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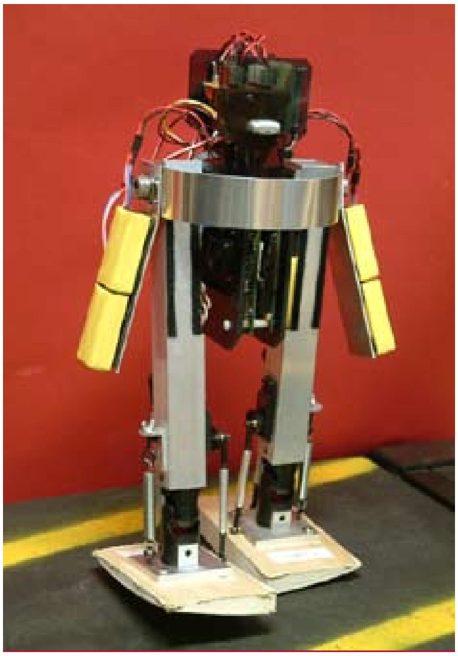

COURTESY MIT NEWS OFFICE

MIT's "Toddler" is no-frills, but its brain enables it to learn to walk (right)

are less energy-sapping. Noting that most of the work in walking goes into redirecting the body's downward motion when the forward foot hits the ground, they are starting to design artificial legs with spring-like units that can store energy and release it during the stepping cycle. "The basic idea is to store the energy from the downstroke, using a spring in the foot, and use it to propel the upstroke," Collins says.

Many existing prosthetic legs already incorporate springs and rubber bumpers in the foot or between articulating joints. But Collins thinks that he and his colleagues have hit on a more efficient arrangement. The main difference between their design and others, he says, is that the energy is returned at the time it would be supplied by the ankle during normal gait. In one device, a spring stores the energy at the heel when the foot strikes the ground and returns it at the toe during push-off.

Even more dramatic enhancements may be possible. In a paper to be published in the journal *Physical Review E*, Ruina and his student Mario Gomes have shown that a passive walker with spring-loaded legs can in principle walk over level ground with no energy cost at all, and so keep walking forever with no energy input. Of course, no real walker could do that; friction and air resistance will inevitably cause some energy to leak away. But the researchers were interested only in the walking action itself, so they ignored these losses in their model.

Their strategy is to eliminate energy-dissipating downward collisions of the foot with the ground. Ruina and Gomes showed that such a collision-free gait exists for a walker made up of two rigid legs connected by a hinge and springs to a torso that tilts backwards and then forwards during each step. In the middle of the step, the walker scuffs the swinging leg along the ground, and in the model this scuffing is treated as frictionless. In practice, friction between the foot and the ground would lead to energy losses, but by giving the legs knees, scuffing could be avoided without fundamentally altering the gait.

A human walk doesn't look anything like this. But the model raises the intriguing idea that by hooking ourselves up to a system of weights and springs that produce a similar effect, we might be able to walk immense distances at very little metabolic cost. "I think it would be possible to build passive prostheses that reduce the cost of walking," Ruina says. "I don't know how clumsy they would be, but I have great confidence that such things could be built in the relatively near future."

Simple mechanical devices that reduce the energy cost of walking and running might also improve the performance of sprinters, marathon runners and high jumpers. "I do think that human performance can be augmented," says Collins. Such devices might pose a problem for sports regulators, though they wouldn't do much more than springy-soled running shoes do at present: they wouldn't use anything more than the energy the athlete's body produces by itself.

The dilemma is not likely to arise any time soon, however. "We're probably a long ways from energy-saving Nikes," Collins admits. "I think the Olympics are safe from us for quite some time." ●

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Cheap gaits

Why do humans walk and run when we could use any number of gaits? Andy Ruina and his student Manoj Srinivasan at Cornell University in Ithaca, New York, think they can explain. A simple mechanical model predicts that walking and running take less energy than other possible gaits (*Nature*, vol 439, p 72).

The researchers idealised the human body as a mass supported by two legs that swing at the hip. To allow the foot to push off and clear the ground on each swing, they included a piston at the knee that extends and retracts the leg like an old-fashioned telescope. They looked for motions that would propel the body for the least amount of piston work.

By varying the force of the pistons, the researchers were able to generate an infinite number of gaits. Out of these, they found that just three seemed to minimise energy cost. One was a standard walk, with legs swinging and the body bobbing up and down. At higher speed, the cheapest gait was a run, in which the leg flexed with each step to push the body into flight. Intriguingly, at speeds in between, Ruina and Srinivasan discovered a third gait, like an odd cross between walking and running, but they suspect it might disappear in a more realistic model that includes muscles, tendons and pivoting ankles.

Does this mean nature has designed us to be walking and running machines? Not so fast. While biomechanics expert McNeill Alexander of the University of Leeds, UK, recognises the model as "a beautiful and enlightening theory", he cautions that "it is so greatly simplified, in comparison to human walking, that it cannot tell us anything about human evolution".