Unlike our ape cousins, humans require high levels of physical activity to be healthy

By Herman Pontzer

Illustration by Bryan Christie

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IN THE PREDAWN DAMP OF A UGANDAN RAIN FOREST NEARLY 20 YEARS AGO, I STARED UP THROUGH the crowded canopy at a party of eight chimpanzees sleeping overhead. Our team of three researchers and two field assistants had woken up an hour before, wiggling into rubber boots and hastily assembling backpacks before setting out on muddy trails by headlamp. Now at our destination, the lights were off, and we stood there silently, submerged in a black ocean of forest, the surface 30 meters above, listening to the chimps chuffing and shifting in their leafy nests.

IN BRIEF

Our closest living relatives, the great apes, have habitually low levels of physical activity yet suffer no ill health effects from being lazy.

Humans have evolved to require far higher levels of exercise to be healthy.

New research reveals that as human anatomy and behavior shifted over the past two million years, so, too, did physiology.

Our physiology adapted to the intensive physical activity that hunting and gathering requires.

As a young Ph.D. student studying human and ape evolution, I was in Kibale National Park that summer to measure how much chimpanzees climb each day. It seemed to me that the energy spent climbing might be a critical factor in chimpanzee ecology and evolution, shaping their anatomy to maximize climbing efficiency, thus sparing calories for reproduction and other essential tasks. Months earlier, while mulling over summer research plans from the comfort of my desk at snowy Harvard University, I envisioned chimpanzees waging a heroic struggle for existence, working hard on a daily basis to eke out a living. But as I settled into the rhythm of fieldwork that summer, following chimpanzees from dawn to dusk, I came to a very different conclusion: chimpanzees are lazy. Only recently have I come to appreciate what ape idleness tells us about human evolution.

People are drawn to apes because we see so much of ourselves in them. It is not just that we share more than 97 percent of our DNA with orangutans, gorillas, chimpanzees and bonobos. Apes are clever, use tools, fight and make up, and sneak off to have sex. Some will kill their neighbors over turf and hunt other species for food. The kids learn from their mothers, wrestle and play with one another, and throw tantrums. And the further back in time we go in the fossil record, the more apelike our ancestors look. No species alive today is a perfect model of the past—all lineages change over time. But living apes provide the best chance to see where we came from and to understand how much of us is ancient and unchanged.

And yet it is the differences, rather than the similarities, between humans and apes that are casting new light on the way our bodies work. Discoveries from fossil excavations, zoos and laboratories around the world are revealing just how radically our bodies changed over the past two million years. For decades researchers have known that this last chapter of our evolution was marked by major anatomical and ecological changes—among them, ballooning brain size, hunting and scavenging, increasingly complex stone tools and larger body size. But they have generally assumed that these were changes in shape and behavior, not in the fundamental function of our cells. Current advances are overturning that view, showing how humans have changed physiologically as well. Unlike our ape cousins, we have evolved a dependency on physical activity. We must move to survive.

PARADISE LOST

A TYPICAL DAY'S AGENDA for a chimpanzee in the wild reads like the daily schedule for lethargic retirees on a Caribbean cruise, though with fewer organized activities. Wake up early, crack of dawn, then off to breakfast (fruit). Eat until you are stuffed, and next find a nice place for a nap, maybe some light grooming. After an hour or so (no rush!), go find a sunny tree with figs and gorge yourself. Maybe go meet some friends, a bit more grooming, another nap. Around five o'clock have an early dinner (more fruit, maybe some leaves), then it is time to find a nice sleeping tree, build a nest and call it a night. Sure, there are frenetic pant-hoot choruses when the fruit is really great and the occasional scuffle or monkey hunt, and the alpha male needs to carve some time out every day to thrash a few victims or display mightily. But in general, chimpanzee life is pretty mellow.

