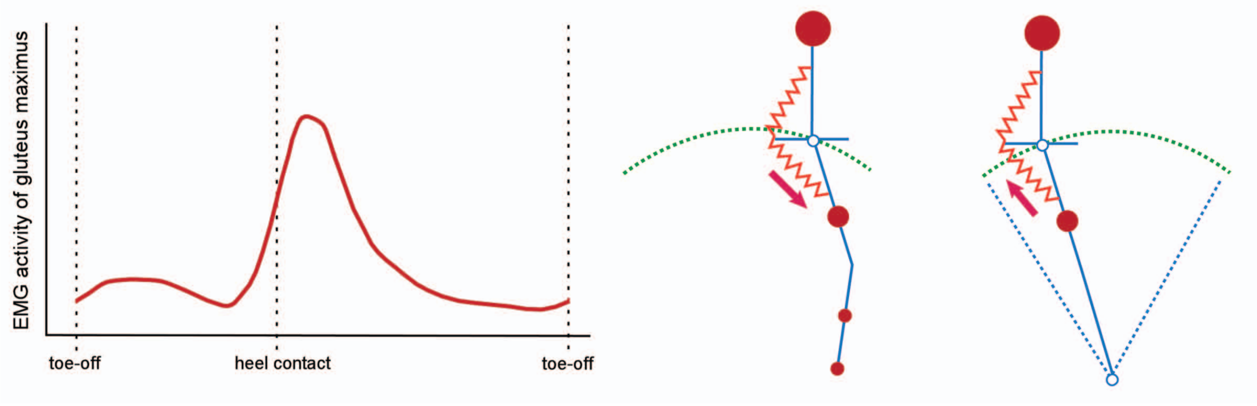


Figure 9: On the left, we see EMG activity of gluteus maximus.[7] The image on the right shows how the energy stored when braking the swing leg is used to help lift up the inverted pendulum. The gluteus maximus shows its strongest performance when the leg is distinctly flexed.

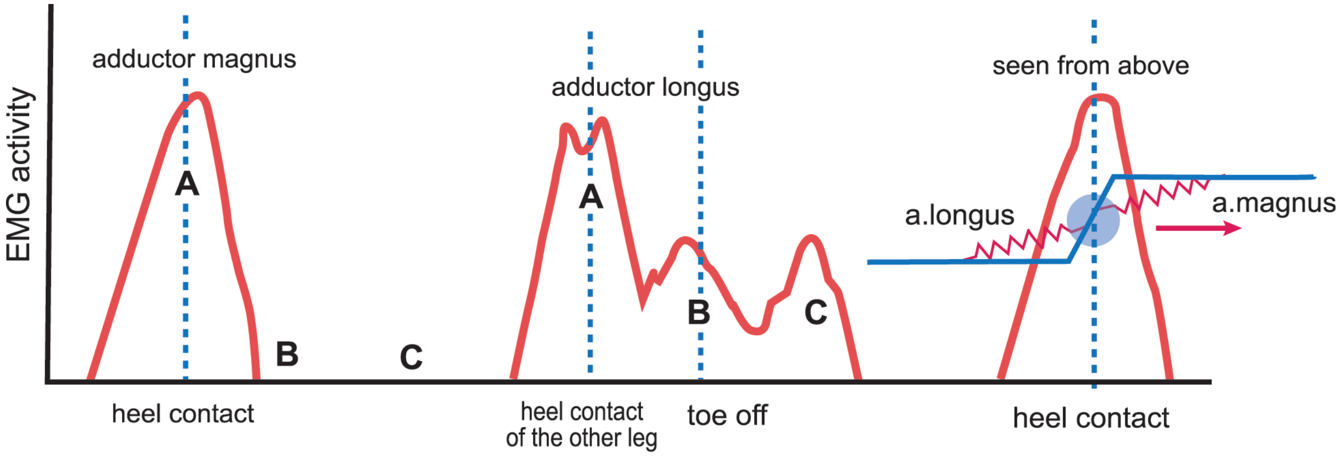


Figure 10: This shows the action of the main adductors.[20] In region A, both muscles are almost serially acting to build a torsion spring pendulum (decelerating and then accelerating back the rotations between the legs and the pelvis).

Applying a pre-tension to a spring that is assembled in a system of levers, masses, and other springs changes the natural frequencies of the system. Therefore, just by changing their isometrically held length, the muscle actuators can set up the fascial springs, and with them the velocity of passive locomotion. This mechanism was probably very important when human gait evolved, and men and women of different stature, carrying different loads, had to walk energy-efficiently together. A comparable adjusting mechanism for pendulums would involve changing the mass distribution in the body – for instance, lifting the lower arms when changing from walking to running – and is, obviously, much less flexible than the elastic adjustments.

The Lumbodorsal Muscle and Its Proximal Tendon

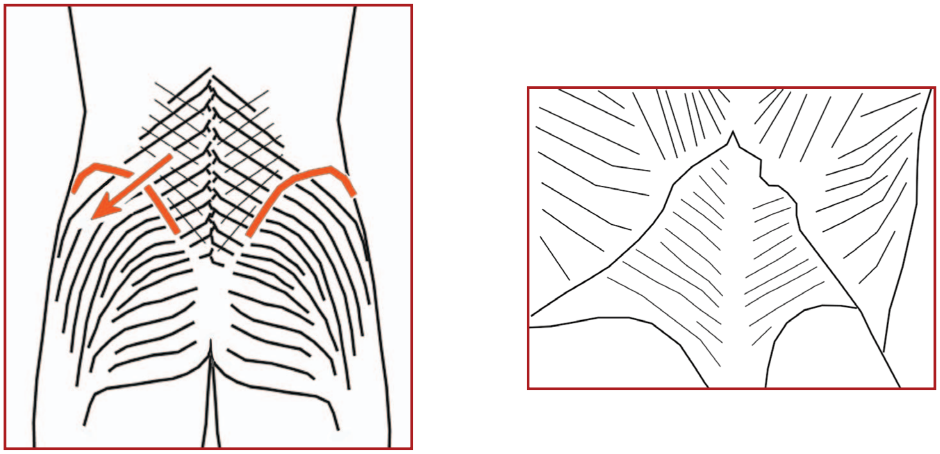
In this section and in the following, we identify some of the anatomical structures that provide the springs for walking.

A very interesting structure is the lumbodorsal fascia, especially “the superficial lamina of the posterior layer of the lumbodorsal fascia,” called PLF from here forward. We include the supraspinous ligament as part of the lumbodorsal fascia, as it is just a thickening of the lumbodorsal fascia that attaches it onto the vertebrae. The PLF is a flat sheet diagonally connecting the spinous processes of the lumbar vertebrae with the iliac crest and the gluteus maximus muscle.

The PLF is a huge structure in a central position, and we are absolutely unable to provide an explanation as to why it is so thoroughly ignored. Although it connects all four limbs, it has never been examined for its role in human locomotion, with possible exceptions in the form of work by Andry Vleeming[21], as well as Serge Gracovetsky.[22]

The PLF has likewise been ignored by researchers in the field of back pain. Nonspecific back pain is one of the most expensive diseases, causing a great number of sick days and costing, for example, the German national economy approximately 25,000 million euros per year. However, it seems that, until very recently, there has not been a single cent spent on determining whether the lumbodorsal fascia might be a possible source of back pain, with the exception of the relatively unknown work of R.J. Dittrich.[23] It wasn’t until 2009 that Jonas Tesarz showed that the PLF is a highly innervated tissue in rats and sends a lot of signals to the spinal cord if the back muscles are chronically inflamed.[24]

The gluteus maximus muscle, which researcher Jack Stern called the “hallmark of bipedality,”[25] is usually assumed to be firmly attached to the iliac crest. However, it has been shown that a considerable percentage of the fibers of the PLF connect directly to the gluteus maximus.[11] In addition, the fiber orientation of the PLF shows a continuation of the fiber orientation of the gluteus maximus, and the line of the iliac crest runs almost orthogonal to both (Fig. 11). These facts suggest a joint action of the PLF and the gluteus maximus.



