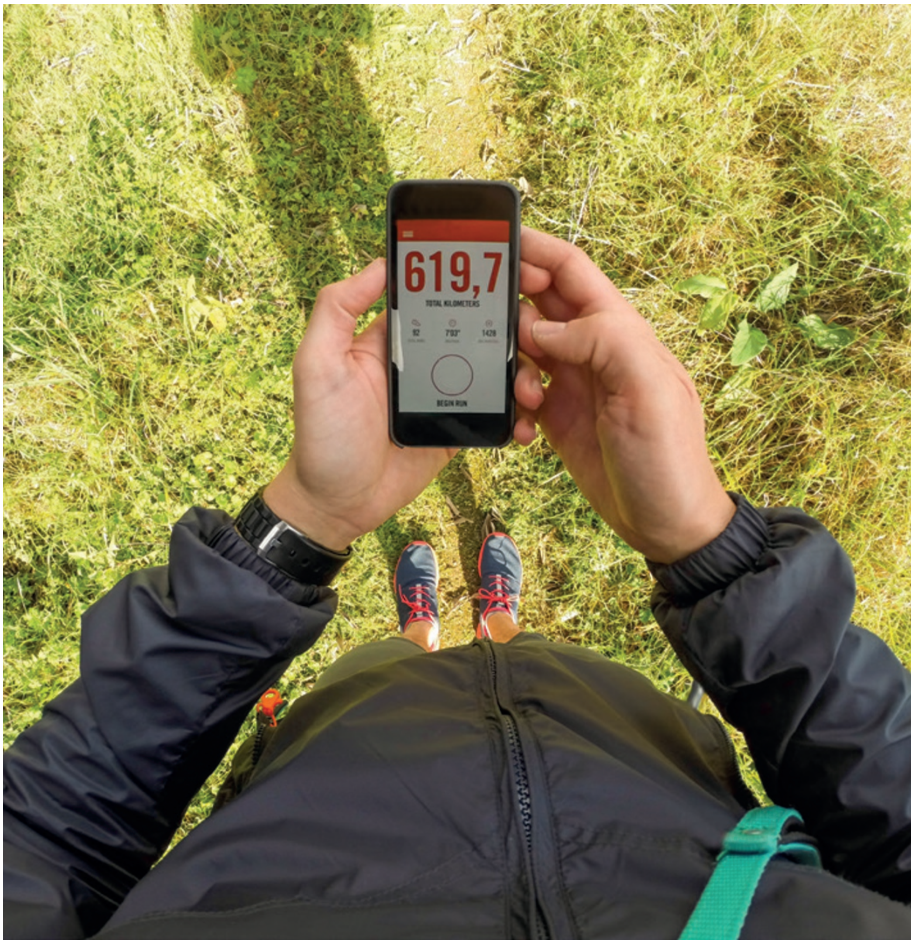

Smartphone fitness apps enable researchers to gather health data from large numbers of people.

ARTUR DEBAT/GETTY IMAGES

MOBILE DATA

Made to measure

Wearable sensors and smartphones are providing a flood of information and empowering population-wide studies.

BY NEIL SAVAGE

For decades, doctors around the world have been using a simple test to measure the cardiovascular health of patients. They ask them to walk on a hard, flat surface and see how much distance they cover in six minutes. This test has been used to predict the survival rates of lung transplant candidates, to measure the progression of muscular dystrophy, and to assess overall cardiovascular fitness.

The walk test has been studied in many trials, but even the biggest rarely top a thousand participants. Yet when Euan Ashley launched a cardiovascular study in March 2015, he collected test results from 6,000 people in the first two weeks. “That’s a remarkable number,” says Ashley, a geneticist who heads Stanford University’s Center for Inherited Cardiovascular Disease. “We’re used to dealing with a few hundred patients, if we’re lucky.”

Numbers on that scale, he hopes, will tell him a lot more about the relationship between physical activity and heart health. The reason they can be achieved is that millions of people now have smartphones and fitness trackers with sensors that can record all sorts of physical activity. Health researchers are studying such devices to figure out what sort of data they can collect, how reliable those data are, and what they might learn when they analyse measurements of all sorts of day-to-day activities from many tens of thousands of people and apply big-data algorithms to the readings.