It is not just chimps. Orangutans, gorillas and bonobos also lead the sorts of seemingly idle lives that children's fables and high school drug programs warn you about. Great apes spend eight to 10 hours a day resting,

LOUNGING AROUND: Mountain gorilla family relaxes in Rwanda. Great apes remain healthy at low activity levels.

grooming and eating before knocking off in the evening for nine or 10 hours of sleep per night. Chimps and bonobos walk about three kilometers a day, and gorillas and orangutans travel even less. And the climbing? As I discovered that summer, chimpanzees climb about 100 meters a day, the caloric equivalent of another 1.5 kilometers of walking. Orangutans do about the same, and although their ascent has yet to be measured, gorillas surely climb less.

In humans, these activity levels would be a recipe for serious health problems. Our taking fewer than 10,000 daily steps is associated with increased risk of cardiovascular and metabolic disease. U.S. adults typically clock about 5,000 steps, which contributes to the alarming rates of type 2 diabetes, affecting one in 10 Americans, and heart disease, which accounts for a quarter of all deaths in the U.S. By these lights, apes should be in trouble. Converting their walking and climbing to steps per day for comparison across species, we see that great apes rarely accumulate even the modest step counts seen among sedentary humans and never approach the human benchmark of 10,000 steps a day.

Then there is all the sitting and resting. In humans, sitting at a desk or in front of the television for protracted periods is associated with increased risk of disease and a shorter life span, even among people who exercise. Worldwide, physical inactivity is arguably on par with smoking as a health risk, killing more than five million people annually. Among Scottish adults, those watching more than two hours of television a day had a 125 percent increase in cardiac events such as heart attack or stroke. A study in Australian adults reported that every hour accumulated watching television shortened life expectancy by 22 minutes. I will save you the math: bingeing all 63½ hours of *Game of Thrones* in its entirety will cost you one day on this planet.

Yet chimpanzees and other apes remain remarkably healthy at their habitually low levels of physical activity. Even in captivity, diabetes is rare, and blood pressures do not increase with age. Despite having naturally high cholesterol levels, chimpanzee arteries do not harden and clog. As a result, chimps do not develop humanlike heart disease or have heart attacks from occluded coronary arteries. And they stay lean. In 2016 I worked with Steve Ross at Lincoln Park Zoo in Chicago and a team of collaborators to measure metabolic rates and body composition in zoo-living apes across the U.S. The results were eye-opening: even in captivity, gorillas and orangutans average only 14 to 23 percent body fat and chimpanzees less than 10 percent, on par with Olympic athletes.

Among our primate cousins, we humans are clearly the odd ape out. Somehow humans evolved to require much higher levels of physical activity for our bodies to function normally. Sitting for hours on end, grooming and napping (or watching the tube) have gone from standard practice to a health risk. When did we trade the low-key existence of our fellow apes for a more strenuous way of life and why? Fossil discoveries are helping to piece the story together.

BRANCHING OUT

OUR LIMB OF THE PRIMATE FAMILY TREE, the hominins, split from that of chimpanzees and bonobos about six million or seven million years ago, near the end of Miocene geologic time period. Until fairly recently, there were few hominin fossils recovered from the earliest portion of the lineage. Then, in quick succession during the 2000s, paleoanthropologists working in Chad, Kenya and Ethi-

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opia reported finds of three hominins from this critical period: *Sahelanthropus, Orrorin* and *Ardipithecus*.

Each of these early hominins is distinct from any of the living apes in the anatomical details of their cranium, teeth and skeleton. Nevertheless, aside from walking on two legs, it appears these species lived a very apelike existence. Their molars were similar in size and sharpness to chimpanzees, with somewhat thicker enamel, suggesting a mixed diet of fruit and other plant foods. *Ardipithecus,* found in 4.4-million-year-old deposits in Ethiopia and by far the best known early hominin, had long arms, long, curved fingers and grasping feet, indicative of a life spent partly in the trees. New biomechanical analyses, led by my City University of New York graduate student Elaine Kozma, show that *Ardipithecus* had evolved changes in its pelvic anatomy to permit fully upright, energetically efficient walking without compromising the ability to power itself into the canopy. Our early ancestors were clearly comfortable in two worlds, on the ground and in the trees.