Human Fascia **Gorilla Fascia**

Figure 11: On the left is the fiber orientation of gluteus maximus and lumbodorsal fascia (posterior layer) in a human body.[11,26,27] The arrow shows the direction of the motion of the iliac crest shortly after heel strike.

On the right is the fiber orientation of the lumbodorsal fascia (posterior layer) in a gorilla. Notice the “opposite” angle due to the continuation of the latissimus dorsi fibers. *Courtesy of Institute for Plastination, Heidelberg.*

It is generally accepted that the gluteus maximus muscle acts as a hip extensor. This function is taken for granted, and the question rarely arises as to why the orientation of its fibers is so distinctly oblique. Some of the muscle's fibers are even oriented completely horizontally, which means that, when used in straight standing as hip erectors, both sides pull in opposite directions and waste energy by doing a no-winner tug of war. In addition, the muscle's fibers show a distinct curvature. However, when the hip extensor function of the gluteus maximus is optimized for the position at the moment of heel strike in walking, the oblique fiber direction parallels the oblique directed leg, the curvature diminishes, and the fiber orientation makes perfect sense (Fig. 12).

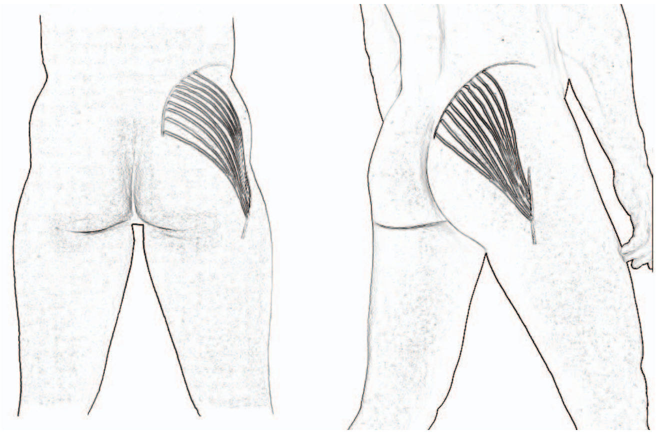


Figure 12: This image illustrates the efficiency of the gluteus maximus when functioning as a hip extensor in standing and at the moment of heel strike in walking. Compare this with Figure 11, which shows the continuation by the lumbodorsal fascia.

Like a half-turn of a helix – being the shortest line between two points on a cylindrical surface – the fibers of the gluteus maximus and the PLF connect the thigh directly to the upper lumbar vertebrae. Accordingly, the human gluteus maximus shows its strongest activity around the heel strike while walking (Fig. 13 and pages 16 and 185 in this book).

At the moment of heel strike, two strong forces are necessary:

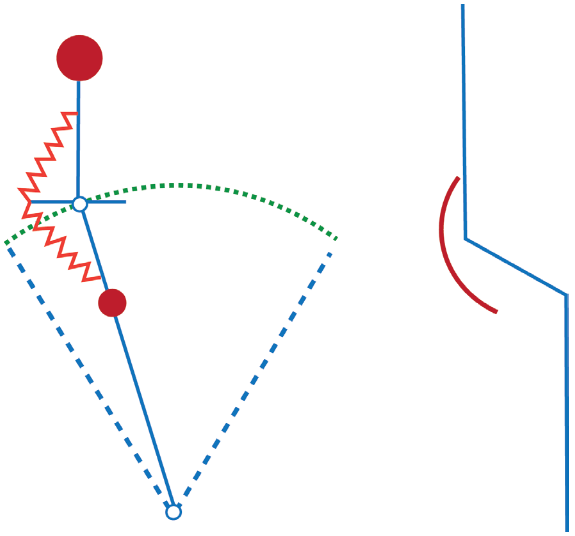


Figure 13: On the left is a simplified model that suggests action of the gluteus maximus and the PLF as adjustable springs at the moment of heel strike in the sagittal plane.

On the right is the position and pathway of the gluteus maximus and the PLF at the moment of heel strike in the transverse plane.

1. Extension of the leg to prevent collapsing to the ground and to provide a propelling force.
2. Extension of the spine (on the hip) to prevent the upper body from falling forward and to maintain balance.

We assume that the PLF does most of the work in skillful coordination, as explained below. Then, these two strong forces negotiate the position of the iliac crest (rotating around the hip joint) between one another, meaning that the iliac crest is, to some extent, floating between the gluteus maximus and the PLF. The PLF then actually acts as a tendon of the gluteus maximus.

This muscle coordination can easily be spoiled. Chronically tensed back erector muscles can provide a „shortcut“ for the PLF. Tensed hip flexors or lazy abdominals allow the pelvis to drop in front and compress the lumbar region in the back (see pages 20 and 81 in this book). In both cases, the PLF, with its elasticity, is taken out of the system – and might take revenge in the form of pain.

The Other Side

In the previous section, we discussed a spring in the back of the body. Now, we seek its antagonist in the front, necessary for balance.

We assume, in the elastic action of walking, the partner of the gluteus maximus/lumbodorsal fascia on the front side of the body is the psoas major muscle (Fig. 14).

Back in 1867, Duchenne concluded from his observation of polio victims with various paralyzed muscles that the only indispensable muscles for walking, with or without mechanical support devices, are the hip flexors, such as the psoas, which are responsible for the forward movement of the swing leg.[4] Even considering these long-ago findings, our knowledge of the function of the psoas in walking is still surprisingly limited. When the function of the psoas major as a hip flexor has been examined, its performance at an extended hip – the starting position of the swing leg – has been ignored in most cases.

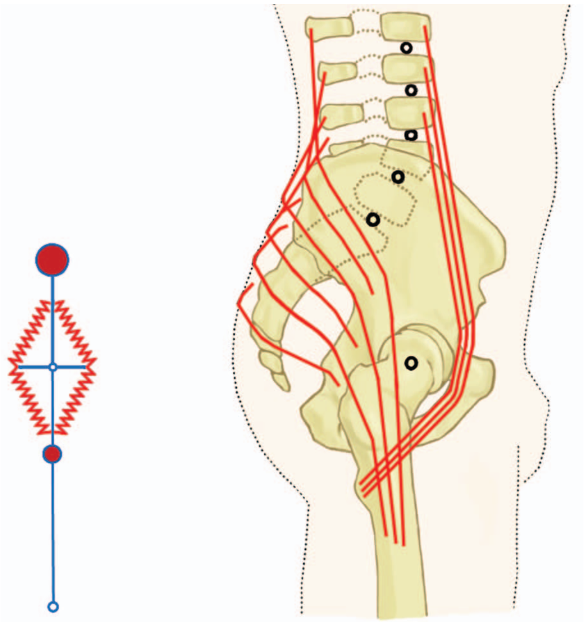


Figure 14: Gluteus maximus, lumbodorsal fascia, and psoas major are in a good position to maintain balance of the upper body while driving the leg. Ida Rolf: “If the psoas is involved, each step does not start in the legs, but at the 12th thoracic vertebra.“[28]

Mainly, the literature on the psoas addresses only its assumed function as a stabilizer of both the hip joint and the lumbar spine.[29] Dr. Nikolai Bogduk, a professor of biomedical sciences at the University of Newcastle in Australia, disagrees with the “stabilizing function.” He reports: “A striking feature of the fascicles of psoas major is their similarity of length. This suggests that the psoas is designed to act from the lumbar spine on the femur. With all fascicles of similar length, they would all undergo the same relative shortening and would share to the same extent the linear excursion of their common site of attachment on the femur.”[30] This statement seems to support our assumption that the muscle fibers act mostly isometrically as they draw the tendon spring in the Fukunaga-like manner outlined earlier in this chapter.

