

Running Faster and Easier Through Improved
Economy and Biomechanics: A Kinesiological Analysis

K. G. Harper, November 2006

Brigham Young University Hawaii

Table of Contents

Introduction	Page 3
Teaching/Coaching Experience	Page 4
Mechanical Analysis	Page 5
Kinesiological Analysis	Page 10
Summary	Page 12
Bibliography	Page 14

Introduction

Some would say that running is easy, you just go out and do it right? Unfortunately, much of what the vast majority of distance runners know about running technique is wrong. Paying attention to running biomechanics is serious and is a major player in how effective a runner is at what he does, regardless of his skill level. Learning to run effectively and efficiently is a tough task for most runners. There are a blessed few who run efficiently, but most of the running population (including elite athletes) has to work on it. Changing running form is a long process that includes training muscles in a whole new way than most runners are used to.

After undergoing an analysis of elite distance runners down to the back of the pack, the author noted that the runners at the front ran the most efficiently, while efficiency (or proper technique) generally decreased as the speed of the runners decreased. This article will endeavor to explain through kinesiological analysis how a distance runner can run most biomechanically efficient using recent research and the technique of the world's best distance runners as a guide.

Distance running with proper biomechanical technique requires a concerted effort and involves the entire body. In overview, the feet should strike the ground as close to midfoot as possible. The legs should drive forward in a straight line. Hips should be forward while the center of gravity should be positioned directly over the foot. To help the legs drive straight and the foot to strike underneath the center of gravity, the arms should go forward and back with as little side to side sway as possible and the elbows should never cross forward pass the torso.

Teaching-Coaching Experience

The author has spent much time observing distance running technique during the 2006 Cross Country season at BYU Hawaii. As with the observation of elite distance runners versus slower runners, the athletes who were at the front of the Cross Country races during the season seemed to be the athletes that were the most biomechanically sound. They appeared to be exerting the least amount of effort and using their body to as much benefit as possible. In addition, degradation of technique tended to progress along with degradation of performance---the slower runners generally tended to possess the worst form.

The author has spent a good deal of time working on improving running technique with members of his community, customers of Runner's Corner in Orem, Utah, and the BYU Hawaii Cross Country team.

This time spent has been very convincing that a persons running technique is gradually attained over a long period of time and that it is difficult to change such a habit. However, it has also been convincing that with effort, running technique can be changed with very beneficial results. Several members of the community report decreased fatigue and less pain due to positive modifications of their form. The author used himself during the 2006 study and was very successful in implementing changes (most notably shortening stride and increasing frequency) that more than likely resulted in increased performance and definitely made the effort feel easier.

The conclusions of this experience are that running form can make a big difference in both the performance of the runners and their ability to stave off injury.

However, changing technique in adults requires concerted effort, repeat coaching, and even a change in what muscles are being emphasized during the activity.

Mechanical Analysis

Proper running technique requires more mechanical concepts than the average runner (or person) would think of. The motion of the legs is very important, but so is the placement of the hips, the posture of the runner, and arm movement.

Starting from the top of the body and working down will allow the runner to more easily grasp the most important aspect of what they are doing, the movement of the legs. The head should sit squarely and comfortably in an upright position facing straight ahead. While many runners like to focus on the person in front of them, it is suggested that the head is kept erect while the eyes gaze down as to not throw off the rest of the body. This will allow the shoulders to stay relaxed which will permit the arms to do what they need to do. In addition, the jaw and face should be extremely relaxed.

While arm movement doesn't tend to add to performance, improper arm use can decrease performance. Proper arm movement can be summarized by saying it should be straight, high, compact, and relaxed. The arms should swing comfortably at the sides of the body driving as close to straight back as possible with very little side to side sway. Since the backwards pump of the arms is the drive phase, the forward motion should be a recovery phase used mainly to set up another drive phase. In distance running, the angle of the elbows should be at 90 degrees or less, which will feel very compact to most people. Elite distance runners often have elbow angles far less than 90 degrees.

While the shoulders should be relaxed, the general position of the arms could be said to be high---that is, the general positioning of the arms is such that the hands generally stay in the vicinity of the chest and mid torso. In watching Olympic performances, you will rarely see the hands of these runners drop below their hips.

