New Scientist

ESSENTIAL GUIDE Nº16

THE HEALTH BENEFITS OF EXERCISE
RUNNING VS WALKING
THE SURPRISING EFFECTS OF STRENGTH
EXERCISE AND METABOLISM
THE PSYCHOLOGY OF SPORT
EXERCISE AND THE BRAIN
AND MORE

EXERCISE

THE REAL SCIENCE OF PHYSICAL FITNESS

EDITED BY
CATHERINE DE LANGE

NEW SCIENTIST ESSENTIAL GUIDE

EXERCISE

THE human species was made to move. In recent years, research has overturned many of our assumptions about what exercise does for us, and revealed quite how vital it is to our health and well-being. It is little surprise that physically activity has come to be seen as a wonder drug, essential for the body and mind to function at their best.

This wealth of old and new information has led to us being bombarded with advice in the media and from health bodies about exercise, but not all of it is grounded in the latest evidence, or any evidence at all.

The aim of this *Essential Guide* is to cut to the facts about exercise and why it really is the best thing you can do if you want to live a long and healthy life. We will start with the basics: what exercise actually is, what we know – and still don't know – about what it does inside the body.

Then, we will take a look at specific activities and what kinds of benefits they bring, as well as examining the role exercise might play in keeping us trim. Of course, many of us struggle to move enough, so in the final chapter we will reveal ways to make it all feel a little bit easier. I hope this guide leaves you feeling empowered to move in the way that works for you, ready to enjoy the health boost it can bring.

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NEW SCIENTIST ESSENTIAL GUIDES ARE PUBLISHED BY NEW SCIENTIST LTD
ISSN 2634-0151
PRINTED IN THE UK BY PRECISION COLOUR PRINTING LTD AND DISTRIBUTED BY MARKETFORCE UK LTD
+44 (0)20 3148 3333

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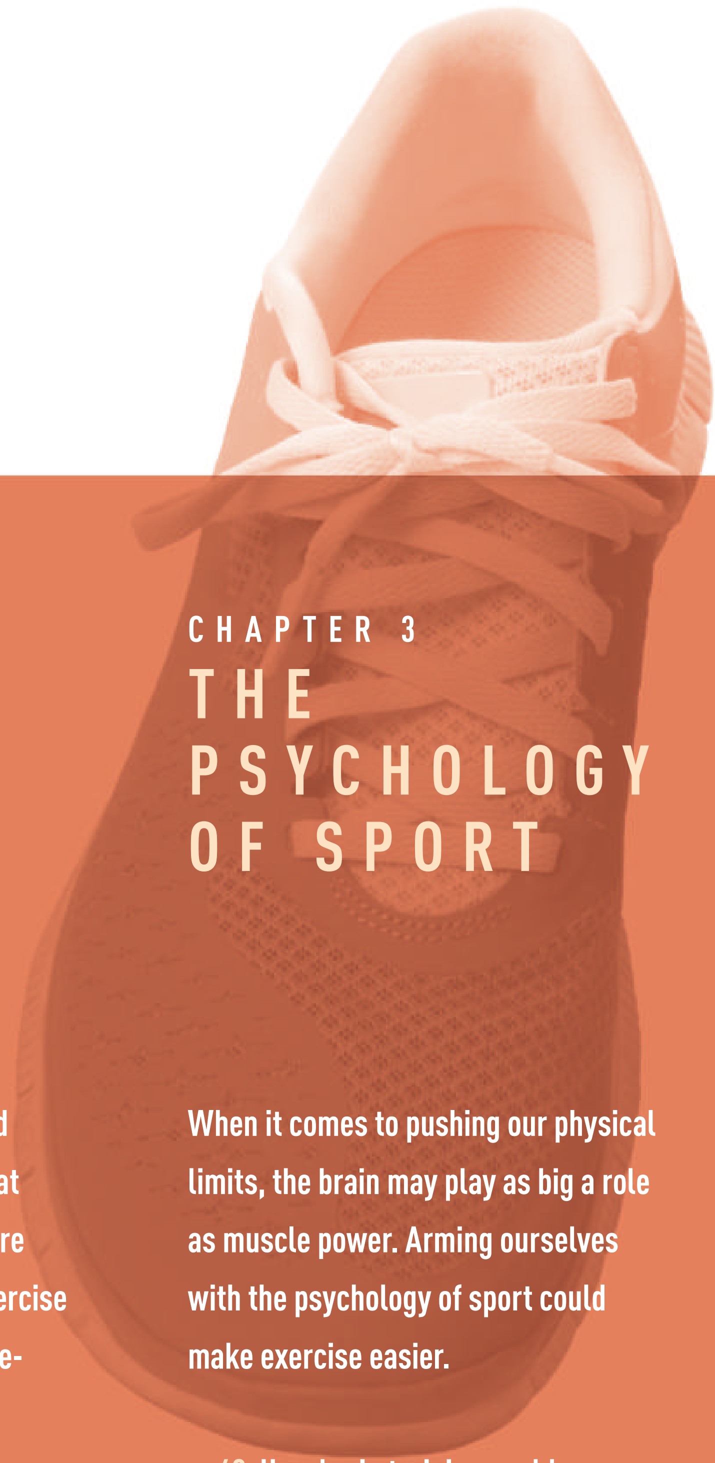

CHAPTER 1

THE BASICS OF EXERCISE

It is often said that exercise is the best medicine, and it is true that the benefits to both body and mind are innumerable. Exactly why it is so good for us, however, is a question that takes us deep into our evolutionary past.

CHAPTER 2

THE BEST KIND OF EXERCISE

Now we know exercise is so good for us and why, let's take a look at how to make it work for you. There are proponents of all sorts of exercise trends and fads, and it's not a one-size-fits-all recipe.

CHAPTER 3

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When it comes to pushing our physical limits, the brain may play as big a role as muscle power. Arming ourselves with the psychology of sport could make exercise easier.

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Anyone who exercises regularly will know how good it can make you feel to get moving, but the benefits of exercise for the brain and mind extend way beyond an endorphin buzz.

CHAPTER 6

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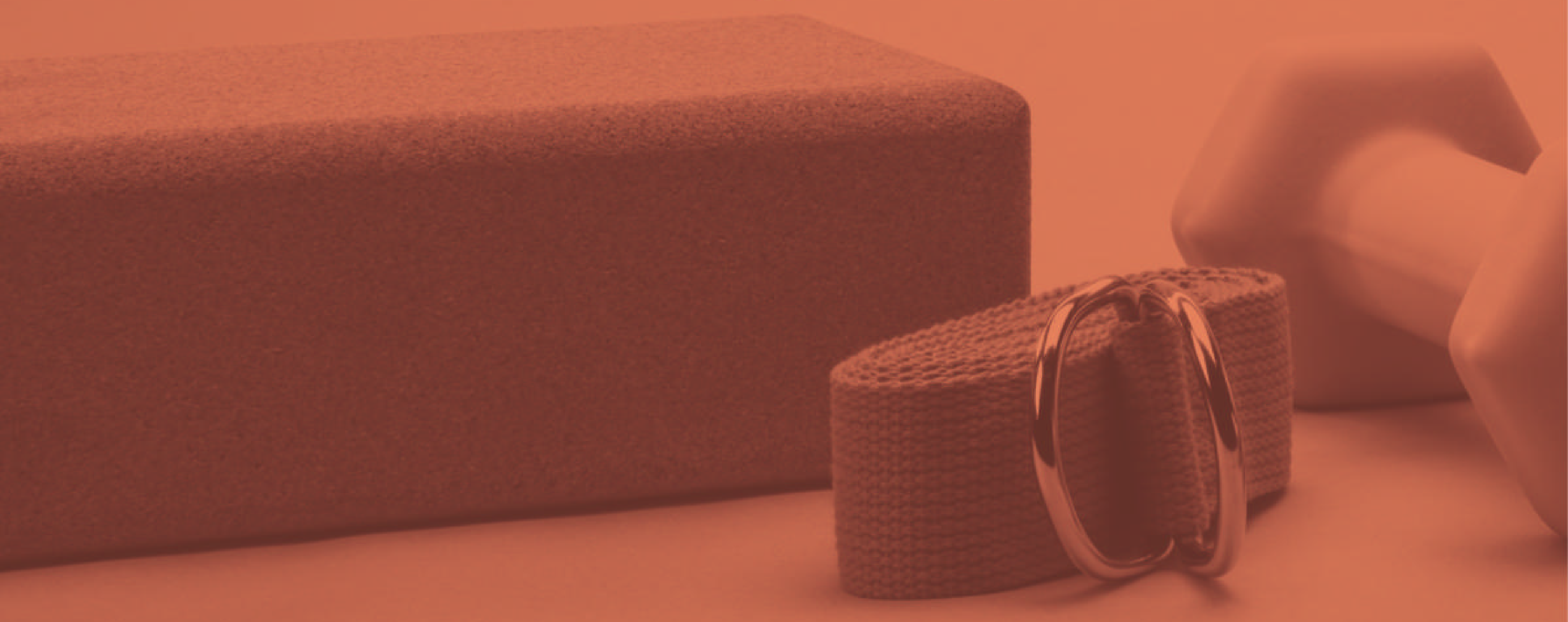
More than a quarter of people around the world don't get enough physical activity, which is expected to have a huge toll on health and economies. Simply telling people about the health benefits of exercise clearly isn't enough to get people moving. But there are ways to make it seem less of a chore.

CHAPTER 1

THE BASICS OF EXERCISE



It is often said that exercise is the best medicine, and it is true that the benefits to both body and mind are innumerable. If only it could be distilled into pill format and dispatched to everyone.

Exactly why exercise is so good for us, and inactivity so bad, however, can be a complicated question to answer – one that goes back deep into our evolutionary past.

Understanding why exercise is such a tonic is only the start, though. We then have to ask what is the best dose, and how often we should take this remedy, if we truly are to reap the benefits.

WHAT IS EXERCISE?

We are told that exercising is the key to vitality, and yet it isn't necessarily obvious which types of physical activity count as exercise. Before we can work out if we are getting enough, we must get to grips with how to measure it.

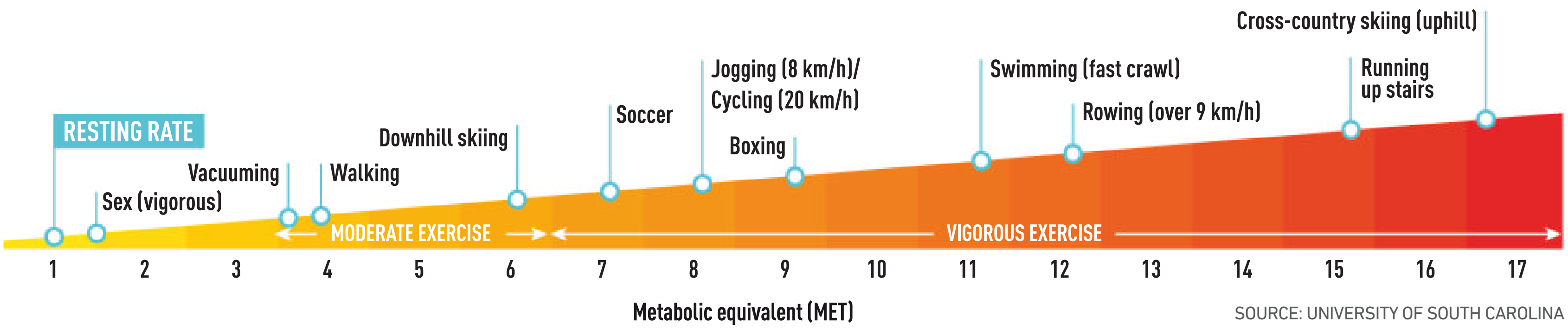
RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: SKODONNELL/ISTOCK

IT IS a shocking fact that many of us today are almost entirely sedentary. The current US and UK government guidelines for physical activity recommend that adults do at least 2.5 hours of moderate exercise or 75 minutes of vigorous exercise every week. In the US, only half the population meet these guidelines, and the situation is only slightly better in the UK. But to work out whether you are doing enough, you first need to know what counts as moderate and vigorous.

Physical activity is any type of movement that uses up energy. So you can think of exercise as a type of physical activity that is done in a structured way and has as its goal some sort of physical fitness – though as we will discover in the following chapter, those outcomes can vary wildly.

To try to quantify it all, back in the late 1980s, Bill Haskell at Stanford University in California asked the same question and came up with a benchmark to compare exercise against – sitting quietly. When seated, we expend about 1 kilocalorie per hour for each kilogram of body mass. Haskell and his colleagues called this a metabolic equivalent, or 1 MET. For an 80-kilogram person, this resting metabolic rate represents around 1920 kcals per day. ›

The World Health Organization recommends at least 150-300 minutes of moderate or 75-150 minutes of vigorous exercise a week. It measures intensity using metabolic equivalent (MET): the ratio of your metabolic rate during exercise to that at rest. Different activities have vastly different METs



SOURCE: UNIVERSITY OF SOUTH CAROLINA

All physical activities can be expressed in METs, and there is now a Compendium of Physical Activities that contains an eclectic mix of them described using this system. This elegant solution to the definition of exercise has three categories: light exercise up to 3 METs, moderate exercise between 3 and 6 METs and vigorous exercise for anything over 6 METs.

Strolling, at about 2 METs, is light exercise, while walking briskly is in the middle of moderate at 5 METs. The transition to running at around 7 kilometres per hour is where exercise enters the vigorous category.

There is now plenty of unequivocal evidence that physical activity is good for us, with benefits ranging from reduced risk of diseases including stroke, diabetes, heart disease, and cancer, as well as improving mental health and quality of life. Yet we don't have a full picture of the mechanisms that bring about these effects.

Most of what we know about the effects of exercise on the body is from studies of aerobic endurance training. This is because experiments designed to probe the physiology of exercise are mostly done on mice and rats, animals that take easily to running on wheels. It is trickier to persuade them to lift weights, let alone perform upward-facing mouse.

These studies have taught us that muscles act as control centres, hosting proteins that sense the body's increased activity and drive widespread changes to deal with the challenge. Signals, such as falling energy levels or a flood of calcium ions generated by contracting muscles, trigger the release of messenger molecules. These stream to various organs, where they initiate a range of responses. They might ask the brain to grow fresh neurons, for example, or stimulate bones to get stronger.

→ See page 11 for more on why exercise is so good for us

You may have come to think that to get these effects, you have to work out to the point where you are dripping with sweat. Not so.

Regardless of temperature, some of us are simply prone to sweating more, says Declan O'Regan of Imperial College London, whose work has shown how exercise benefits your heart. Genetics plays a part, as does how fit you are to begin with. Perhaps surprisingly, research shows that people perspire more as they get fitter because their body adapts to dealing with the effort, and sweating more helps them keep cool. And men tend to sweat more than women when they exercise.

When it comes to getting fit, moderate exercise that gets you moving but not necessarily sweating can be enough, says Kristian Gundersen at the University of Oslo in Norway. "You need to get your pulse up, but that would be sufficient," he says. ▮

→ Turn to page 14 for more on how much exercise is the right amount

BORN TO MOVE

Today, many of us see exercise as something we need to fit in to our busy schedules. It is a counterbalance to too much time spent sitting. Of course, things haven't always been that way, and our physical requirement to move is a reflection of our evolutionary past.

AS A species, humans evolved from lazy stock. All animals rest when they can, saving precious calories for survival and reproduction, but by any measure, our great ape relatives are impressively sedentary, resting and sleeping for 18 hours a day. However, when our ancestors began hunting and gathering, around 2.5 million years ago, it put an evolutionary premium on physical exertion.

These activities are incredibly demanding, requiring hours of effort each day to find food. Individuals that were more active found more food and had more offspring – and these, in turn, inherited their desire to move. Over generations, the human brain evolved to reward hard work, releasing endorphins and endocannabinoids – the body's homemade, feel-good drugs – in response to endurance exercise. The "runner's high" was born, taking up residence in our brains alongside our ancient, simian desire to rest. These two competing drives were balanced by a lifestyle that demanded hard work but rewarded strategic laziness.

These sirens continue to call from opposite shores inside our evolved minds, luring us towards idleness or action. But recently, and in the blink of an evolutionary eye, our environment has changed. In the well-stocked human zoos many of us now inhabit, we have largely engineered away hunger, fear and the other demons that got our hunter-gatherer ancestors moving. We have made it easy to overindulge, leading to heart disease, obesity, diabetes and other plagues of civilisation. In our Palaeolithic past, we could know what our bodies needed by listening to what they wanted. In the modern world, relying on our neural reward systems to deliver the proper dose of exercise feels a bit like trusting a 4-year-old to serve themselves healthy portions of broccoli and ice cream.

Our strange modern environment has also exposed our seemingly paradoxical relationship with exercise. Some of us seek it out in large doses, feeding the evolved craving for physical activity. Yet, mostly we avoid it. Our lazy inner ape calls the shots far too often.

One way to begin to redress the balance is to remember that there is an endurance athlete in all of us. Daniel Lieberman is by his own admission not a great runner, and yet when he took part in a 25 mile slog in the Arizona heat he managed to outrun all but 13 of his 52 competitors – all of them horses.

Lieberman studies human evolutionary biology at Harvard University, and part of his work over the past 15 years has focused on a unique set of adaptations that suggest modern humans evolved not just to walk, but to run long distances.

One is our cooling equipment. "The fact we have sweat glands all over our body and we've lost our fur enables us to dump heat extremely effectively," says Lieberman. This is crucial when running for long periods. It helps to explain why animals struggle to beat us in the heat, even though sled dogs can run more than 100 kilometres a day pulling humans in cold climates. Hence also Lieberman's success in Arizona. ›

Other primates are impressively sedentary

GABRIEL CODARCEA/ISTOCK

ON YOUR FEET!

Early humans, we always thought, first struggled onto two feet after a long period of gorilla-like knuckle-walking. But a newer hypothesis suggests that our move to bipedalism began much earlier, at a time when our ancestors were still living in the trees.

According to this line of thought, about 15 million years ago, our tree-dwelling ancestors began to spend more time standing up, at first holding onto branches with their hands and gradually balancing independently. One study found that even lightly touching a moving branch with the fingertips provides enough sensory feedback to the brain to stay balanced. If this is true, then learning to balance is an integral part of what made humans what we are today.

→ Turn to page 72 for more on balance

"The hotter it is, the better humans are able to run compared with horses," he says.

Then there are adaptations that offset our clumsy, inefficient bipedal frames. Short toes and large gluteal muscles assist with balance and stability. The Achilles tendon and other springs in the feet and legs help us to store and release energy. We tend to have a high proportion of slow-twitch muscle fibres, which produce less power but take longer to tire than the short burst, fast-twitch fibres needed for sprinting.

The nuchal ligament at the base of the skull also helps to keep our heads, and therefore our gaze, steady when we run. Other decent runners such as dogs and horses have one, but they're not found in poor runners such as pigs and non-human primates or early hominids like *Australopithecus*. Many of these adaptations are specific to running, suggesting we're not just good at it because we are good walkers.

→ For more on the benefits of walking vs running, turn to page 22

This all fits with the theory is that we began running as scavengers, where an ability to outrun other carnivores to reach fresh meat was to our advantage. As we improved, we became better hunters, able to track and outrun our prey over large distances before we had spears and arrows. This all helped to provide us with the extra protein we needed to acquire our greatest advantage: a bigger brain. "The features that we see in the fossil record that are involved in running appear about when we start to see evidence for hunting. And soon thereafter their brains start to get bigger," says Lieberman.

If you are keen to unleash your inner runner, genetics will play a part but training is key. You'll need stronger leg and gluteal muscles, to be sure, but you can get these simply by starting to run. You will find it hard to increase the proportion of slow-twitch muscle fibres you have, but if you find yourself flagging, take your time and take comfort in the fact we evolved to jog, rather than sprint, over the finish line. "Millions of people run marathons and people tell us we are crazy," says Lieberman. "Actually, it's part of who we are." ∎

WHAT ARE THE HEALTH BENEFITS OF EXERCISE?

Even Socrates, not remembered as an athlete, recognised that exercise led to good health, and bemoaned the lack of fitness among his students. Today, many people would like to be more active to improve their health. Before we look at the amount of exercise we should be aiming for, we need to understand exactly what it does to our bodies. It has taken a surprisingly long time to figure that out, but recent work is illuminating.

FIRST, the obvious benefits: exercise keeps our muscles and hearts strong, our blood vessels pliant and improves aerobic fitness. When we get our heart rate up, the stresses imposed by the blood rushing through our arteries promotes the production of nitric oxide, which helps repair blood vessels and keep them elastic. Maintaining strength and aerobic fitness is particularly important as we age. Older adults who can cover at least 365 metres in a standard 6-minute walking test have half the risk of dying in the subsequent decade as their peers who can't make 290 metres.

Additional robust evidence comes from the Exercise is Medicine initiative pioneered by the American College of Sports Medicine in Indianapolis, Indiana. Researchers there have collated studies over decades looking at people who follow the US government's advice on physical activity. What their findings show is that this weekly dose reduces the risk of premature death through heart disease by 40 per cent, approximately the same as taking statins.

Chi Pang Wen of the National Health Research Institute in Zhunan, Taiwan, offers some insights into precisely how physical activity prevents cardiovascular diseases. "Exercise can stimulate circulation, flush out fatty deposits in the walls of blood vessels and dilate small vessels that could otherwise be the cause of a heart attack or stroke," he says. He conducted a study of more than 430,000 Taiwanese men and women, showing that exercise reduced the risk of heart attacks by 30 to 50 per cent.

Exercise also keeps blood vessels clear by helping to destroy the most dangerous fats, because it alters the › structure of fatty triglyceride particles in the bloodstream, making it easier for enzymes to destroy them before they can gum up the works. Many risks to circulatory health come from such fatty particles, in the form of chylomicrons produced in the gut, or very low density lipoproteins (VLDLs) pumped out by the liver. The bigger the VLDL particles are, the easier they are for enzymes to break down, and the findings show exercise causes the particles to enlarge by about a quarter.

One of the most startling findings of the Exercise is Medicine initiative is that a modest weekly dose of exercise lowers the chances of developing type 2 diabetes by 58 per cent, twice the preventive power of the most widely prescribed anti-diabetes medication, metformin.

Type 2 diabetes affects adults when they stop responding efficiently to the hormone insulin, which orders muscle and fat cells to absorb surplus glucose from the bloodstream. When insulin loses its punch, glucose continues circulating and creates the potentially fatal sugar imbalances that are the hallmark of diabetes. It has now been shown that exercise significantly increases how responsive cells are to insulin.

As cells reawaken to insulin, it seems that surplus glucose gets sponged from the circulation. The post-exercise boost has been shown to last for up to two days in humans.

What's more, both insulin and muscle contractions during exercise activate a molecule in muscle and fat cells called AS160, which helps them absorb glucose. Once activated, AS160 orders the cell to send molecules to the cell's surface to collect glucose and bring it inside. Without these transporter molecules, glucose cannot get through the fatty cell membrane.

That's not the only way exercise helps cells burn off excess sugar. Muscle cells absorb glucose and fatty acids from the bloodstream to replenish adenosine triphosphate (ATP), the molecular fuel found in most living cells. As ATP is used up, it produces waste products that are sensed by another molecule, AMPK. AMPK then orders cells to recharge by absorbing and burning yet more fat and sugar. In the mid-1990s, Grahame Hardie at the University of Dundee, UK, found exercise accelerates this process because muscle contraction activates AMPK.

Hardie says exercise has the potential to reverse obesity and diabetes and prevent cancer. The findings of the Exercise is Medicine initiative show that taking the US government's recommended weekly dose of exercise halves the risk of breast cancer in women and lowers the risk of bowel cancer by around 60 per cent.

How exercise does this is not yet clear – not least because so many factors are involved in cancer's appearance and progression, including sex hormone imbalances, the ability of the immune system to clear cancer cells, and damage to genes and DNA.

However, some clues are beginning to emerge.

IS EXERCISE WORTH IT?

Runners and other active people tend to live longer. But if these bonus years are equivalent to all the time spent working up a sweat throughout life, then is it all a waste of time? It is a pertinent question for those who find exercise a penance.

Duck-chul Lee of Iowa State University and his colleagues dug into the data to find out. They calculate that between the ages of 44 and 80, someone who runs 2 hours per week will spend a total of 0.43 years running. This would still provide an average "bonus" of 2.8 additional years of life on top of the time spent running. In other words, 1 hour of running typically adds an extra 7 hours to lifespan. "It is controversial whether progressively more running provides further mortality benefits, but running certainly provides cost-effective longevity benefits," they concluded.

Exercise can help to reduce body weight, which is a known risk factor for some cancers.

