FEATURES

THE CALORIE COUNTER

Evolutionary anthropologist Herman Pontzer busts myths about how humans burn calories—and why

By **Ann Gibbons***, in Durham, North Carolina;*
Photograph by **Justin Cook**

On a warm Wednesday morning in October, Herman Pontzer puts on a wrinkled lab coat, adjusts his mask, and heads into his lab at Duke University, hoping to stress out a student. An undergraduate named Christina is resting on a lab table with her head in a clear plastic hood. Pontzer greets her formally and launches into a time-honored method to boost her blood pressure: He gives her an oral math test.

"Start off with number 1022 and subtract 13 until you get to zero," he says, speaking at full volume to be heard over a clanking air conditioner. "If you make a mistake, we'll start over again. You ready to go?"

"1009, 997," Christina says.

"Start over," Pontzer barks.

Christina, who has signed up for a "stress test," laughs nervously. She tries again and gets to 889, only to have Pontzer stop her. This happens again and again. Then Pontzer asks her to multiply 505 by 117, out loud. By this point, she is clenching her sock-clad toes.

Postdoc Zane Swanson and undergrad Gabrielle Butler monitor her heart rate and how much carbon dioxide (CO_2) she exhales into the hood. Then Pontzer asks a set of questions designed to boost a student's stress levels: What's her dream job, and what exactly is she going to do after graduation?

It's another day in the Pontzer lab, where he and his students measure how much energy people expend when they are stressed, exercising, or mounting an immune response to a vaccine, among other states. By measuring the CO_2 in Christina's breath, he is finding out how much energy she has burned while coping with math anxiety.

At 44, Pontzer's life's work as a biological anthropologist is counting calories. It's not to lose weight—at 1.85 meters tall and about 75 kilograms (6 feet 1 inch and 165 pounds), with a passion for running and rock climbing, he is "a skinny to normal size dude," in the words of an online reviewer of Pontzer's 2021 book *Burn: New Research Blows the Lid Off How We Really Burn Calories, Lose Weight, and Stay Healthy*.

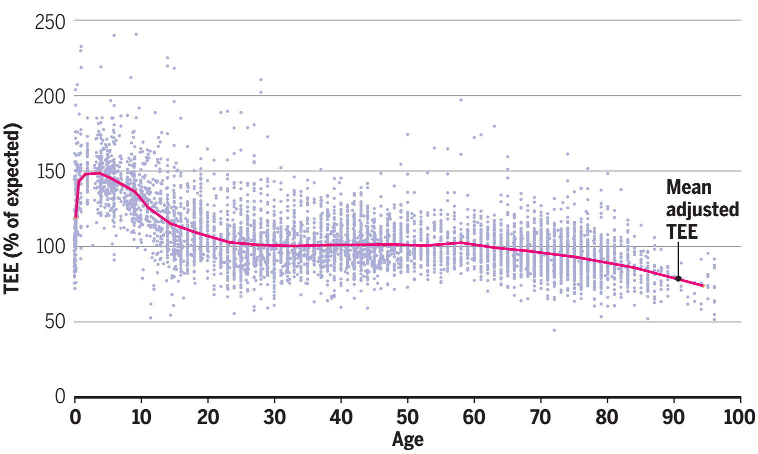
Pontzer is happy to expound on weight loss on *The Dr. Oz Show* and NPR, but his real mission is to understand how, alone among great apes, humans manage to have it all, energetically speaking: We have big brains, lengthy childhoods, many children, and long lives. The energy budget needed to support those traits involves trade-offs he's trying to unravel, between energy spent on exercise, reproduction, stress, illness, and vital functions.

By borrowing a method developed by physiologists studying obesity, Pontzer and colleagues systematically measure the total energy used per day by animals and people in various walks of life. The answers coming from their data are often surprising: Exercise doesn't help you burn more energy on average; active hunter-gatherers in Africa don't expend more energy daily than sedentary office workers in Illinois; pregnant women don't burn more calories per day than other adults, after adjusting for body mass.

Herman Pontzer in the hood and metabolic chamber he uses to measure carbon dioxide, a gauge of how fast the body burns calories.