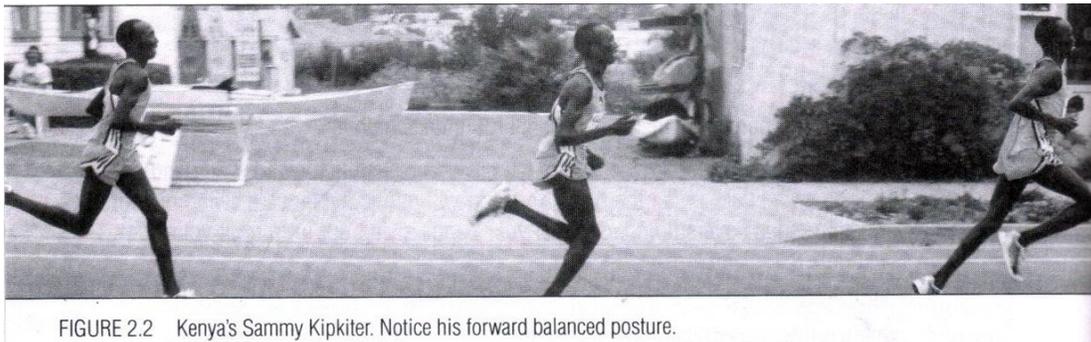
The arms should follow a principle of not crossing two certain lines or planes. First, when dividing the body using the median or sagittal plane, the fists should not cross this plane while coming forward. In other words, if you were to split your body into a left side and a right side down the center, the fists should never swing in so much as to cross that midline. Second, also upon pumping forward, the elbows should not overextend much past the coronal or frontal plane which divides the body in half front to back. In essence, as the arms come forward in the recovery phase the elbows should not come forward past the hips.

Keeping the arms straight forward and back will ensure efficiency in going from point A to point B (i.e. running in a straight line) while keeping the elbows from crossing forward past the hips helps prevent excessive heel strike (more on this later). Remember, the backswing is what allows for forward power and the arms only swing forward in order to recover for the next backswing. The fists of elite distance runners usually recover somewhere up between the chest and even as high as the chin, i.e. Khalid Khannouchi breaking the world record at the 1999 Chicago Marathon, (CBS, 1999).

In addition, hands and wrists should feel natural to the runner. This generally means that the wrists are relaxed and the hands are in a loose fist. It should be noted that while the positioning and movements of the arms are important, the legs are what does

the work. Proper arm movement and positioning just allows the legs to better do their job.

One major difference between that of sprinting and distance running seems to be in the position of the upper body. While many older sources (Galloway, 1984) proliferate the claim of running erect as sprinters do, newer research (Miller, 2002; Romanov, 2006) suggests that distance runners should use gravity to their advantage and run with a slight forward lean. (Image from *Programmed to Run*, p. 34)



In observation, elite distance runners tend to run nearly upright but with their chest pushed slightly forward, in a seeming attempt to use gravity to their advantage. Their hips are also forward as to lead the top half of the body along ahead of the legs. This (in combination with proper arm positioning as discussed above) allows the foot to strike directly below the center of mass and makes it very difficult to over-stride and heel strike.

In Tom Miller's Book *Programmed to Run* he notes that the previously called incorrect, leaning form is “identical to that of most Kenyans”, while the previously

considered correct, erect technique is “similar to that of runners who follow in the Africans' wakes.” Mr. Miller (possibly the most respected distance running form and technique coach in America) calls the leaning form “balanced posture” because the body weight is balanced over the pelvis during running. He notes that as you add forward momentum to the body, an adjustment of posture is needed to keep the body weight balanced. “During leg drive, your body develops a slight lean to align itself with the direction of the driving force.”

Miller also notes that if a runner's posture is too erect, muscles will need to be used to offset the backward movement of the upper body as the lower body is propelled forward. (This could be a possible explanation of why many runners experience lower back pain or soreness after a race or hard effort.) It causes the arms to swing too far forward as well as the legs in front of the center of gravity, which leads to a more straight-legged (less of a loaded spring) foot contact as well as a heel strike.

