



Elite athletes and members of the military need to keep ticking in the most challenging of circumstances. Scientists are looking to these super users of the human body in the search for ways to optimize human performance.

PITTSBURGH AS A HUMAN PERFORMANCE CITY

BY ELAINE VITONE

# PERSONAL BEST

**F**or U.S. Army truck drivers on major supply routes in Afghanistan, a daily commute amounts to several anxious hours in a convoy of dozens of vehicles. Every morning, they wake up knowing they will be attacked on that road to Bagram Airfield. They know because it's happened to them before—30, 40, even 50 times.

A truck might be hit by an IED, says the University of Pittsburgh's Ronald Poropatich. Or, just as dangerous is when a driver falls asleep at the wheel. "That happens a lot," says Poropatich. So the soldiers get hurt or die because of a simple thing we all take for granted: sleep.

Other service members commute via "HALO" jump—high altitude (maybe 30,000 feet, to evade radar), low opening (at 1,500 feet, *BAM!*, open chute). They hurl themselves out of a jet to certain danger behind enemy lines, hooked up to an oxygen mask. Because the air is thin those miles above the Earth.

Dangerous doesn't even begin to cover it.

ILLUSTRATIONS | MICHAEL HIRSHON

But as it turns out, the most common reasons for American soldiers to be medically evacuated from combat theatre today are not injuries from jumping from planes or taking enemy fire. They're musculoskeletal injuries, but largely from training and carrying around a rucksack.

Everyday wear and tear on the joints. Sleep, or lack thereof. Both the mundane and the obviously death-defying can do us in.

How do we keep ticking? Researchers in a growing field known as human performance optimization want to know how we can function at our best even when our circumstances aren't. Human performance is a crucial concern for the American military, says Poropatich, director of Pitt's Center for Military Medicine Research (CMMR), which works closely with the Veterans Affairs and the Department of Defense (DOD) research arms to solve military medical problems.

But improving performance isn't just in the interest of service members, of course. "There are lots of people at Pitt" chasing down this goal, says Rory Cooper, "whether it's post-transplant, or post-spinal cord injury, or amputation, or our own Division I athletes, or special operations forces." Cooper himself, founder of the Human Engineering Research Laboratories (HERL) and Distinguished Professor in the Department of Rehabilitation Science and Technology in Pitt's School of Health and Rehabilitation Sciences, has garnered numerous awards for his contributions to assistive technology, a field that enhances daily living for persons with disabilities. He's also an elite athlete, medaling in the

Paralympics and National Veterans Wheelchair Games year after year. (He's racked up 150 Wheelchair Games medals.)

In June, Pitt will host a national conference on human performance optimization, organized by collaborators across the health sciences. In September, the DOD will join in on a two-day meeting with Poropatich and others at Pitt to discuss how academia can fill in gaps in the DOD's own efforts. "To open their eyes to areas of human performance optimization that they're not currently thinking about," says Poropatich.

Across campus, with full support from university leadership—notably, Chancellor Patrick Gallagher—a movement is afoot to plant a flag here and unify disparate and complementary human performance efforts more formally. In October 2018, Pitt released a 30-year master plan that includes a massive redevelopment of the athletic campus; a Human Performance Center features prominently in a new area dubbed Victory Heights.

When scientists study a disease, they often start with the most extreme cases and work their way back. In the study of our physicality and its limits, soldiers and elite athletes are super users. And at Pitt, both are in abundance: Service members and veterans have been volunteering for Pitt studies for years. A number of national sports franchises are expressing interest in partnering with the University. And NCAA Division I athletes are just outside the doors of Pitt scientists.

Pitt, it seems, is uniquely positioned to anchor Pittsburgh as a Human Performance City. ■

## Right Time, Right Place

When Freddie Fu became head physician for Pitt Athletics in 1986, there was a regular fixture on the sidelines of seemingly every college and pro football game: an oxygen tank. Throughout the '70s and '80s, coaches had their players inhaling 100 percent oxygen between plays—to speed up recovery, beat fatigue, and enhance their performance, the thinking went.

"It was a placebo," recalls Fu. "Just hocus-pocus." And he told everyone so, over and over, for years. (The *Journal of the American Medical Association* published a study with the same conclusion in '89.) Still, it took a decade to get the tanks rolled away, and not without plenty of complaints from fans. "It's so hard to change the mentality of people," says Fu, chair of orthopaedic surgery at Pitt.