EMG measurements of the psoas in walking are difficult and rare due to its deep location. Usually, data given on the “iliopsoas” actually refer to the iliacus. In 1966, noted orthopedic surgeon Dr. Robert D. Keagy implanted electrodes in the psoas during the course of lumbar sympathectomy surgeries on five patients. He reported activity in each patient during heel-rise and for the initial 40 percent of the swing-phase.[31] In 1997, guided by ultrasound technique, researcher Eva Andersson inserted needle electrodes from the back in four people. She found a sustained activation overlapping the end of the stance period and the beginning of the swing phase.[32] Both results resemble the activity pattern illustrated in Figures 8 and 9 and, therefore, support our muscle spring hypothesis. However, these results alone are not sufficient for us to fully accept the hypothesis.

In walking, the psoas is stretched most when the hip is in internal rotation. In his book *Iliopsoas*, Dr. Arthur A. Michele writes, “When through secondary muscle group action the hip is stabilized in a position of internal rotation, the action of the iliopsoas is enhanced. At this time, the lesser trochanter is posterior and medial to the axis of the femur, and contraction of the iliopsoas when riding anteriorly over the crest of the pubis produces reinforced and more deliberate lateral flexion and rotation of the spinal components through the transverse processes, which are posterior and lateral to the central axis of the vertebral bodies.”[33] This rotation between pelvis and spine supports the stretch of the PLF on the other side. We speculate that a small rotation indicates a slight utilization of the psoas and the PLF. On the other hand, the great rotations we have found in walking people in remote Africa might be an indication of the greater potential usage of psoas and PLF.

For reasons of simplification, in the last two sections, we only consider one muscle spring each for the back and the front side of the body. We chose the muscle spring that we feel to be the most important. We did not consider other muscles, although for the actions described in the following sections to occur, we would also expect synergistic action of the hamstrings, the adductor magnus, the tibialis anterior, the erector spinae with the gluteus maximus and the iliacus, the adductor longus, the triceps surae, and the abdominals with the psoas. Besides, many other collagenous structures are surely involved (see e.g. the chapter by Serge Gracovetsky in this book.

Is the Action of the Lumbodorsal Fascia Actually a Bootstrap Mechanism?

In this section and the following, we explain what the above-introduced springs are actually doing in a walking body. It turns out that they move the legs by maintaining the balance of the upper body and vice versa – they also maintain the balance by moving the legs.

It has been observed that women of some African tribes are able to walk with loads on their heads without using much more energy than if they were not loaded.[34] Balancing such a load while expending almost no energy is a trick British army recruits were not able to perform.[35] It was also found that the varying distribution of mass among obese and nonobese men and women has no influence on energy expenditure – an unknown "novel energy-saving mechanism adopted by obese people" was assumed.[36]

The involvement of elastic fascia, especially the gluteus maximus and the psoas springs, might provide a possible explanation as an energy-saving mechanism. To understand how elastic elements can make a difference, let us first explore a model of a single inverted pendulum with an elastic spring (Fig. 15).

This design has three kinds of energy: kinetic energy and gravitational potential energy (as in the ordinary inverted pendulum), plus the elastic potential energy of the spring. To some extent, the elastic energy takes over the job that the kinetic energy was supposed to do alone in the classical inverted pendulum model – acting as a counterpart for the potential energy of gravity. Therefore, less kinetic energy is needed.

The spring can also be short and stiff (like collagen). Then it stretches only for a brief moment near the turning points and has slack in between. Such a spring can be easily overlooked, because most of the time this design is indistinguishable from a simple inverted pendulum without a spring (Fig. 15).

The addition of a spring to the inverted pendulum has important consequences: If the spring parameters are adjusted properly, meaning that the spring is neither too loose nor too stiff, this structure oscillates and has a natural frequency. In this sense, it is a true pendulum.

The addition of a spring to the inverted pendulum has important consequences.

Near the turning points, the stretched spring effectively brakes the movement. The reduced velocity facilitates the solution of the above-mentioned step-to-step transition problem, preventing the collision of the falling inverted pendulum with the ground.

At this point, we would like to introduce an invention that we see as the most exciting innovation in the development of human walking, and also most peculiar in the field of technical mechanics and human technology: The inverted

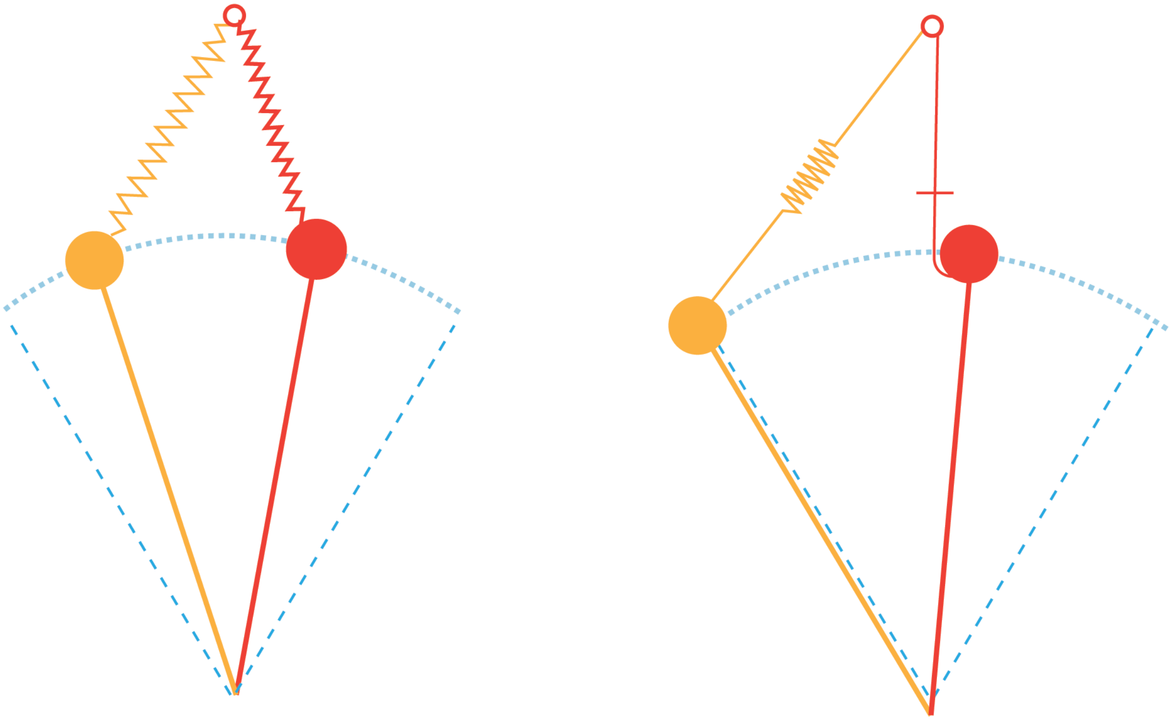


Figure 15: Here we see the inverted pendulum at a spring suspension.
On the left is the fundamental design. On the right, we see it with a short, stiff spring, which stretches only near the turning points and has slack in between.

pendulum itself carries around the suspension point of its own supporting spring. In accordance with some analogies in human technology, we can say it is "bootstrapping" itself. The term bootstrapping, or just "booting," is used in technology to describe a device that feeds back a certain part of its output into its own input. The origin of this expression was also in reference to gravity: According to a German tale from the 18th century, the Baron Münchhausen pulled at his bootstraps to lift himself out of a swamp.