It could also be that reducing fat deposits in the body results in less exposure to circulating hormones, growth factors and inflammatory substances.

Another potential protection against cancer might come back to the ability of exercise to stimulate AMPK. Exercise stimulates cells craving extra energy to burn unwanted rubbish, including faulty or mutated DNA that could trigger cancer if it hangs around.

Some research hints that the same processes could be at play in brain cells, suggesting that exercise might play a role in staving off dementias and neurodegeneration.

Exercise strengthens our hearts and muscles, then, and can help the body regulate sugar and fats, keep our weight in check – with being overweight a high risk factor for many diseases – and can help to keep cancer at bay.

One way to think about these beneficial effects of exercise isn't what it dials up in the body, but what it dials down. That's because exercise triggers helpful suppressive effects all over the body. It reduces chronic inflammation, moderates levels of the reproductive hormones testosterone, oestrogen and progesterone, and blunts our physiological response to stress. This suppression has big health impacts. Chronic inflammation and stress are indiscriminate killers, increasing the risks for heart disease, cancer, diabetes, mental illness and other maladies.

Research is revealing how exercise keeps our brains fit too. Aerobic activity increases blood flow to the brain and causes the release of molecules that stimulate the generation of new brain cells and keep old ones healthy.

→
See chapter 5 for more on how exercise impacts the brain

Running, cycling and walking also challenge the brain to coordinate myriad signals involved in balance, navigation and movement, helping to maintain our cognitive reserve – a kind of mental padding that is thought to help ward off dementia and other forms of cognitive decline.

Counter-intuitively, one thing that exercise doesn't do very well is increase our daily energy expenditure. Research done by Herman Pontzer at Duke University, along with David Raichlen at the University of Southern California and others, reveals that Hadza hunter-gatherers in Tanzania burn the same number of calories a day as adults in the US and Europe, despite being five to 10 times as active.

It isn't that exercise is less energetically expensive for the Hadza. Instead, their bodies have somehow adjusted to their physically active lifestyle by spending less energy on other tasks, which keeps their total daily calorie expenditure in check.

The same seems to be true for people everywhere: being physically active doesn't change the number of calories your body spends each day, it changes how you spend them.

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For more on the work of Herman Pontzer on metabolism, turn to chapter 4

This may be bad news for people relying on exercise to lose weight, but it does help us understand why activity is so important in the modern world. It may well be that this "metabolic management" underpins the suppressive effects of regular exercise.

For those of us who live mostly sedentary lives, the body has an abundance of calories at its disposal. As a result, physiological activities such as inflammation and the fight-or-flight response, which are normally short-lived and sporadic, are always on, raging in the background.

Similarly, our reproductive systems produce an overabundance of sex hormones – twice the levels we see in populations like the Hadza.

As we have already seen, exercise can have a suppressive effect. In other words, exercise helps us regulate these and other overzealous activities. By forcing our bodies to economise, it helps prevent many of the diseases that haunt the developed world. ■

HOW MUCH EXERCISE DO WE NEED?

We have seen that exercise is akin to a wonder drug, and yet around the world, 1 in 3 women and 1 in 4 men don't do enough physical activity to stay healthy. What is the ideal dose?

DESPITE everything we know about the benefits of exercise, lifts and escalators are jammed with people who wouldn't consider taking the stairs. In fact, the average person in the US takes fewer than 5000 steps a day and in the UK it isn't much more. Our governments and health agencies strive to put numbers to how much exercise we should do, which can serve as an initial guide, but what should we really aim for?

According to standard advice issued by the World Health Organization, adults should in general be getting at least 150- 300 minutes of moderate physical activity or 75-150 minutes of vigorous activity per week, or a combination of both, to extend their lives, get fit, have stronger muscles and be a healthy weight. If that didn't already sound a lot, the WHO says to increase that if you want to reap further benefits. And strength training is additionally recommended for adults over 65.

The good news for the exercise-averse is that it's possible to stick to these guidelines without entering a gym or breaking into a jog. The WHO's definition of moderate exercise includes domestic chores and gardening, and active recreation.

This idea fits with evidence from a study of more than 130,000 people in 17 countries, which found that walking to work and household chores such as vacuuming or scrubbing the floor are activity enough to reduce the risk of early death by 28 per cent, as long as you do 150 minutes a week.

If you aren't one for housework, you will be pleased to hear that your weekly dose of exercise can be

“Just 15 minutes a day of moderate exercise was enough to reduce the risk of death”

BEE32/ISTOCK

Why walk up the stairs when the stairs can move for you?

crammed into the weekend with no ill effects, says Gary O’Donovan then at Loughborough University, UK. Most governments urge people to do a little every day, or at least spread their exercise over the week. But his team analysed data from more than 63,000 adults in the UK spanning 18 years and found that people who opted for a “weekend warrior” regime had pretty much the same reduced risk of early death from all causes, including cardiovascular disease and cancer, as those who spread out exercise. “One weekly bout is usually sufficient to reduce mortality and morbidity,” O’Donovan says. Even weekend warriors who did less than the recommended amount for the week fared better than inactive people.

Even a small amount of exercise brings significant health gains. This was the case in a massive study from 2011 that followed more than 400,000 people in Taiwan over an average of eight years, noting their exercise habits and the number of deaths from different causes. This showed that just 15 minutes a day of moderate exercise such as fast walking was enough to reduce risk of death by 10 per cent compared with sedentary participants. This effect could also be gained by around 5 minutes of vigorous exercise such as running, giving a time-versus-benefit ratio between running and walking of three to one.

Yet it seems you can do too much exercise. Many large studies reveal that extreme exercisers have slightly higher mortality rates than people who work out a couple of times a week. We also know that the rigorous regimes of elite athletes can lead to overtraining syndrome, a constellation of problems including reduced immunity and fertility. White blood cell counts crash, colds last longer, libido drops, women stop ovulating. Exercise stops being healthful and starts being harmful.

So how do we judge the amount of exercise that would be best for us? One way to work out how much of this marvellous medicine we need is once again to look to traditional hunter gatherer communities, such as Tanzania's Hadza, who live an active life foraging for food and are afflicted by very few of the diseases that plague more industrialised ways of life. After all, our body's response to exercise evolved to meet the physical demands of hunting and gathering.

In communities like the Hadza, adults get about 2 hours a day of moderate-and-vigorous physical activity – meaning anything more strenuous than a casual stroll. This stacks up as far more than the WHO guidelines, and most of this comes in the form of hard walking: moving fast over hilly terrain, while scouring the landscape for food. They do plenty of other activities too, though. Women often spend an hour or more digging starchy wild tubers from rocky ground. Men climb trees and chop into branches to expose bees' nests and take honey. Children drag firewood or haul buckets of water back to camp. Other indigenous communities have similar workloads.

Men and women in these communities regularly live into their 60s and 70s without any sign of the problems we often see as the inevitable consequences of ageing. They have the healthiest hearts on the planet, never develop diabetes, and stay strong and spry into old age. They are getting the daily dose of exercise that humans evolved to require, and the health benefits are apparent.

Two hours of exercise each day might seem like a lot. But people who manage it do get huge benefits. A study of postal workers in Glasgow, UK, found that those who clocked more than 15,000 steps a day carrying the mail, which equates to about 2 hours of brisk walking, had cardio-metabolic health on a par with hunter-gatherers – and this in a city with the lowest life expectancy in the country. A much larger study in the US followed 4840 adults to see whether physical activity reduced the risk of dying over the next five to eight years. No surprise, it found that more active people had lower mortality rates. Just 25 minutes of moderate-and-vigorous activity a day reduced the risk of dying within this timeframe by 25 per cent compared with the least active people. And more was better. Adults who were active for 100 minutes or more each day had the lowest mortality rates: 80 per cent lower than the couch potatoes.

These and other similar studies suggest that current public health guidelines set the bar too low, and we should strive for more. Benefits continue to accrue with more exercise, and the optimal dose seems to be closer to the levels we see with the Hadza. Higher exercise workloads may be particularly important for people who spend their days at a computer. A recent study of nearly 150,000 Australian adults found that it took over an hour a day of vigorous exercise to cancel out the ill-health effects of sitting during work hours.

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For more on the perils of sedentary behaviour turn to page 89

But if 15,000 steps a day/2 hours' brisk walking is a distant goal for you, don't be discouraged. A little of this medicine is still far better than none. Studies consistently show that even modest amounts of exercise confer huge health benefits compared with a slothful existence. For the most sedentary among us, an extra 30 minutes a day of activity that elevates our heart rate would halve our mortality rate, adding high quality healthy years to our lives. If you find a way to stay active that tickles your brain's reward centres, you are doing it right. The best dose of exercise is the one that gets you coming back for more. ∎

10,000 STEPS

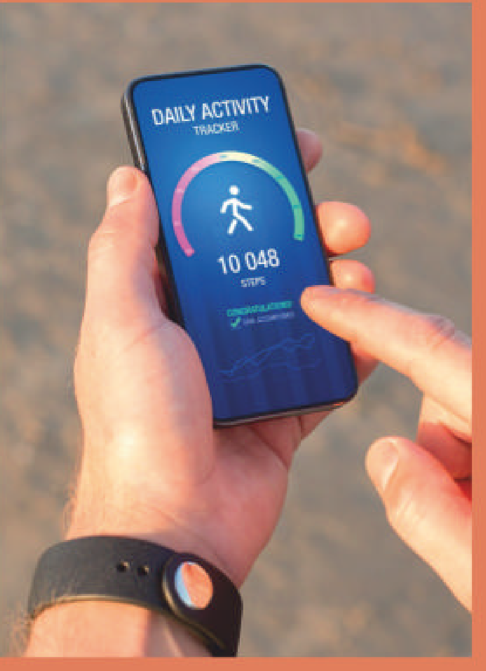
In the mid-1960s, a small, plastic pocket watch-like device went on sale in Japan. Called the "manpo-kei", it was the world's first commercial pedometer. Roughly translated, manpo-kei means "10,000 steps meter".

Why 10,000? "It likely originated as a marketing tool," says I-Min Lee, an epidemiologist at Harvard University. Not only is 10,000 an easy number to remember, the character for 10,000 in Kanji, a script used in Japanese, looks a little like a person walking.

This health target, then, didn't originate with science. Can we scrap it and have a nice sit down? As we've already seen, one way to investigate such questions is to look to our past way of life. Studying the Hadza, hunter-gatherers in Tanzania, as a window into how humans lived thousands of years ago, and the levels of activity our bodies were built for, Herman Pontzer at Duke University and his colleagues measured more than 2000 days of Hadza activity, and found that Hadza men aged 18 to 75 walked on average 18,434 steps a day, while women in the same age range walked 10,921.

And yet 10,000 plus might not be necessary. In a 2019 study, Lee and her colleagues found that women who averaged 4400 steps a day had lower mortality rates than those who took fewer than 3000 steps. Mortality rates decreased as step rates increased up until around 7500 steps, beyond which no additional mortality benefit was observed.

Lee's study only examined mortality – not quality of life – and



10,000 steps a day started as a marketing ploy

GRINVALDS/ISTOCK

she doesn't want to dissuade anyone who does get their 10,000 steps. "Stepping more is better, but we don't necessarily need to reach that 10,000 number," she says. She studied older women, but says her findings are applicable to "a broader group of people who aren't very active".

Another thing worth remembering is that a step counter on your wrist or in your pocket doesn't really measure steps at all, but the motion of your hands or hips. According to Tessa Strain at the University of Cambridge, who studies the epidemiology of physical activity, step counts are a rough proxy for energy expenditure, and what is really important is the amount of energy you expend. Not all steps, then, are created equal.

Using the measure of energy expenditure known as METs, walking slowly on level ground requires 2.8 METS; walking briskly, say at 3.5 miles per hour (5.6 km/h), is 4.3 METs; and walking briskly uphill accounts for 5.3 to 8 METs, depending on how steep the ground is.

← Turn back to page 6 for more on METs

The upshot is that if you have only done a few thousand steps but they were brisk and uphill, there is no need to walk around in circles to get to 10,000. And if you average nowhere near 10,000, the important thing to remember is that any steps are good, but at the lower end of the scale, more is better. In a 2020 paper, Strain found that the biggest differences in health risk were between those doing minimal amounts and those doing slightly more.

If you want to make the most of the steps you are doing, the way you walk might also be worth considering, with research showing it can affect your outlook. In experiments, people manipulated into walking with an "upbeat" gait remembered more positive words from a list, whereas those who walked with a "sad" gait remembered more negative words.

Nearly anyone holding a smartphone is likely to walk with their gaze towards the floor. This not only slows you down, but risks neck strain and possible injury

In short, try to move more and with a spring in your step, but don't feel beholden to 10,000 steps. After all, the number was originally a marketing ploy.

EXERCISE AT ANY AGE

If one thing is becoming clearer than ever, it is that we need to throw out the idea that exercise and fitness are the preserve of the young, and that older generations should be putting their feet up. Keeping fit and strong into old age brings innumerable physical and mental benefits.

IT IS common to assume your 20s were your physical prime, suggesting that the rest of your life is an inevitable decline. But the truth is more complicated.

When it comes to fitness, it is true that elite swimmers usually reach peak performance at 20, and sprinters tend to do the same at 24 to 26 – after which there is often a steady decline in performance in these sports. This is the result of biological changes, such as the loss of some "fast twitch" muscle fibres, which create the sudden bursts of energy necessary for high speed and explosive strength.

For professional sprinters, this soon creates an insurmountable barrier. "At that level, even a 0.5 per cent decline in overall performance can hold you back," says Gennaro Boccia at the University of Turin in Italy, who has studied age-related changes in the performance of Italy's top athletes. But such impacts are generally irrelevant for the rest of us in our everyday attempts to remain fit and active. "In the general population, you only start seeing a decline in your performance after 40," Boccia estimates.

If your 20s were defined by speed, then your 30s might be considered the decade of endurance.

This is evident in the peak performance of long-distance athletes. For male marathon runners, the ideal age appears to be 31 years old. For women, it is slightly less, 27 years, although champions like Paula Radcliffe have continued to win until their mid-30s. The peak age for a 100-mile ultramarathon, meanwhile, is 37 for men and 38 for women.

Why would this be? The loss of fast-twitch muscle fibres will have little impact for sports that rely on stamina. But people in their 30s do face a drop in aerobic capacity – the body's efficiency at delivering oxygen to the muscles – which could reduce performance. The extra years of experience may, however, bring the advantage of improved emotional regulation and planning, and these can help athletes to

CECILIE_ARCURS/ISTOCK

Exercising with others brings extra benefits

pace themselves during endurance events and to cope with the inevitable stress and exhaustion. This could offset the early stages of the physiological decline, creating a sweet spot in an athlete's 30s.

Unless you are extremely lucky, your body will have started to slow down by your 50s and 60s. But that is no reason to stop working out. A growing number of studies show that our psychological outlook and physical lifestyle continue to have enormous consequences in later life.

Scientists didn't always promote the benefits of exercise in later life. With the assumption that this was a time of inevitable decay, people were generally encouraged to take it easy. "We used to think vigorous exercise would be dangerous for older adults, that they might suffer a heart attack or fall or break bones," says Margie Lachman, director of the lifespan development lab at Brandeis University in Massachusetts.

Lachman's own research has helped to change these views. In the middle of the 1990s, her team began following more than 3000 people aged between 32 and 84. Over the course of a decade, the participants' general health was measured as well as three potentially protective factors: their physical activity, their social support and their sense of control over their life.

In terms of overall health, Lachman found that those in their 50s and 60s who scored well on those three factors looked much more like those who were in their 30s to 40s in the study than people of their own age.

The potential for interventions is obvious. "Promoting group exercise or sharing one's exercise successes with friends and family can be a way to increase activity and social support, both of which are beneficial for health," says Lachman. And keep active. One study, for instance, found that a programme of strength training improved the mobility of people in their 90s.If you want to remain healthy, then regular, challenging activity is essential into your 70s and beyond. "It is never too late to make some changes," says Lachman. ∎

CHAPTER 2

THE BEST KIND OF EXERCISE

Now we have established how good exercise is for us and why, let's take a look at how to make it work for you. There are proponents of all sorts of exercise trends and fads, and it's not a one-size-fits-all recipe – it all depends what you are trying to achieve. Here we look at different types of exercise and what they offer.

RUNNING VS WALKING

Running can get your heart pumping, but while some people are addicted to pounding the pavements, for others the very thought of doing it brings discomfort and dread. Is it really necessary, or could a brisk walk be just as effective?

RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: KYOSHINO/ISTOCK

THE idea that running is the best exercise for us – indeed, that it is part of what makes us human – has many champions. Among them is Daniel Lieberman at Harvard University, who maintains that we evolved to run long distances. He thinks that our now largely untapped talent for persistence hunting – chasing animals over long distances – in hot conditions gives us an edge over other animals and shaped our evolutionary history.

←
Turn back to chapter 1 for more on why we are born to run

And we aren't just good at running because we are good at walking – technically they are quite different. A range of adaptations such as sweat glands and hairless skin to aid cooling, the right balance of muscle types and a special ligament to keep our head stable when running all mean that, over long distances, we can outrun almost any other animal. "Thanks to our evolutionary history, all of us have the anatomy and physiology needed to walk and run – assuming we are not disabled," says Lieberman. "In today's world, we have medicalised, commodified and commercialised exercise, but physical activity, at its heart, is something we evolved to do." ›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To investigate the question of whether running is necessary, let's consider the measure of energy use called METs. This elegant solution to the definition of exercise has three categories: light exercise up to 3 METs, moderate exercise between 3 and 6 METs and vigorous exercise for anything over 6 METs.

← For more on METs, turn back to page 6

Strolling, at about 2 METs, is light exercise, while walking briskly is in the middle of moderate at 5 METs. The transition to running at around 7 kilometres per hour is where exercise enters the vigorous category. A really brisk walk and a slow run are roughly the same, in terms of effort and calories burned. Is this true of their health benefits too?

At first glance, it might seem that running has the upper hand here. One compelling study looked at 138 first-time marathon runners and found that training for and completing the 26-mile race, even at a slow pace, is equivalent to a 4-year reduction in age of the cardiovascular system, or even more for those who are older and less fit.

Running also gets a glowing bill of health in several large-scale studies that follow people for many years: they show that this exercise has a dose-related effect. More running is better, though with diminishing returns, but the good news for couch potatoes is that, as with exercise in general, the largest gains come by going from nothing to something. "The biggest health benefits are observed with just a little running per week, less than 60 minutes, an amount that would fit in most people's schedules," says Angelique Brellenthin, an exercise researcher at Iowa State University.

Further points in favour of running come from long-term US studies. In the National Walkers' and National Runners' health studies, Paul Williams and Paul Thompson of the Lawrence Berkeley National Laboratory measured the health of about 16,000 walkers and 33,000 runners over six years. Compared with walkers, runners had a 38 per cent lower risk of high blood pressure and a 71 per cent lower risk of type 2 diabetes.

When the researchers controlled for energy expenditure and weight difference between the groups, however, the benefits from walking and running were comparable. Williams later analysed data for breast and brain cancer, and the running or walking-linked reductions in risk of premature death were, again, similar if energy expenditure was the same.

So far, so clear. If you have time on your hands, the gains of walking are comparable to those of a jog so long as you are moving at a moderate pace. But for the time poor, running is the best way to get a dose of exercise.

This is great news for joggers and hikers, but we often hear that running is bad for our joints. If the body gets worn out or injured in the process, could this risk outweigh the benefits?

There is no doubt that running is a high-impact activity. When the foot hits the ground, a force equivalent to two or three times your body weight pushes up through the body. Bones, joints, muscles and ligaments must absorb this force. The question is whether this wears your joints out, as many of us believe.

Alister Hart, a surgeon at the Royal National Orthopaedic Hospital in London and his colleagues recruited 82 runners taking part in the London

“The idea that running wears the body out is a myth. In fact, it is quite the reverse”

MECHANICS OF LOCOMOTION

When people walk, at least one foot is always touching the ground. It is an efficient technique in which, mechanically, the body acts like an inverted pendulum during each foot’s contact. Each of us has an optimum stride frequency related to the length of our legs – the longer they are, the lower the frequency.

Running is less efficient and the motion is more like the compression of a spring than a pendulum’s swing. The movement is characterised by a flight phase when both feet are airborne, followed by one foot making contact with the ground for a mere quarter of a second or so. During this impact, the body experiences forces that are more than double those encountered when standing.

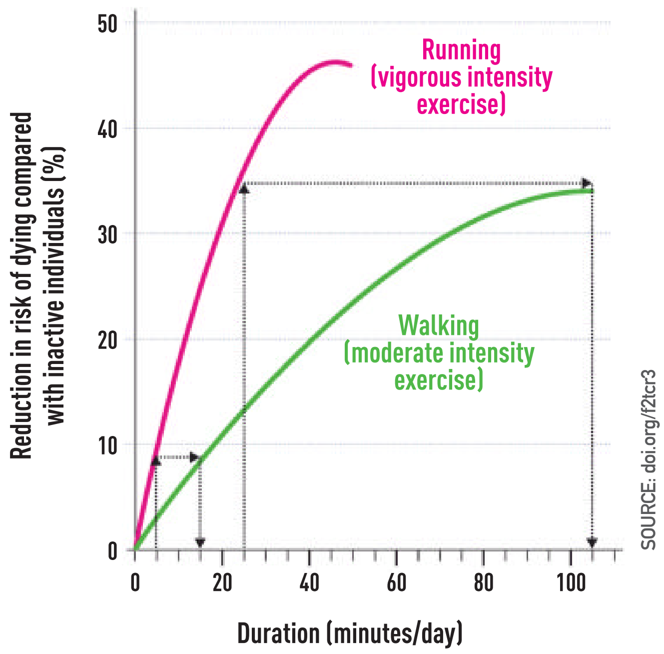
marathon, all of whom were over 40 and had never run this distance before. Using MRI, the runners’ knees were scanned in detail six months before the race and again a few weeks after. To their surprise, the scans revealed that the knee’s main weight-bearing compartments – the parts most likely to develop arthritis in the long term – had become stronger as a result of the marathon training.

The kneecap part of the joint, however, did show damage, but follow-up scans revealed that this had reversed six months later, when the participants had reverted to less intense running regimes. Hart’s take-home message is that distance running can have long-term benefits for your knees. The team also did a study on hips, which found that 560 kilometres of a marathon training programme, ending in the race, didn’t cause pre-arthritic changes in the hip joint.

Another treasure trove of data on wear and tear comes from the National Walkers’ and National Runners’ health studies. As part of this, Williams looked at osteoarthritis, which is caused by the breakdown of bones or cartilage in joints. He found that doing more running or walking actually reduced the risk of osteoarthritis and the need for hip replacements. It didn’t seem to matter if the participants walked briskly or ran slowly.

The idea that running wears the body out is a myth, says Lieberman. “In fact, quite the reverse. Running helps activate all kinds of repair and maintenance mechanisms,” he says.

But it is possible to overdo it. A 2017 meta-analysis including more than 125,000 people found that 3.5 per cent of recreational runners had osteoarthritis in the hip or knee compared with 10 per cent of sedentary non-runners. Yet 13 per cent of elite runners who had ›



Even a small amount of exercise boosts health, but this effect tapers off with increasing time spent exercising

A 5-minute run generates the same benefits as a 15-minute walk, and a 25-minute run is equivalent to a 105-minute walk

taken part in international competitions had such osteoarthritis. For recreational runners at least, it seems there is a sweet spot at which running protects against osteoarthritis.

When it comes to injuries such as sprains, walking beats running hands down. A study of the exercise habits of more than 14,000 Spanish graduates, for instance, found walking resulted in 40 per cent fewer injuries than running for equal energy expended. The injury rate of running was less than that of football, and sailing, and similar to that of skiing and tennis.

The risk of injuries from running depends on factors such as how long you have been doing it, as well as your age and sex. A 2015 meta-analysis of 13 studies of running-related injuries found that novice runners were most likely to get injured, sustaining around 18 injuries per 1000 hours of exercise. At an average pace of nearly 10 kilometres per hour, this is equivalent to about one injury every 540 kilometres, more than double the rate of more experienced runners. Unsurprisingly, one of the most important risks is the existence of a previous injury.

More recently, Lucy Gates at the University of Southampton and her colleagues studied people who did various forms of exercise including walking, cycling and playing sports. At the start of the study, participants were asked how long they exercised for and at how many METs. They were then followed up for anywhere between 5 and 12 years. At the end of the studies, the likelihood of developing arthritis didn't correlate with activity levels, either by how much time people spent exercising each week or by their combined time and MET scores.