Metabolism over the life span

Adjusted for body mass, toddlers burn the most calories per day. Total energy expenditure (TEE) declines after age 60, although individuals show some variation (gray dots).



Pontzer's skill as a popularizer can rankle some of his colleagues. His message that exercise won't help you lose weight "lacks nuance," says exercise physiologist John Thyfault of the University of Kansas Medical Center, who says it may nudge dieters into less healthy habits.

But others say besides busting myths about human energy expenditure, Pontzer's work offers a new lens for understanding human physiology and evolution. As he wrote in *Burn*, "In the economics of life, calories are the currency."

"His work is revolutionary," says paleoanthropologist Leslie Aiello, past president of the Wenner-Gren Foundation, which has funded Pontzer's work. "We now have data … that has given us a completely new framework for how we think about how humans adapted to energetic limits."

THE SON OF TWO high school English teachers, Pontzer grew up on 40 hectares of woods in the Appalachian hills near the small town of Kersey, Pennsylvania. His dad, who helped build their house, taught Pontzer to be curious about how things worked and to fix them. "No one ever called plumbers or electricians," Pontzer recalls.

Those lessons in self-sufficiency and an outgoing nature helped him cope when his dad died when Pontzer was just 15. An older cousin also took him climbing, which taught him to be both brave and organized—skills he says later helped him take intellectual risks and challenge established ideas. "When you have a bad experience and life plucks you off your track, it's scary," Pontzer says. "You have to move forward, though, and that teaches you not to be scared of new things."

Pontzer applied to a single college—Pennsylvania State University, whose football games were a highlight of his childhood. "I assumed I'd be my dad—go to Penn State, get my teaching degree, and stay in Kersey," he says. But once at Penn State, he worked with the late, renowned paleoanthropologist Alan Walker and found himself considering grad school in biological anthropology.

After learning his promising student was choosing schools based on their proximity to mountains, Walker was blunt: He told Pontzer he was an idiot if he didn't apply to Harvard University—and, once Pontzer was accepted, he'd be an idiot if he didn't go.

Pontzer went. In the early 2000s, scientists knew little about humans' total energy expenditure (TEE)—the number of kilocalories (the "calories" on food labels) a person's 37 trillion cells burn in 24 hours. Researchers had measured the rate at which our bodies burn energy while at rest—the basal metabolic rate (BMR), which includes energy used for breathing, circulation, and other vital functions. They knew BMR was roughly the same among larger mammals, when adjusted for body size. So although BMR only captures 50% to 70% of total energy use, researchers figured that, kilo for kilo, humans burn energy at roughly the same rate as other apes.

But humans have an added energy expense: our big brains, which account for 20% of our energy use per day. Aiello had proposed that our ancestors had compensated for those expensive brains by evolving smaller guts and other organs (*Science*,

CREDITS: (GRAPHIC) C. BICKEL/*SCIENCE* AND N. DESAI/*SCIENCE*; (DATA) H. PONTZER *ET AL.*, *SCIENCE*. 373, 6556 (2021)

15 June 2007, p. 1560). Others thought humans had saved energy by evolving to walk and run more efficiently.

At Harvard, Pontzer wanted to test those ideas. But he realized there weren't enough data to do so: No one knew how much total energy primates use when they move, much less how differences in anatomy or trade-offs in organ size impact energy use. "We talked about locomotor adaptations in hominins, we talked about efficiency, power, and strength, but it [was] all sort of made up," Pontzer says.

He realized he had to go back to basics, measuring the calories expended by humans and animals walking and running on treadmills. Mammals use oxygen to convert sugars from food into energy, with CO_2 as a byproduct. The more CO_2 a mammal exhales, the more oxygen—and calories—it has burned.

For his Ph.D. thesis, Pontzer measured how much CO_2 dogs and goats exhaled while running and walking. He found, for example, that dogs with long legs used less energy to run than corgis, as he reported in 2007, soon after he got his first job at Washington University in St. Louis. Over time, he says, "What started as an innocent project measuring the cost of walking and running in humans, dogs, and goats grew into a sort of professional obsession with measuring energy expenditures."