In the first half of the movement period, shown in Figure 16 from left to right, the left spring – gluteus maximus/PLF – is pulling the lower pendulum upward and forward. Therefore, less momentum, or kinetic energy, is needed to reach the summit. At the same time, the left spring prevents the upper pendulum from falling forward by decelerating it. During the second half, the right spring – the psoas with its long tendon – is braking the falling movement of the lower pendulum, thus reducing its final speed. Simultaneously, the right spring is preventing the upper pendulum from falling backward by accelerating it. The two kinds of energy loss (the up and down in the field of gravity and the acceleration and deceleration) don't add up – to some extent, they cancel each other out. This design actually *needs* a certain amount of mass as a counterweight, balancing high above the hip joint as is typical for the human species and its erect posture in walking.

At this point in our thinking, we ask ourselves: Is the performance of such a structure theoretically possible? Is it capable of moving completely passively, with no pushing or correction by muscles? Will the upper inverted pendulum really finish the movement with zero degrees of deviation from the ideal balance? And not sway too much in between? And even if it does, will the nonsymmetric action of the swing leg not spoil everything?

To find the answer, we created a similar sagittal plane model in a computer program and endowed it with the precise anthropometric data for the stance

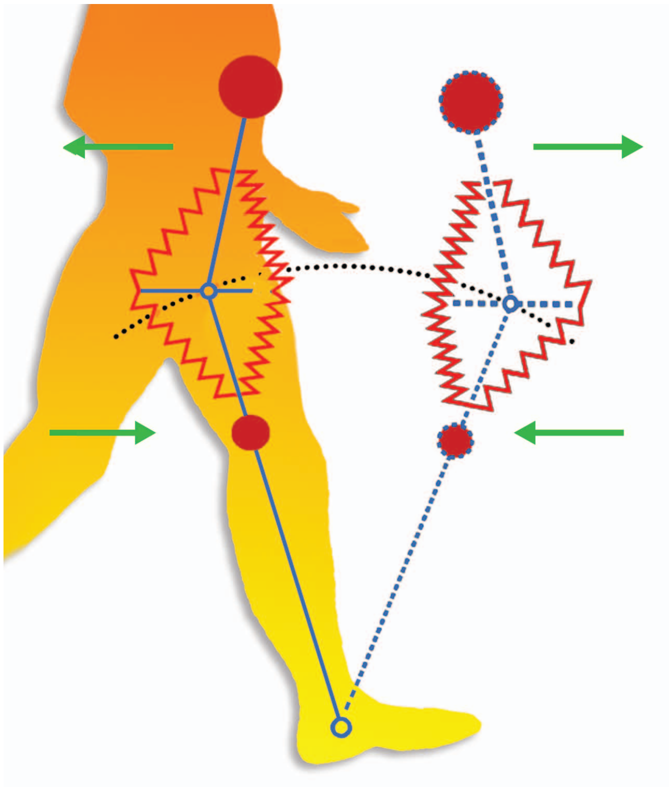


Figure 16: Two inverted pendulums connected with two springs build a bootstrap design for the lower inverted pendulum. Here we see two snapshots of their movement. The arrows symbolize the resulting motion from the pulling forces of the springs. The left spring represents the gluteus maximus/PLF. The right spring represents the psoas with its long tendon.

leg and the upper body. We added a swing leg, which moves per constraint condition, together with the stance leg. The muscles were regarded as fixed-length strings doing no work. We solved the movement equations with the help of some mathematical tools of applied mechanics and determined the spring parameters (length and stiffness) that make the design work properly.

We found that, after proper adjustment of the spring parameters, such a structure is indeed able to work well, at least in principle. At the end of the motion, the upper body is held in perfect balance. The maximum deviation from balance during the whole period is always less than three degrees.

There are several spring pendulums in this model: the standing leg and the foot, the calf and thigh of the swing leg, and the arms, to name a few. It is hard to see, but the trunk is also swinging back and forth with perfect resonance. While the base of the trunk (the hip) accelerates and decelerates in the forward direction, the head moves with constant velocity – making it easier to watch out for dangerous predators. The trunk also oscillates around the vertical axis as a torsion spring pendulum. (Gracovetsky[37])

Interestingly, just by changing the resting length of the springs, and with them the natural frequencies of these spring pendulums, our model can adapt to various velocities, anatomical variations, and even to a certain amount of carried weight. And all of this completely passive, without any action by engines (muscles) or any other expenditure of energy.

In the bootstrap model the muscle springs move the legs by maintaining the balance of the upper body and vice versa – they maintain the balance by moving the legs.

The Throw Leg

In this section, we deal with another "mystery" of human walking: the purpose of the swing leg. We will show how the seemingly awkward swing leg is actually necessary to human gait and perfectly suited to work with the bootstrap model.

Of course, the bootstrap mechanism suggested in the last section has one significant snag: No catapult or arch bow can work without a person to draw the string. Looking at Figure 16, you can see that the stance leg starts the step extended – with a tensed gluteus maximus/PLF spring on the left side and a slack psoas spring on the right side – and ends in the opposite orientation.

What is transferring the tension from the right spring back to the left spring to prepare the structure for the next cycle? We hypothesize that this job is done by the swing leg.

Compared with other animals, humans have heavy legs and very heavy feet (Fig. 17). This feature is as unique as the erect posture, although less commonly noticed.

Even more peculiar, humans sometimes like to wear heavy footwear. The history of human warfare provides countless accounts of armies that had to quick march over long distances and arrive as fresh as possible at the battlefield with their very survival at stake. However, there are no accounts of armies whose soldiers put on sandals and carried their heavy boots in their rucksacks.

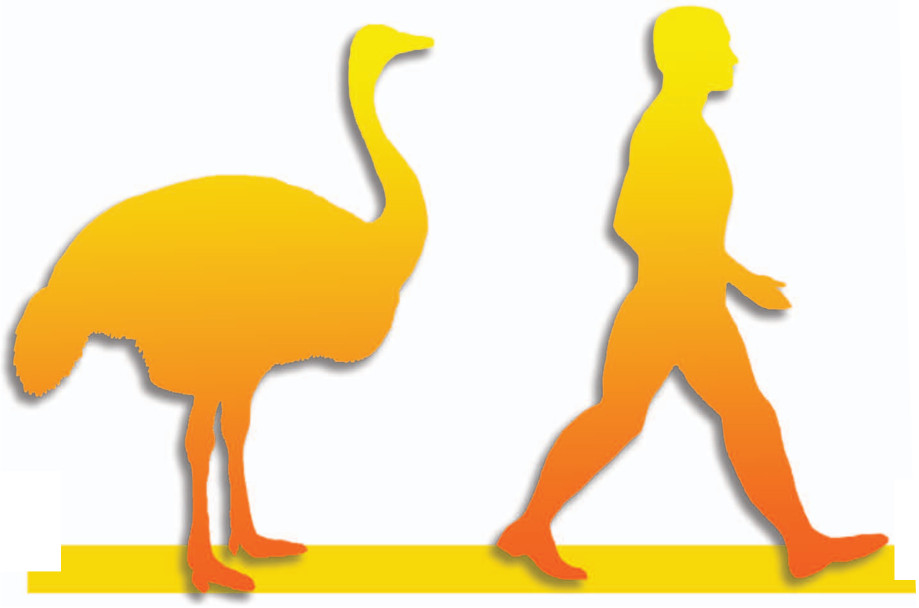


Figure 17: Illustrated here is mass distribution (moment of inertia) below the hip joint in ostrich and man. The greater the dark region, the more weight has to be flung around for the swing leg action.

