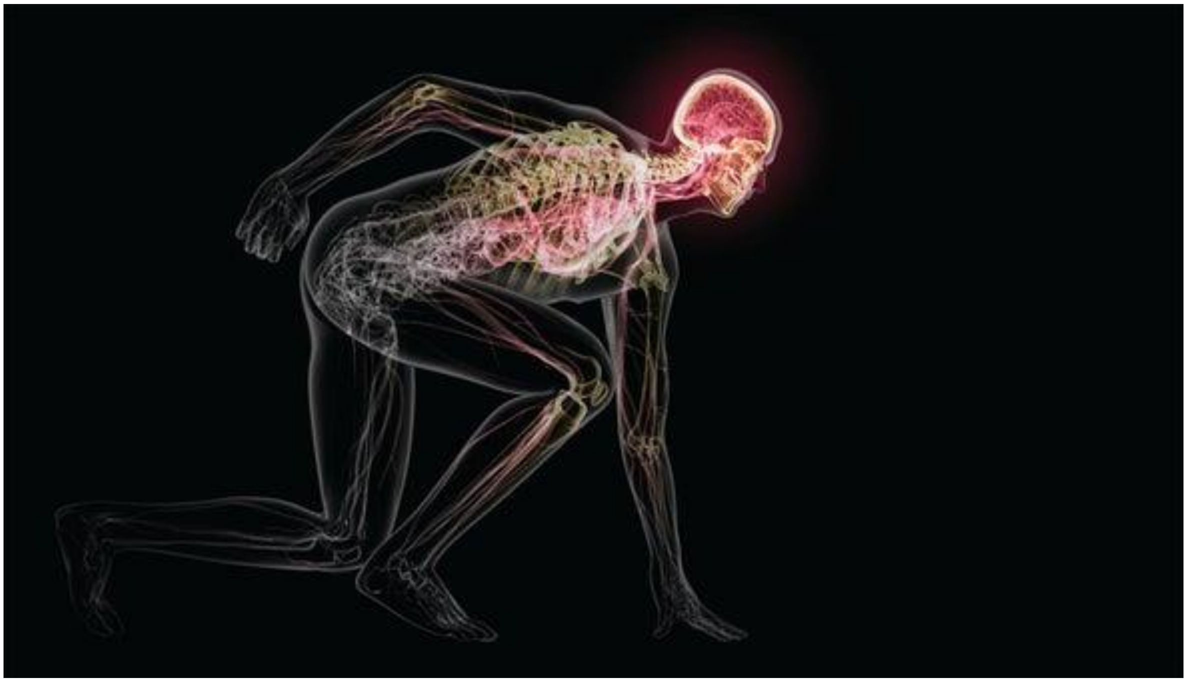
FEATURE



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Why Your Brain Needs Exercise

The evolutionary history of humans explains why physical activity is important for brain health

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In Brief

- **It is by now well established that exercise has positive effects on the brain**, especially as we age.
- **Less clear has been why physical activity** affects the brain in the first place.
- **Key events in the evolutionary history** of humans may have forged the link between exercise and brain function.
- **Cognitively challenging exercise may benefit** the brain more than physical activity that makes fewer cognitive demands.

In the 1990s researchers announced a series of discoveries that would upend a bedrock tenet of neuroscience.

For decades the mature brain was understood to be incapable of growing new neurons. Once an individual reached adulthood, the thinking went, the brain began losing neurons rather than gaining them. But evidence was building that the adult brain could, in fact, generate new neurons. In one particularly striking experiment with mice, scientists found that simply running on a wheel led to the birth of new neurons in the hippocampus, a brain structure that is associated with memory.

Since then, other studies have established that exercise also has positive effects on the brains of humans, especially as we age, and that it may even help reduce the risk of Alzheimer's disease and other neurodegenerative conditions. But the research raised a key question: Why does exercise affect the brain at all?