BINGEING ALL 63½ HOURS OF *GAME OF THRONES* WILL COST YOU ONE DAY ON THIS PLANET.

From about four million to two million years ago the hominin record is dominated by the genus *Australopithecus,* with at least five species recognized today, including the famous "Lucy" and her kin. Anatomical changes in the lower limb point to improved walking ability and more time on the ground compared with earlier species. The grasping foot is gone in *Australopithecus,* the big toe in line with the others, and the legs are longer, the same ratio of leg length to body mass that we see in living humans. Analyses of the pelvis by Kozma, together with recent work on the fossilized footprints from Laetoli in Tanzania, indicate that this creature had an effectively modern gait. Long arms and fingers tell us these hominins were still regularly in the trees to forage and perhaps to sleep. Analyses of the wear patterns on their teeth suggest *Australopithecus* species primarily ate plant foods, just as the earliest hominins did before them and living apes do today. Based on their large, thick-enameled molars, *Australopithecus* diets most likely leaned more on harder and more fibrous foods, particularly when preferred foods were not available.

The evolution of an upright, striding bipedal gait in these early hominins is important, indicating a different approach for navigating their landscape. Covering more ground for fewer calories might have enabled these species to expand their range and thrive in less productive habitats than apes today. There are other notable and intriguing changes, too, such as the loss of big, sharp canines in males, which seem to reflect changes in social behavior. Yet the plant-based diet and retained climbing adaptations tell us their foraging ecology and daily activity remained quite apelike. Distances traveled per day were probably modest, with lots of time spent resting and digesting bellyfuls of fibrous plant food. It is unlikely they needed, or often got, their 10,000 steps a day.

Some two million years ago the telltale signs of curious or clever hominins experimenting with new ideas and approaches began to emerge. In 2015 Sonia Harmand of Stony Brook University and her team recovered large, unwieldy stone tools, some weighing more than 30 pounds, from 3.3-million-year-old sediments on the western shore of Lake Turkana in Kenya. In the past 15 years excavations at 2.6-million-year-old sites in both Ethiopia and Kenya have found stone tools associated with fossilized animal bones bearing the unmistakable gouges and scrapes of butchery. By 1.8 million years ago cut-marked bones and stone tools were the norm, and it was not just the sick and injured animals that fell prey to these hominins. Analyses of butchered bones at Olduvai Gorge in Tanzania show that prime-aged ungulates were targeted. Just as important, unlike every hominin before, by 1.8 million years ago hominins had expanded outside of Africa into Eurasia, from the foothills of the Caucasus Mountains to the rain forests of Indonesia. Our predecessors had jumped the ecological fence and were capable of thriving nearly anywhere.

Forget the tales of some clandestine meeting in the Garden of Eden or of Prometheus doling out fire. It was this million-year dalliance with stones and meat and the development of a hunting-and-gathering strategy that pushed our lineage away from the other apes, changing things irrevocably. This tectonic shift marked the evolutionary emergence of us, the genus *Homo*.

FOOD FOR THOUGHT

IN ECOLOGY AND EVOLUTION, diet is destiny. The foods animals eat do not just shape their teeth and guts but their entire physiology and way of living. Species evolved to eat foods that are abundant and stationary need not roam too far or be too clever to fill up; grass does not hide or run away. Eating foods that are hard to find or capture means more travel, often coupled with increased cognitive sophistication. For instance, fruit-eating spider monkeys in Central and South America have larger brains and travel five times farther every day than the leaf-obsessed howler monkeys that share their forests. Carnivores on the African savanna travel three times farther a day than the herbivores they hunt.