The swing leg must strongly accelerate at the beginning of each step and decelerate again a short moment later. Having so much weight, it is not surprising that its action has been estimated to "consume" one-third or one-fourth of the net energy needed for walking.[38,39]

In traditional gait analysis, the swing leg is treated as if its action is not connected to the rest of the gait – as if its only task is to return to the start position. In such an analysis, its heavy weight appears to cost a great deal of energy. In our model, however, the swing leg fits the gait like a jigsaw piece and serves the purpose of saving energy.

We suggest that the nature of the swing leg's action is fundamentally elastic, and, thus, is not only energy-conserving, but also adjustable to different requirements for speed and load. The swing leg might actually be an *elastic oscillator* (a "spring pendulum") as shown in Figure 18.

In such a structure, the stretched spring accelerates the pendulum mass, thus transferring its potential energy into kinetic energy. Then the other spring decelerates the pendulum, again transferring the kinetic energy back into potential energy. After this half-cycle, the springs have exchanged their states of tension. If nothing happens, the pendulum would then reverse its direction, and after the next half-cycle everything would be exactly as it was at the beginning. In real walking, however, the back swing is prevented by the dropping of the foot onto the ground (heel strike) after one half-cycle.

This catch mechanism acts as an escapement and allows only half a full

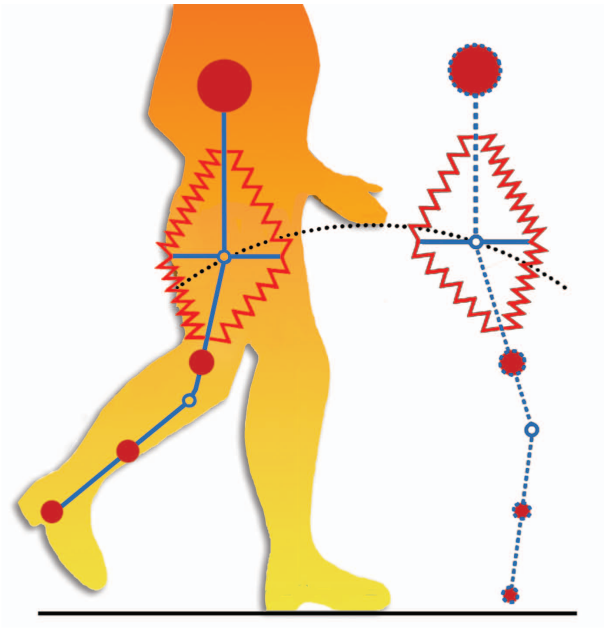


Figure 18: This illustrates the suggested action of the free leg swinging from the hip joint. Being simplified to frictionless pendulums, masses, and springs, this design is a real oscillator and can swing back and forth without any energy expenditure. Its frequency can be set by the adjustment of the spring parameters.

In real walking, the springs on the left side might be the gluteus maximus and lumbodorsal fascia, and those on the right might be the psoas major and its tendon. The dropping of the foot onto the ground stops the oscillation when the pendulum has reached the right turning point and the lumbodorsal spring has its maximum stretch.

oscillation cycle, in the very same way as the anchor of a mechanical clock: The back-and-forth oscillation is transformed into a pure forward motion. The natural movement is stopped when the spring has its maximum tension, and instead of a back swing of the swing leg pendulum, the tension of the spring is used for the stance leg action.

A consequence of the escapement action and, therefore, a typical feature of controlled oscillators[40] is the "ticking" – well known from mechanical clocks and watches. In walking, the ticking[40] is the heel striking.

The great inertia of the heavy leg and foot – the pendulum masses – is necessary to store enough kinetic energy to take over the load of the psoas spring and transfer it to the gluteus maximus/PLF spring, thus preparing the next stance leg for action. Seen from this perspective, the "swing" leg could also be regarded as a "throw" leg. In 1965, researcher and physician Dr. Wladimir T. Liberson reported in the *Archives of Physical Medicine and Rehabilitation*: "One unexpected correlation was that the maximum acceleration of the leg corresponds to the onset of dorsiflexion of the foot after push off."[41] This occurs because the spring catapult acts in an instant after releasing and throws the weight. After that, the gluteus maximus/PLF spring catches the weight again.

If the swing leg were just a simple pendulum, as it is considered to be by some researchers, there would not be many possibilities to adjust its velocity. But the spring-driven oscillator can easily be adjusted by the spring parameters to different requirements for speed and load.

Catch mechanisms and escapements are known to be necessary to secure the temporal stability of controlled oscillators.[40] From neurological research, we know that "sensory input is particularly crucial at the transitions between both phases of the step cycle."[42] We hypothesize that one of the functions of the heel strike ticks, controlled by the brain, might be the synchronization of the two freely oscillating structures of the stance leg, with the upper body, and the swing leg. Physicists would say that the brain makes sure that the two oscillators are "phase locked."

In our opinion, the model of a rolling egg, mentioned at the beginning of this chapter, is not a good analogy for human walking. Far more apt would be the precision of a Swiss clock, running a long time without needing a windup.

The controlled, guided, restrained nature of the elastic actions of both the stance leg and the swing leg might be the reason why this has escaped the attention of many researchers so far. As demonstrated in the quote from Wallace Fenn on page 104[14], many researchers have taken for granted that elastic action has to manifest itself in bouncing-like motions.

Who is Able to Walk Elastically?

In this section, we discuss how the swingwalking model applies to our everyday lives. Does the swingwalking model represent the normal gait style, or just the advanced ability of exotic movement artists?

Traditional gait analysis assumes that "healthy persons" – people not suffering from back pain, Parkinson's disease, club foot, palsy, prostheses, and so on – have a "normal" gait. Often, for example, gait analysts will explain what "the" gluteus maximus muscle is doing – as if there were only one way of walking. However, this type of analysis contradicts the common observation that there are many different gaits. Among people regarded as clinically healthy, there are great variations of gait style, and some of them might promote the development of pain more than others. We are very interested in finding a classification of gait styles practiced by clinically healthy persons.

Examining the results of our computations, we were surprised at how sensitively the springs must be adjusted in order to work properly. Even deviations of less than one millimeter of the resting length of the springs make the system crash to the ground within the first two cycles. In real life, such deviations would have to be corrected by the neuromuscular system in a costly manner. And these consequences happen even in our highly simplified model!

We assume that it is always possible to tramp forward without much elasticity, driven by muscles, but an energy-efficient, swinging, and elastic walking style requires a very sensitive, sophisticated, and skillful multi-balance adjustment (see also page 374 in this book).

We assume that it is always possible to tramp forward without much elasticity, driven by muscles, but an energy-efficient, swinging, and elastic walking style requires a very sensitive, sophisticated, and skillful multi-balance adjustment.