What about those terrifying stories of people who cross a marathon finish line only to drop dead? Some studies show that the health benefits of running tail off, or even reverse, when running more than 4.5 hours a week. Crucially though, the risks from any amount of running are always lower than from doing no running at all and, on average, runners live three years longer than non-runners.

Runners tend to weigh less than walkers, too. This could be because thinner people are more likely to run, but a study by Williams suggests running helps shed excess weight. It showed that reductions in body mass index were significantly greater from running compared with walking when these activities were matched for energy expenditure. This could be due to a greater increase in metabolic rate after more intense exercise.

So where does this leave us in the walk/run debate? The research clearly shows that both are good for you. They improve cardiorespiratory fitness and reduce blood pressure, body mass index and the risk of a host of diseases. For the biggest bang for your buck though, running has the edge, mostly because you can get more exercise done in a given time. But if you expend the same amount of energy when you walk, the benefits are quite similar. In other words, if you prefer walking, go for a long one, ideally with a few hills. And remember that any amount of exercise is better than none. ∎

THE BENEFITS OF STRENGTH TRAINING

When it comes to fitness, building muscle power has long played second fiddle to aerobic exercise, perhaps because many people think it is simply for bulking up muscle. But strength training could add years of life and protect you from some major killers. Skip it and you could be overlooking one of the best forms of exercise for the body and mind.

FOR many of us, fitness means getting out and about, religiously racking up steps on a pedometer or pounding the pavements. Aerobic exercise was once seen as the holy grail of fitness, but another kind of workout is just as important – if not more so. Something we can all do from the comfort of our homes without any equipment: strength training.

Our muscle strength peaks in our 30s, then slowly declines. Eventually, it can drop so much that we are unable to get out of chairs or climb stairs. It isn't just older people who would benefit from improving their strength, though. We are discovering that building muscle can bring unexpected health boosts for all adults that go way beyond simply being strong.

Its importance is so great that the UK government's latest physical activity guidelines emphasise muscle strengthening over aerobic workouts. "It's an urgent message that needs to get through," says Stuart Gray, who studies metabolic diseases at the University of Glasgow, UK. "People need to know that strength training is important at any age."

Still, because the health boost that comes with aerobic exercise is so widely recognised, most people focus on getting the recommended 150 minutes of aerobic activities a week – running, brisk walking, swimming or anything that gets your heart pumping and you breathing faster.

That message started to evolve more than a decade ago, and in 2011, UK exercise guidelines stated for the first time that all adults should perform muscle strengthening activities two days a week.

Still, about 50 per cent of the UK population fail to get enough aerobic exercise and only 25 per cent get enough strength exercise. It is a similar story in the US, despite physical activity guidelines from both the US government and the World Health Organization also recommending at least two sessions of strengthening activities per week.

One of the main reasons for this is what happens to our muscles as we get older. Age-related muscle loss happens to everyone. Around the age of 30, we start to lose up to 5 per cent of our muscle mass each decade, and this accelerates at 70 (see graphic, overleaf). This effect was first brought under the spotlight by Irwin ›

Rosenberg of Tufts University in Massachusetts back in 1988 after he attended a meeting on ageing. In his notes on the meeting, he wrote that "no decline with age is more dramatic or potentially more functionally significant than the decline in lean body mass. Why have we not given it more attention?"

That time has finally come, and we now have a good picture of what happens to muscles as we age. Over time, the kinds of fibres in our muscles change, with "type two" fibres, which help us bear heavy loads for short spells, slowly being replaced with more "type one" fibres that are more efficient over long periods but less able to carry weight.

Our muscles also stop using protein as efficiently and so are less able to repair themselves. These age-related changes have many causes, including alterations in the levels of hormones such as testosterone, and a reorganisation of brain cells that control movement.

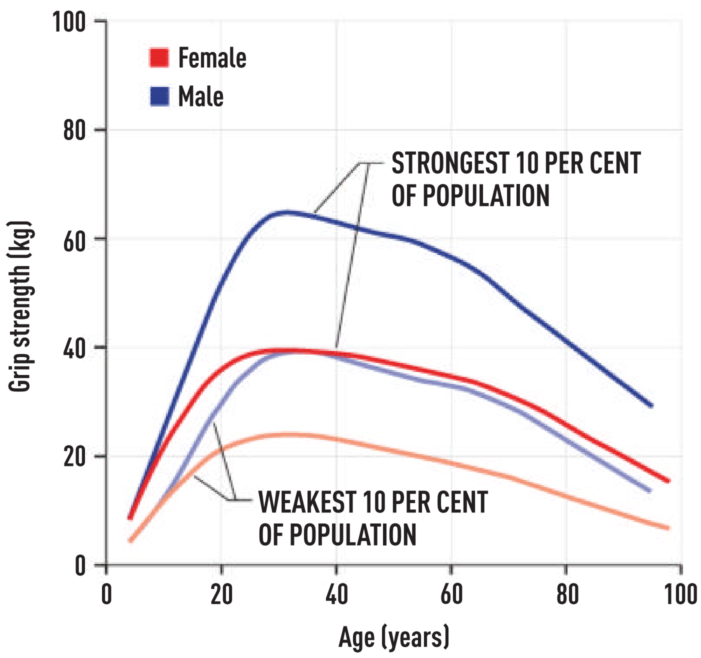
All this might explain why in the past, efforts to tackle muscle loss were focused on people in their later years. But that's only one part of the story. Today, a mountain of evidence points to the benefits of fighting muscle wastage throughout life.

The best evidence comes from studies of the exercise habits of large numbers of people. One showed that lifting weights for less than an hour a week reduces the risk of heart attack and stroke by up to 70 per cent – independent of any aerobic training.

Another study of 100,000 women found that those who did at least an hour a week of strength training significantly lowered their risk of type 2 diabetes. And people with better grip strength – a proxy for overall muscle strength – have a lower risk of cardiovascular disease and cancer and are at reduced risk of premature death by any cause.

One reason stronger muscles keep us healthier is that they help prevent the debilitating effects of wobbles,

Muscle strength peaks in early adulthood, then declines. There are big differences between men and women, and between the strongest individuals and the weakest. Overall muscle strength can be assessed by measuring grip strength



SOURCE: doi.org/gbsfzs

falls and problems moving, increasing well-being in the process. For instance, when residents at a nursing home performed one set of six resistance machine exercises twice a week for 14 weeks, they not only increased their overall strength by 60 per cent, but also improved their ability to live independently by having the power to cope with everyday activities like getting to the bathroom.

And while you don't have to look like a bodybuilder to reap the benefits of weight training, having bigger muscles is also linked with longer survival for people with cancer, probably because the disease decreases muscle mass, so it is helpful to have a bigger resource to start with to keep the body going for longer.

Muscle also plays an important role in regulating the body's glucose levels. With the help of insulin, it soaks up glucose from the blood and stores it in the form of glycogen. Bigger muscles mean a bigger sink for glucose and a higher number of cells that transport and clear glucose from the body, which all helps ward off type 2 diabetes, in which blood glucose levels become too high.

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Chapter 4 has more on exercise and metabolism

Another surprising benefit of strength training is how it burns calories, even after the exercise is over. Weight training increases your basal metabolic rate – the amount of energy your body consumes when at rest – in two ways. First, bigger muscles require more energy to fuel their tissue maintenance. So simply having more muscle mass uses more calories. Second, in the short term, lifting weights causes tiny tears in your tissue that require a relatively large amount of energy to remodel. This increase in energy demand can last for three days after a workout.

Let's say you perform two 20-minute resistance training workouts a week. Each session requires about 200 extra calories to perform, but over the next three days, you will use another 100 extra calories a day to help repair your muscles. Over the month, those two workouts a week have consumed a whopping 5000 extra calories.

All of this helps if you want to decrease body fat, a factor associated with lower cholesterol, lower blood pressure and improved insulin sensitivity and glucose control, which all contribute to a decreased risk of type 2 diabetes and cardiovascular disease. This is one of the reasons why getting stronger protects you from heart attacks.

But strength training really trumps aerobic exercise with its effect on bone. Our bones start to degrade as we age, losing mass and making us more prone to fractures. Aerobic exercise is beneficial to a lot of systems in the body, but there is little evidence that it protects us from bone loss.

Our bones are in a constant flux of being broken down by cells called osteoclasts and being built up again with osteoblasts. Strength training places stress on the bones, triggering the activity of osteoblasts and inhibiting osteoclasts, helping us to maintain, and even build, denser bones. This significantly lowers the risk of osteoporosis, which causes around 1.66 million hip fractures globally every year.

If that weren't enough to convert you to the weights room, building muscle can also boost your brain. Several studies show that people with a better grip strength – hence better overall body strength – score higher on tests of memory and reaction time, as well as on assessments of verbal and spatial abilities. This means that grip strength can be used as a marker of cognitive decline.

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For more on the effects of exercise on the brain, turn to chapter 5

It seems there is something special about muscle training specifically, rather than exercise in general. For instance, older women who lifted weights once a week for a year had significant improvements in cognitive tests of attention, compared with women who performed balance and toning classes.

The underlying mechanisms aren't fully understood, but strength training seems to trigger the release of several brain chemicals, including one called BDNF, that support the health of neurons, helping them to communicate, grow and resist age-related decline, all contributing to a healthier brain.

What's the best way to reap the benefits? There is no easy answer, says Gray. It is trickier than it is to tell people to get 150 minutes of aerobic exercise a week, because the type of strength exercises a person can do will differ wildly depending on their age and circumstances.

That said, advice from the American College of Sports Medicine couldn't be simpler: it says that adults should perform strength exercises on all major muscle groups – legs, hips, back, abdomen, chest, shoulders and arms – at least twice a week.

That advice comes from evidence that your first workout of the week will give you the most benefit compared with nothing at all. Your second workout will give a bit more benefit, as will the third, but then the results plateau.

But don't get carried away in the details of what you are doing in these sessions, says Jason Gill, also at the University of Glasgow: "If you exercise a particular group of muscles until it's tired, it doesn't really matter how heavy the weight is or how many times you lift it. The benefits for a non-athlete are broadly the same whether you lift a light weight 20 times, or a heavy weight five times."

Determined to make things even simpler, Gill's group is testing whether tiny amounts of exercise a day can make a difference to health. "The idea is, if you can do 1 minute of each exercise a day, press-ups Monday, squats Tuesday, then it's a way to build resistance exercise into your week very easily," he says. You could even boost your muscle strength without lifting a finger.

Like most things in life, a balance of activities is best. "Both aerobic and strength exercises seem to boost our health in slightly different ways, and most studies point to a bit of both being better than either alone," says Gill.

The heart, for instance, responds to both strength and aerobic training, but the two kinds of exercise cause it to adapt in a different way structurally. And remember that many aerobic activities, which get the heart rate up, are also good for muscle strength, including circuit training and dancing.

Let's not overthink it, says Gray. Anything is better than nothing, and little things squeezed into your everyday routine can make a big difference, without the need for any equipment.

Any form of resistance training – exercises that cause muscles to contract against an external force – helps build strength. This external resistance can be in the form of weights, but also elastic bands, special resistance training machines or just your own body weight. Press-ups on the floor, or if that's too hard, against the wall or kitchen worktop are a simple way to build strength. Squats and lunges can be done in front of the TV. Even lifting shopping bags and children count.

Whatever you do, just make sure it wears you out, Gray says. "If you just do whatever strength exercise gets you knackered in a reasonable amount of time, you'll probably get the same benefit to your health as if you were following a highly specific training routine." ▮

THE POWER OF HIIT

The promise of getting super fit with very short bouts of exercise might sound like wishful thinking, but high intensity interval training can be worth working up a sweat about.

GETTING fit in 4 minutes: this is the promise of high-intensity interval training, marketed in gyms as HIIT. The idea was thought up by Izumi Tabata and a team of researchers from the National Institute of Fitness and Sports in Japan in the 1990s. Tabata showed that 4-minute workouts, comprising repeated cycles of 20 seconds of all-out work followed by 10 seconds of rest, done four days a week, brought greater aerobic improvements than an hour's normal workout done five days a week for six weeks.

But does it deliver the goods? "The answer to that is absolutely, definitely," says sports scientist Chris Easton at the University of the West of Scotland, UK. "High-intensity training works: it's been shown pretty consistently to make you fitter, make you healthier," he says.

That's because pushing the body out of its comfort zone for short bursts forces it to adapt. The higher the intensity, the greater the adaptation, with benefits for your lungs, heart and circulation. "High blood flow through the heart, through the muscle, is the thing that causes those large changes in a short space of time," says Easton.

MICROGEN/ISTOCK

That's not all. One study compared muscle samples from younger and older people who had regularly done either HIIT training, a weights workout or both for three months. The researchers found that HIIT reduced, and even sometimes reversed, the effects of old age on mitochondria, the energy powerhouses inside cells. With age, mitochondrial deterioration causes fatigue and can contribute to diabetes. What's more, high-intensity training helps boost your metabolic rate, which means you burn more energy even at rest.

Sounds great, but full-on HIIT isn't for everyone, Easton warns: done properly, it is an unpleasant experience. "I do this with my students and invariably after all-out 30 seconds of maximal work on a bike, half of them are physically sick." But incorporating some element of vigorous exercise in a longer routine – whether faster-paced walking or jogging, some hills, burpees or just a few stairs – will deliver benefits. "In terms of disease risk, what is protective is substantially improved when there's a higher intensity component," says Easton.

Not all stretches are equally beneficial before a race

ROWAN JORDAN/ISTOCK

DO YOU NEED TO STRETCH BEFORE EXERCISE?

A quick warm up followed by stretches was once the staple of pre-exercise preparation to prevent injuries and prepare the body to move. But studies on the benefits gave conflicting results, leading people to question if stretching makes exercise safer, and even whether it could harm performance.

Then, in 2016, David Behm at Memorial University in Newfoundland, Canada, and his colleagues reviewed the evidence. They concluded that, while much is still unclear, stretching before exercise is more beneficial than it is harmful for both injuries and overall performance.

In terms of preventing acute muscle injuries, stretching before exercise reduced the risk of injury to muscles by up to 54 per cent. These benefits were mostly confined to activities that involve explosive movements, such as sprinting or jumping. Sports that involve endurance or brute force, however, got less benefit from a pre-emptive stretch.

Another hotly debated topic is the effect of stretching on performance. In the early 2000s, research started to come out indicating that static stretching – where a single position is held for a period of time – decreases performance. “This had really big consequences,” says Markus Tilp at the University of Graz in Austria. “Nobody dared to do static stretching anymore.”

However, Behm’s review concluded that any such reductions were small, temporary and, for anyone who isn’t an elite athlete, hardly worth worrying about.

Long, static stretches, held for more than 1 minute, resulted in a small but measurable detrimental effect on muscle power – yet this was less than 5 per cent and only lasted for a few minutes after stretching. At an elite level, that might enough to make the difference between gold and silver, so athletes might be better off with shorter stretches lasting less than 1 minute, which had no effect on performance.

Many people strive to touch their toes or do the splits, but it is perfectly possible to get all the benefits of stretching without pushing your body to its limits.

HOW IMPORTANT IS FLEXIBILITY?

"I BEND SO I DON'T BREAK."

No one knows who first coined this phrase, but search for it online and you will find it accompanying numerous pictures of yogis in various states of contortion. Flexibility, according to common wisdom, is not only impressive to look at, but something we should actively work towards.

Scientifically, however, the question of whether we should stretch to become more flexible has been difficult to answer. Even in sports science, where most of the research has been conducted, there has been little agreement.

←
See the opposite page for more on stretching before exercise

In recent years, though, answers have started to emerge. The surprising outcome is that, while stretching may well be good for us, it is for reasons that have nothing to do with being able to get your leg behind your head.

One thing is for sure: stretching feels good, particularly after a long spell of being still. We aren't the only species to have worked this out. As anyone with a dog or cat will know, many animals take a deep stretch after lying around. This kind of stretching, called pandiculation, is so common in nature that some have suggested it evolved as a reflex to wake up the muscles after a spell of stillness.

Pandiculation aside, other species don't seem to spend any time maintaining and extending their range of motion. Which raises the question, is there any reason why we should?

Our flexibility is controlled by the tissues of our musculoskeletal system, which determine the maximum range that our joints can move without causing injury. For a long time, flexibility has been considered a key component of physical fitness by groups such as the American College of Sports Medicine. Its latest guidelines, for example, recommend stretching all the major muscles groups at least two or three times a week, holding the stretch for anywhere from 10 seconds to 1 minute.

Even for exercise-phobes, there are good reasons to stretch: our species is unique in having invented a way of resting that works against the needs of our bodies. Anthropological evidence suggests that from at least 2 million years ago, and until the invention of chairs, our ancestors rested by squatting on their haunches, a position that is still common among young children, modern hunter-gatherers and in cultures across Asia. For those who are used to it, squatting is a comfortable resting position, and has the added bonus that it keeps the hips, calves and ankles mobile through the range of motion needed to walk, run and otherwise move › around in the world.

Resting in chairs, however, does the opposite, causing us to stiffen up. A study in 2021 by researchers at the University of Salford, UK, suggested that this has a real impact on range of motion. People who regularly sat for less than 4 hours a day and were generally active had 6 degrees more range of motion in their hip joints than less active people who sat for more than 7 hours.

There is also evidence that sedentary lifestyles in general are having a knock-on effect on overall flexibility. A 2012 analysis by the US Institute of Medicine in Washington DC of data from the now-defunct Presidential Physical Fitness Test, which, between 1966 and 2012, included a sit-and-reach flexibility test for all US schoolchildren, found that flexibility in young people had decreased over the decades, particularly among boys.

By early middle age, the most sedentary people are so stiff that they can injure themselves even while sitting at a desk. "We see that starting at age 30 or so, people get problems from non-sporting activities like moving the computer mouse," says Markus Tilp at the University of Graz in Austria, who studies stretching.

What's more, it isn't just the physical act of sitting that leaves us feeling tight. Concentrating on a mental task contributes to tension in the shoulder girdle, arm and neck. This is partly because when we focus our eyes on a screen, we often tense our shoulders to increase our ability to focus visually (and mentally). One study found that the trapezius muscles in the upper back, which help keep the head upright, are particularly sensitive to the difficulty of the task – the more we need to concentrate, the more they tense up.

For people who sit a lot and are under a lot of stress, then, stretching and mobilising stiff parts does relieve tension and lengthen muscles – at least temporarily. It is also well known that, when done regularly, stretching can lengthen muscles and connective tissue, restoring their length and a full range of motion to underused joints.

Which all sounds like case closed for the benefits of stretching, especially for those who feel their bodies are tight, weak and inflexible. But this doesn't necessarily mean we should devote lots of time to stretching to get more flexible as part of an exercise regime. In fact, according to exercise scientist James Nuzzo, at Edith Cowan University in Australia, this type of stretching isn't worth the effort.

Nuzzo says that the hype about stretching dates to 1980 when exercise scientists Charles Corbin and Larry Noble, then at Kansas State University, first made the case for its importance in overall health. They argued that flexibility was important to maintain posture and protect the back, while allowing the body "freedom to move". Soon afterwards, the sit-and-reach test was incorporated into the first version of US standardised physical fitness tests as a measure of flexibility, and the idea that stretching is the way to improve flexibility became entrenched in the popular consciousness. However, in his 2020 paper "The case for retiring flexibility as a major component of physical fitness", Nuzzo, then at the University of New South Wales in Australia, argues that, while maintaining a healthy range of motion is important, stretching has a reputation that far outstrips what it can actually do for our physical fitness.

For a start, the degree of flexibility you need very much depends on what you plan to do with your body. Normal human movement only requires the hips to be sufficiently flexible to allow the legs to extend backwards to an angle of 30 degrees from upright. In other words, for everyday activities, you only really need the flexibility to get halfway to the splits, at most, and there is little reason to push your hips any further.

What's more, the kind of extreme flexibility that makes a great social media post can be more trouble

JACOBLUND/ISTOCK

Stretching could help people relieve inflammation

than it is worth. As many as 20 per cent of people have hypermobile joints, which extend further than the normal range. This can lead to physical problems, such as joint pain and dislocations, if the joint hasn't been strengthened throughout its full range. Most cases of joint hypermobility are inherited, caused by an unusually loose form of collagen, but some researchers think that certain types of extreme stretching – dance training, for example – can lead to joint hypermobility and the problems this can cause. This suggests that a training regime with flexibility as its sole aim may not be such a good idea.

Nuzzo's main problem with stretching, though, is that for our overall health, it's largely a waste of time. "There is not strong evidence that flexibility really correlates with a lot that's hugely important," he says. Cardiovascular fitness, muscle strength and endurance all correlate with a lower risk of mortality, he argues. Flexibility, not so much.

That isn't to say that we shouldn't aim to maintain a healthy range of motion, and to extend that range if necessary, says Nuzzo. People who spend most of the day sitting and then exercise in frantic bursts are at risk of doing themselves an injury if they don't take the time to maintain a useful range of motion. But he argues that there are better ways to achieve this goal than a dedicated stretching regime.

Resistance training – in particular eccentric contractions, where muscles are loaded as they lengthen (for example, the lowering phase of a bicep curl or walking down the stairs) – has the same effect on the muscles as pulling them into a stretch, he says. Doing this, you get strength as well as flexibility, with no need to tag on a series of stretches afterwards.

In fact, keeping the joints oiled doesn't need to involve anything that you might think of as exercise. Squatting onto your haunches when you need to reach something on the floor will release sitting-related tension without the need to contort your body into an "official" glute stretch. Reaching to grab something from a high shelf or playing frisbee will help free up the shoulders too.

The benefits of choosing strong mobility over flexibility is that you get side benefits in terms of increased strength and endurance, which – unlike flexibility – have been shown to bring significant benefits for overall health and longevity.

But don't abandon your flexibility training just yet, as it has surprising benefits for the cardiovascular system.

Over the past decade or so, studies have revealed a link between inflexibility and risk factors for cardiovascular disease. For instance, a 2009 study of Japanese adults led by Kenta Yamamoto at the National Institute of Health and Nutrition in Tokyo found that the stiffest participants (as measured by a sit-and-reach test) aged 40 or over had stiffer arteries, and this effect was independent of the aerobic fitness levels of the participants.

What's more, a 2018 study of 1354 Japanese men aged 35 to 59 found that the least flexible showed the highest levels of atherosclerosis, the build-up of plaque in the arteries, which is another risk factor for cardiovascular disease. This implies that it may be possible to improve our cardiovascular health via a regime of stretching, or at least by keeping our joints and muscles oiled. A growing number of studies show that this is indeed the case.

In 2008, researchers from the University of Texas at Austin were investigating whether strength training could reduce arterial stiffness. Their control group undertook a mild stretching programme: holding stretches of all the major muscle groups for 20 seconds, three days a week for 13 weeks. The unexpected finding was that strength training had no effect, whereas stretching reduced arterial stiffness by 23 per cent.