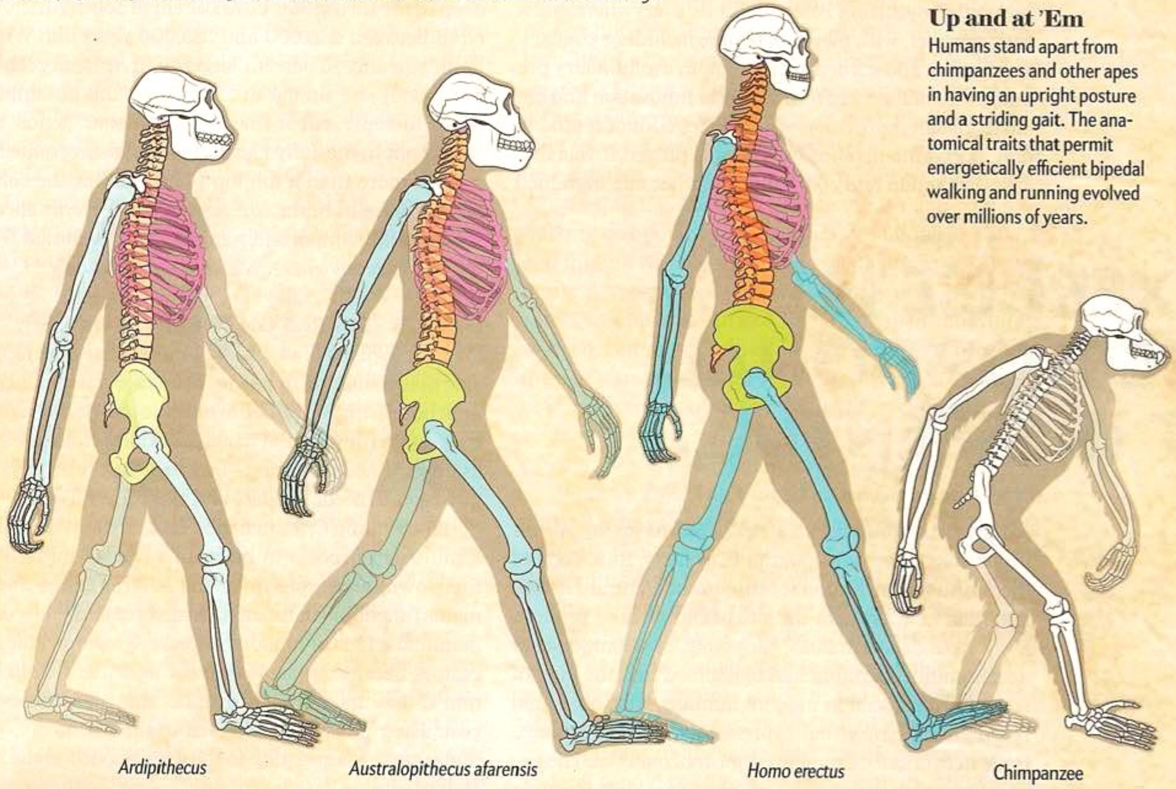
Shifting from the pure gathering lifestyle of apes and early hominins to the hunting-and-gathering strategy that marks the genus *Homo* had major ramifications. It made these social primates even more tightly knit.

Built to Move

As hominins evolved anatomical changes that facilitated upright walking (*shown*), they were able to cover more ground for fewer calories, allowing them to expand into new habitats. The subsequent advent of hunting further increased activity levels of hominins, requiring them to travel farther to find food. Our physiology has adapted to this physically active way of life, such that we must exercise to be healthy.

Up and at 'Em

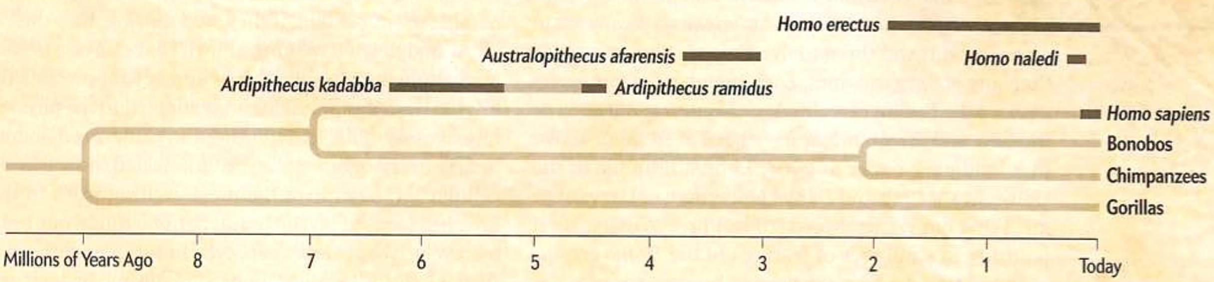
Humans stand apart from chimpanzees and other apes in having an upright posture and a striding gait. The anatomical traits that permit energetically efficient bipedal walking and running evolved over millions of years.