Such a scheme gives an entirely new meaning to the term "balance" – applicable not only in space but also in time. As neurophysiologist Nikolai Bernstein says, a regular movement is actually a four-dimensional (space-time) **structure**.[43]

We speculate that this space-time balance is a "higher" function in the brain and, therefore, develops late in childhood and can get lost rather early with aging. This theory might explain why providing Parkinson's disease or stroke patients with rhythmic music therapy improves their walking.[44]

It is possible that the ability to walk with optimal elasticity only truly develops if learned from early childhood and prompted by the environment. It is also possible that the environment of Western industrial civilization simply does not require children to learn efficient, elastic walking. Therefore, the figure of speech "having a spring in the step" usually refers to an *extraordinary* person or state, but evolution may have intended this for everyone. We suppose this lack of proper usage of elastic fascia contributes to the pandemic of lower back pain in the Western world.

Figure 19: Children in Northern Ghana

We ask ourselves how people might walk in areas where mechanical transport is not available – not even for carrying water, where roads with flat surfac-

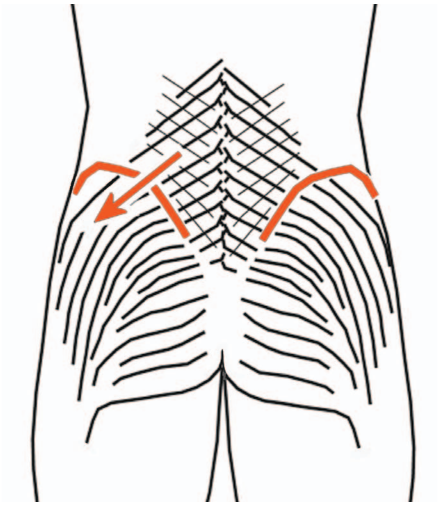


Figure 20: Here we see the lumbodorsal fascia, gluteus maximus, and the movement direction of the pelvic crest shortly after heel strike (Fig. 11).

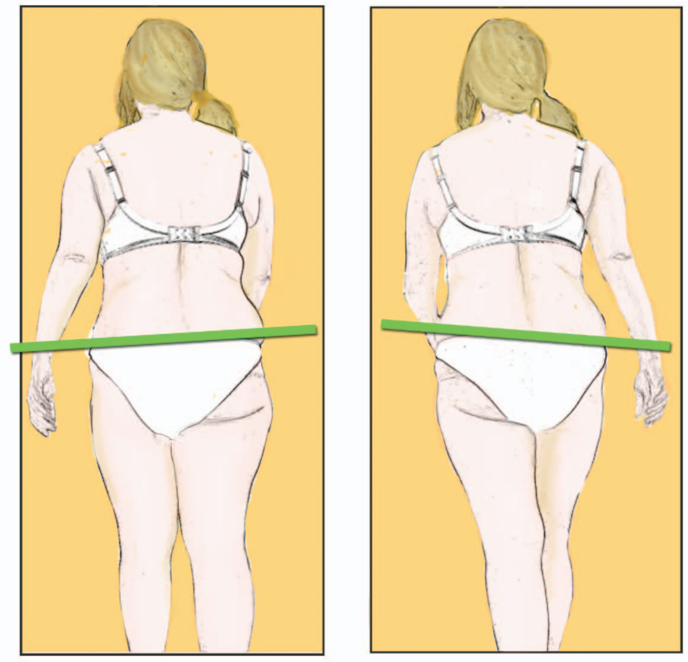


Figure 21: This is an example of a typical European pattern, with maximum values of the rotation in the frontal plane.

es are not known, and where children leave school after three or four years and are then expected to contribute to the daily workload.

It has been observed – and is still a puzzling issue for researchers – that women in some African tribes are able to walk with quite heavy loads on their heads, while not using much more energy than when they are not loaded.

In fact, as we noted earlier in this chapter:

It has been observed – and is still a puzzling issue for researchers – that women in some African tribes are able to walk with quite heavy loads on their heads, while not using much more energy than when they are not loaded.[34]

We suspected that elasticity might provide the explanation, so we prepared a three-dimensional (3D) camera, which was basically two cameras meticulously calibrated, mounted at the ends of a long bar, and carefully stored into a gun case. We then traveled into remote regions of Zambia and Ghana. Unfortunately, it seems to be much easier to mobilize funding for projects in which Africans learn from “superior” Europeans, rather than *vice versa*. The airline we could afford from private resources showed a certain reluctance to accept a gun case as hand luggage. The camera survived the rough African baggage handling but the calibration was lost.

As a consequence, the results of our 3D camera were not fully usable. We could only obtain a lot of two-dimensional data, which at least gives us the possibility of examining the motion of the iliac crest in the frontal plane. The data clearly shows that, on average, African pelvises rotate much more than European ones. This might be an indication of

Figure 22: Here we see a woman in remote Zambia carrying a load of 15 kilograms on her head. The images show maximum values of the rotation in the frontal plane. This woman carries water from the village well home several times each day. A video is available at www.swingwalker.net

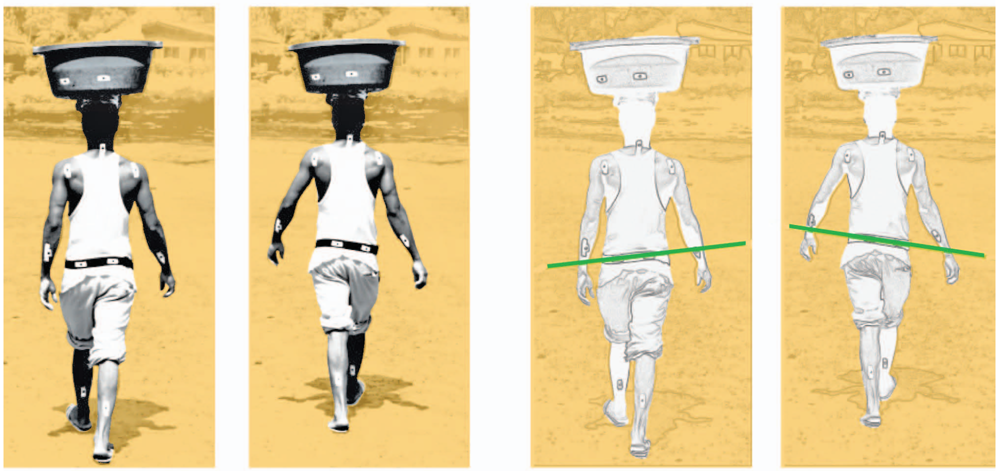


Figure 23: Here we see a man in remote Ghana carrying a load of 15 kilograms on his head. The images show the maximum values of the rotation in the frontal plane. This man makes his living from farming and selling firewood – all things are transported by head carrying.

an extended stretching and recoiling usage of the lumbodorsal fascia (Figs. 20-23).

Please note that the images show the respective moment of maximum rotation in the frontal plane.

It may be objected that we show the Africans with and the European without loads on their heads, and that this cannot be seen as a fair comparison because the load might influence the style of gait. This is a good point, and we could add that the ground that the European walked on was very flat and even, that the European shoes were fancier, and that the Africans smiled a lot more. But it is our intention to compare people walking with the typical styles of their daily lives. Anyway, please feel free to check your pelvic rotation while carrying a head load and smiling.

Finally, we should mention that we observed strong rotations of the pelvis not only in the frontal plane, but also in the transverse plane, suggesting a contribution from the "spinal engine." (Gracovetsky[37]) Furthermore, a highly pronounced arm swing is common in the African style of walking.