Physical activity improves the function of many organ systems in the body, but the effects are usually linked to better athletic performance. For example, when you walk or run, your muscles demand more oxygen, and over time your cardiovascular system responds by increasing the size of the heart and building new blood vessels. The cardiovascular changes are primarily a response to the physical challenges of exercise, which can enhance endurance. But what challenge elicits a response from the brain?

Answering this question requires that we rethink our views of exercise. People often consider walking and running to be activities that the body is able to perform on autopilot. But research carried out over the past decade by us and others would indicate that this folk wisdom is wrong. Instead exercise seems to be as much a cognitive activity as a physical one.

In fact, this link between physical activity and brain health may trace back millions of years to the origin of hallmark traits of humankind. If we can better understand why and how exercise engages the brain, perhaps we can leverage the relevant physiological pathways to design novel exercise routines that will boost people's cognition as they age—work that we have begun to undertake.

Flexing the Brain

To explore why exercise benefits the brain, we need to first consider which aspects of brain structure and cognition seem most responsive to it. When researchers at the Salk Institute for Biological Studies in La Jolla, Calif., led by Fred Gage and Henriette Van Praag, showed in the 1990s that running increased the birth of new hippocampal neurons in mice, they noted that this process appeared to be tied to the production of a protein called brain-derived neurotrophic factor (BDNF). BDNF is produced throughout the body and in the brain, and it promotes both the growth and the survival of nascent neurons.

The Salk group and others went on to demonstrate that exercise-induced neurogenesis is associated with improved performance on memory-related tasks in rodents. The results of these studies were striking because atrophy of the hippocampus is widely linked to memory difficulties during healthy human aging and occurs to a greater extent in individuals with neurodegenerative diseases such as Alzheimer's. The findings in rodents provided an initial glimpse of how exercise could counter this decline.

Following up on this work in animals, researchers carried out a series of investigations that determined that in humans, just like in rodents, aerobic exercise leads to the production of BDNF and augments the structure—that is, the size and connectivity—of key areas of the brain, including the hippocampus. In a randomized trial conducted at the University of Illinois at Urbana-Champaign by Kirk Erickson and Arthur Kramer, 12 months of aerobic exercise led to an increase in BDNF levels, an increase in the size of the hippocampus and improvements in memory in older adults.

Other investigators have found associations between exercise and the hippocampus in a variety of observational studies. In our own study of more than 7,000 middle-aged to older adults in the U.K., published in 2019 in *Brain Imaging and Behavior*, we demonstrated that people who spent more time engaged in moderate to vigorous physical activity had larger hippocampal volumes. Although it is not yet possible to say whether these effects in humans are related to neurogenesis or other forms of brain plasticity, such as increasing connections among existing neurons, together the results clearly indicate that exercise can benefit the brain's hippocampus and its cognitive functions.

Researchers have also documented clear links between aerobic exercise and benefits to other parts of the brain, including expansion of the prefrontal cortex, which sits just behind the forehead. Such augmentation of this region has been tied to sharper executive cognitive functions, which involve aspects of planning, decision-making and multitasking—abilities that, like memory, tend to decline with healthy aging and are further degraded in the presence of Alzheimer's.

Scientists suspect that increased connections between existing neurons, rather than the birth of new neurons, are responsible for the beneficial effects of exercise on the prefrontal cortex and other brain regions outside the hippocampus.

Upright and Active

With mounting evidence that aerobic exercise can boost brain health, especially in older adults, the next step was to figure out exactly what cognitive challenges physical activity poses that trigger this adaptive response. We began to think that examining the evolutionary relation between the brain and the body might be a good place to start. Hominins (the group that includes modern humans and our close extinct relatives) split from the lineage leading to our closest living relatives, chimpanzees and bonobos, between six million and seven million years ago.

In that time, hominins evolved a number of anatomical and behavioral adaptations that distinguish us from other primates. We think two of these evolutionary changes in particular bound exercise to brain function in ways that people can make use of today.