Piecemeal Evolution

Early human ancestors, including *Ardipithecus* and *Australopithecus*, walked on two legs yet also retained adaptations to climbing in the trees, ate a plant-based diet like today's apes do and lived exclusively in Africa. By 1.8 million years ago *Homo* had evolved modern body proportions, adopted a dietary strategy of hunting and gathering, and spread out of Africa into Eurasia.

Vertical torso and centrally located hole in skull base to admit spinal cord		
Spine shape unknown	S-shaped spine	Enlarged lumbar vertebrae
Bowl-shaped pelvis	Smaller ischium, or "sit bone"	More robust pelvis
Short lower limbs, long upper limbs	Elongated upper and lower limbs	Long lower limbs, short upper limbs and fingers



Relying on meat requires cooperation and sharing—and not just because you cannot kill or eat a zebra by yourself. Meat is difficult to obtain, and sharing more predictable plant foods is what allows hunting and gathering to work. Hunter-gatherer populations today get roughly half their daily calories from plants. Recent analyses of the food trapped inside their fossilized dental calculus show that even Neandertals, masterful hunters and avatars of vegetable-boycotting Paleo diet bros everywhere, ate a balanced diet, with plenty of plants, including grains.

Hunting and gathering also put an evolutionary premium on intelligence. Technological innovation and creativity meant more calories and better odds of reproduction. Social intelligence would have proved invaluable, as coordination and communication became ingrained parts of the hominin strategy. Discoveries by Alison Brooks of George Washington University, Rick Potts of the Smithsonian National Museum of Natural History and their colleagues at the site of Olorgesailie Basin in Kenya, published in 2018, show that by 320,000 years ago, hominin cognition had blossomed into the kind of sophistication seen in modern humans, with black and red pigments for visual expression and long-distance trade networks for premium stone tool material. The age of these finds corresponds well with the oldest *Homo sapiens* fossils found to date, reported in 2017 from the 300,000-year-old site of Jebel Irhoud in Morocco.

EXERCISE IS NOT OPTIONAL; IT IS ESSENTIAL.

Moreover, hunting and gathering required hominins to work harder for their food. Simply moving up the food chain means food is harder to find; there are a lot more plant calories on the landscape than animal calories. Hunter-gatherers are remarkably active, typically covering nine to 14 kilometers a day on foot—about 12,000 to 18,000 steps. Work that David Raichlen of the University of Arizona, Brian Wood, now at the University of California, Los Angeles, and I have done with the Hadza hunter-gatherer population in northern Tanzania shows that men and women in that group log more physical activity in a day than Americans typically get in a week and travel three to five times farther every day than any of the great apes. Early members of our genus, without the benefit of technological innovations such as the bow and arrow, might have been even more active. In a landmark paper in 2004, Dennis Bramble of the University of Utah and Daniel Lieberman of Harvard argued that our genus evolved to run prey to exhaustion, pointing to a number of features in the *Homo erectus* skeleton that appear to reflect endurance running.

The steady increases in brain size and technological complexity over the past two million years seem to accumulate like a snowball rolling downhill, but any impression of momentum is an illusion. Evolution has a great memory but no plans. In 2015 Lee Berger of the University of the Witwatersrand in South Africa and his team announced their discovery of hundreds of fossils of *Homo naledi,* a new species recovered from deposits deep in the Rising Star Cave system in South Africa, dated to between 236,000 and 335,000 years old. With a brain size only 10 percent larger than *Australopithecus* and a body size similar to early *Homo,* this hominin appears to represent a lineage within our genus that stalled out in the early Pleistocene, persisting quite happily for more than a million years without the continued increase in brain size seen in other *Homo* species. *H. naledi* is an important reminder that evolution is not trying to get anywhere. We were not inevitable.