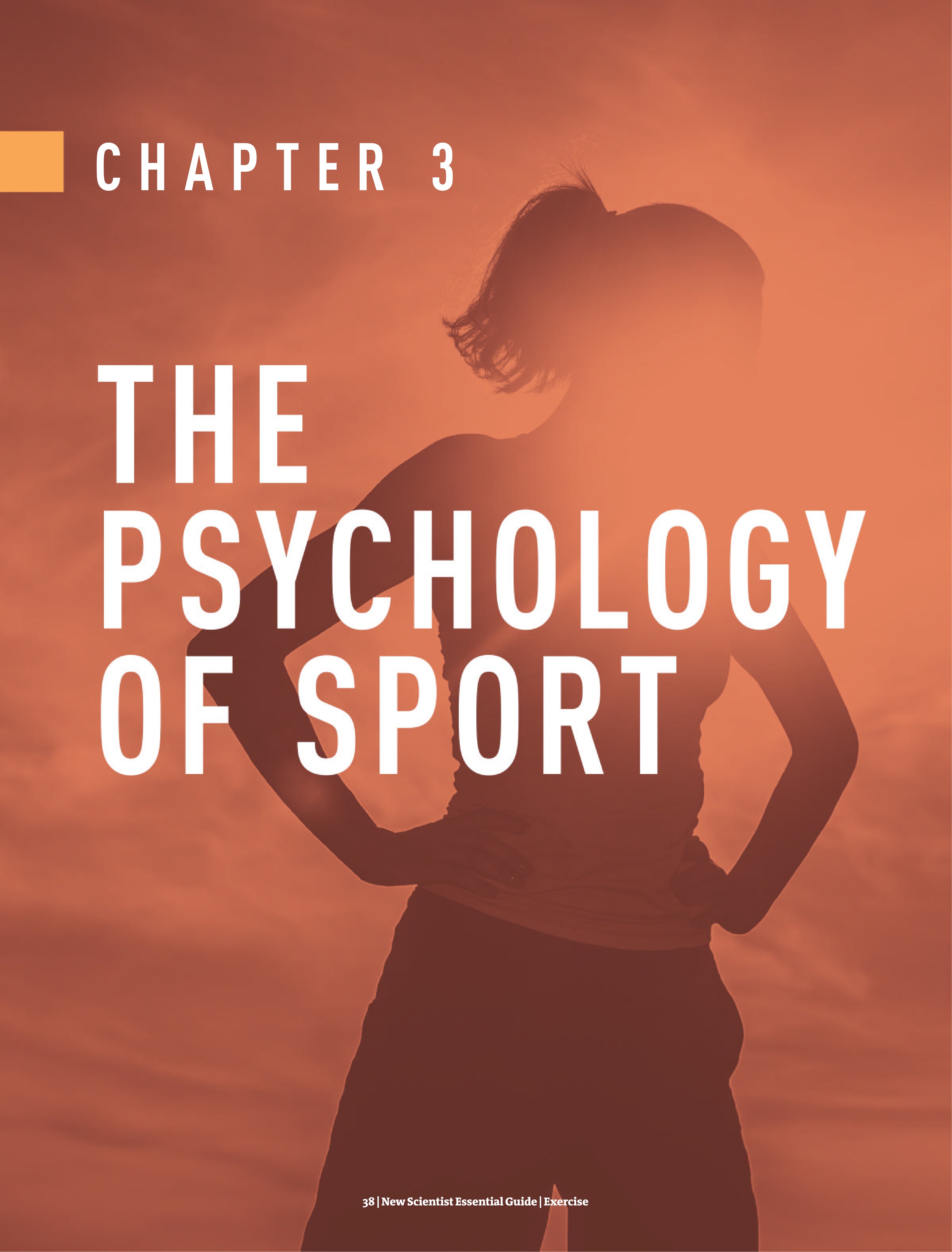
Another Japanese study found that middle-aged people who carried out a four-week regime of static stretches of all the major muscle groups had significantly reduced arterial stiffness. The mechanism behind this effect is still a mystery, though there are a number of proposed explanations. One is that improving the elastic properties of our skeletal muscle also improves the elasticity of our blood vessels.

Another is that atherosclerosis is an inflammatory condition, which is somehow alleviated by the physiological effects of stretching. Evidence for this comes from studies of the fascia – the layers of connective tissue that surround muscles and allow them to slide over each other. Long thought to be nothing more than nature's version of plastic wrap, the fascia are now known to be biologically active and may play an important role in the management of inflammation.

Experiments by Helene Langevin and Charles Serhan, then both at Harvard University, show that when samples of rats' fascia are gently stretched, cells within the tissue rearrange to become flatter and longer, whilst secreting anti-inflammatory molecules.

→ Chapter 5 has more on exercise and inflammation

These studies have revealed that stretching injured tissue speeds up healing and increases levels of chemicals called resolvins that are made by the body to turn off the inflammation response. But Langevin stresses that, while stretching may be beneficial, extreme bendiness is likely to be surplus to requirements. Just stretching until you feel it is probably enough. ▮



CHAPTER 3

THE PSYCHOLOGY OF SPORT

When it comes to fitness, strength and endurance it is often said that the brain plays a stronger role than the body in pushing us through our limits. **Arming ourselves with a better understanding of the new psychology of sport can make exercise feel easier and help us achieve new personal bests.**

HOW BRAIN TRAINING COULD SMASH WORLD RECORDS

The limits of endurance are set not by the body but the brain. Overriding it could push us to dramatic new feats of athletic performance.

ANYONE who has attempted an endurance race such as a marathon will have had a silent word with themselves at some point along the route. It can be tough to find the mental strength to keep going when fatigue, boredom, pain and self-doubt kick in. But until recently, scientists concerned with the limits of human endurance performance tended to overlook the mental muscle and focus on the physiological – how the body functions, in other words – and the environmental. Over the past decade, however, they have come to understand that, to a greater extent than ever previously imagined, those limits are determined by the grey lump between your ears. The brain makes the call to slow up or break down long before the lungs and limbs are finished. Understand how, and all of us, not just elite athletes, could be on our way to cheating fatigue.

In the world of exercise physiology, fatigue is the inability of muscles to maintain desired force. It has typically been viewed as a mechanical breakdown. You reach a limit in your ability to pump oxygen to muscles, lactic acid accumulates in the blood and you slow down or give up. Alternatively, you exhaust glycogen reserves in the muscles, meaning you can't create sufficient energy to carry on.

Most efforts to close the gap still focus on the same ›

RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: SANJERI/ISTOCK

physical characteristics, but overlooking the role of the brain could be a big mistake.

The idea that our physical limits might be imposed by the mind is not entirely new. In the late 1990s, Tim Noakes at the University of Cape Town in South Africa proposed that the brain holds the levers of a subconscious safety device that kicks in to prevent organ damage. This self-preservation mechanism, known as the "central governor", seemed to explain why athletes running on hot days tended to start slower than on cool days: if the subconscious brain perceives a threat, it slows you down to prevent your core temperature rising to dangerous levels. Perhaps this self-preservation apparatus is what has prevented even the fastest marathon runners from ever finishing in less than 2 hours.

That is not how Samuele Marcora sees it. An exercise physiologist at the University of Kent, UK, Marcora agrees that the brain controls the body's brakes, but he has a different take on how it makes the decision to apply them. He argues that fatigue depends primarily on the conscious brain and specifically how we perceive effort. As a result, he insists that even the greatest athletes quit or ease off not because their bodies can no longer go on, and not because the subconscious brain steps in to protect their organs, but because they think they have reached some maximum level of effort. At that point, they make a conscious choice to stop.

Marcora has produced evidence to support his idea. In one study, he recruited 10 men from Bangor University's rugby team for a "trial to exhaustion". He put them on exercise bikes and had them pedal at a

DOES LISTENING TO MUSIC MAKE EXERCISE EASIER?

Many gym bunnies live with headphones in their ears, and that could be a good idea. For starters, listening to tunes can ease the pain of a workout, to the extent that music has been likened to a performance enhancing drug – albeit a legal one. Listening to tunes while you exercise can improve power, strength and endurance. But your choice of drug matters: achieving the runner's high might be easiest when the music's tempo matches your own.

It turns out we unconsciously move to the beat of our playlist. When researchers secretly sped up or slowed down music that cyclists were listening to, they quickened or eased their pace accordingly. Choosing songs that match the rhythm at which we cycle or run can make exercise feel like a breeze. A study of runners found that listening to either a metronome or music at a tempo that tallied with their typical stride rates helped them run for longer than they could without music. While the metronome helped them maintain a consistent pace, the runners said music made the workout feel easier.

In another study, volunteers were asked to cycle at a set pace and listen to music that was either in or out of sync with their pedalling. When the music matched the tempo of their exercise, the cyclists used less energy than when the music was slower.

To try this trick, count how many times one foot hits the ground or one pedal completes a rotation in a minute and double it to get your stride or pedalling rate. Then find a song with a similar number of beats per minute. Certain apps even offer up playlists of music that fit your pace. For example, if you run at around 160 strides a minute, *Ready for It?* by Taylor Swift might be just what you need to crush your next workout.

“Exercising when you are feeling physically or mentally drained could build up your resistance”

fixed power output based on 90 per cent of their maximum aerobic capacity – on average 242 watts – until they could no longer maintain it. Then, as soon as the riders had given up, they were told to pedal as hard as possible for another 5 seconds. They produced an average of 731 watts – way above the output that had just driven them to exhaustion.

Marcora suggested that although the rugby players had suffered lactic acid build-up and glycogen depletion, such physiological effects had not directly stopped their muscles working. Rather, those effects had made the mental effort required to carry on harder and harder until the riders gave up. Ultimately, then, endurance performance comes down to your conscious perception of how much you’ve put in.

But not everyone is convinced by this idea, and most people who have pushed the limits of their endurance will have experienced this “second wind” at some stage, perhaps when the finishing line finally comes into view. Besides, even if the brain is pulling the strings, it might not be a conscious perception of effort that is the ultimate regulator of endurance performance. Noakes argues that it is too simplistic to think that we have complete control over when we call it a day.

For elite athletes and rank amateurs alike, how you train depends on who you believe. Noakes’s central governor model supports high-intensity training techniques such as interval and hill sprints, where you punctuate full-throttle workouts with short rest periods. The idea is to convince the brain that the body can delve into its reserves without damaging vital organs.

←
Turn back to chapter 2 for more on high intensity training

Marcora’s conscious decision model, on the other hand, suggests a novel approach: if it all comes down to how the brain interprets signals about effort, perhaps the best approach is to change the way it interprets those signals.

To some extent, that is what coaches get paid for. They psychologically prepare their athletes for the moment when motivation begins to yield to fatigue. Now, though, Marcora has begun testing “brain endurance training” methods designed to raise an athlete’s perception-of-effort threshold.

In one study, for instance, he asked 35 British soldiers to take a 60-minute cycle trial, during which he measured physiological limiters. Then he split the subjects into two groups. Both trained on an indoor bicycle three times a week for 12 weeks, but one group performed a mentally fatiguing task – picking out combinations of letters on a screen – as they pedalled.

The results raised a few eyebrows. While the control group improved their time to exhaustion by 42 per cent, the brain-training group improved by 126 per cent. The latter group also reported finding the test less painful. “The results showed that the subjects could tolerate a harder perceived effort, so when the cognitive task was removed, the effort felt easier,” says Marcora.

There are important caveats. Studies like this are subject to placebo effects because it is difficult to properly “blind” subjects – the soldiers who did the › brain training may have raised their levels because they knew that was predicted. But let's say the results can be replicated, the question remains: how does this brain-training method work?

Marcora suspects that answers lie in the anterior cingulate cortex, a brain region that has been implicated in a variety of cognitive and emotional functions. His hypothesis is that if you systematically stress this brain region with cognitive tasks, you build up its resistance.

He also proposes that monotonous mental tasks might lead to a build-up of adenosine, a brain chemical produced by neurons during prolonged activity. It accumulates when you are deprived of sleep, binding to adenosine receptors on cells in the brain and elsewhere. By slowing down the activity of those cells, it makes us feel mentally fatigued. That's why caffeine, which blocks adenosine receptors on neurons, makes us feel awake.

Marcora suggests that consistently flooding the brain with adenosine by doing mundane mental tasks forces your brain cells to adapt, building resistance to this fatigue-inducing chemical. The result is that your sense of exertion goes down for the same level of actual effort.

Sadly, you cannot become a world-class marathon runner by curling up with a copy of *Puzzler* magazine instead of putting in the hard yards. Even so, if Marcora's idea is correct, you should make a point of exercising when feeling mentally drained – after an energy-sapping day at work, say, or a bad night's sleep. You might find yourself cursing him as your adenosine levels soar, but the idea is that you build up your resistance and, over time, keep that "I've had enough" feeling at bay for longer.

Marcora has caused a stir among endurance researchers, but he is not the only one convinced that manipulating the brain could bring performance gains.

In 2011, Kevin Thompson, now at the New South Wales Institute of Sport in Australia, had a group of

SOUTH_AGENCY/ISTOCK

Exercising when tired can boost performance

cyclists undertake a 4-kilometre time trial at personal-best pace. He then had them race against an on-screen avatar that they thought was going at their best pace when really it was going 2 per cent faster. The riders kept up, cycling faster than they ever had before. But when the avatar was set to go 5 per cent faster, the riders couldn't handle it. "That showed us the body has an energy reserve of 2 to 5 per cent," says Thompson, and suggested that it can be tapped by tricking the brain.

The method seems to work even when the riders know they are being conned. Ren-Jay Shei at Indiana University in Bloomington worked with Thompson to replicate the study in 2014 and again the majority of riders beat their best by 2 per cent. When the researchers told the athletes they had been deceived and asked them to race the avatar one more time, they still managed to go 2 per cent faster than their personal best. "They'd shifted their pacing template," says Thompson.

The trouble is that such trickery is harder to pull off out there in the real world, not least because it would be hard to find human pacemakers up to the task.

What's more, it is not yet clear if brain training or deception will work for elite athletes. After all, they are the elite because they have trained their minds to tap energy reserves that most of us can't reach. Even so, some of the world's leading elite endurance sports teams have begun to test a more direct way to alter perception of effort: zapping the brain with electricity.

Transcranial direct-current stimulation (tDCS), where a weak electrical current is applied to the brain, has been used in a number of sports to see if it might boost performance of athletes, but the results have been mixed.

The trials build on work suggesting which brain regions it might be best to target. In 2011, a team led by Kai Lutz at the University of Zurich in Switzerland measured the electrical activity in the brains of cyclists as they pedalled to exhaustion. As the subjects tired, Lutz noticed a steady increase in the intensity of communication between the motor cortex, which controls movement, and the insular cortex, which processes signals from the muscles and other components of the body. The results indicate that your insular cortex responds to signals of distress by ordering the motor cortex to give it a rest.

Based on this, Alexandre Okano at the Federal University of Rio Grande do Norte in Natal, Brazil, gave a group of cyclists a 10-minute bout of tDCS over the insular cortex. He found that they generated 4 per cent more power and reported lower perceived effort levels than before the brain zaps. But even if brain zapping does help athletes cross the line faster, it leads to ethical questions about whether it qualifies as a performance enhancing drug. That is a debate for another day, even if that day might arrive sooner than you think. ▮

THINK YOURSELF FIT

New research into the body-mind connection is revealing that the way you think about your body and your lifestyle could be directly affecting how physically fit you really are.

"OUR MINDS AREN'T PASSIVE OBSERVERS SIMPLY OBSERVING REALITY AS IT IS; OUR MINDS ACTUALLY CHANGE REALITY. THE REALITY WE EXPERIENCE TOMORROW IS PARTLY THE PRODUCT OF THE MINDSETS WE HOLD TODAY."

That's what Alia Crum told global movers and shakers at the World Economic Forum in Davos, Switzerland. It may sound like New Age nonsense, but Crum, who heads the Mind & Body lab at Stanford University in California, can back up her claims with hard evidence showing the mysterious influence the mind has over our health and well-being, including the impact that exercise has on us.

Crum's pioneering research was inspired by her own experiences as a child gymnast and college ice hockey player. "You can be the same physical being from one › day to the next," she says, "but your mindset can have a dramatic effect on performance and physiological capabilities." She often wondered why. Then, as a psychology student, she read about the placebo effect and had a eureka moment: if our expectations can influence the effectiveness of a drug, perhaps something similar can happen in other situations, too.

Placebos are inert pills used in most clinical drug trials. The participants are divided randomly into two groups: half take the drug being tested, the rest, for comparison, take an identical-looking sugar pill. With no active ingredient, the placebo shouldn't have any effects. Yet it often brings about measurable changes, triggering the release of natural painkillers and lowering blood pressure, for example – all because of people's expectations. Patients sometimes reap these benefits even when they know they are taking the placebo. On the downside, our expectations of a pill can also produce side effects, including nausea and skin rashes. This is the placebo effect's "evil" twin, the nocebo effect.

When Crum first learned of these powerful effects, she was "blown away". But what surprised her most was the fact that very little research had been done to understand and harness them to improve health and well-being. Governments spend huge amounts of money encouraging us to adopt healthier lifestyles. What if our efforts could be boosted, or undermined, by the very psychological processes that influence a drug's efficacy?

One of Crum's first experiments into this question examined the fitness of 84 hotel cleaners. She suspected that few of them would be aware of the sheer amount of exercise their job entails, and that this might prevent them from gaining the full benefits of that workout. To manipulate their mindsets, she gave half of them detailed information about the physical demands of their work – such as the fact that hoovering burns 200 calories an hour – and told them that their activity met the US surgeon-general's exercise recommendations. The other half did not receive this information.

One month later, despite reporting no change to their diet or activity outside work, the cleaners who received the information had lost about a kilogram each, and their average blood pressure had dropped from elevated to normal. The others showed no difference. It was, admittedly, a small study and Crum didn't record actual behaviour. "It could be that they were putting slightly more oomph into making the beds," she says.

However, a follow-up study with her colleague, Octavia Zahrt, bolstered the idea that people's expectations directly influence their body's response to exercise. That study used data from health surveys monitoring more than 60,000 people for up to 21 years. Zahrt found that the "perceived fitness" of the participants – how they felt compared with the average person – was a better predictor of their risk of mortality than the amount of time they said they spent exercising. Crucially, some of them wore accelerometers for part of the survey period – yet, after taking their actual physical activity into account, the influence of their perceived fitness remained. Overall, people who took a more pessimistic view of their fitness were up to 71 per cent more likely to die during the survey than those who thought they were more active than average – whatever their exercise routine.

How this works is still a bit of a mystery. We do know that the brain can directly control blood pressure through the autonomic nervous system. In addition, Crum suspects that a poor perception of your fitness could be triggering inflammation and the release of hormones such as cortisol, which might help determine how the body responds to exercise. Her team is investigating possible mechanisms but, she says, it's not too early to take advantage of these effects.

For those who want to tap in to the power of mindset for fitness, Crum's advice, which she follows herself, is not to deceive yourself about your fitness, but to make sure that you don't undervalue the exercise you do either. You should also avoid comparing yourself critically with your peers, particularly if they are exceptionally sporty. ∎

IS IT EASIER TO RUN ON A TREADMILL?

In the dark days of winter, opting to run on an indoor treadmill rather than braving the cold may seem tempting. But is it cheating?

THERE'S something so wholesome about lacing up your trainers and going for a run outside, that replicating the experience indoors can feel a cop out. But when it's cold, wet and dark outside, is running on a treadmill really so bad?

One thing that could indeed make the treadmill easier is the lack of air resistance – you don't have to displace the air in front of you when you run on the spot. To make up for this and ensure an indoor workout isn't too easy, some people religiously set the treadmill's incline to 1 per cent.

That figure originated from a 1996 study that found runners doing a 7-minute-per-mile pace used similar amounts of energy to run over ground as they did on a treadmill with a 1 per cent incline.

However, at slower speeds, there were no differences in the energy costs of running over ground or on a flat treadmill. So at an easy pace, there is no need to touch the incline dial – the treadmill isn't any easier than outside.

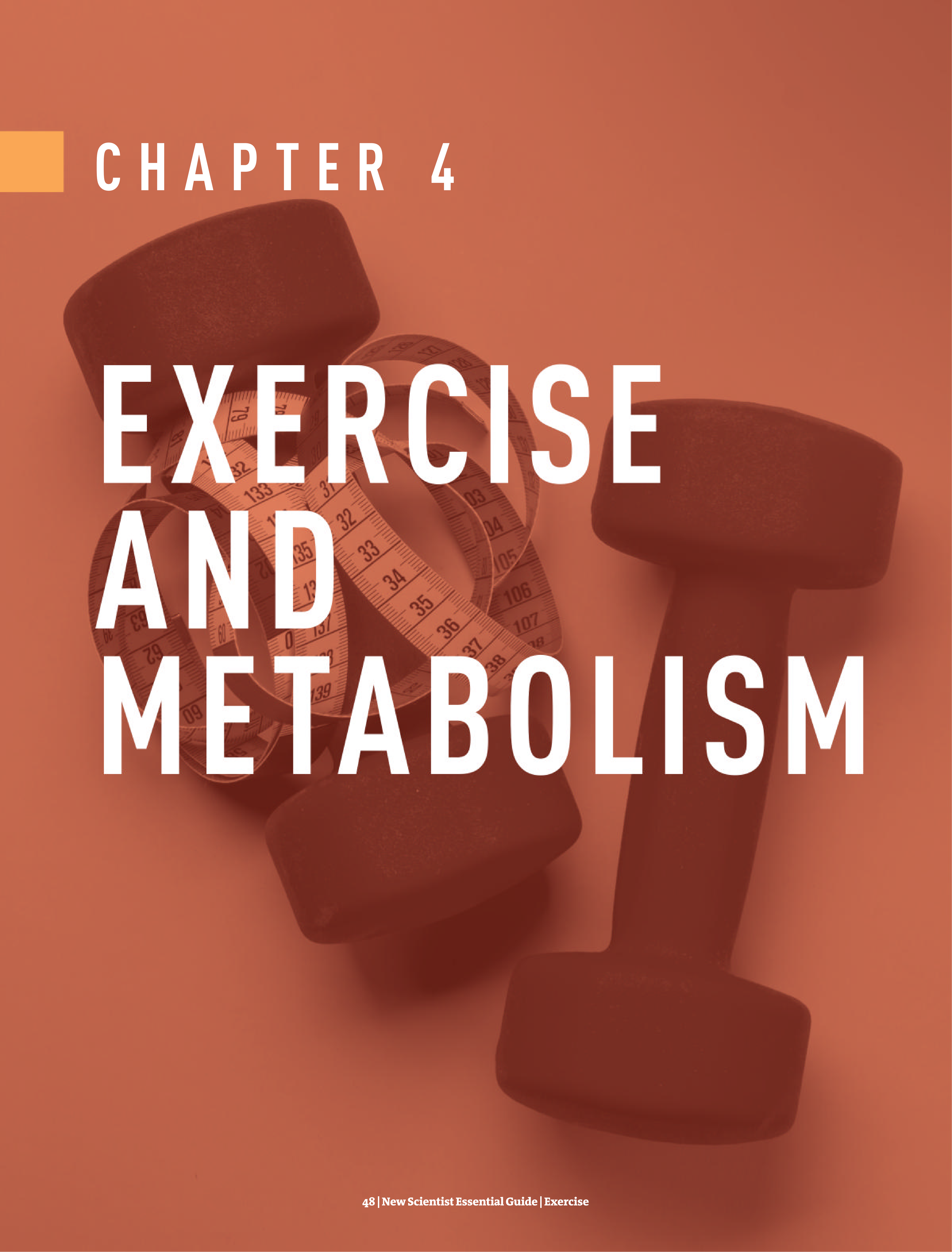
Many people think the "dreadmill" feels harder, not easier. Runners on a treadmill asked to replicate a pace they had previously run on a track, for example, jogged more than 2 minutes per mile slower. One explanation is that the treadmill forces you to maintain one speed, which is tiring and unnatural. When you run outdoors, you're constantly speeding up and slowing down, which means it's easier to adjust your speed to your level of fatigue.

Another explanation is the lack of visual cues that help you gauge your pace. You're often looking at a wall or a window.

What's more, there can be added psychological benefits to running outside in pleasant scenery or in a green space. A review of studies that compared exercising indoors and outside found that people who worked out in the fresh air had higher levels of satisfaction and enjoyment, and said they were more likely to do it again than those who exercised indoors.

For those who still prefer the treadmill, you might want to adjust the speed throughout the workout according to how you feel. And for those 1 percenters, why not vary the incline, to keep things interesting and better mimic an outdoor run. ▮

TINA ZUPANCIC/ISTOCK



CHAPTER 4

EXERCISE AND METABOLISM

For many of us, exercise is part and parcel of maintaining a healthy weight. The assumption is that calories we burn off need to exceed the calories we consume through our diet if we want to lose weight. And yet in practice, many such attempts fail due to a fundamental misunderstanding of metabolism. Our bodies aren't simple calorie-burning engines that we can easily manipulate to keep us looking trim and feeling good. The equation is much more complex.

WHY YOU CAN'T OUTRUN A BAD DIET

Forget the idea that to lose weight you just need to work off more calories than you consume. The truth is far weirder. Exercising more doesn't mean more weight loss. Researchers are scratching their heads as to how to reconcile this.

RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: KARANDAEV/ISTOCK

IN FRANCE, in the winter of 1782, the chemist Antoine Lavoisier and his polymath friend Pierre-Simon Laplace placed an unwitting guinea pig into a double-walled metal chamber, the world's first calorimeter, and sealed the lid. They had packed snow into the space between the walls, and by comparing the rate at which the guinea pig's body heat melted the snow to the rate of carbon dioxide it exhaled, they discovered metabolism – the "fire of life" that drives our very existence. At last, science had a physical measure of the life force that enables us to grow, reproduce and move. Physiologists have been counting calories ever since.

Even so, Lavoisier and Laplace might be surprised at the place their discovery plays in the collective psyche of the millions of people trying to lose weight. For a simple calculation lies at the heart of a lot of mainstream weight loss advice. If calories out exceed calories in, you will lose weight. It is why both exercise and diet are said to be key to staying trim, and why many of us feel we can make amends for overindulging by hitting the gym or dusting off our running shoes.

But if you have ever increased how much exercise you do and found it did little to shed the pounds, ›

you have probably had an inkling that the sums don't add up. Despite tipping the balance in favour of calories out, the scales don't budge. This is the so-called exercise paradox.