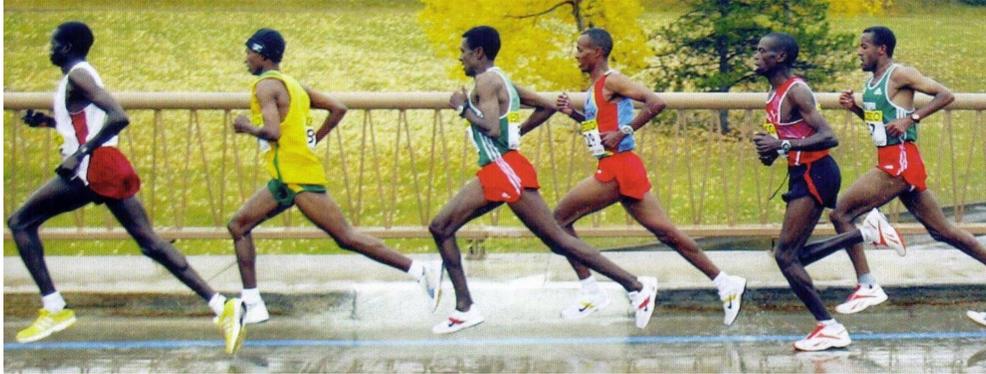
As far as the legs go, the movement should be as efficient as possible. The legs should follow the trend of the rest of the body as far as keeping in a straight line. The knees and feet should drive straight forward and back with as little deviation as possible (although genetic differences make it impossible for many to completely perfect this action). If we start during the support phase (center of gravity directly over the foot with a bent knee), the runner's forward momentum should carry them over the center of gravity at which time the foot lifts off the ground toward the buttocks in order to shorten the lever (the leg) so that it can make the most efficient and straight movement possible forward until the knee begins to extend. At this point, the foot should be relaxed and contact the ground somewhere near mid-foot directly under the body's center of gravity.

If you are still not convinced that an emphasis on heel striking is not technically sound, take off your shoes and go for a run barefoot on the concrete.

Contrary to popular belief, high knee lift is not a necessary component and can actually be a detriment. As far as back kick goes, it is important to avoid shuffling and dragging the feet. While elite distance runners tend to have a slightly higher back kick than elite sprinters, an extremely high back kick is not entirely necessary. What is important is that the foot takes the most direct and efficient path from take off through the position where the knee is at its most extended. Therefore it is inefficient to try and extend the leg all the way straight as this keeps the foot in contact with the ground longer.

Buckalew et al. (1986) did studies on stride length on frequency where it was noted that it is very important for a runner to push off from well behind their center of gravity. This is supported by many other coaches of running form today.

While stride length is important, most runners emphasize it way too much and also go about it the wrong way---that is---by reaching more forward. Effective lengthening of the stride can only be done properly by pushing off more forcefully (spending more time in the air and less on the ground, thus covering more ground). This condemnation of increasing stride length by reaching forward is taught by renowned speed coach Brooks Johnson (1997), Tom Miller, and many others.



Note in this picture of elite African distance runners leading a race the elements of proper technique that are consistent with each of them: head looking forward, slight forward lean, arm angle of 90 degrees or less with emphasis on a powerful back drive and high relaxed recovery, foot contact near midfoot underneath the center of gravity with push off well behind, and all momentum going in the forward direction.

It should be noted that technique changes with speed. An athlete running at five minute pace following the principles of proper technique is going to look different at eight minute pace. In general for distance runners, there is an increase in back kick and backwards arm motion. Also of note is that relaxation is very important to make this whole process work.

Kinesiological Analysis

There are many changes that will need to be made in order for a runner to undergo positive changes in running technique. Obviously, a change in which muscles of the legs will be used is paramount, but changes in hip, torso, and arm movement are needed as well.

When learning to run this way, it is often beneficial to start standing with the arms back as if they were both pumping back. The runner can then push their chest forward (and hips slightly) so that they feel their body start to fall forward which is an indication to take their first step and begin running.

Most people are familiar with the movement of running so assumption will be made that the reader has run before and therefore has an idea of what is being discussed. Therefore, changes in the movement will be discussed. As the foot comes toward striking the ground, extensor muscles of the foot should engage to bring the foot down on the ground as closely to flat as possible. This is considered the contact phase and as the muscles taking the abuse should now be the plantar fascia muscles as well as the anterior flexor muscles of the lower leg, especially tibialis anterior. The quadriceps also absorb much of the impact.

As the loading phase occurs (while the foot is left behind the body's center of gravity), a shift is made to the posterior flexor muscles of the lower leg and especially to the soleus and gastrocnemius muscles.

For most runners, the main thing that will need to be changed is placing more emphasis on the soleus and gastrocnemius muscles of the calf. Costill (1986) noted in his research that elite runners fatigue their gastroc and soleus muscles first when run to exhaustion which is consistent with Johnson's (1997) teachings and that of other exercise physiologists.