By July, more than 40,000 people in the United States had signed up to participate in Ashley’s study, which uses an iPhone application called MyHeart Counts. He expects the numbers to surge as the app becomes more widely available around the world. The study — designed by scientists, approved by institutional review boards, and requiring informed consent — asks participants to answer questions about their health and risk factors, and to use their phone’s motion sensors to collect data about their activities for seven days. They also do a six-minute walk test, and the phone measures the distance they cover. If their own doctors have ordered blood tests, users can enter information such as cholesterol or glucose measurements. Every three months, the app checks back to update their data.

Physicians know that physical activity is a strong predictor of long-term heart health, Ashley says. But it is less clear what kind of activity is best, or whether different groups of people do better with different types of exercise. MyHeart Counts may open a window on such questions. “We can start to look at subgroups and find differences,” he says.

It is the volume of the data that makes such studies possible. In traditional studies, there may not be enough data to find statistically significant results for such subgroups. And rare events may not occur in the smaller samples, or may produce a signal so weak that it is lost in statistical noise. Big data can overcome those problems, and if the data set is big enough, small errors can be smoothed out. “You can take pretty noisy data, but if you have enough of it, you can find a signal,” Ashley says.

AN APPLE A DAY

Gathering that much data is possible because of Apple software called ResearchKit, which can be used to develop iPhone-based apps for such studies. MyHeart Counts was one of five apps that were launched on the same day that ResearchKit was released. The others are trying to harness the power of big data to study Parkinson’s disease, breast cancer, diabetes and asthma.

The Parkinson’s study, which enrolled about 16,000 people by July, also uses a walking test, because Parkinson’s manifests as a movement disorder. People walk 20 steps in a straight line, and the phone’s accelerometer and gyroscope measure their gait to assess their motor control. They are also asked to say “Aaah” for 10 seconds into the phone; measuring how much the voice quavers can help to tell doctors about their muscle tone. “It is very well fitted for using the sensors native to the mobile device,” says John Wilbanks, an open-data advocate at Sage Bionetworks, a non-profit biomedical research consultancy based in Seattle, Washington, that developed the Parkinson’s mPower app with doctors at the University of Rochester in New York. The app also uses questionnaires

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and can be linked to a fitness tracker to collect even more data.

Similar apps are being written for other smartphone operating systems, such as Windows and Android, and their associated smart watches. There has also been a proliferation of wearable fitness devices from various companies including Basis, Fitbit and Jawbone. Additionally, researchers are developing other types of wearable sensor to collect data over time, including temporary tattoos and contact lenses that measure glucose levels in tears. Meanwhile, existing devices, such as continuous glucose monitors for people with diabetes, are rapidly evolving and adding their data to the mix on smartphones.

Researchers are now trying to use smartphones to go beyond measuring physical fitness. Some, for instance, track mental state and emotional health, by listening to the sound of a person's voice to identify stress, or by tracking their movement to determine their social interaction to figure out if they may be depressed.

As portable devices are increasingly used to measure a whole range of human activity, and computers are now powerful enough to sift through this mountain of data, researchers are hoping to obtain unprecedented insight into human health.

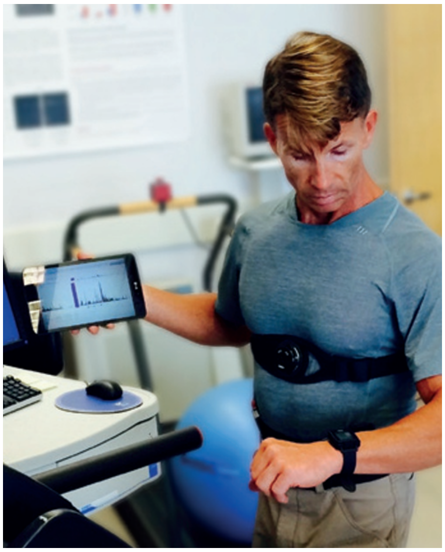
MEASURING UP

The wide variety of measurements from an ever-growing array of devices leaves researchers having to figure out how to handle it all. "It's just an exciting mess," says Ida Sim, co-director of the biomedical informatics division at the University of California, San Francisco.