In truth, working out a lot doesn't appear to burn more calories than doing a little. In fact, going mad in the gym doesn't seem to burn any more calories than moderate activity a few days a week and taking the stairs, for instance.

Some of the biggest clues that something was up come, like many other insights, from studies of Hadza hunter-gatherers in Tanzania by Herman Pontzer and his team. He wasn't expecting to reveal anything big about exercise. "It started off that we wanted to just ask a basic question: 'How many calories do you need to burn to live as a hunter-gatherer?' " he says.

→
For more on the Hadza, turn back to chapter 1

To find out, Pontzer, and his colleagues turned to the gold standard test for measuring daily energy expenditure, known as the doubly labelled water method. This involved the Hadza drinking water laced with slightly different forms of oxygen and hydrogen, called isotopes. How much of these isotopes are left in their urine accurately reveals how much energy they have used.

Far from burning through huge amounts of calories on their daily expeditions, the Hadza got through only slightly more than Westerners who drive to a job to sit all day, with the men using up about 2600 calories and the women 1900. "I couldn't believe it," says Pontzer.

The findings caused a stir. They called into question the widely accepted idea that sedentary lifestyles in many societies are responsible for the obesity epidemic. Instead, Pontzer and his team began to wonder whether our daily energy expenditure could have evolved to be fixed at these levels, regardless of whether we sit at a desk all day or search the plains looking for our next meal.

To back up the idea, what's needed is to study other ways of living too, including populations with Western lifestyles. That's where Lara Dugas of Loyola University Chicago comes into the story. Her team kitted out nearly 2000 people from the US, Ghana, Jamaica, South Africa and the Seychelles with activity monitors for eight days to gauge their basic pattern of physical activity. She then tracked their weight over several years. The upshot? Activity levels didn't predict weight two years later. In fact, those who met the US guideline of 150 minutes of moderate-intensity exercise per week, according to the monitor data, tended to have put on more weight than those that did less. A paradox indeed.

In 2016, Pontzer and Dugas joined forces. They looked in more detail at more than 300 of the people in Dugas's original study. It turned out that those who were moderately active used up about 200 more calories per day than sedentary people, but after that, calorie burning plateaued. Those who exercised every day didn't burn any more than those who worked out a few times a week.

This view tallies with calculations of how much people exercise when viewed over longer time spans, says Glenn Gaesser at Arizona State University. "If you add up the amount of calories individuals would expend doing 150 minutes [of exercise] a week, times 52 weeks of the year, you come up into the literally tens of thousands of calories that are expended." And yet

“The idea that activity dictates how many calories you burn now looks pretty naive”

exercisers only weigh around 2 kilograms less on average, he says. As the evidence piles up, says Pontzer, the idea that activity dictates how many calories you burn looks “pretty naive”.

It seems time to put the calories in, calories out equation to rest. But how can it be that people do more exercise without seeming to expend extra energy?

The assumption has been that they eat more to make up for it, whether because they are hungrier or feel like they have earned it. “You can consume a doughnut in less than a minute,” says Gaesser. “But that minute of consuming the doughnut might take an hour or more of walking to match in terms of calories.”

→ See page 55 for more on diet and weight loss

It also doesn’t help that people grossly overestimate their energy use during exercise. In one study, people were assigned a treadmill workout and then told to estimate how many calories they burned and eat an equivalent amount from a buffet. They guessed they used up 800 calories and ate about 550. In reality, they had burned just 200. That might help explain why Dugas found that those meeting US exercise guidelines tended to have put on more weight. But it wouldn’t explain why the Hadza’s prolific activity doesn’t add up to much more energy consumption over the course of a day than a sedentary lifestyle.

So another suggestion for the exercise paradox is that our bodies compensate for a hard workout by moving less during the rest of the day. Some clues have come from mice. When given running wheels to prompt exercise, they were found to move around less than usual in between bouts of activity. The number of calories saved by doing this almost exactly negated the calories burned by running.

It seems people make similar sorts of adjustments when they embark on a new exercise regime, even if they don’t realise it. For example, after a hard morning workout, obese adolescents have been found to reduce energy expenditure in the afternoon, resulting in similar total calorie burn on days with and without exercise. Another study of obese teens found a dialling down of activity for six days after a workout.

Rather than think of people as active or sedentary, an increasing number of us are both active, playing sports or working out regularly, and sedentary, spending the rest of the day sitting, says James Betts, who studies nutrition and exercise at the University of Bath, UK. So it is a mistake to just count the calories burned on a treadmill and not consider the rest of the day, he says. “All these other parts of exercise, just moving around more, can be the biggest component of energy expenditure and can dictate which person might be lean and which person might be obese,” he says.

But Dugas doesn’t buy the idea that an afternoon’s sloth negates a morning workout. Furthermore, she was surprised to see activity monitors continuing to buzz late into the night for many of her US participants. The people were working three jobs, on their feet packing groceries and boxes all day. “This notion that people are just sitting down and not doing anything is just not true,” at least not for everyone, she says.

Which takes us to a third explanation for the paradox. We are starting to discover just how much the body adapts and slows down calorie burning when you exercise above a certain level.

Evidence of this comes courtesy of runners in the Race Across USA, in which participants run a › marathon on 140 consecutive days. Pontzer and Dugas teamed up once more to study them. During the first month, the metabolism of the runners skyrocketed, but after that it flattened out and eventually dropped in some of them. "This notion that we can keep increasing our calorie burning is not supported by the evidence," says Dugas.

What's more, calories out can vary even when two people are perfectly matched for body size, body fat and activity level. One might burn several hundred more calories per day than the other. "We really don't understand why that variability exists or what causes it, but it's not activity," says Pontzer.

He thinks the answer might lie in our resting metabolism – how many calories the body burns when not exercising – which contributes more to the variation between people and accounts for a bigger portion of daily calorie expenditure than exercise. "We talk about the energy that we spend running or walking or being active and those are important things to do, but you are ignoring what the biggest part of your budget is, which is all this internal stuff," says Pontzer. Rather than people compensating, knowingly or not, for exercise by moving less at other times, the body could be cutting down on its internal activity instead. "Your body has adjusted by shifting around all the internal stuff to make room for your active life," he says.

Intriguingly, it could be that these metabolic adjustments that frustrate weight loss are a big reason why exercise is so good for us. The body might be responding to increased activity by cutting down on other tasks. For example, immune systems quieten down, reducing inflammation, which is important because we know that inflammation is a serious risk factor for cardiovascular disease and a range of other health problems.

People who exercise regularly also respond to stressful events with smaller surges of the stress hormones cortisol and adrenaline, reducing their risk of stress-related disease. Even reproductive hormones seem to be produced more judiciously. Comparisons of oestrogen and progesterone in women and testosterone in men commonly show reduced levels among adults in physically active populations. These reductions don't appear to harm fertility, but they have been linked to a lower risk of reproductive cancers such as prostate and ovarian cancer, as well as breast cancer. Exercise seems to fine-tune all the unseen tasks our bodies do throughout the day, helping to protect us from heart disease, diabetes and cancer.

←
For more on why exercise is so beneficial for health, turn back to chapter 1

This fits with what we know about athletes with extreme training regimes. "If they train too hard for too long, their bodies wear down, because there's too many trade-offs, their bodies are spending too much on activity and they don't have enough calories left over for everything else," says Pontzer. As a consequence, they often suffer ill effects such as an injury that doesn't heal, a cold they can't shake or, in some women, disruption to their menstrual cycles.

Ultimately, it is hard to avoid the conclusion that, for many people, diet offers greater potential than exercise to get the calorie equation working more in your favour. But exercise does still have a place in the weight-loss journey: once you lose weight, it can help prevent the common problem of putting it back on. An analysis of contestants on *The Biggest Loser*, a TV weight-loss show, found that during the 30-week competition, weight loss and amount of exercise weren't correlated. However, six years later, those who increased physical activity the most regained the least weight or kept it off.

As we know, there are plenty of other, excellent reasons to exercise too. And you can take comfort in the knowledge that there is no need to somehow compensate through intense amounts of exercise to make up for overindulgences. Diet is key though. "If you want to watch your weight, watch what you eat," says Pontzer. ∎

Even those who manage to increase the amount of energy they burn through exercise typically find it hard to lose weight. There seems to be a cap to how much exercise can help if we do want to shed a few kilos.

CATCH 22: EXERCISE AND APPETITE

DOES THE ‘FAT BURNING ZONE’ EXIST?

It is the perfect carrot to dangle if you are more likely to be sliding off the couch than running out of the door: exercising at lower intensities can burn more fat than a strenuous workout. This idea of the “fat-burning zone” starts with the fact that the body can quickly turn carbohydrates into fuel, so they are called upon in an intense workout – whereas fat is burned more slowly, making it an ideal fuel for a slower pace.

Unfortunately, that is a bit of a confusing message. At very low intensities, we burn proportionally more fat than carbohydrate – but the amount of both burned will be much higher at higher intensities. So unless you are prepared to keep going for a very long time, you are better off getting your skates on.

A RECENT review of 61 exercise studies, totalling more than 900 participants, lays out the grim evidence that will be familiar to many.

Weight loss often starts off well at the beginning of a new exercise regime, but it fades over time, so that a year or so later, the weight lost is a vanishing fraction of what we would expect from all the calories burned through working out.

In one of the longer trials, men and women in the US burned 2000 calories per week during supervised exercise sessions for 16 months. After nine months, the men had lost around 5 kilograms, after which their weight plateaued. Women in the study lost no weight over the entire 16 months. Neither men nor women lost what we would have expected based on their exercise workload, despite the fact that their daily energy expenditures had edged up slightly.

The reason for this is frustratingly simple: when you burn more calories, you eat more calories. You might not mean to, of course, but that is the problem. The complex systems working subconsciously to regulate your hunger and satiety do an exceptional job of matching energy intake to expenditure. What else would we expect from half a billion years of evolutionary tuning, where losing weight was generally a sign of impending doom? As a result, the amount of weight you can expect to lose from exercise alone over the course of a year is a paltry 2 kilograms or less. ▮

HOW TO AVOID HITTING THE WALL

It doesn't matter whether you are a seasoned runner or a newbie, when faced with your first marathon, it is impossible to ignore talk of "bonking" or "hitting the wall". Those who have been through it describe the experience as a sudden onset of debilitating fatigue and loss of energy during the race's latter half. Formerly speedy runners slow to a shuffle, often capitulating to the need to walk, and a racer swiftly switches from a desire to finish in a certain time to a yearning to just finish at all.

From a physiological standpoint, we know we hit the wall when we run out of glycogen, a carbohydrate stored in our muscles and liver that provides a readily available source of energy. At this point, the body switches to its fat stores. Fat is a great fuel source because we have loads of it, but we are much less efficient at turning it into energy than carbs.

This means runners can't maintain the intensity they were moving at, and have to drop to a walk.

→ For more on burning fat during exercise, turn to page 59

So far so simple, but athletes and researchers alike have been left scratching their heads as to why people only hit the wall some of the time – and how to avoid it.

One study looking at more than 300 marathoner runners found that only 43 per cent reported hitting the wall during this 42-kilometre challenge. Men were much more likely to do so, while runners who boasted a longer maximum training run were less likely to bonk than those who had never gone further than 32 kilometres. Pacing yourself could be key to avoiding the phenomenon, as this might ease the transition from carbohydrates to fat stores and ensure you don't run out of glycogen too abruptly. So it could be that women are more disciplined about training and pacing themselves during a run.

Psychology plays a role too. If you expect to hit the wall, you are more likely to do so.

There are ways to hone your thinking, says Clare Stevinson at Loughbourgh University in the UK. Her work shows that runners who daydream during a race are more likely to hit the wall, but also that those who spend too much time thinking about breathing hit the wall sooner. She suggests focusing on something external like the scenery and spectators, and paying attention to race conditions, distance markers and drink stations.

So the best way to avoid the wall is to do some long-distance training, pace yourself and develop a mental strategy. "Carb loading" before a race can increase the amount of glycogen we start off with, but eventually those stores run dry.

DOES CARB LOADING IMPROVE PERFORMANCE?

Many endurance athletes swear by piling on the carbohydrates before a race. That can work – but you should be wary of the downsides.

IF ONE of the reasons you signed up for exercise was the thought of guilt-free bowls of pasta, you had better make sure you are working for it. Unless you are planning to go hard for 90 minutes or more, you can step away from the carbonara, the extra fuel isn't necessary.

However, for long workouts, like a big race, it can help. When elite male cyclists doubled their normal carb intake for three days, they increased their power output by 6 per cent and their speed by 1.3 kilometres per hour in a 1-hour time trial that followed a strenuous 2-hour ride.

A general guideline is to eat 8 to 12 grams of carbohydrate per kilogram of body weight per 24 hours for 1.5 to two days before long, hard events like marathons or football matches.

Glucose-containing sports drinks and gels can give you a top-up when your stores start to drop off during very long or intense sessions. But they may also give a boost by activating the parts of the brain that sense when there are carbohydrates in the mouth. "They seem to tell the brain: there's plenty of fuel on board, you can keep pushing the body at the highest rate possible," says Louise Burke who studies sport and nutrition at the Australian Catholic University.

You could even trick your brain without the calories. Endurance runners who simply rinsed their mouths with a carbohydrate solution at regular intervals during a treadmill challenge were able to run 10 minutes longer before reaching exhaustion.

Then again, amateur athletes should be careful about overdoing their carb consumption, says Timothy

Noakes, a sports scientist at the University of Cape Town in South Africa. He carb-loaded for 33 years to help sustain him through 70 marathons and ultramarathons, but was then diagnosed with type 2 diabetes. He attributes this to excess carbohydrate intake combined with a family history of the disease.

One alternative which has gained popularity in recent years is to train the body to use fat as a fuel instead of carbs.

→ See the next page for more on hacking your metabolism

Yet despite the hype surrounding low-carb, high-fat diets, there is no robust evidence that they improve athletic performance. Then again, if you don't mind running a marathon at a moderate pace and you don't want to carb-load, a high-fat diet could help to keep you going.

What about post-workout? This is when it is important to eat protein, because it provides the building blocks required for replenishing muscle, says Burke.

She recommends eating about 20 grams of protein within 30 to 60 minutes of finishing an exercise session to build new muscle. In addition, she advises including 20 grams of protein in every main meal for the next day or two because your muscles will still be responding to the last workout. "If you continue to prime your body with more protein, you're going to get the maximum benefit from that session." Go on, you earned it. ▮

ALLE12/ISTOCK

For shorter workouts you can skip the carb-loading

THE IMPORTANCE OF METABOLIC FLEXIBILITY

Training your body to switch between breaking down carbohydrate and fat can have a huge positive effect on your metabolic health. The best way to start? Exercise, of course.

ONE of the greatest hurdles with understanding metabolism is that it is extremely complex, and trying to measure what a person's body is doing at any point in time has typically required some pretty elaborate equipment. That means studies only involved a small number of people and standard advice had to be generalised. But start to look at the individual, and a very different picture emerges.

Let's take the question of calories, used to express the energy content of food. General advice suggests that men should consume 2500 calories and women 2000 each day. One gold-standard way to see what someone's metabolism is doing is to put them in a sealed room, pump fresh air in and continually analyse the amount of carbon dioxide and oxygen. That's because oxygen is used by our cells as they work, producing carbon dioxide that is ultimately exhaled. But these recommendations didn't originate from this kind of physiological study of people.

Instead, the figure originated in the 1990s when the US Food and Drug Administration (FDA) asked the nation to self-report their energy intake. In the study, women claimed to consume between 1600 and 2200 calories a day, while for men it was anywhere between 2000 and 3000. The FDA pinned 2350 as the average and then rounded the figure down, further simplifying the message and to avoid overconsumption in women. Even in the original research, then, 2000 calories per day was an estimate. What's more, such a one size fits all approach simply doesn't take into account the fact that every individual has a very different metabolism, and possibly one that responds differently at varying times of day and at different stages of life. It is no wonder, then, that people are turning to technologies that could help them better understand what is going on inside their own bodies.

In the last few years, a number of technologies have become available that promise to give you more personal glimpses into your metabolism in action, and apply this knowledge not just to diet but also to exercise.

Rather than focus on calories, the idea is to look instead at macronutrients, the core components of our diets – in particular protein, fat and carbohydrate, the last two of which are the only types of fuel our bodies can use. Protein is important for building muscle, but isn't used as a direct energy source, except in extreme cases where all available carb and fat stores have been used.

If carbohydrates, which are present in the blood as glucose, are available, the body will prefer to burn these over fats. Metabolising fat is hard for the body – it requires more chemical reactions than metabolising carbs, so provides less energy in the same amount of time.

This is the key concept behind one new system called Lumen, which was devised by twin sisters Merav and Michal Mor, both physiologists and endurance athletes.

Anyone competing in endurance events is acutely aware of the body's preference for carbs over fats. Once you run out of carbs, you tend to "hit the wall", where muscles feel heavy and everything tells you to rest. ›

Turn back to page 56 for more on hitting the wall

The twins wanted to devise a way to hack their metabolism to improve their ability to burn fat, so they could fuel themselves better for their Ironman races. They soon realised this might also be useful for anyone who wanted to improve their metabolism.

Lumen claims to be able to monitor whether your body is burning carbs or fat in real time and to train it to switch between the two, burning fat when you want it to and using carbs only when you need that disposable energy. It works by monitoring the amount of carbon dioxide and oxygen in your breath, replicating a test of metabolism that has, until now, only been available in a laboratory setting. The accuracy of the device was verified against the lab version in a small, peer-reviewed study.

There are good reasons why you might want to know whether your body is burning carbs or fats, and get better at swapping between the two. Being able to easily switch between burning fats and carbs is a measure of metabolic flexibility. And it turns out that being metabolically flexible could be hugely beneficial for your health.

The term "metabolic flexibility" was first used in the 1980s to describe an unusual ability of parasitic worms, which could switch between using different energy sources depending on their environment. Scientists started to wonder how important metabolic flexibility was to our own health. They found that people who were lean and healthy were good at using up glucose in the blood, and that people who were overweight had a lower capacity to burn carbohydrates. They were also interested in whether or not people were able to switch their fuel source depending on whether they needed a burst of energy for exercise. The answer emerged: people who are metabolically flexible rely on fats after not eating for several hours, then shift to carbohydrates after they have eaten. Their bodies find it easier to burn through the carbs available and switch back to fats when necessary. Importantly, the ability to shift between the two was a marker of overall metabolic health.

The question then was whether we can help people to improve their metabolic flexibility, says Audrey Bergouignan at the University of Colorado, Denver.

This is where Lumen aims to help. The idea is that by switching more often between burning fats and carbs, you can train your body to do it more efficiently.

Metabolic flexibility

This is important because if you have carbs in your bloodstream constantly, your body doesn't have a chance to get in the mode of burning fats. Thankfully, you aren't trying to cut carbs from your diet completely. In fact, to encourage metabolic flexibility, Lumen will suggest a low-carb quota if you wake up burning carbs. Once you are better at burning fat, it will recommend high-carb days to keep your metabolism on its toes, making that important switch.

Research indicates that being metabolically flexible is key to beating metabolic syndrome, which is a cluster of symptoms such as high blood pressure, high cholesterol and obesity that puts you at greater risk of heart disease, type 2 diabetes and stroke. Indeed, studies show that people with metabolic syndrome are much worse at switching between carbs and fats – they are metabolically inflexible.

It is much easier for the body to metabolise carbohydrate than fat

Of course, it could be that they are metabolically inflexible because they already have health issues. To get to the bottom of this, Bergouignan and her team went to the extreme. They knew that habitual physical activity is a good predictor of metabolic flexibility, so they took a group of women without any significant health problems and confined them to bed rest for two months. The participants were fed a balanced diet, and yet not only did they become metabolically inflexible, they also became worse at controlling their blood glucose levels – predisposing them to metabolic syndrome.

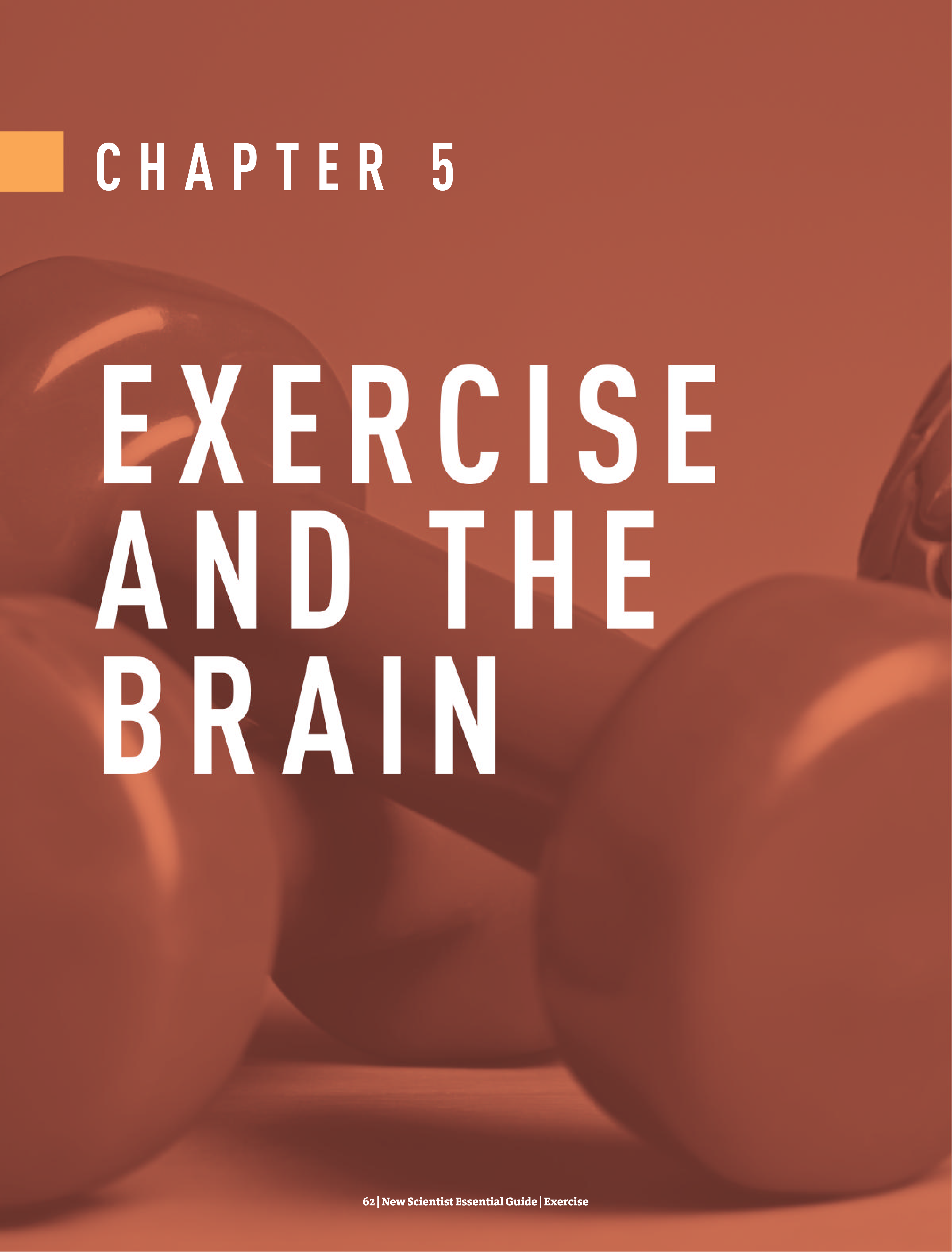
In addition, long-term research has found that metabolic flexibility is a predictor of how much body fat and weight gain a person will go on to have five years later.

The takeaway from all this is that metabolic flexibility is to be taken seriously. Luckily, we can improve it, with exercise being one option. Bergouignan's bed-rest studies may have been extreme, but her team has discovered that the same things happen when people simply take fewer steps.

The key is to exercise regularly. In further reseach, Bergouignan's team found that just three days of physical inactivity can make you metabolically inflexible.