Runners who over-stride (heel strike) should focus on taking emphasis off of the hamstring muscles for pulling action. Miller (2002) says that "tight hamstrings are one of the biggest thieves of speed and are almost always associated with over-striding.

Hamstrings are not prime movers. Their design is more suited to providing balance and bending the knee when the foot is unweighted.”

While Romanov (2006)---the inventor of the now popular Pose Method of running which condemns heel strike and emphasizes the use of gravity as a friend---emphasizes the contraction of the hamstrings mainly to lift the heels quickly during the recovery phase, Miller (2002) respectively disagrees and suggests that forward momentum should carry you over your center of gravity before pushing off, thus aligning the hips and reducing the contractile force needed by the hamstring muscles. This seems to be confirmed by watching elite distance runners compete. The hamstrings are then used to support in facilitating knee flexion, quickly bringing the heel through at which time the quadriceps kick in to facilitate knee extension.

For these same runners trying to change their form, an additional amount of use of the quadriceps muscles will take place. In doing this, a greater amount of musculature is used, reducing injury and improving performance. Often, the glute muscles (Gluteus Maximus, Gluteus Minimus, and Piriformis) muscles will become sore when adopting this new style of running. This should be taken as a sign of progress as the hamstrings are being relegated to support and also antagonist status while the quadriceps and glutes become the main movers.

There should also be a decrease in the amount of pressure on the anterior portion of the lower leg (in part due to the lack of a heel strike and less dorsiflexion), reducing pressure on the Tibialis Anterior and toe flexor muscles while the nearly flat foot-strike should spread the muscle distribution evenly between the plantar fascia muscles, plantar flexors, and toe extensors.

Summary

Proper running technique is an art and should be taken seriously by runners who should become students of their sport just as most other successful athletes are generally scholars in their field of expertise. Changing technique will require time and effort and a change in mechanics which will initiate a change in musculature used.

Foot contact should occur near midfoot under a bent knee with after the leg has begun to swing back under the body. Your upper body should carry over your foot leaving your feet to push off and extend behind your center of gravity. The chest should push forward slightly as your arm pumps backward while your hips extend and knees straighten to engage a powerful propulsion. Hands should stay near the chest with a compact arm swing.

Volumes could be dedicated to going in to detail on technique and form as well as the changes in musculature needed. For more information, the author recommends reading Tom Miller's book *Programmed to Run* which pulls together a good deal of observation and research to arrive at logical conclusions that can be grasped by any runner, beginner to elite.

Runners of all levels would benefit greatly by studying running form and mechanics as well as knowing which muscles are contributing. Not only will speed increase with efficiency, but injuries will become less common as well. The author has, while working with others for many years, has used these techniques of running form as much or even more as a way for treating injury as he has for helping people increase their

speed. Knowing the muscles involved and how they work with the body during each stride and in relation to aches and pains is a great help for anyone who is a runner. While concerted and dedicated effort are needed to make the appropriate changes to run efficiently, the benefits can be seen very quickly and are considered to be “life changing” by many runners who have taken the effort to change.

Bibliography

Burfoot, A. 1986. Screen Tests. Written from research compiled by D. Buckalew et al. *Runner's World* (March) 48-49.

CBS Chicago. LaSalle Bank Chicago Marathon 2002. Chicago, Illinois. October, 2002.

Costill, David. Inside Running: Basics of Sports Physiology. Indianapolis, IN. 1986.

Galloway, Jeff. Galloway's Book on Running. Bolinas, CA: Shelter Publications.

Harper, Kenneth. Analysis of Elite Distance Runners in World Class Events. BYU-Hawaii: Laie, HI. November 2006.

Johnson, Brooks. Speed Master. Running Times, June 1997. Pgs 25-30.

Kokkonen, Juoko. EXS 341 Kinesiology Packet. BYU-Hawaii: Laie, Hawaii. Fall 2006.

Mann, Ralph. The Biomechanical Analysis of Sprinters. Track Technique: Mountain View, California. Dec. 1986.

Miller, Thomas. Programmed to Run. Human Kinetics, Champagne, IL. 2002, 23-31.

Romanov, Nicholas. Training with Dr. Romanov: I Just Want to Run. October, 2006. Sourced from: <http://www.posetech.com/training/archives/000393.html>