Sim is a co-founder of Open mHealth, a non-profit company that is developing software to help clean up the mess by standardizing, storing and processing data collected from a variety of devices and apps. "Everybody hates standardization, but without it, it's hard to put data together accurately," she says. For a doctor to correctly interpret a glucose reading, for instance, it is important to know whether that person had been fasting for a period of time.

"You can take pretty noisy data, but if you have enough of it, you can find a signal."

Any effort to establish standards must address two critical questions. How accurate are the readings from these devices? And what exactly is being measured? Today's fitness trackers are designed to tell users whether they have walked more this week than last week, say, not to collect laboratory-quality measurements. "What they know is general movements, which they try to convert to steps, some better than others," says Stephen Intille, who studies personal health informatics at Northeastern University in Boston, Massachusetts.



DIEGO ARGUELLO/STEPHEN INTILLE

Researchers at Northeastern University calibrate sensors during a range of activities in the lab.

To get a better sense of what devices are actually measuring, Intille brings volunteers into his lab and attaches various sensors to both arms and both legs — not only the commercial devices, but other, laboratory-calibrated sensors that record movement, heart rate, breathing and other data points. For 2–3 hours, he takes readings as the volunteers walk, do chores, ride a bicycle and carry out similar activities. Intille then removes some of the sensors and sends the person home, where the remaining devices collect real-world data for another couple of days. For the next three months, he cuts back to the one or two devices he is studying.

This way, Intille can see precisely what the commercial devices are recording during a particular activity. For instance, a Fitbit monitor may produce a certain set of readings when a person is ironing clothes, while the lab equipment records heart rate and breathing. If the computer can be trained to recognize how different activities produce different Fitbit readings in the lab, it may also be able to identify those activities in the real world and analyse their impact on physical fitness.

"I don't personally believe these things are ever going to work really well without some interaction with the end user," says Intille. He wants a phone to tap into data from a fitness tracker and, having learned something about the individual's habits, ask questions, such as: "Are you walking the dog right now?" For a fuller picture, he says, people would need to wear more than one device, perhaps one on the wrist and another on the ankle.

Such detailed information will be needed for researchers to obtain a broader understanding. It's easy to have people report how far and how frequently they run, for example, or how intensely they work out at the gym, but little is known about the effect of day-to-day activity on people's health, says physiologist William Haskell, emeritus professor of medicine at the Stanford Center on Longevity.

"We don't know a lot about the light-intensity range, from standing and just walking about," says Haskell, who has collaborated with Intille and worked to validate the measurements from commercial trackers. "How useful is a standing desk, where you get up and just stand for three hours a day, versus where you have a nice walk around the office? We just don't know."

Haskell started using accelerometers to track physical activity 40 years ago, and he is excited about the possibility of learning from wearable devices. "We think the technology is here," he says. "We just need to validate it and use it to look at a 24-hour activity cycle."

WEAR NEXT?

Obtaining vast amounts of data can improve the power of fitness studies, but wearable technologies also open up the possibility of collecting different kinds of data that were not previously available: the long-term, round-the-clock monitoring of people just going about their business.

"A lot of the promise of big data is that you're not just looking at a lot of data, but you're looking at a lot of data from a lot of different sources," says Sim.

When she sees patients, she interacts with them for about 20 minutes. "For all the time they're not in my clinic, I'm completely blind," she says. "I have no idea what's going on in their lives." Constant data collection could ultimately change that equation and help doctors tailor their care to individual patients. Right now, though, Sim says that there is still a crucial missing link: no one has yet designed a way to send meaningful data from commercial devices to doctors. "It's not built to fit into the physician's workflow at all," she says.

But such pervasive gathering of health information could also offer broader societal benefit. Data from thousands of individuals, collected unobtrusively with technology that is increasingly ubiquitous, could allow for population-wide studies of factors that can affect health. Ashley envisages a mobile-health version of the decades-long Framingham Heart Study, which has helped to identify risk factors for heart disease. He has already started to link the data he is collecting from iPhones with genomic data, which he collects from users who are patients at Stanford Medical Center.

Intille believes that as bigger data sets are created, health researchers will be able to answer a whole range of new questions. "At the individual level we just haven't had any data like this at all," he says. "It's simply not possible to detect it until you have mobile devices. It's totally different from the way we've dealt with health and medicine in the past." ■

Neil Savage *is a freelance science and technology writer based in Lowell, Massachusetts.*