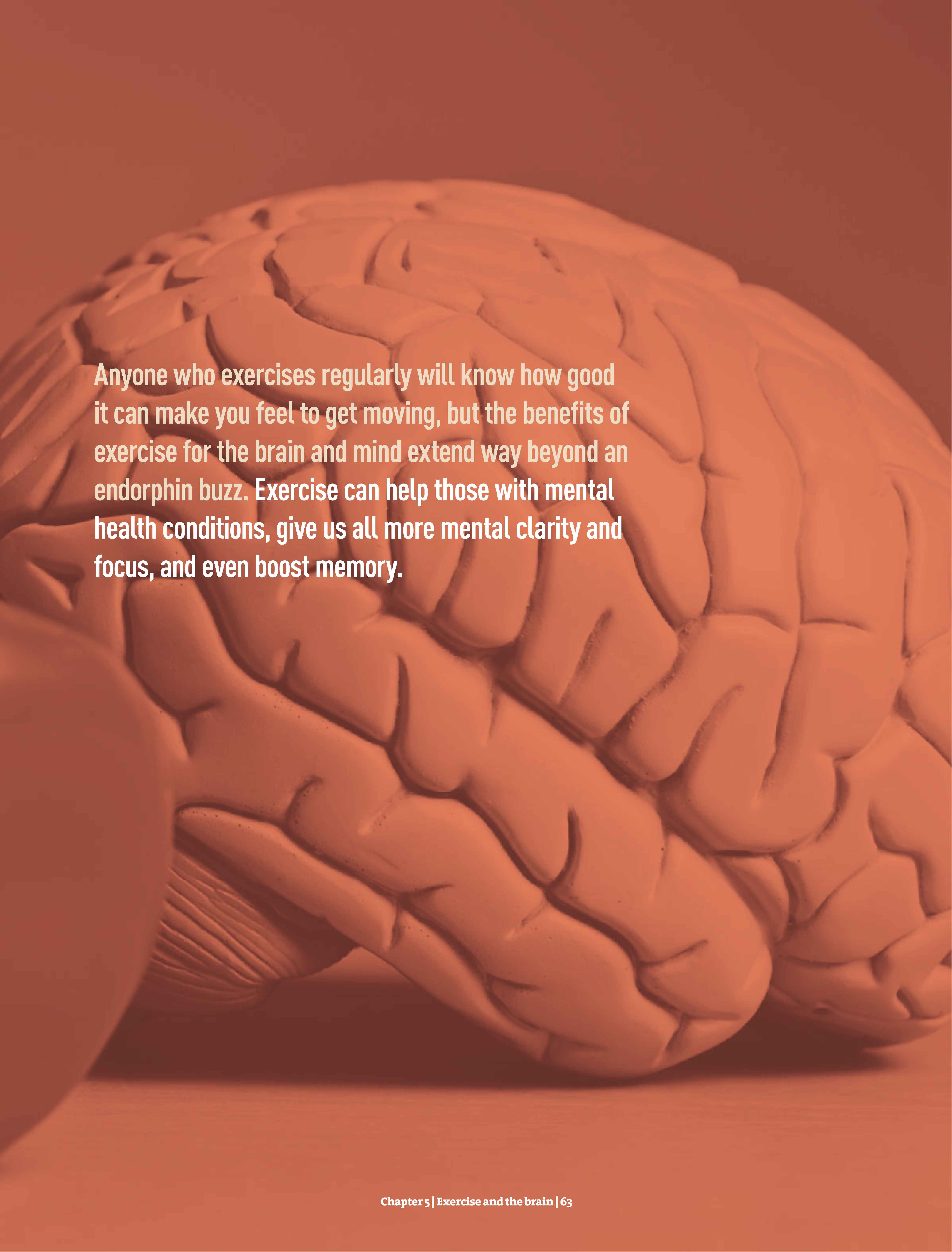
Responsible fasting is another way to improve metabolic flexibility. Your body doesn't need large amounts of energy at night, so the advice is to stop eating a couple of hours before you go to bed.

As we start to understand individual variability in our metabolism, it is likely that we will see many more devices come on the market. How they will ultimately affect our lives and health remains to be seen, but if the latest discoveries in metabolic flexibility are anything to go by, we have yet another reason to keep active. ∎



CHAPTER 5

EXERCISE AND THE BRAIN



Anyone who exercises regularly will know how good it can make you feel to get moving, but the benefits of exercise for the brain and mind extend way beyond an endorphin buzz. Exercise can help those with mental health conditions, give us all more mental clarity and focus, and even boost memory.

EXERCISE TO KEEP THE BRAIN YOUNG

If there was a silver bullet to keep our brains young, it would be exercise – it slows down age-related changes and even reverses them.

RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: RAPIDEYE/ISTOCK

THERE are five places around the world that have become renowned for the fact that their inhabitants tend to live the longest, healthiest lives of anywhere on the planet. In all of these places, which have the highest concentrations of centenarians, physical activity is a way of life. And in Ikaria in Greece, Loma Linda in California, Nicoya in Costa Rica, Okinawa in Japan and Sardinia in Italy, dementia and cognitive decline are 75 per cent less frequent than throughout most of the Western world. Decades of research concludes with overwhelming evidence that aerobic exercise has beneficial effects on the brain, including improved mood and thinking skills. Exercise reduces inflammation, which can inhibit the growth of new brain cells. If that weren't enough, exercise actually increases neurogenesis, or the growth of new brain cells, via the release of a critical protein called brain-derived neurotrophic factor (BDNF).

Whatever it is that you want from your mind – more creativity, improved resilience or higher self-esteem – the evidence shows that there is a way of moving the body that can help.

HOW THE WAY YOU MOVE CAN CHANGE THE WAY YOU THINK AND FEEL

Sometimes referred to as brain fertiliser, BDNF spurs the creation of neurons in the hippocampus, a part of the brain that helps consolidate memories, and new connections between them. Exercise also boosts the number of mitochondria, the energy factories of cells, inside the brain. Together, these changes seem to bolster the brain against dementia and Alzheimer's disease. It isn't clear exactly how exercise translates into a brain boost, although one idea is that it is down to increased blood flow to the area.

To raise your BDNF levels, you need at least 30 minutes of daily exercise, things like brisk walking or cycling. If you really want to max out your BDNF, you must push that up to vigorous exercise, things like jogging or high-intensity workouts.

←
Turn back to chapter 1 for more on how much exercise is ideal

However, the sobering news is that even if we exercise daily, prolonged sedentary behaviour may wipe out the benefits. As many as 13 per cent of Alzheimer's disease cases globally are the result of inactivity. So the advice if you want to keep your brain young is simple: avoid sitting or adopt a more active sitting position and stand wherever and whenever possible. At the very least, get up out of your chair for 10 minutes in every hour. ∎

→
For more on sitting, turn to chapter 6


MASTER1305/ISTOCK

A standing desk would have been fine

FILTER-FEEDERS aside, humans are the only creatures that can get away with sitting around all day. But there is a huge cost to our sedentary ways, not only to our bodies, but also our minds. Falling IQs and the rise in mental health conditions have both been linked to our lack of physical movement.

And the connection between movement and the brain doesn't stop there. A revolutionary new understanding of the mind-body connection is revealing how our thoughts and emotions don't just happen inside our heads, and that the way we move has a profound influence on how our minds operate. This opens up the possibility of using our bodies as tools to change the way we think and feel.

Evidence is starting to stack up that this is indeed the case, and it isn't all about doing more exercise.

GET ON YOUR FEET

It isn't exactly news that walking and running help to clear the mind, but research into the reasons why these activities affect our heads suggests that different speeds provide different mental benefits.

Running or walking at a pace that feels easy to you allows the mind to wander by temporarily reducing activity in the prefrontal regions of the brain. These areas favour rational, straight-line thinking, and studies suggest that reducing their activity allows broader, more creative ideas to flow.

The effects spill over for at least 15 minutes after you have finished walking, according to researchers at Stanford University, California, who speculated that a walk before an ideas meeting could pay dividends. But there is a catch: walkers performed slightly worse in tests of straightforward, linear problem-solving compared with those who remained seated.

Intriguingly, even the gentle pressure of footfall on a slow walk has a big impact on blood flow to the brain. Studies by Dick Greene at New Mexico Highlands University in Las Vegas and his colleagues suggest that when our feet hit the ground, their arteries are compressed. This increases turbulence in the blood, providing it with an extra rush towards the brain of up to 15 per cent.

Pick up the speed to a marching pace and things get even more interesting. In Greene's experiments, the biggest boost to blood flow happened when people's step rate and heart rate synchronised at 120 steps and 120 beats per minute, hinting at a possible sweet spot. What exactly this extra blood does when it gets to the brain is unclear, but we do know that exercise in general increases grey matter in the hippocampus, which is crucial for memory processing and spatial awareness.

All this makes sense if you consider that walking a lot, running a little and using our big brains to hunt and gather are what humans are built for. Anthropologist David Raichlen at the University of Southern California has said that we evolved to be "cognitively-engaged endurance athletes", so it shouldn't be surprising › that our bodies are set up in a way that means moving and thinking are intertwined.

As for why running clears the mind, you can think about relaxation in terms of the sympathetic and parasympathetic nervous systems. Both are involved in unconscious actions, but the sympathetic nervous system ramps up the fight-or-flight response, generating damaging particles called free radicals. The parasympathetic system kicks in when you relax, giving your body a chance to recover.

When you're jogging, you don't usually feel in danger, which means you tap out of the sympathetic system. If you run outside, that connection to nature has also been found to be especially restorative. Topped off with the release of endorphins, feel-good chemicals produced during exercise, it's no wonder that running feels so good.

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Turn back to chapter 1 for more on how we evolved to move

GET STRONG

If you are a millennial, you might want to avoid picking a fight with your dad. Today's men appear to be markedly weaker than their counterparts in the 1980s, according to a 2016 study in the US that measured maximum grip strength, which is a proxy for overall muscle strength. The next generation, it seems, are weaker still. A 2019 study found that 10-year-olds in England were 20 per cent weaker and had 30 per cent less muscle endurance in 2014 than children of the same age measured in 1998.

Sedentary lifestyles are almost certainly to blame, and it matters for our physical and mental health alike. People who are stronger in middle age have more grey matter and better memory a decade later. One explanation for this could be a hormone called osteocalcin, which is released from bones when we move against gravity in any form of weight-bearing exercise. In rodent studies, its release has been linked to the size and connectivity of the hippocampus. Studies in humans are ongoing, but there are signs that a lack of osteocalcin could be linked to age-related cognitive decline and neurodegenerative disease.

The benefits of being strong don't stop there. It has been known for many years that physical strength is linked to higher self-esteem and a feeling of being capable in all walks of life.

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For more on the benefits of strength training, see chapter 2

One explanation for why physical strength provides mental resilience is that our sense of self – and, more importantly, our sense of what we can achieve in the world – is built on the foundations of our bodily sensations. Neuroscientist and philosopher Antonio Damasio at the University of Southern California says that as well as keeping tabs on heart rate, blood pressure and blood sugar levels, our body has an unconscious sense of the health and state of our muscles and bones. This "musculoskeletal division" constantly sends messages about the strength and agility of the body's movement apparatus – the muscles, bones, tendons and ligaments that allow us to move. This then feeds into our implicit sense of what we can handle.

If that is the case, the decreasing levels of strength in modern society are troubling. It is tempting to think that this decline may even play into the epidemic of anxiety and mental health conditions that is affecting people of all ages – perhaps the message from the musculoskeletal divisions of our bodies is giving us nothing to feel confident about?

The good news is that we can update this body-mind conversation at any time. Strength training is emerging as a powerful tool to tackle depression and anxiety, even when it isn't done as part of a wider fitness programme. This doesn't have to involve going to a gym or even buying a set of dumb-bells; you can use your own body weight. Even spending more time sitting on the floor is a good way to strengthen leg and core muscles, because at some point you have to stand up. Strong legs also boost balance and coordination, both of which are suffering in our sedentary lifestyles.

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For more on the best ways to sit and rest, see page 89

DANCE

The power of dance to bring humans together is so strong that some governments and religious groups around the world have tried to ban it at times.

It is a futile strategy. As a species, we are born to dance. Brain-imaging studies of newborns have shown that they notice if rhythmic music unexpectedly skips a beat. By the time they are 5 months old, this ability ties in with movement, too. Research shows that babies are able to move their bodies in time with music at this stage, and that the better they are at bopping along, the more they smile. Even at a tender age, moving to music seems to make us feel good.

According to studies led by neuroscientist Morten Kringlebach at the University of Oxford, the feel-good factor is because our brains work as prediction machines that constantly make guesses about what is likely to happen next. In this view, a regular beat is satisfying because it makes it easy to predict what is coming. Each time we are correct, we get a small hit of dopamine, a neurotransmitter involved in feelings of pleasure.

Following the beat with your body provides a second dopamine hit, and may also create the illusion that our movements are producing the beat in the first place, says music psychologist Edith Van Dyck at Ghent University in Belgium, which makes us feel powerful and in control.

As such, moving to music when we are alone can make us happy. Doing it in a room with others takes things to the next level, adding the pleasure of social bonding into the mix, too.

Experiments with toddlers have shown that they are more likely to help an adult, by picking up a dropped item for instance, after being bounced in time to music, than after they have been bounced out of time with the beat. In adults, studies have shown something similar: moving in synchrony with others makes us more likely to care about them and share with them.

One proposal for how this happens is that we usually base our sense of self on our perception of our bodies' movements. When we synchronise with other people, this "proprioceptive" sense gets blended with information about others' movements coming in through our additional senses in such a way that the boundaries of self and other become temporarily blurred.

The result is a state of closeness and understanding, as well as a desire to help others. Plenty of reasons to dust off your dancing shoes. ›

YOLYA/ISTOCK

BREATHE

It is the smallest of movements, and you don't need to be fit to do it. But controlling the muscles in your chest and diaphragm can make a big difference to the way you think and feel.

Incredibly, when you regulate your breath, what you are really doing is taking charge of your brainwaves and tying them to the rate at which air travels into and out of your nose.

This link comes via sensory neurons at the top of the nose, which fire when air flows past them. Because this air contains information about the outside world, it makes sense that activity in scent-related brain regions begins to synchronise with the breathing rate, allowing information to be processed as it comes in. Recent studies, however, have shown that this synchronisation doesn't stop there. It spreads to areas involved in assigning meaning to the information, such as memory, and those involved in planning and decision-making.

Coordinated, rhythmic activity across different regions allows the brain to share information more easily. Some researchers believe that the brain's ability to synchronise with breath may be a fundamental feature of the way it processes information.

The easiest way to put this into practice is to close your mouth and breathe at the rate of six breaths per minute: inhaling for 5 seconds, then exhaling for 5 seconds. Breathing at this pace has been shown to be the most efficient way to fill the air sacs of the lungs, where oxygen diffuses into the blood. This can raise oxygen saturation by a couple of per cent, enough to make a small difference to brain function.

Inhaling and exhaling six times per minute has also been shown to stimulate the vagus nerve, part of the parasympathetic nervous system, which resets the body to a state of calm after stress. Intriguingly, studies of religious chanting and prayer have found that they tend to slow breathing to six breaths per minute – which may explain why people find these practices calming.

At three breaths per minute, something else happens entirely. A 2018 study led by Angelo Gemignani and Andrea Piarulli of the University of Pisa, Italy, in which volunteers had air wafted up their noses to simulate breathing at a rate of three inhalations per minute found that brainwaves synchronised in the low-frequency delta and theta bands, particularly in brain regions involved in emotional processing. Theta waves are associated with deep relaxation and a state of "being" rather than "thinking", a condition that was experienced by many of the study volunteers. So it seems that slow breathing is a free ticket to an altered state of consciousness, no added chemicals necessary.

STRAIGHTEN UP

If you practice yoga or pilates as a way to help improve your alignment and posture, you might be on to something. A slouched posture has long been linked to negative thinking and feelings of defeat, according to psychological research, while an upright, expanded posture brings a more positive mental attitude. Experiments also show that holding the body upright during a stressful event helps people experience less stress and recover faster.

The problem is that, until recently, there wasn't a

Simply breathing differently can reset your brainwaves

convincing mechanism to link the physical act of holding your body upright with a positive and confident state of mind.

Intriguing new research hints at an answer. Peter Strick at the University of Pittsburgh in Pennsylvania stumbled on a potential explanation while tracing neural pathways that connect the brain and the adrenal glands, which are located at the top of the kidneys and are responsible for the adrenaline rush caused by acute stress. Strick and his team found that the inner part of these glands, called the adrenal medulla, is linked to regions of the brain's motor cortex, which controls voluntary movements. In turn, this neural pathway connects to the muscles of the core that stabilise the torso and support posture.

While it is too soon to be certain what information is being relayed along these routes, Strick thinks that the link could explain the stress-relieving effects of core-based exercise, such as Pilates, yoga and tai chi. Then again, all movement involves bracing the core to some extent. So however you choose to move, this pathway almost certainly comes into play at some point.

STRETCH

Stretching out stiff muscles feels good, but there seem to be some surprising additional benefits of loosening tight muscles. Emerging research suggests that stretching leads to changes in the fascia, sheets of connective tissue that wrap our muscles and allow them to slide over each other when we move.

Research by Helene Langevin, then at Harvard Medical School, found that stretching rat tissue causes cells within the fascia to release adenosine triphosphate. This molecule manages levels of inflammation, which is the immune system response that ramps up in times of stress or when we have an injury or infection. In a 2016 study, Langevin and her team injected carrageenan, a substance that causes local inflammation, into rats' back muscles. Two days later, half of the rats were encouraged to stretch, while the other half weren't. The rats that stretched not only had significantly lower levels of inflammation, but also higher levels of molecules that help resolve inflammation at the cellular level.

Other studies have found that the fascia are structured like a fluid-soaked sponge that drains into the lymphatic system. This could mean that stretching helps move the body's fluids along, allowing the immune system to give these liquids a regular clean-out and deal with inflammation as it arises.

This matters for the mind because uncontrolled inflammation is linked to depression, chronic pain and fatigue. It is also exacerbated by modern lifestyles and obesity, and accelerates as we age.

Human studies into stretching and inflammation are still ongoing, but if it is confirmed that stretching and squeezing the fascia turns off inflammation after the threat has passed, it could help explain why people who do yoga and tai chi have lower levels of inflammatory markers in their blood. This could provide yet another reason to take regular breaks to stretch. ∎

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Chapter 2 has more on the surprising effects of stretching

LOSING OUR BALANCE

It seems our ability to balance – one of humanity's hardest-won evolutionary skills – is beginning to fade away thanks to modern lifestyles. Around the world, falls that lead to serious injury or death are on the rise, even in the young. The good news is, it's never too late to regain your poise.

GLOBALLY, falls are the second biggest cause of accidental death after traffic accidents. Between 1990 and 2017, the total number of deadly falls around the world nearly doubled. Risk of losing your balance increases with age, so you might think this simply reflects the huge number of baby boomers entering their twilight years. But recent estimates suggest the incidence of falls is rising at a rate that outstrips what would be expected from a growing, ageing population.

Instead, scientists are now taking a closer look at the complex brain-body interactions that underpin our ability to balance, and the ways that it is tied to both cognitive and emotional processing. This system is remarkably complicated, but it turns out that the problems undermining it are relatively simple to pin down.

It all starts with our ability to walk upright. We may take it for granted, but bipedalism is far from easy – particularly the way people do it, with our torsos balanced precariously over our legs. In fact, this is such a precarious way of getting from A to B that we are the only species on the planet that uses it as our primary mode of transport.

The human body, when standing upright, is inherently unstable. Our bodies are top-heavy, with a tiny base of support relative to our height. Worse, our centre of gravity sits way up at pelvis height and slightly forward of our ankles. Even without a heavy head and chest swaying around, standing up would be risky.

When in good health, we manage it by using a vast brain-body network which integrates information from our muscles, eyes and the vestibular system of the inner ear. It then engages muscles of the legs and core to make necessary adjustments to posture. While the core muscles often get the credit for keeping balance, it is the leg muscles that do most of the work.

Integrating constantly changing information coming from the muscles, joints, senses and the environment is a massive computational challenge, and neuroscientists don't fully understand how the brain accomplishes it. They have identified a few key players, however. Perhaps the most important is the cerebellum, the small, bulbous region at the bottom of the brain that contains more neurons than all other brain areas combined. Evolutionary studies have shown that it rapidly increased in size as our ancestors began walking on two feet.

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For more on bipedalism, turn back to chapter 1

It is thought that our ability to rapidly react to different situations is thanks to the brain making predictions based on previous experience. Some neuroscientists have suggested that these predictions happen in the cerebellum. The area is linked with other brain regions including the motor cortex, which directs movement, in closed loops that shoot information back and forth. The cerebellum acts as a kind of super-fast processing outpost that supports all other operations.

We have long known that the cerebellum plays a part in movement control. More recently, research has shown it has a role in fine-tuning our thoughts and emotions too. This could explain why some mental health conditions also commonly feature poor balance.

Anxiety, depression, schizophrenia and other mental health conditions have been shown to affect balance in a way that influences both standing posture and gait.

Ron Feldman at Tel Aviv University in Israel says there are many potential reasons why. People with depression tend to have a more stooped posture with significantly slower movements. This increases the risk that, if they stumble, any righting movements will happen too slowly. For people with schizophrenia, symptoms of mental distress are often accompanied by a swaying posture, which has been linked to problems with integrating visual information with other components of balance. For those with anxiety, fear of falling can, paradoxically, affect posture in such a way as to make a fall more likely.

Yet this new understanding hasn't translated into new methods of diagnosis or treatment so far. "The physical elements are usually not addressed in mental disorders," says Feldman. That may be a missed opportunity, he says, because the relationship between balance and mental health might go both ways; work to improve your balance could benefit your mental health too.

The newly discovered connection between the cerebellum and our thoughts could also explain studies in which people who are asked to do a cognitively demanding task don't balance as well at the same time, and those trying to balance do worse in cognitive tasks. It turns out that it might be quite apt when people invoke the language of balance when describing feelings, such as feeling emotionally "stable" or "having a wobble".

Walking seems effortless to most people, but a lot goes unnoticed. When researchers at Ohio State University attached reflective markers to the hips, ankles and feet of volunteers and used an infrared › camera to track their movements while they walked on a treadmill, they found that, even on a stable surface, walking is basically a refined version of a drunken stagger or a stumble after an unexpected nudge.

It turns out that every step, even on the smoothest surface, is a process of re-righting ourselves as our upper bodies lurch from side to side. Usually, we don't look as if we are staggering thanks to the way that the cerebellum, senses and muscles work together to make micro-corrections mid-stride. These studies revealed that this is largely because the brain keeps tabs on the position of the pelvis and adjusts the leg position accordingly. According to Manoj Srinivasan at Ohio State University's Movement Lab, who co-authored the research, we step not towards where we want to go, but "in the direction of where we are falling".

Because the body's balance-control system is made up of so many interconnected parts, it can be challenged in many different ways. Uneven ground, a problem with the vestibular system, weaker muscles or greater speed can make it more difficult to keep upright and can turn a wobble into a fall. Pregnancy, illness and injuries – particularly to the legs – are among the things that can affect the inputs into the system enough to make a fall more likely. Inflammation, which is linked to obesity, stress, injury and infection, has also been shown to change balance enough to affect the way we walk, potentially increasing the risk of falls.

When people's balance is tested by asking them to stand on one leg with eyes open or closed, it reveals that the ability to maintain our equilibrium begins to decline as early as our 20s or 30s. By midlife, there is an increase in the likelihood of serious falls. That seems to be getting worse. One analysis has found that fatal falls for people in the US aged between 45 and 64 jumped by 44 per cent between 1999 and 2007. This increase has researchers scrambling to figure out which aspects of this complex system are getting out of sync.

The first problem, says Dawn Skelton at Glasgow Caledonian University, UK, is that children aren't moving enough. Our stability is built up by trial and error as we learn to walk, gradually refining a toddle into effortless striding and running. The more this system is challenged in childhood and early adulthood, the more reserve we have to draw on in later life. Too much sitting, cuts in school sport provision and shorter break times mean that young adults are hitting their 20s with a wobblier stance than they should, says Skelton. From there it is all downhill. These same factors mean the muscles we need for balance are weaker than they should be.

Through midlife, sedentary lifestyles become even more common, leading to a drop in strength that can make falls more likely. The trend towards sitting for longer probably accounts for some of the rise in falls in younger adults too. A general lack of fitness hammers in the final nail: when we do less physical activity, the balance system is left unchallenged, getting less effective by the day.

All of this adds up to a perfect storm of falling younger. "I commonly see people in their mid-40s that have worse balance than 70 or 80-year-olds," says Skelton. Research on falls used to focus on people aged 65 and up; studies now report on falls in 50-year-olds. ›

WILLIAM87/ISTOCK

HOW TO IMPROVE YOUR BALANCE

Want to boost your balance? First, test it out. If you can't stand on one leg with your eyes closed for at least 30 seconds, Dawn Skelton at Glasgow Caledonian University, UK, suggests you should start balance training as a priority.

Standing on one leg is a good measure of balance skills because it taxes the balance system as a whole. The eyes-closed version of the test is particularly revealing because it takes vision out of the equation, showing how your muscles and the vestibular system of your inner ear alone cope with the challenge of staying upright.