Pontzer still measures exhaled CO_2 to get at calories burned in a particular activity, as he did with Christina's stress test. But he found that physiologists had developed a better way to measure TEE over a day: the doubly labeled water method, which measures TEE without asking a subject to breathe into a hood all day.

Physiologist Dale Schoeller, now at the University of Wisconsin, Madison, had adapted the method, first used in mice, to humans. People drink a harmless cocktail of labeled water, in which distinct isotopes of hydrogen and oxygen replace the common forms. Then researchers sample their urine several times over 1 week. The labeled hydrogen passes through the body into urine, sweat, and other fluids, but as a person burns calories, some of the labeled oxygen is exhaled as CO_2. The ratio of labeled oxygen to labeled hydrogen in the urine thus serves as a measure of how much oxygen a person's cells used on average in a day and therefore how many calories were burned. The method is the gold standard for total energy use, but it costs $600 per test and was out of reach for most evolutionary biologists.

Pontzer's first of many breakthroughs with the method came in 2008 when, with $20,000 from the Wenner-Gren Foundation, he got the chance to collect urine samples at what was then the Great Ape Trust, a sanctuary and research center in Iowa. There, primatologist Rob Shumaker poured isotope-laced sugar-free iced tea into the mouths of four orangutans. Pontzer worried about collecting the urine from a full-grown ape, but Shumaker reassured him the orangs were trained to pee in a cup.

Later that fall, when Pontzer got the urine results, he didn't believe them: The orangutans burned one-third of the energy expected for a mammal their size. A retest returned the same results: Azy, a 113-kilogram adult male, for example, burned 2050 kilocalories per day, much less than the 3300 a 113-kilogram man typically burns. "I was in total disbelief," Pontzer says. Orangs were perhaps the "sloths in the ape family tree," he thought, because they suffered prolonged food scarcity in their past and had evolved to survive on fewer calories per day.

Subsequent doubly labeled water studies of apes in captivity and in sanctuaries shattered the consensus view that mammals all have similar metabolic rates when adjusted for body mass. Among great apes, humans are the outlier. When adjusted for body mass, we burn 20% more energy per day than chimps and bonobos, 40% more than gorillas, and 60% more than orangutans, Pontzer and colleagues reported in *Nature* in 2016 (see graphic, left).

Pontzer says the difference in body fat is just as shocking: Male humans pack on twice as much fat as other male apes and women three times as much as other female apes. He thinks our hefty body fat evolved in tandem with our faster metabolic rate: Fat burns less energy than lean tissue and provides a fuel reserve. "Our metabolic engines were not crafted by millions of years of evolution to guarantee a beach-ready bikini body," Pontzer writes in *Burn*.

Our ability to convert food and fat stores into energy faster than other apes has important payoffs, however: It gives us more energy every day so we can fuel our big brains as well as feed and protect offspring with long, energetically costly childhoods.

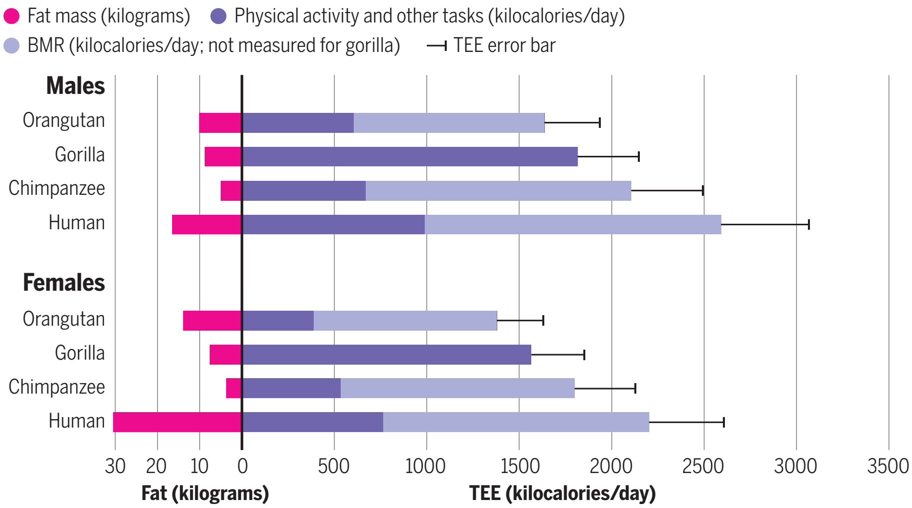
Pontzer thinks characteristically human traits in behavior and anatomy help us maintain amped-up metabolisms. For example, humans routinely share more food with other adults than do other apes. Sharing food is more efficient for the group, and would have given early humans an energy safety net. And our big brains created a positive feedback loop. They demanded more energy but also gave early humans the smarts to invent better tools, control fire, cook, and adapt in other ways to get or save more energy.

