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Improving the Way Humans Walk

By OTTO POHL

NAIROBI, Kenya — As dawn breaks, Linnette Otieno leaves her small house on Nairobi's outskirts and walks five miles to market. On her head is a load of firewood she plans to sell. The load weighs about 65 pounds. She hardly sweats.

"I've been doing this since I was 6," she explains as she hoists the wood onto her head with an experienced motion.

When she was growing up in her home village in western Kenya, she had to walk even farther to gather firewood, up to eight hours a day. By now, at age 35, she says long journeys with heavy loads are second nature.

Scientists have long wondered how women like Ms. Otieno are able to carry so much so easily. Now, in a study to be published shortly, two researchers from Europe describe the trick in detail: women from certain African tribes unconsciously modify their gait to walk using less energy. The energy they save is applied to carrying the weight.

The study, which follows two previous articles in the journal Nature, is the first documentation of humans' improving the economy of walking.

"Every person and every animal that we have yet tested has roughly the same walking economy, except for these African women," said an author of the study, Dr. Norman Heglund, a physiologist at the Catholic University of Louvain in Belgium. "We were pretty surprised."

Dr. R. McNeill Alexander, an expert on biomechanics who has written a number of books on human and animal locomotion, said the study could be an important step to understanding how to improve the human walk.

Using the results, he said, "we might be able to teach hikers with rucksacks and soldiers with heavy packs to save similar amounts of energy."

The research began when Dr. Heglund was working in Kenya in 1977. He became intrigued when he saw how easily the women walked while carrying heavy loads.

To test his observations, Dr. Heglund and his colleagues asked several women to walk on a treadmill, then measured oxygen consumption and heart rate while they carried a range of weights.

They found that the women could carry 20 percent of their own body weight with no additional exertion. "There wasn't even a blip in their oxygen usage," Dr. Heglund said.

In a control group at Harvard, he asked subjects to walk on a treadmill wearing bicycle helmets lined with varying amounts of lead. Oxygen consumption rose with even the

lightest helmet.

Dr. Heglund found an old Army study documenting the amount of energy that recruits needed to carry heavy packs and found that it rose significantly when they carried the same weight that the African women bore without extra strain.

Looking for a hypothesis, Dr. Heglund turned to Dr. Giovanni Cavagna, a physiologist at the University of Milan, who had created a model of how reduced gravity would affect astronauts walking on the moon. Dr. Cavagna suggested he consider whether the women were changing the way they walked. That proved to be critical, and now, many years later, the two have written the new study explaining the phenomenon.

The walking human can be imagined as a small steel ball (the center of mass) propelled forward on top of two stiff wires (the legs). With each step forward, one end of a wire is planted on the ground, and the steel ball swings in an arc around the other end, just like an upside-down pendulum. As the ball reaches the end of its arc, the other wire is planted farther forward on the ground, and the process is repeated.

To maintain forward movement, the energy of the steel ball needs to be transferred from one pendulum to the other. In normal walking humans, only 65 percent of that energy is actually transferred; the rest is dissipated and must be replaced by additional muscle energy.

But the African women have a secret weapon, the researchers discovered. As they transfer their weight, they transfer at least 80 percent of their forward energy to the next step. Only 20 percent must be replaced by the muscles, leaving plenty of energy in reserve to carry the weight on their heads.

The secret of this efficiency lies in the difference between the two components of energy, potential and kinetic. Potential energy is stored by moving an object to a higher location, able to be released — as kinetic energy — when the object falls.

In a pendulum, there is a near- perfect back and forth transferral of energies: at the height of the pendulum's swing, the ball is not moving and all of the energy is potential; as it falls it is converted into kinetic energy; at the bottom of the swing all of the energy is kinetic. As the ball begins its movement back up the other side of the arc, the energy is transferred back into potential energy, and the process is repeated.

Since each step of a walking human can be understood as an upside- down pendulum, a similar transferral takes place. But the system is nowhere near as efficient as a pendulum. At the height of each step, the normal walking human begins to drop down, losing potential energy without transferring it into kinetic energy, which would generate additional forward speed. The African women, however, are able to minimize this loss through a tiny alteration of their gait.

Interestingly, they apply this trick only when they are carrying things on their heads. When they walk unloaded, Dr. Heglund found, they waste as much energy as all other walkers. It is only as they begin to balance heavy loads on their heads that they change their steps.

It's a tiny difference that is almost invisible to the naked eye, and "even the women don't know how they do it," Dr. Heglund said. But with a sophisticated training program, he went on, "you could train other people to do the same thing."