Swinging Lumbars

So, after all, what is the advantage of exercising elastic walking?

Unfortunately, collagenous fibers sustain aging processes. Certain cells, the fibroblasts, are responsible for maintenance of the fibers and are always active with repair and replacement. However, these cells can only survive and do their job if provided with oxygen, nutrition, and waste removal. Most of these fibroblasts are located very far from the next transport pathway, because the strong tensile forces exerted on the fibers generate a high pressure in the vicinity, preventing blood vessels from working properly.

The lack of fibroblasts is obvious in joint cartilage and intervertebral discs, but a similar lack is found in other high tensile fascial tissue, too. The only available transport mechanism, besides the rather weak diffusion, supplying the cells is the back-and-forth squeezing of the tissue fluid due to movement – like the "muscle pump." Just as soup needs to be stirred so that it does not scorch, the fascial tissue needs movement lest it starve.

In many people from our culture, the lower back is a desert territory suffering famine.

In many people from our culture, the lower back is a desert territory suffering famine. This famine results in degenerating collagenous fibers – a syndrome we might call "frozen lumbars." While walking, the lower back moves like a monolithic block, showing little motion within. The lumbodorsal fascia can seldom stretch itself, and the discs are buried alive.

Instead, we would like to see in any walking person a swinging motion of the lumbar vertebral bow. The discs should rock back and forth, and the lumbodorsal fascia, the disc walls, and the surrounding fascial tissue should have to stretch – exercise – rhythmically (Figs. 24 and 25, see also page 376 in this book).

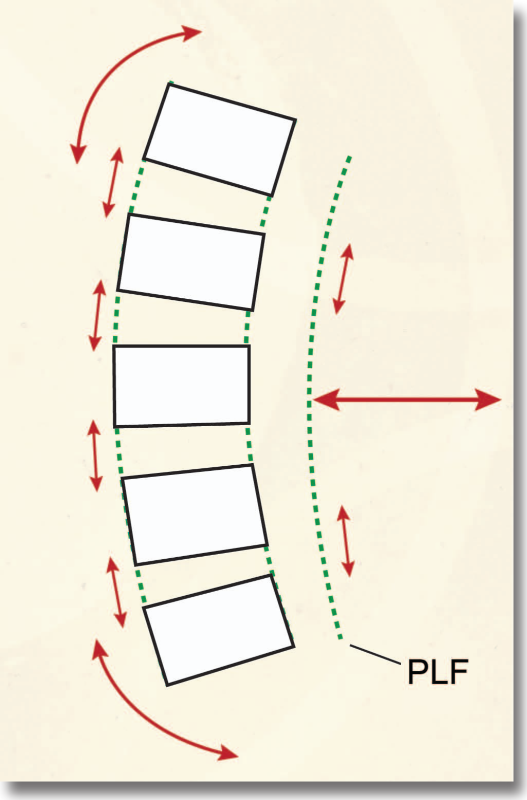


Figure 24: This illustrates the motions of lumbar swing.

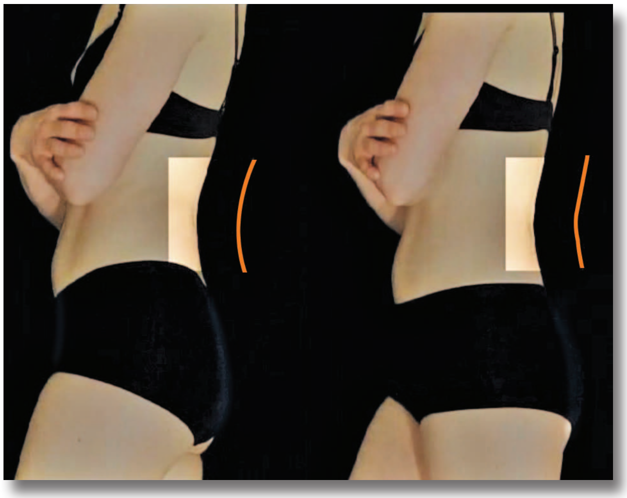


Figure 25: The lumbodorsal bow should show a slight swinging motion.

Put a Spring in Your Back: Practical Advice

Finally, we arrive at the nuts and bolts.

The bootstrap action of the stance leg and the spring pendulum action of the swing leg are only hypotheses at the moment, and we are fully aware that nature likes to falsify elegant, convincing hypotheses. Much more research about the possible elastic mechanisms of human walking is necessary. Therefore, it is quite foolhardy to give practical advice based on these thoughts and deliberations. Besides, teaching movement in a book is almost as questionable as teaching digestion in a book.

In other words, please don't take this too seriously. Look on it as an experiment. If any of our advice increases pain anywhere, please return immediately to your normal style of walking! You might wait a few days and make a new attempt, thus showing "patient stubbornness," but keep in mind that our hints might be wrong for *your* body. In any case, after some experimentation with our suggestions, change everything and create your own system.

Here in Germany, the lumbodorsal fascia of new Rolfing® clients on the treadmill rarely show any movement at all. Generally, we have some success treating this condition by teaching a new style of walking and supporting it with manual treatment. Interestingly, when the pelvis starts to increase its mobility, the same strange thing almost always happens: The client starts to smile a certain way. If we ask the person why he or she is smiling, we hear a wide range of explanations. Nevertheless, we have learned to call it the "pelvic smile."

These are some suggestions we often give our clients:

1 In gait analysis, it is often considered "normal" for the knee to still be bent in the middle of the stance phase. Sometimes, this is even demanded under the heading "unlocking the knees," and the position is assumed to bring elasticity into the system. On the contrary, we think it takes elasticity out of the system and advise against it.

Look sideways into a shop window, let the lower leg (and the toes) relax at the end of the swing phase and *try not to have a visibly bent knee* in the stance leg at all. Don't stop, even if it feels weird! Imagine the old Egyptian pictures of Pharaohs – the straight legs were supposed to underline their divine nature. If somebody tells you "relax your knees" – meaning you should bend them – don't listen!

The opposite of "locked knees" is not bent knees but relaxed knees, and only with straight knees can the muscles be relaxed. In a healthy, relaxed straight knee, the cruciate ligaments are doing something that is uniquely human – the so-called "locking home" or "screwing home" of the knee joint, which stabilizes the joint against rotations.

A friend might help you illustrate the importance of straight knees by pushing heavily down on your shoulders. If your protecting (and protesting) reflexes work, your knees will straighten immediately. Walk tall and think of this quote from revolutionary leader Emiliano Zapata: "I'd rather die on my feet than live on my knees."

2 Although Africans don't do it, and although it does not look very elegant for women, we suggest, for the purpose of exercise, to spread the *feet farther apart*, laterally. Walk toward a shop window and make sure you can look through your feet. Most likely, then, the *medial* side of each foot takes over more weight than before. Don't stop, even if it feels weird!

Check your reflection again – contrary to your actual feeling, you don't look like John Wayne playing a seaman. If any healthcare practitioner insists that the outside (lateral side) of the foot should carry the weight, don't listen! This challenges the function of the elastic foot structures, and the pelvis starts to move in a salsa-like fashion, thus giving the sacroiliac joint back its natural job (compare "hip drop on page 58 in this book). Now you look like a pharaoh from the side and a Cuban dancer from behind.