PONTZER GOT A LESSON in the value of food sharing in 2010, when he traveled to Tanzania to study the energy budgets of the Hadza hunter-gatherers. One of the first things he noticed was how often the Hadza used the word "za," which means "to give." It's the magic word all Hadza learn as children to get someone to share berries, honey, or other foods with them. Such sharing helps all the Hadza be active: As they hunt and forage, Hadza women walk about 8 kilometers daily; men, 14 kilometers—more than a typical American walks in 1 week.

To learn about their energy expenditure, Pontzer asked the Hadza whether they'd drink his tasteless water cocktail and give urine samples. They agreed. He almost couldn't get funding for the study, because other researchers assumed the answer was

The high-energy ape

Humans burn far more energy daily—and also store much more energy as fat—than other apes. Our total energy expenditure (TEE) includes our basal metabolic rate (BMR) plus other activities including exercise.



CREDITS: (GRAPHIC) C. BICKEL/*SCIENCE* AND N. DESAI/*SCIENCE*; (DATA) H. PONTZER *ET AL.*, *NATURE*, 533, 390 (2016) obvious. "Everyone knew the Hadza had exceptionally high energy expenditures because they were so physically active," he recalls. "Except they didn't."

Individual Hadza had days of more and less activity, and some burned 10% more or less calories than average. But when adjusted for nonfat body mass, Hadza men and women burned the same amount of energy per day on average as men and women in the United States, as well as those in Europe, Russia, and Japan, he reported in *PLOS ONE* in 2012. "It's surprising when you consider the differences in physical activity," Schoeller says.

One person who wasn't surprised was epidemiologist Amy Luke at Loyola University Chicago. She'd already gotten a similar result with doubly labeled water studies, showing female farmers in western Africa used the same amount of energy daily when adjusted for fat-free body mass as women in Chicago—about 2400 kilocalories for a 75-kilogram woman. Luke says her work was not well known—until Pontzer's paper made a splash. The two have collaborated ever since.

Pontzer is "very good at selling big ideas," whether on social media or writing for general audiences, says his former postdoc, Sam Urlacher of Baylor University. "That ruffles some feathers, but he's not afraid of being proven wrong."

Studies of other hunter-gatherer and forager groups have confirmed the Hadza are not an anomaly. Pontzer thinks hunter-gatherers' bodies adjust for more activity by spending fewer calories on other unseen tasks, such as inflammation and stress responses. "Instead of increasing the calories burned per day, the Hadza's physical activity was changing the way they spend their calories," he says.

He backed this up with a new analysis of data from another team's study of sedentary women trained to run half marathons: After weeks of training, they barely burned more energy per day when they were running 40 kilometers per week than before they started to train. In another study of marathoners who ran 42.6 kilometers daily 6 days per week for 140 days in the Race Across the USA, Pontzer and his colleagues found the runners burned gradually less energy over time—4900 calories per day at the end of the race compared with 6200 calories at the start.

As the athletes' ran more and more over weeks or months, their metabolic engines cut back elsewhere to make room for the extra exercise costs, Pontzer says. Conversely, if you're a couch potato, you might still spend almost as many calories daily, leaving more energy for your body to spend on internal processes such as a stress response.