Skelton suggests practising rocking forward and back between the heels and toes and also foot strengthening exercises, such as picking up a marble or pen between your toes. Going barefoot indoors and wearing minimal shoes can also help keep the feet fit and strong, she says.

Skelton doesn't rate pilates or slow-moving kinds of yoga as ways to improve balance. They are great for core strength and can also build up leg muscles in a way that improves standing balance, she says. But because they mostly involve assuming still postures fairly slowly, they don't tax the body's ability to combine sensory information from the eyes with internal sensations coming from the vestibular system of the inner ear. "Eyes open, head moving: that's what trains your vestibular system," says Skelton.

This means that gym bunnies who train inside on static bikes and treadmills aren't doing their balance skills any favours. In contrast, road cycling and mountain biking involve balancing while looking around for cars or trees. Similarly, running outside involves dodging pedestrians and negotiating uneven ground. Running while staring at a screen at the gym, less so. The need to resist gravity also has to be a factor in any balance-training exercise. That is why swimming isn't especially good for balance, despite the fact that you need to turn your head.

If you want to start simple and be sure that what you are doing will benefit your balance and reduce your risk of falls, the UK's National Health Service recommends practising walking sideways, crossing your feet as you do so, or standing on one leg with or without your eyes shut. Hold onto a wall for support until you are sure you won't fall. For the more acrobatic, practising standing and moving on a wobbleboard, doing slalom walks on stable and uneven surfaces and balancing on beams or logs can take things to another level.

Age-related declines in brain function really start to show at about the age of 50, and the cerebellum is one of the first regions to go, particularly in women. We don't know exactly how or why this happens, but we do know that oestrogen has a protective effect on the brain and declining levels of the hormone during the menopause might be part of the answer.

Fortunately, there are steps we can take to slow or even reverse this decline. Balance training, which can be as simple as standing on one leg, sitting on a balance ball or practising walking heel-to-toe along a line on the floor, has been shown to bring improvements in young people, older adults and in those with balance issues resulting from illnesses such as Parkinson's disease.

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See "How to improve your balance" on the previous page, for more tips

As if to underline the "use it or lose it" nature of balance, the more work you do on your balance, the greater the improvement. The dose required for older people is around double that for the under 40s. One study found that, to see a noticeable improvement in their balance, older people needed to do 36 to 40 training sessions of at least 35 minutes, whereas people under the age of 40 needed only 16 to 19 sessions of 15 minutes.

What's more, balance and strength training can help reduce the fear of falling, which encourages further exercise, setting up a virtuous circle of improvement.

There are other reasons to combine the two. A recent study looking at the long term health of a group of women in the US found that balance strength and mobility were the biggest predictors of a long and healthy life, more so than whether the woman had lost weight.

As well as physically training the balance system, there is intriguing evidence that engaging in cognitive challenges might help. This may work by engaging parts of the brain responsible for motor function and other complex tasks that are linked to the cerebellum, and by reducing the cost of thinking while walking.

The cerebellum operates on the same use-it-or-lose-it basis as the rest of the brain, so the most important thing is to give it something to do. In one study, people who did 100 days of cognitive training over a six-month period had less shrinkage of the cerebellum than those who didn't.

If physical and cognitive training are good in isolation, doing both at the same time is even better. Tai chi, which involves focused attention and a series of fluid physical movements, has been shown to not only improve balance, but also boost cognitive skills and reduce the fear of falling, the number one risk factor for falls.

The good news, says Skelton, is that there is no need to enrol in any specific balance-related programme. "If you want to stop the rot, you don't have to go and do a structured exercise programme," she says. "Just any activity that challenges you to stay upright." Whatever your age and ability, the time to start is now. ▮

IS COLD-WATER SWIMMING REALLY WORTH IT?

Social media is awash with people claiming that regular cold dips have transformed their health and well-being. Is it worth taking the plunge?

THE idea that cold water can shock the body back to health isn't new. In Victorian Britain, the great and the good flocked to the spa town of Malvern to take the "water cure", a treatment that involved being wrapped in cold, wet sheets and taking regular cold showers and baths. Nursing pioneer Florence Nightingale credited it with restoring her health after the Crimean war. Charles Darwin believed it cured him of fatigue and stomach pains. "I feel certain that the Water Cure is no quackery," he wrote at the time.

That fashion has made a comeback. Once the preserve of a handful of seriously tough year-round swimmers, an estimated 7.5 million people now swim outdoors in the UK alone, with an increasing number swimming through the winter. Global figures are hard to come by, but the International Winter Swimming Association has seen a boom in registered winter swimmers around the world, even in China, Russia and Finland, where water temperatures can drop below 0°C. Is it worth the chill?

Much of the research so far has focused on the fact that plunging a warm body into cold water brings about some very predictable physiological changes, some of which may affect health.

The first thing to happen is a "cold shock" response stimulated by cold receptors on the skin. Studies by Mike Tipton at the University of Portsmouth, UK, who researches the effects of extreme environments on the body, suggest that this response is strongest in waters with a temperature of around 10 to 15°C. Below 8°C, the cold also triggers the skin's pain receptors.

The aim of the response is to signal imminent danger. During cold shock, concentrations of the hormone noradrenaline, which prepares the body for action, shoot up to more than five times resting levels, while levels of dopamine, a neurotransmitter involved in reward processing as well as adapting to shock, are more than doubled. It is no wonder that swimmers feel invigorated after a chilly dip. "It's like an amphetamine rush," says Tipton.

On the downside, cold shock also causes a strong involuntary gasp, which is almost impossible to suppress, followed by hyperventilation. "This is the body's way of trying to get more oxygen into the system to deal with the emergency it senses," says Tipton. If this happens when your mouth is submerged, however, there is a high chance of inhaling a lungful ›

JAX10289/ISTOCK

Cold water swimming is like a "vaccine for stress"

of water, which could lead to drowning.

Heart attacks are another risk at this stage, even for people without existing heart conditions. While the cold-shock response revs up the nervous system, cold water on the face simultaneously triggers a "diving response" via the trigeminal nerve in the cheek, which slows down the heart rate and breathing. When the body tries to increase and decrease heart rate at the same time, the heartbeat can become dangerously irregular. Even if this isn't fatal on its own, it can incapacitate a swimmer for long enough to cause drowning.

Survive the initial shock, however, and there is evidence that the benefits of cold-water swimming come down to that familiar idea: what doesn't kill you makes you stronger.

We know that chronic stress harms the body, not least by increasing levels of inflammation, which is linked to long-term health problems including heart disease, cancer and depression. Acute stress, though, seems to do the opposite, allowing the body to habituate and become resilient to future stressors. This is a concept known as hormesis, and there is some evidence that building resilience to one kind of stress can help people adapt to another. In one study, volunteers who were immersed in cold water for 5 minutes showed an improved ability to exercise at low oxygen levels afterwards. "When we train our body to respond to an acute stressor, we are building fitness of our stress-response systems, much like we would build a muscle," says Elissa Epel at the University of California, San Francisco. "I believe that cold water is a beautiful way to build stress inoculation."

The full picture of exactly how this kind of "toughening" response might work is still being established. Some research has looked at the methods of Dutch cold-water evangelist Wim Hof, also known as the iceman, who advocates a mixture of ice baths, meditation and breath control to build resilience and holds a number of world records for tolerating extreme cold.

In 2014, researchers at Radboud University in the Netherlands investigated one of Hof's bolder statements: that his regime can be used to control the immune system. They put his claim to the test, injecting him with a bacterial toxin that causes an immune response to see how his body would respond.

Blood tests revealed that Hof's adrenaline levels were unusually high at baseline, peaked during the breathing exercises he uses to prepare for cold exposure and which he also did before the injection. This was followed by an unusually low immune response to the toxin. A further study, using 12 healthy volunteers, yielded similar results, backing up Hof's claim that anyone could do the same.

The researchers concluded that the unusual immune response was linked to the fight-or-flight response. This, in turn, correlated with lower levels of pro-inflammatory markers.

In 2019, Matthijs Kox, who led the research, and his colleagues reported that Hof's intervention was safe for use in young people with rheumatoid arthritis. After eight weeks, people who followed Hof's regime "showed fewer symptoms and had lower inflammatory markers and a higher quality of life", says Kox.

Inflammation may also be relevant to the many

"One day, the brain benefits of cold shock might be available in pill form"

anecdotal reports that cold-water swimming helps to alleviate depression. A 2018 case report in the *BMJ* found that, for one woman, a programme of weekly cold-water swims resulted in an immediate lifting of mood. She was also able to stop taking medication for the depression and anxiety she had been experiencing for many years.

In a follow-up study, the team enrolled 59 people with anxiety and depression into an eight-week sea-swimming course. Not only did they see an improvement in their symptoms during the course, but more than 80 per cent were still engaging in the activity and finding benefit from it three months later.

Cold-water swimmers will also welcome the news that exposure to cold water affects the brain in ways that may guard against dementia.

It has long been known that cooling can protect the brain – it is used medically after head injuries and during cardiac surgery – but it wasn't known why. An answer came from studying hibernation. When mammals hibernate, they cool down, their metabolism slows and the synapses that connect their brain cells are dismantled to save energy. In spring, when the animals awaken, their synapses are reassembled at a furious pace. This process is controlled by a cold-shock protein called RBM3, which is produced in the brain and other key organs in response to a drop in body temperature.

A loss of synapses is a key feature of dementia, so Giovanna Mallucci, who heads the UK Dementia Research Institute's centre at the University of Cambridge, and her team wanted to see what effect cooling had on both RBM3 levels and synapses in mice with dementia-like symptoms. The results were striking: cooling the mice, and hence boosting the levels of RBM3 in their brains protected them from neurodegeneration.

Due to the ethical difficulties of inducing hypothermia in healthy people, Mallucci wasn't hopeful about repeating the study in humans. But after discussing her research in the media, she was contacted by Martin Pate, who swims at London's Parliament Hill Lido throughout the winter. Together, they devised a study to test RBM3 levels in a group of 44 winter swimmers compared with a control group who practised tai chi at the poolside, while the swimmers were in the water.

The study found that the longer and more frequently that people swam in the water, which was between 4 and 14°C, the higher their RBM3 levels. The cold-shock protein wasn't found in the tai chi group. "It is a very strong trend," says Mallucci.

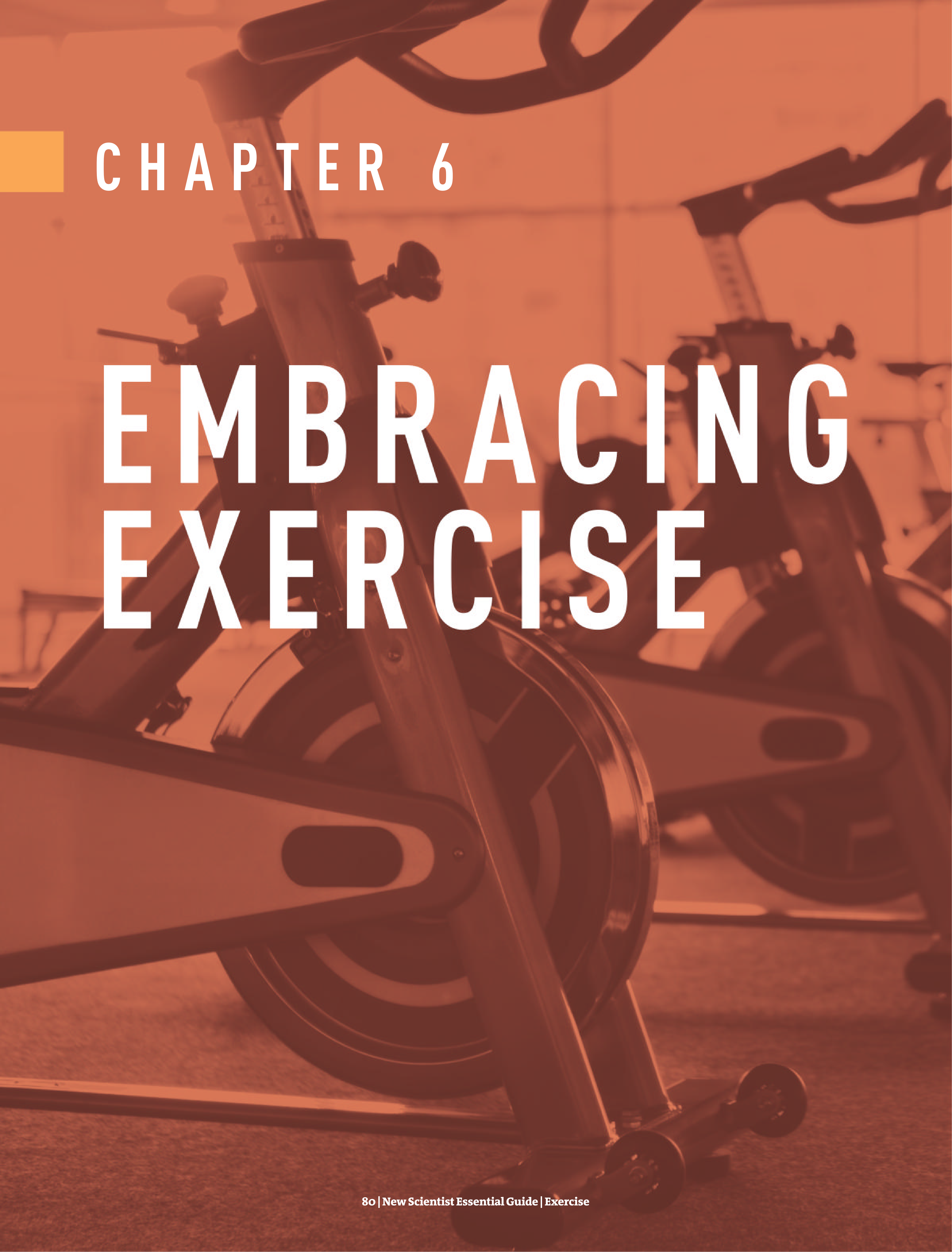
Mallucci didn't scan the swimmers' brains to measure their connectivity, but based on animal experiments, she speculates that increased RBM3 levels may have a measurable impact on their brains.

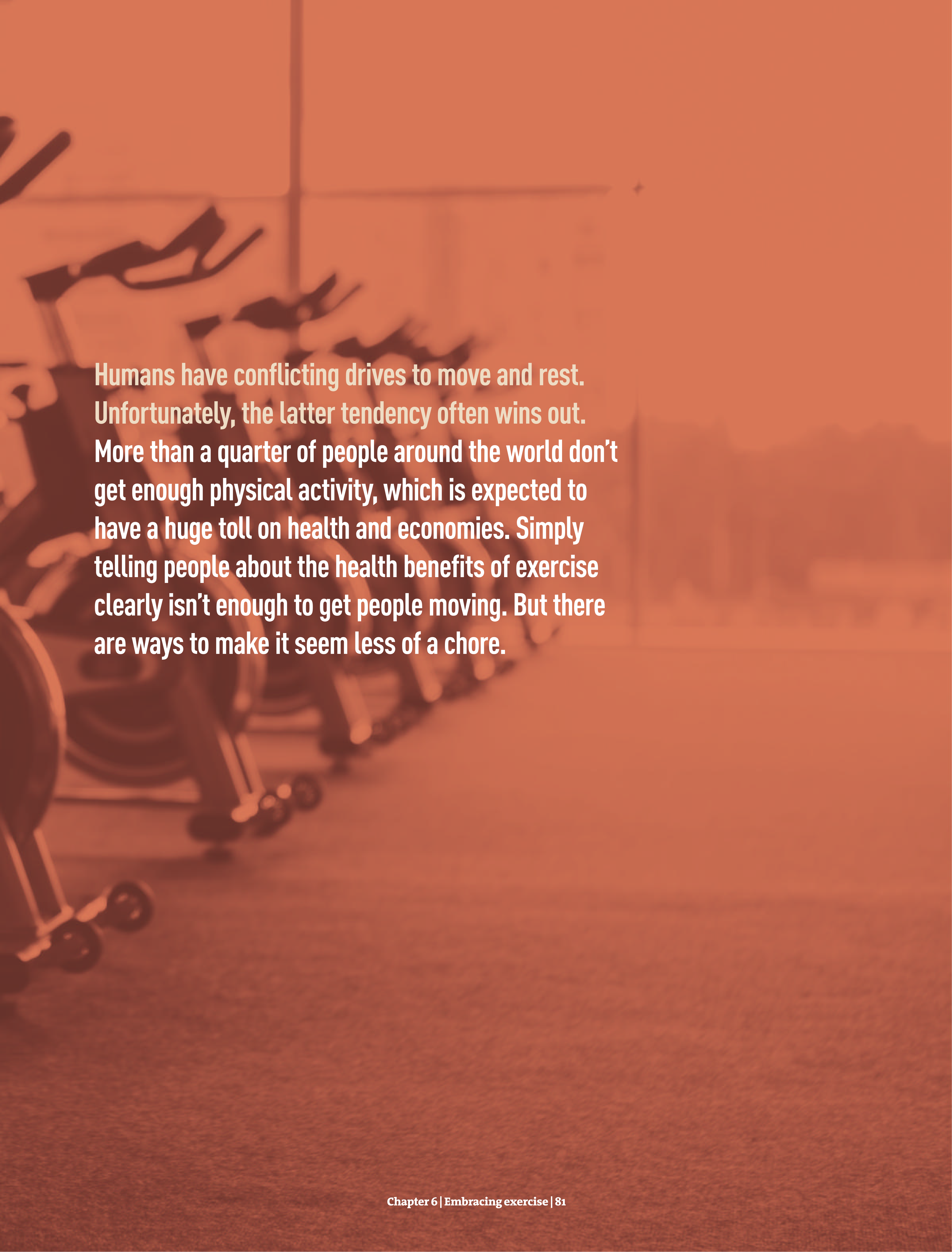
Mallucci is now researching whether levels of this protein could be boosted by drugs rather than freezing temperatures. If so, it might one day be possible that the brain benefits of cold shock will be available in pill form, offering a new way to treat neurodegeneration.

This would be good news, not only for people with an understandable aversion to the cold but also because it avoids the dangers of cold-water immersion, both from the initial shock and the longer-term effects of hypothermia. ∎

CHAPTER 6

EMBRACING EXERCISE





Humans have conflicting drives to move and rest. Unfortunately, the latter tendency often wins out. More than a quarter of people around the world don't get enough physical activity, which is expected to have a huge toll on health and economies. Simply telling people about the health benefits of exercise clearly isn't enough to get people moving. But there are ways to make it seem less of a chore.

MOTIVATIONAL MIND HACKS

Humans seem to have an ingrained propensity for laziness, but the science of motivation can offer tips to overcome it.

NUMEROUS studies have demonstrated that exercise can improve our cognitive functions and enhance the production of brain chemicals that help us feel motivated. The problem is that exercise and motivation can have a cyclical relationship: you have to be motivated to get moving in the first place.

In 2018, Matthieu Boisgontier, a neuroscientist at the University of Ottawa in Canada, looked into a paradox involving exercise – even though the vast majority of us intend to be physically active, many don't do any exercise at all. Boisgontier and his colleagues found that the brain has to exert more effort to avoid sedentary behaviours than it does to just go along with them. This led him to conclude that humans have an "automatic attraction to effort minimization".

Boisgontier argues that our brains evolved this way because the energy savings gave us a survival advantage. But fortunately, the science of motivation itself offers us ways to overcome this evolutionary propensity to laziness. ›

RIGHT: RACHEL TUNSTALL
PREVIOUS PAGE: PROSTOCK-STUDIO/ISTOCK

GET ORGANISED

It might seem obvious, but it's easy to overlook the power of planning. Organising our time in a way that forces us to be active – by planning your journey to work so it involves a walk, for example – we can overcome our automatic attraction to physical laziness. Once we exercise consistently and develop a habit, we enter a "virtuous cycle" in which it takes fewer cognitive resources to motivate ourselves to work out.

THINK REALISTICALLY

Having positive thoughts and mental images about a desirable future makes us feel better in the moment. But in the long-term, positive thinking saps motivation, according to Gabriele Oettingen, a psychologist at New York University. Oettingen has found that people who engage in positive fantasies work less hard and perform less well than people with more questioning, realistic thoughts. The trick, she suggests, is to combine the two: think of a desired future as likely, but visualise the obstacles involved in reaching it, too.

REWARD YOURSELF

It is quite simple: "Any action that is rewarded is more likely to be repeated," says Tali Sharot, a neuroscientist at University College London. If you are the sort of person who doesn't feel an intrinsic buzz after exercise, for instance, you could find a way to reward or bribe yourself. Multiple studies suggest that financial incentives boosted the willingness of a previously sedentary individual to exercise.

A large trial of multiple incentive programmes for gym goers found that few had any lasting effects, but payments equivalent to just a few cents were the most effective nudge for people to keep active. Katherine Milkman at the University of Pennsylvania and her colleagues looked at more than 60,000 members of a US gym chain called 24 Hour Fitness.

The team tested 54 different month-long motivational schemes, such as reminder text messages, getting people to make pledges and rewarding people with audiobooks or small payments in the form of points that could be exchanged for Amazon vouchers.

Nearly half the schemes increased weekly gym visits over the course of the month, by between 9 and 27 per cent. But only four had an effect that continued after the nudges finished.

The most effective intervention involved offering people points that could be redeemed with Amazon; this was equivalent to 22 cents for every workout attended, plus 9 cents if someone returned to the gym after one missed workout. Schemes that paid people for going to the gym without skipping a session proved less effective once the programme had finished.

CONNECT WITH YOUR FUTURE SELF

Altering our sense of how close the future is can enhance motivation, says Daphna Oyserman, a psychologist at the University of Southern California. Her studies show that when high school students are taught to relate to their future selves in both positive and negative scenarios, they work harder and get better grades. One approach might be to imagine yourself months or years from now, in a future where your exercise endeavours have gone according to plan, and write down what it looks like. ∎

EXERCISE PILLS

For some people, exercise feels an insurmountable chore. For others, being physically active isn't an option. But what if a pill could do the heavy lifting instead?

WE HAVE seen what a wonder drug exercise is. And yet despite the numerous and well documented health benefits of exercise, most of us don't move as much as we should. No one has come up with a good remedy for this. Simply telling people to eat more healthily and exercise more doesn't work. We may be designed to move, but evolution has also programmed us to store fat to survive winter and famine. So it isn't entirely your fault if you don't exercise as much as you should. On top of that, plenty of us have physical limits on how active we can be. Putting exercise in actual pill form would allow people who can't exercise to get some of the benefits.

The first step to designing such a medicine is to work out how physical activity elicits its effects. We know that muscles act as control centres, with proteins that trigger a cascade of changes around the body as a result of exertion.

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Turn back to chapter 1 for more on how exercise exerts its effects

A pill that sought to replicate this – an "exercise mimetic", as it is known, would have to be very different from the majority of common medicines. Many of these are based on small molecules that target proteins responsible for a specific job in the body, either helping the protein do its job more quickly or stopping it working. Statins, for example, inhibit a protein that is needed to make cholesterol, and so help lower our blood cholesterol level.

But one drug under investigation in mice seems to work as a master switch that, when flicked, activates a wide-ranging genetic programme. When Ronald Evans, a biologist at the Salk Institute in La Jolla, gave a drug called GW1516 to unfit mice, they turned from couch potatoes to endurance athletes – able to run twice as far on their wheels as mice that hadn't been given the drug. GW1516 targets a protein called PPAR-delta. The effects that follow include shifting the composition of muscles – reducing the amount of "fast twitch" fibres, built for explosive bursts of energy, and increasing the proportion of "slow twitch" ones that favour endurance. It also prompts the body to switch from burning sugar to fat.

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For more on metabolic flexibility see page 59

Flipping this particular switch isn't the only way to create sedentary supermice. In 2012, Bruce Spiegelman at the Dana-Farber Cancer Center in Boston discovered a hormone released by muscles during exercise, which he named irisin. It is a messenger chemical that helps tell various parts of the body to engage exercise mode. In obese mice, boosting irisin levels converted inactive white fat into energy-burning brown fat, and caused the animals to lose weight even on a high-fat diet. In 2018, Spiegelman and his colleagues also pinned down the mechanism by which irisin triggers changes to bones.

Meanwhile, Ali Tavassoli at the University of Southampton, UK, has found a small molecule known as compound 14, which indirectly activates a metabolic sensor called AMPK. To see if compound 14 might be ›

a good treatment for metabolic disorders, he and his colleagues fed mice a high-fat diet so they became obese and developed diabetes-like symptoms, then gave them compound 14.

"The results floored us," says Tavassoli. After just seven daily doses of the drug, the mice lost weight and their diabetes symptoms disappeared. By comparison, people whose diabetes is treated with metformin, which works through a similar pathway to compound 14, tend to gain weight. Compound 14, says Tavassoli, appears to be "profoundly reprogramming" the metabolism of these mice.