3. Look sideways into a shop window and make sure your thorax is not leaning behind the pelvis (hanging in locked lumbars). If necessary, shift the *thorax a little bit forward* without moving the pelvis backward, thus putting the "waistline back," as Ida Rolf would say. Most likely you are now looking down at the ground in front of you, so lift your head and look to the horizon without leaning back again. Don't stop, even if the head might feel all wrong (too far forward) and strange, like a ski-jumper leaning forward at the start.

4. Look sideways into a shop window and make sure the front side of your pelvis is not hanging down too much. If necessary, try to lift the *pubic bone up* (without lifting the chest) and, in Rolf's words again, "horizontalize your pelvis." Check that your thorax doesn't lean back again. While walking in this manner, you might feel a stretching at the hip flexors. Most likely, you have a tight "butt grip" now, so hold the pelvis in place but let your buttocks drop.

Enjoy your long back. This will involve the rectus abdominis and bring us into deep trouble, because this muscle is taboo. It is a celebrity muscle in the gym, and the disdained urchin among most practitioners of complementary care – sadly, including many Rolfers. We want it neither weak and loose, nor tight and bulging, as is sometimes encouraged in gym workouts. We want it "competent and elastic," according to Rolf, like a drum skin, with the breath as the drummer.

With the help of the abdominal muscles, the pelvis can be carried with active, aware balance, instead of loosely bumping around. Then the lumbodorsal fascia can get a pre-tension in order to become a rhythmically stretching spring, propelling you forward, instead of being a neglected piece of crumpled tissue. The pubic bone should be the pitch elevator (as in aviation) of body movement and the tuning key for the lumbodorsal *fascia engine*. Imagine an embryo carried in the pelvic bowl wanting to feel safe – neither being in danger of being squeezed like a lemon, nor of getting dropped out in front. At the beginning, this balancing of the pelvis on the femur might feel unbearably strenuous. Don't stop, even if it feels weird or if exercising the rectus abdominis is contrary to your training as a practitioner. Encourage yourself with this affirmation: "Being human means to balance!"

5. When walking, shift *the whole weight forward* until your forefeet carry, on average, more weight than before. Lengthen your step, and push off the ground with the help of the straight knee. Your walking is probably more silent now, indicating that you have started to walk with the feet (not only heels) and do more elastic work with the Achilles tendon. Again, don't stop, even if it feels weird! Rasta people cultivated this movement to show their superior (more elastic) way of walking to the Yankees. Think of a bouncing rubber ball. You are 10 years younger now.

6. Swing the arms far behind you until you can turn the "heel strike" into a heel contact – soft like a cat's paw. Now, your *pelvis* is *rotating* in the horizontal plane. Don't worry, male readers! It might feel strange, but it does not look effeminate.

7. Now comes the most difficult part: When walking, try to let your *sacrum bone drop*, as if yielding to a great weight. Relax the erectors in the back – the long ones next to the vertebral column. It may help to imagine "directing the inhale into the lower back." Think of the hip-hop kids with the baggy, deep-hanging pants. "In walking, the pelvis should move like a rocking chair," according to Rolf. If it feels weird, you're doing well! Ask somebody if your lumbar vertebrae are swinging when you walk – Rolf's "psoas walk" – and if they are, try to feel the difference yourself.

8. Walk tall, as if you have a weight on your head. Try to push the weight as high as you can. Pretend you are trying to push it into the sky, then try to push the weight up a little more. As Rolf would say, "Top of the head up!"

While you are walking tall, make sure your shoulders can freely move, so that neck rotation is possible. This posture engages the deep neck musculature and relaxes the outer, often too hysteric, muscles.

Feel proud! Allow every part of your body to swing loose, while maintaining a determined tonus in the forefeet, the pubic bone holder, and the muscles engaged in balancing weight on your head. Don't forget to breathe. Don't stop, even if it looks weird! This is the patrician rhetoric posture: upright and serene.

9 Try to maintain a little smile the whole time.

Yes, this ***is*** a little bit weird. As weird as human walking.

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Figure 26: Adjo Zorn, walking in Berlin

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Adjo Zorn, Ph.D.

Adjo Zorn has a Ph.D. in the physics of solar cells, as well as a German state license in Naturopathic medicine. He is now working as a freelancer in several fields: as a software engineer for car manufacturers, in his own Rolfing practice, and as a psychologist with detoxification and cancer clinics. He is a movement enthusiast and has been training in different movement schools (jazz dance, rock-climbing, Tai Chi, Karate) since the age of 15. For the last four years he has enjoyed struggling with Capoeira.

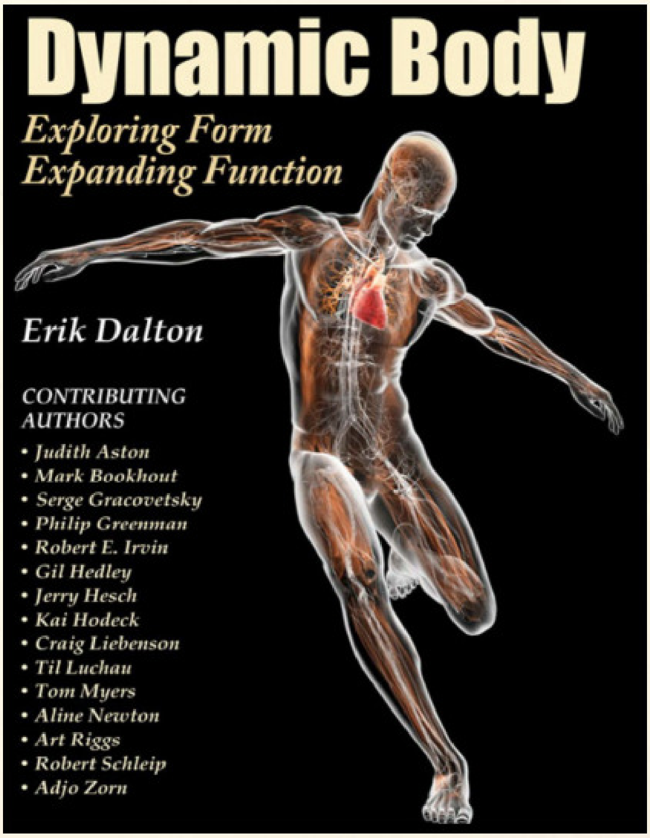
In his attempt to combine all these interests he has started a research project about the biomechanics of human walking in the Fascia Research Department at the University of Ulm. Hopefully this will help him to improve his most sophisticated activity of all - good walking.

For more information, visit www.swingwalker.net.

Kai F. Hodeck, Ph.D.

Kai Hodeck earned his doctorate in the physics of semiconductor quantum structures at the Berlin University of Technology. Later, his research interests shifted toward biological systems. Today, Hodeck works as a scientist at the Helmholtz Research Center for Materials and Energy, with a focus on the physics of water in biological systems. He is also a member of the Fascia Research Project team at Ulm University, with a Rolfing® practice in Berlin.

Hodeck's lifelong passion for movement and sports has allowed him to compete in judo, water polo, and dancing. For more than 10 years, he practiced and taught martial arts intensively. This led Hodeck to explore yoga, Feldenkrais®, and, eventually, Rolfing.



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CONTRIBUTING AUTHORS

- *Judith Aston*
- *Mark Bookhout*
- *Serge Gracovetsky*
- *Philip Greenman*
- *Robert E. Irvin*
- *Gil Hedley*
- *Jerry Hesch*
- *Kai Hodeck*
- *Craig Liebenson*
- *Til Luchau*
- *Tom Myers*
- *Aline Newton*
- *Art Riggs*
- *Robert Schleip*
- *Adjo Zorn*