This is Pontzer's "most controversial and interesting idea," says Harvard paleoanthropologist Daniel Lieberman, who was Pontzer's thesis adviser. "This morning I ran about 5 miles; I spent about 500 calories running. In a very simplistic model that would mean my TEE would be 500 calories higher. … According to Herman, humans who are more active don't have that much higher TEE as you'd predict … but we still don't know why or how that occurs."

Pontzer's findings have a discouraging implication for people wanting to lose weight. "You can't exercise your way out of obesity," says evolutionary physiologist John Speakman of the Chinese Academy of Sciences. "It's one of those zombie ideas that refuses to die." Already the research is influencing dietary guidelines for nutrition and weight loss. The U.K. National Food Strategy, for example, notes that "you can't outrun a bad diet."

> **"Our metabolic engines were not crafted by millions of years of evolution to guarantee a beach-ready bikini body."**
> **Herman Pontzer**, Duke University

But Thyfault warns that message may do more harm than good. People who exercise are less likely to gain weight in the first place, and those who exercise while they diet tend to keep weight off better, he says. Exercise also can impact where fat is stored on the body and the risk of diabetes and heart disease, he says.

Pontzer agrees that exercise is essential for good health: The Hadza, who are active and fit into their 70s and 80s, don't get diabetes and heart disease. And, he adds, "If exercise is tamping down the stress response, that compensation is a good thing." But he says it's not fair to mislead dieters: "Exercise prevents you from getting sick, but diet is your best tool for weight management."

Meanwhile, Pontzer was laying the groundwork for other surprises. Last year, he and Speakman co-led an effort to assemble a remarkable new resource, the International Atomic Energy Agency Doubly Labelled Water Database. This includes existing doubly labeled water studies of almost 6800 people between the ages of 8 days and 95 years.

They used the database to do the first comprehensive study of human energy use over the life span. Again a popular assumption was at stake: that teenagers and pregnant women have higher metabolisms. But Pontzer found it was toddlers who are the dynamos. Newborns have the same metabolic rate as their pregnant mothers, which is no different from other women when adjusted for body size. But between the ages of 9 and 15 months, babies expend 50% more energy in a day than do adults, when adjusted for body size and fat (see graphic, p. 711). That's likely to fuel their growing brain and, perhaps, developing immune systems. The findings, reported in *Science*, help explain why malnourished infants may show stunted growth.

Children's metabolisms stay high, when adjusted for body size, until about age 5, when they begin a slow decline until age 20, and stabilize in adulthood. Humans begin to use less energy at age 60, and by age 90, elders use 26% less than middle-aged adults.

Pontzer is now probing a mystery that emerged from his studies of athletes: There seems to be a hard limit on how many calories our bodies can burn per day, set by how fast we can digest food and turn it into energy. He calculates that the ceiling for an 85-kilogram man would be about 4650 calories per day.

Speakman thinks that limit is too low, noting that cyclists in the Tour de France in the 1980s and '90s exceeded it. But they were injecting fat and glucose directly into their bloodstreams, a practice Pontzer thinks might have helped them bypass the physiological limits on converting food into energy. Elite athletes can push the limits for several months, as the study of marathoners showed, but can't sustain it indefinitely, Pontzer says.

To understand how the body can fuel intense exercise or fight off disease without busting energy limits, Pontzer and his students are exploring how the body tamps down other activities. "I think we're going to find these adjustments lower inflammation, lower our stress reaction. We do it to make the energy books balance."

That's why he wanted to know how much energy Christina burned while he grilled her in the lab. After the test, Christina said she "definitely was stressed." As it went on her heart rate rose from 75 to 80 beats per minute to 115. And her energy use rose from 1.2 kilocalories per minute to as much as 1.7 kilocalories per minute.

"She burned 40% more energy per minute in the math test and 30% in the interview," Pontzer says. "Think about any other process that boosts your energy by about 40%."

He hopes data points like hers will help reveal the hidden cost of mental stress. Measuring how stress and immune reactions amp up energy use could help reveal how these invisible activities add up and are traded off in our daily energy budgets. Pontzer knows he's got his work cut out for him. "Until we can show how the levers get pulled to make these adjustments in energy use, people will always be skeptical. It's on us to do the next generation of experiments." ■

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