So far, these substances have mostly been tested in non-human animals. But the relevant metabolic pathways are similar in people, which makes Evans optimistic that activating PPAR-delta or similar master switches could "reboot physiology" in us too. He says pressing such switches could be all it takes to go from sluggish and overweight to fit and athletic.

Other researchers hate the idea, though, including some of those who have identified promising exercise-related compounds. "To say 'exercise mimetic' as though you can capture exercise in a pill is absurd," says Spiegelman. He has two big objections. The first is that there are many types of exercise that each have different physiological effects. The molecular pathways involved are too diverse and complex, he says, to hit them all with one pill. John Hawley, who studies the physiology of exercise at the Australian Catholic University in Melbourne, agrees. "There will never be a drug that mimics all the effects of exercise," he says. "It is impossible."

Take the mental health benefits of exercise. It is fair to say that biochemical mechanisms play a role here. There is evidence, for example, that exercising the muscles prompts them to clean the blood of a stress marker called kynurenine, which has been linked to depression and mental illness. Even so, Hawley argues that the mood boost from cycling around a beautiful lake or playing with a close-knit team can't be captured in a pill.

←
Turn back to chapter 5 for more on exercise and the brain

Side effects from any kind of exercise pill are also of concern. Studies of GW1516 were eventually abandoned because high doses, given long-term, caused tumours in mice.

A one-stop exercise pill may be too blunt an instrument. When neuroscientist Henriette van Praag at Florida Atlantic University gave mice a compound that activates AMPK through the same pathway as compound 14, she saw that, after a week, muscle and brain had both benefited. But after two weeks, although the muscles of the mice still looked good, the cognitive effects were "horrible".

The animals had increased inflammation in their brains and performed worse in a maze. When you exercise, your body distributes the benefits over time in a way that's tailored to your own physiology, which is a tall order for a pill.

Rather than using drugs as a long-term pass for inactivity, they might give a short-term boost. They could protect people who can't exercise properly for short periods, such as those recovering from surgery or even astronauts living in microgravity. Maybe they could help very obese people get to a weight where they can begin to exercise.

What excites Spiegelman, though, is something else. He envisions a whole new generation of treatments for specific medical conditions from osteoporosis to liver disease. The idea wouldn't be to trigger the entire metabolic programme associated with exercise, but to go for a switch further down the line, where the effects

"Exercise pills might end up giving people a reason not to be active"

are still powerful, but more targeted. You might say that Spiegelman isn't dreaming of one exercise pill but multiple pills, each harnessing different benefits. The term "exercise mimetic" isn't just misleading, he says, but "not ambitious enough".

He sees particular promise for neurodegenerative disorders, including Alzheimer's disease. Aerobic endurance exercise has a big effect on the brain, increasing blood flow and improving the health and connectivity of neurons. It even triggers the birth of new neurons in the hippocampus, a brain area associated with memory. It is virtually the only thing known to do this. Spiegelman has found that a precursor of irisin reaches the brain and influences the expression of genes related to neurogenesis. With Christiane Wrann, now at Massachusetts General Hospital he is investigating irisin's effects on neurogenesis and cognition, and has set up a small company with the aim of moving irisin-based drugs into clinical trials.

Exercise itself doesn't have a dramatic effect on patients with Alzheimer's disease, which might make you wonder what Spiegelman hopes to achieve. But this is precisely the point. "Why should we limit ourselves to the effects of endurance exercise?" he says. He thinks that drugs such as his can go "beyond exercise". Giving the compounds to patients in higher doses than they would naturally appear in the body might have an effect on conditions that are currently seen as untreatable.

Van Praag is now investigating another molecule, cathepsin b, which she has shown in mice, primates and humans to be associated with enhanced memory after exercise. She suggests the research might lead to tailored treatments for people with cognitive issues, for example by monitoring levels of exercise-regulated biomolecules, and where necessary boosting them.

For now, Evans is following the same approach as Spiegelman: that of developing drugs to treat specific conditions. This is because there is no pathway to regulatory approval for a drug that promotes general health. "The only way that you can get a pill approved is to treat a disease," says Evans.

He advises a Boston-based company, Mitobridge, which is developing two drugs to target PPAR-delta, in order to treat acute kidney disease and Duchenne muscular dystrophy (DMD), a muscle-wasting disease that affects boys.

Evans reckons this could act as a bridge to a broader, health-promoting pill for people who are inactive for whatever reason. Once a drug that targets PPAR-delta is approved for one condition, doctors will be free to prescribe it "off-label" for other conditions, at least in the US. That could open the door to using them for prevention of ill health too.

This is similar to the way statins developed. The drugs were initially approved to treat heart disease; now they're prescribed to reduce the risk of developing it. Evans admits that no drug will ever capture the full benefits of every type of exercise, but sees no reason why we shouldn't get a broad sweep of those benefits from pills.

For some, that is a horrifying vision. Van Praag reckons the way to combat inactivity is to redesign society to support exercise, from building more cycle paths to better education about the pros of activity. Hawley fears that even talking about an "exercise pill" is counterproductive, because it might give people an excuse not to be active.

Exercise pills in some form are now inevitable, insists Evans. Once they are approved, we will face a dilemma. Instead of waiting for chronic diseases and wastage to take hold, should we medicate ourselves in advance, to offset the inevitable health damage done by modern life? "I think it's an important debate to have," he says. "Is society ready to have it?" ▮

SHORTCUTS TO STRENGTH

Want to get stronger without all the hard graft? There are some quick fixes.

While there's currently no workout pill that can replace exercise, there are some that could add to your workout. Vitamin D3 supplementation appears to have an effect on muscle strength. In one study, for example, elite ballet dancers received D3 supplements over winter, resulting in a 19 per cent increase in quadriceps strength and fewer injuries compared with dancers who took a placebo. It isn't clear how this vitamin helps, but it is known to affect a complex process of events that control calcium levels, which are involved in the mechanisms that help muscles contract.

Or you might try a little vibration. Machines that vibrate your body while you work out became popular in the early noughties, but there were few studies to back their use. Now, though, evidence suggests that these machines, plus smaller devices that localise vibrations over particular muscles, can help you get stronger. In one study, participants used a device that sent high-frequency vibrations directly over their major arm and leg muscles, three times a week, for four weeks. They saw improvements in strength tests comparable with those of a control group that did resistance training with no vibration. These changes persisted for at least two months, and were probably due to a vibration-induced rise in growth hormone and other biochemicals that boost muscle performance, as well as increased muscle energy consumption.

And here is something for the real couch potatoes. A remarkable study by Brian Clark at Ohio University showed that you can build muscle just by using your imagination. His team used a surgical cast to immobilise the hand and wrist of 29 volunteers for four weeks. For 10 minutes a day, half the group sat still while imagining performing exercises with their immobilised hand. When the casts were removed, both groups had lost muscle strength in their wrists, but the group who had performed imaginary exercises lost 50 per cent less than the control group. The results suggest that mental workouts strengthen pathways in the brain that control muscle movements, which later translates into greater command over the target muscles, increasing their strength. ∎

HOW TO SIT TO GET FIT

There is a growing awareness of just how catastrophic for our health inactivity can be, but the reasons for this have been hard to pin down. That's an evolutionary paradox we are starting to unravel, and the answer could be as simple as changing the way we sit.

PROFILE
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ANOTHER blistering afternoon in northern Tanzania, another high-stakes game of musical chairs. Stumbling back into camp to escape the sun, desperate for a seat, we glanced at each other and then at the single unoccupied camp chair. In the other, grinning, sat Onawasi, a respected elder with a mischievous bent. He seemed to be enjoying this.

We were spending our summer with the Hadza community, one of the last populations of hunter-gatherers on the planet. Hadza men and women manage to avoid heart disease and other diseases of the more industrialised world, and we wanted to understand why. Our small research team had come in two Land Cruisers loaded with tech to measure every movement made and calorie burned as Hadza men and women scoured the landscape every day for wild game, honey, tubers and berries.

After a long morning, we felt drained by the inescapable heat and humidity. All we wanted to do was sit. Onawasi seemed to feel the same way. He had spent the morning hunting, and certainly deserved the chair more than we did. But this was getting out of hand. Our precious camp chairs that we took into the bush despite their weight were Hadza magnets. Every visitor to our little research area seemed drawn to them like moths to a porch light.

We knew we had a lot to learn from the Hadza about staying physically active. It turns out they also had something important to teach us about resting. Together, over the next 10 years, we would come to understand why chairs are so irresistible, and why they seem to make us ill.

Back in 2012, the world was alerted to a new and insidious danger, an invisible pandemic. I-Min Lee, an epidemiologist at Harvard University, analysed mortality data from heart disease, diabetes and cancer and found a common culprit: sitting. In a landmark paper in *The Lancet*, Lee and her colleagues concluded that prolonged periods of inactivity killed more than 5 million people every year globally, making the health risks "similar to… smoking and obesity". In the media, sitting became the new smoking. Even more alarming for those of us who spend our lives in front of a screen, exercise doesn't fully undo the dangers of sitting. Long hours spent in a chair or on the sofa steal years from our lives, even if we hit the gym religiously. Sitting is different, and maybe worse, than just a lack of exercise.

Priests and public health workers have warned us against the sin of sloth for millennia. But the familiarity of the public health advice to get moving obscures a curious evolutionary puzzle. Why is inactivity bad for us even if we exercise? How could evolution produce an organism that responds so poorly to rest? As Charles Darwin articulated so clearly more than 150 years ago, natural selection favours strategies that direct an organism's resources towards survival and reproduction. Any effort that doesn't ultimately pay off in reproductive success is wasted. Natural selection, the amoral accountant, pays attention only to the number of offspring produced. It would seem to follow that our bodies should be well-adapted to rest whenever possible, sparing resources for future use.

Countless other species seem to be on board with this philosophy. In the ocean, some predators will rest for more than a day waiting for prey to float by. Numerous reptiles and amphibians slip into dormancy to wait out periods of tough weather or limited food. Bears, bats and a handful of other mammals spend their winters in hibernation, showing no ill effects when they wake up in the spring. Even our evolutionary cousins, the great apes, spend hours every day sitting and lying about like hungover spring breakers on the beach.

And despite people's assumption that hunter-gatherers are more active than people in more industrialised societies, we also know from our own experiences with the Hadza community and scientific accounts of other populations that they spend lots of time sitting and resting, too. There aren't a lot of standing desks in Hadzaland. In the heat of the day, when they are back at camp after a foray, men and women invariably find a shady place to sit while they tend the fire, prepare food and socialise. But unlike with people in the more industrialised world, sitting doesn't make them sick. What was their secret? How had we managed to screw up something as simple as sitting?

The first clues that sitting for long stretches caused disease in the industrialised world came from a ground-breaking study of London transport workers published in 1953. Epidemiologist Jerry Morris noticed that bus drivers sat for most of the day while conductors stood and climbed the stairs of the iconic double-deckers. Morris and his colleagues followed about 31,000 men in these roles over two years and found that drivers were about 30 per cent more likely than conductors to develop coronary heart disease, and to do so at a younger age and with worse outcomes. Later research comparing postal workers who delivered the mail with their sedentary office mates showed similar results.

Summarising the findings, Morris focused on the importance of physical activity in preventing heart disease, helping to kick off the modern exercise movement. But beginning in the 1990s, researchers started to wonder whether sitting itself could be leading to problems. Indeed, studies began to show that people had an elevated risk of heart disease and of dying at an earlier age when they reported sitting for long periods while, for example, watching television.

This line of thinking was bolstered by data from attempts to mimic the effects of space travel on the

The Hadza people in Tanzania burn as many calories each day as desk workers

body. As the space race heated up in the 1950s, NASA became concerned with how a lack of gravity might affect astronaut health. The agency began a series of bed-rest studies, where volunteers would lie down for long periods, sometimes more than two months. Their bones thinned and muscles weakened, but there were other, unexpected effects, too. Subjects had higher levels of fats called triglycerides in their blood and other risk factors for cardiovascular disease.

As the evidence for the dangers of inactivity grew, a hypothesis began to develop for why it was so harmful. When we stand and walk, we engage the muscles of our legs and core to hold us upright. Chairs and beds allow us to turn those muscles off, sagging like wet dishcloths into the contours of the cushions. Perhaps muscle activity was the key.

Normally, medical researchers like to test their ideas in rodents, but convincing a rat to sit in a chair and watch television didn't seem a viable option. Undaunted, Marc Hamilton at the University of Missouri and his colleagues suspended rats' hind limbs off the floor by tying their tails to a swivel on the roof of the cage. With no need to support the body, the rats' hind limb muscles switched off and stopped burning fuel. This in turn led to reduced levels of an enzyme needed to provide fuel to working muscles: lipoprotein lipase. This enzyme acts like a triglyceride vacuum cleaner, breaking the molecules into fatty acids that can be burned in the muscles, and thus removing them from the bloodstream.

In Hamilton's rats, triglycerides built up in the blood because the muscles didn't need them and didn't produce the lipoprotein lipase to break them apart. The translation to humans seemed obvious: prolonged sitting allows us to switch our muscles off and causes triglycerides to climb.

Studies in humans have provided support for this mechanism. In several controlled trials, people ›

MOYO STUDIO/ISTOCK

forced to sit for long periods developed elevated triglyceride levels. Importantly, if the sitting time is broken up with light activity, even a bit of slow walking, triglyceride levels are greatly reduced. In fact, people asked to reduce sitting by spending more time walking and standing over a four-day period saw a 32 per cent drop in triglyceride levels. Sitting for long, uninterrupted periods also alters the walls of blood vessels in ways that make them stiffer and more prone to coronary heart disease, but breaking up sitting with light activity restores vessel function.

Perhaps societies like the Hadza avoided the dangers of inactivity by resting less each day, or perhaps they broke up their sitting time with more frequent bouts of standing or walking. That idea certainly had intuitive appeal: it was hard to imagine a Hadza man or woman logging as many hours on their butt each day as a typical US citizen. But our experiences with Onawasi and the irresistible attraction of a nice chair hinted at another, deeper explanation. Perhaps chairs, those sirens calling out to us, were the problem.

Material evolution is a curious phenomenon. Innovations tend to build on one another, as simple solutions give way to more sophisticated designs. Nonetheless, simple and elegant ideas often stay undiscovered for millennia. The ancient Britons who built Stonehenge were wise enough to track the sun and clever enough to move 20-tonne boulders, but never imagined the wheel. Chairs are another surprisingly recent invention. They first appear in the archaeological record less than 5000 years ago, well after the emergence of farming, towns and metallurgy. Our Palaeolithic hunter-gatherer ancestors never had them.

Even today, the Hadza don't use chairs. A Hadza man or woman can manufacture an impressive array of things, from powerful bows and arrows to breezy, weatherproof houses, and summon fire on demand. But they don't make furniture. The closest thing you will find in a typical Hadza household are animal skins for sleeping on the ground.

Without chairs or other furniture, how do we rest? Anthropologist Gordon Hewes was interested in this topic, having spent time teaching in Tokyo in the mid-1950s where seiza-style kneeling was often used as a rest posture in formal settings. Hewes amassed a worldwide compendium of nearly 1000 human postures. In societies with little furniture, Hewes found that resting often involved squatting or kneeling on the ground.

These postures are an ancient part of the human repertoire. Deep squatting flexes the foot upward, pressing the talus, a small bone in the ankle, into the end of the shin bone, or tibia. If it is done often enough, these postures leave a mark on the tibia, called a squatting facet. Palaeoanthropologists have found these facets on fossils of human ancestors going back to *Homo erectus*, nearly 2 million years ago.

In the Hadza community, we noticed that people of all ages spent much of their resting time in a deep squat, heels on the ground, bottoms resting on the back of the ankles. If you don't grow up doing it, you have probably lost the flexibility to squat that deeply (go on, give it a try). Even if it is second nature, as it is for the Hadza, the posture would seem to require more muscle activity than lolling about in a chair. Here, then, was a third hypothesis for how the Hadza avoid the perils of inactivity: rather than sitting less or breaking up their sitting into shorter bouts, perhaps the secret was in the way they sit.

Armed with these insights, we headed back to Hadzaland a few years later with an array of small,

Working on the sofa is not recommended

wearable sensors to record muscle activity and body position. We used the sensors to track the resting behaviours of 28 Hadza men and women for a week, calculating both the average number of hours spent inactive each day and the frequency with which they broke up long periods of sitting to stand up or walk around. We also conducted a set of controlled studies to measure muscle activity in various resting postures, including squatting and sitting in a chair.

The results surprised us. Hadza men and women spent nearly 10 hours every day resting, almost identical to the numbers for people in the US, Netherlands and Australia. The number of breaks was similar across populations as well. Hadza adults switched from resting to active postures like standing or walking roughly 50 times per day, on par with data from Europeans.

Still, Hadza blood profiles and blood pressures showed they were remarkably healthy, with low levels of triglycerides and other markers of heart disease. The Hadza were much healthier than their desk-bound counterparts in industrialised countries, but not because they rested less or got up to stretch their legs more often.

Instead, the big difference we found was in muscle activity during rest. Squatting forces you to keep the body balanced over the feet, requiring between five and 10 times as much muscle activity in the legs as sitting in a chair or on the ground, and sometimes even more muscle activity than we would expect from light activity.

Sure enough, when we tallied the resting postures used around camp, we found that Hadza men and women were squatting and kneeling nearly one-third of this time. Putting the evidence together, we think that the use of "active resting" postures, like squatting and kneeling, might maintain enough muscle activity to prevent triglyceride build up and avoid disease. If our ancestors also used these more active rest postures, then the negative health effects of sitting make perfect sense: our physiology never experienced long periods of quiet muscles, so our bodies never evolved a protective response.

← Turn to chapter 1 for more on evolution and exercise

In the end, how could we blame Onawasi, or anyone, for wanting to sit in our camp chairs? We wanted them for the same reasons: chairs are an indulgence, allowing us to rest our tired muscles. The allure of a good chair has held our collective attention ever since they sprang into our material world. But chairs, once invented, let us rest in ways that are comparatively new to the human body. That novelty is both the draw and the danger.

Should we abandon our chairs? Unless you have been squatting since childhood, forcing yourself to do it may cause pain and discomfort. And Hadza men and women also spend much of their rest time in postures like sitting and lying down that entail low muscle activity, so maybe we don't have to avoid sitting altogether. But, our work suggests that you can improve your cardiovascular health by sitting less, and by breaking up your sitting into shorter bouts to increase muscle activity throughout the day. As our Hadza friends showed us, it is likely that quiet muscles are the enemy. So, while we are working from home or watching TV, let's try to break up the couch time into smaller bits. Get up, move around and if you are limber and feeling adventurous when you turn on Netflix, trying squatting just like the Hadza, in an active resting posture. Your heart will thank you. ▮

THE POWER OF HABIT

"Just do it," they say. If only it were that easy. For some of us, it doesn't seem to matter how much we think we want to get fit, something always comes along to knock us off course. Fortunately, the neuroscience of habit formation can help.

IN THE vernacular, we might refer to habits as anything from brushing our teeth to bad table manners or smoking.

Scientifically, habits are defined fairly broadly as actions performed routinely in certain contexts and situations, often unconsciously. Once a habit is formed, you might think of it like initiating a program that runs on autopilot, making our actions more streamlined.

This process plays a vital part in making our everyday lives easier: imagine if you had to give your full attention to brushing your teeth or the commute to work every time you did it – life would become exhausting.

In fact, as much as 40 per cent of our daily behaviour is habitual, according to Wendy Wood, now at the University of Southern California, who tracked student behaviour to see how much of it fell into this kind of mental autopilot. She found that when students were engaged in well-practised behaviours – such as driving, exercising or brushing their teeth – they were often thinking of something else, allowing them to ruminate and their mind to wander.

All this makes sense from a practical perspective, but it also suggests that something changes in the brain when a conscious action turns into a habit.

The key area responsible is called the striatum, a region important for movement, mood and reward. After a rat learns to navigate a maze and begins to follow the same route out of habit, brainwaves slow down in this part of the brain, which is thought to indicate the creation of the habit, probably because the brain activity in that region has become more coordinated and efficient.

LUZA STUDIOS/ISTOCK

So much of life is done on autopilot

Importantly, it seems that cells within the striatum fire in this way at the beginning and end of a behaviour, as if signalling when the autopilot program is turned on and off. You could think of the brain putting the habitual action between brackets.

As well as the neurons in the striatum that fire in sync at the start and end of a habit, there is another set that fire in the middle. Called interneurons, these inhibit other neurons from firing, presumably to prevent a new routine from starting until the current one has run its course.

Together, this clever system makes it very hard to break a habit once its formed.

One way to snap out of this automatic behaviour and form better habits is to change our environment. We like to think we are creatures of reason and purpose. In reality, we mostly sleepwalk our way through life, responding to whatever is under our noses. Environments cue our behaviour, and the environment often has a stronger influence on our behaviour than the beliefs we hold in our heads.

But the fact that habits are tightly connected to our environment also reveals opportunities for forming new, better ones. One way to hijack the system is to capitalise on big changes in our environment, such as going on holiday or starting a new job. At these times it will be easier to break old habits and form new ones because you will have a fresh set of routines and will have left behind many of the old cues.

The next step is to link the new behaviours you want to turn into habits to a specific part of your routine or a time of day. If, for example, you want to start taking more steps, do an extra lap of the block after dropping your children at school or try walking the first part of the bus route to work – tacking the desired behaviour on to things that are already a routine part of your day. Before long, you'll do it automatically. Piggybacking new habits onto existing parts of our routine gives us the cues our brain needs to eventually make that behaviour an automatic one.

To maximise those chances, it helps to be as specific as you can. So rather than deciding to 'take more steps', try saying 'I will take 5000 steps by lunchtime'. One proven way to get specific and boost habit formation is to use 'if–then' plans. 'If I go to the shops, I will walk, not drive,' for example. This helps to make the behaviour automatic, and bypass the need for conscious thought and self-control.

As well as being specific, you should be realistic with your goals. So if you want to do more yoga, try spending 10 minutes on the mat every day after you wake up, rather than trying to do three longer sessions at some point during the week. Once daily yoga is a habit, you can increase the length.

Whatever the strategy, repetition is key, especially in the early days. Study after study shows that when people are successful at forming new habits, it is the first few times that the behaviour is carried out that play the biggest role in making it automatic. As time goes on, each repeated behaviour makes a bit less of a difference until it reaches a plateau – at which point the habit is formed, and you enter maintenance mode. Not all habits last, but by their very nature, once they are automatic, it is much harder to break them. ∎

EXERCISE AND THE MICROBIOME

Want to become a better runner? You're probably going to have to run faster, smarter and longer. But a piece of the puzzle may lie in a surprising place: the bacteria in your gut.

OUR gut microbiota – the organisms living within our digestive tract – are increasingly being implicated in many aspects of human health. In recent years, that role has been extended to exercise. We know exercise can alter the gut microbiome, but now George Church at Harvard University and colleagues say that the microbiome may be a critical component of physical performance.

The Boston marathon is famously tough to get into, due to its ever-faster qualifying times, so those taking part make a perfect testbed for the relationship between the microbiome and fitness. The researchers took daily stool samples from 15 runners in the 2015 race, one week before and one week after they ran, along with a sedentary control group, to see what was in their gut.

A genetic analysis found a significant increase in one genus of bacteria, *Veillonella*, post-marathon. The results were then successfully replicated by analysing the stool samples of 87 ultramarathoners and Olympic trial rowers before and after exercise.

The correlation raises the prospect of a causal link between the bacteria and physical performance. To find out more, one strain of *Veillonella* taken from one of the Boston marathoners was then put in mice. It allowed them to run 13 per cent longer on a treadmill than a control group without it. Further tests saw the team put forward the idea that the bug has a role in breaking down lactic acid, which can lead to fatigue during running.

The research potentially points the way to a future where probiotic supplements could change your microbiome and make you a better runner. But it's too early to tell if that will come to pass, Church says.

We simply don't know if *Veillonella*-boosted humans would be able to run longer like the mice, and there are reasons to be cautious given the large differences not just between humans and mice, but among humans too, and the sample size in the research was small.

As well as performance, gut microbes could influence propensity to exercise. Mice with depleted levels of certain gut bacteria ran for less time, and had lower levels of dopamine in the brain – which is known to influence motivation – than mice with intact gut microbiomes.

←
Turn back to page 82 for more on motivation

Tailored probiotic supplements to help us run faster or boost motivation to exercise don't exist yet, and may be a long way off. Even if the research is right and this is a route to becoming a better runner, the effect would probably be pretty small – old fashioned training would probably have more impact. ∎

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