SHARKS ON THE SAVANNA

NO TRAIT EVOLVES IN ISOLATION: brains must fit snugly inside their skulls, teeth inside their jaws; muscles, nerves and bones must function harmoniously. Behavioral traits are no different. When a behavioral strategy—such as hunting and gathering—becomes the norm, physiology adapts to accommodate and even depend on it.

Take vitamin C, for instance. Early mammals evolved a multistep process to make this crucial nutrient on their own, a cascade involving several genes that remains functional in rodents, carnivores and many other mammals. Tens of millions of years ago our primate ancestors became so fixated on eating fruits rich in vitamin C that making their own became an unnecessary cost. Their physiology adapted to their behavior, with mutations accumulating in the gene needed in the final step of synthesis. Consequently, today's anthropoid primates—monkeys, apes and humans—cannot make vitamin C. Without it in our diets, we get scurvy and die.

Further afield, yet closer to home, is the evolution of a specialized form of breathing called ram ventilation in several species of sharks and scombrid fish (the group that includes tuna and mackerel). These lineages evolved highly active foraging behavior, swimming nonstop day and night. Their anatomy and physiology adapted, using the constant forward motion to ram water into their mouths and past their gills. This change eliminated the need to pump water past the gills, leading to the evolutionary loss of the associated gill musculature. This loss saved energy but left these species vulnerable to suffocation. If they stop moving, they die.

Although we have long known that exercise is good for us humans, we are only beginning to appreciate the myriad ways our physiology has adapted to the physically active way of life that hunting and gathering demands. Nearly every organ system is implicated, down to the cellular level. Some of the most exciting work in this area has focused on the brain. For one thing, our brain has evolved to get less sleep, even in societies without artificial lighting or other modern nighttime distractions.

Humans around the globe—whether it is the Hadza on the African savanna, the Tsimane horticulturalists in the Amazonian rain forest or urbanites in New York—clock about seven hours of sleep a night, far less than apes. Raichlen and his colleagues have shown that our brain has evolved to reward prolonged physical activity, producing endocannabinoids—the so-called runner's high—in response to aerobic exercise such as jogging. Raichlen and others have even argued that exercise helped to enable the massive expansion of the human brain and that we have evolved to require physical activity for normal brain development. Exercise causes the release of neurotrophic molecules that promote neurogenesis and brain growth, and it is known to improve memory and stave off age-related cognitive decline.

Our metabolic engines have evolved to accommodate increased activity as well. Humans' maximum sustained power output, our VO_{2max}, is at least four times greater than that of chimpanzees. This increase stems largely from changes in our leg muscles, which are 50 percent bigger and have a much greater proportion of "slow-twitch" fatigue-resistant fibers than the leg muscles of other apes. We also have more red blood cells to carry oxygen to working muscles. But the adaptations to exercise appear to go even deeper, accelerating the rate with which our cells function and burn calories. My work with Ross, Raichlen and others has shown that humans have evolved a faster metabolism, providing fuel for increased physical activity and the other energetically costly traits that set humans apart, including bigger brains.

All of this evidence points toward a new way of thinking about physical activity. Since the sweaty spandex excitement of the 1980s, exercise has been sold as a way to lose weight or as a health-conscious buffet item to add to our lifestyle, like oat bran muffins. But exercise is not optional; it is essential, and weight loss is probably the one health benefit it largely fails to deliver. Our bodies are evolved to require daily physical activity, and consequently exercise does not make our bodies work *more* so much as it makes them work *better*. Research from my lab and others has shown that physical activity has little effect on daily energy expenditure (Hadza hunter-gatherers burn the same number of calories every day as sedentary Westerners), which is one reason exercise is a poor tool for weight loss. Instead exercise regulates the way the body spends energy and coordinates vital tasks.

Recent advances in metabolomics have shown that exercising muscles release hundreds of signaling molecules into the body, and we are only beginning to learn the full extent of their physiological reach. Endurance exercise reduces chronic inflammation, a serious risk factor for cardiovascular disease. It lowers resting levels of the steroid hormones testosterone, estrogen and progesterone, which helps account for the reduced rate of reproductive cancers among adults who exercise regularly. Exercise may blunt the morning rise in cortisol, the stress hormone. It is known to reduce insulin insensitivity, the immediate mechanism behind type 2 diabetes, and helps to shuttle glucose into muscle glycogen stores instead of fat. Regular exercise improves the effectiveness of our immune system to stave off infection, especially as we age. Even light activity, such as standing instead of sitting, causes muscles to produce enzymes that help to clear fat from circulating blood.

No wonder populations such as the Hadza do not develop heart disease, diabetes or the other maladies that afflict industrial countries. But we do not need to cosplay as hunter-gatherers or run marathons to reap the benefits of a more evolutionarily informed life. The lesson from groups such as the Hadza, Tsimane and others is that volume matters more than intensity. They are on their feet and moving from sunrise until dusk, racking up more than two hours of physical activity a day, most of it as walking. We can emulate these same habits by walking or biking instead of driving, taking the stairs, and finding ways to work and play that keep us off our butts. A recent study of Glaswegian postal workers shows us what this can look like. These men and women were not committed athletes but were active throughout the day, handling the mail. Those who got 15,000 steps or spent seven hours a day on their feet (numbers similar to what we see with the Hadza) had the best cardiovascular health and no metabolic disease.

While we are at it, we might take other lessons for living well from groups like the Hadza. Beyond the copious amounts of exercise and whole food diets, daily life for these cultures is full of fresh air, friendships and family. Egalitarianism is the rule, and economic inequality is low. We do not know exactly how these factors affect the health of hunter-gatherers, but we know their absence contributes to chronic stress in the developed world, which in turn promotes obesity and disease.

Embracing more physically active life habits would be easier if we did not have to wrestle with the 400-pound gorilla in our head. Like vitamin C for our anthropoid ancestors, exercise was unavoidable and plentiful during the last two million years of hominin evolution. There was no need to seek it out, no evolutionary pressure to lose the ancient, simian weakness for gluttony and sloth. Today, as masters of our environments, we are giving our inner apes too much say in how the modern world is engineered: filling up on easy food, bingeing *The Walking Dead* instead of actually walking, sitting for hours at our desks grooming one another on social media. We are fascinated when we see ourselves in great apes, but we should worry when we see them in us. Underneath the surface, we are more different than we seem. SA

MORE TO EXPLORE

The Crown Joules: Energetics, Ecology, and Evolution in Humans and Other Primates. Herman Pontzer in *Evolutionary Anthropology*, Vol. 26, No. 1, pages 12–24; January/February 2017.

Economy and Endurance in Human Evolution. Herman Pontzer in *Current Biology*, Vol. 27, No. 12, pages R613–R621; June 19, 2017.

FROM OUR ARCHIVES

The Exercise Paradox. Herman Pontzer; February 2017.

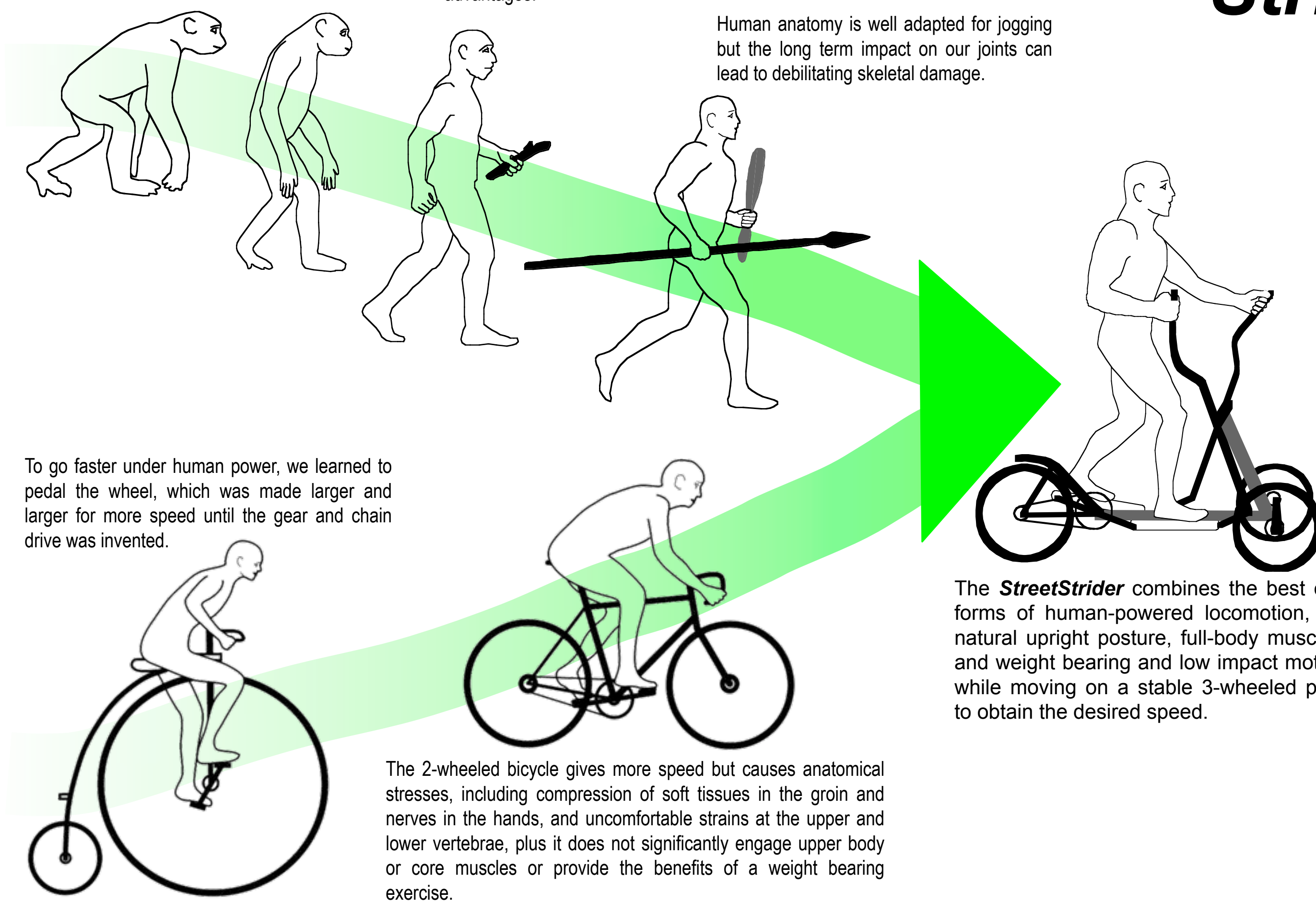
scientificamerican.com/magazine/sa

Evolution to Stride

As hominids adapted bipedal locomotion, a cardiovascular system with endurance, and the ability to stay cool by sweating, they became the ultimate hunters by being able to run their prey to exhaustion.

Being able to carry and throw weapons and/or implements with their arms/hands while jogging gave them further advantages.

Human anatomy is well adapted for jogging but the long term impact on our joints can lead to debilitating skeletal damage.



To go faster under human power, we learned to pedal the wheel, which was made larger and larger for more speed until the gear and chain drive was invented.

The ***StreetStrider*** combines the best of both forms of human-powered locomotion, with a natural upright posture, full-body muscle use, and weight bearing and low impact motion, all while moving on a stable 3-wheeled platform to obtain the desired speed.

The 2-wheeled bicycle gives more speed but causes anatomical stresses, including compression of soft tissues in the groin and nerves in the hands, and uncomfortable strains at the upper and lower vertebrae, plus it does not significantly engage upper body or core muscles or provide the benefits of a weight bearing exercise.