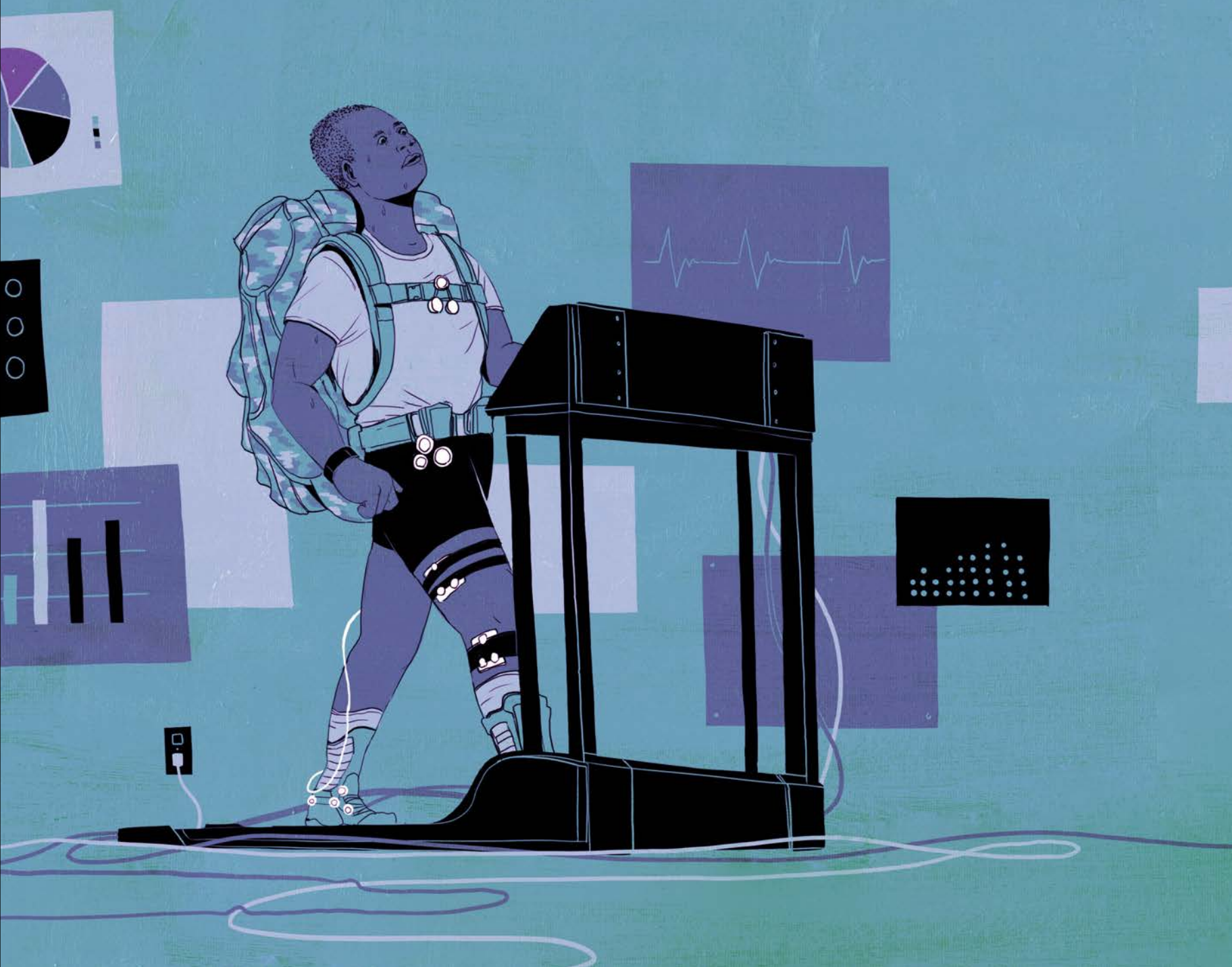
Sports medicine has not been immune to the haste to find the Best New Thing to gain a competitive edge, he says. Through the years, a number of surgical and medical approaches, high on hype and low on hard science, have done more harm than good for patients. For example, pain pumps, once all the rage for post-op

pain, proved damaging to joint linings and turned the rare unfortunate patient arthritic.

Fu, world renowned for innovating and evaluating surgical fixes for injured athletes' knees, has made Pitt a powerhouse in probing the biomechanics of sports injuries. He helped conceptualize the UPMC Rooney Sports Complex, which opened in 2000 on the South Side. (It's where the Steelers and Panthers do indoor training.) The sports medicine center there was just named for Fu. And in 2015 the UPMC Lemieux Sports Complex, a comprehensive outpatient sports medicine facility and training site for the Pittsburgh Penguins, opened in Cranberry. ("Nobody else has *two* sports centers," Fu says.)

Fu oversees one of the largest, most comprehensive sports medicine clinical and research operations in the world. And he has worked to bring human performance optimization from the realm of the hocus-pocus to solid, replicable, peer-reviewed science.

Ten years ago, his department opened the Orthopaedic



Biodynamics Laboratory, equipped with technology that illuminates previously unseen details of joint function before and after surgery. “We call it EKG of the knee,” he says.

In 1990, with an investment of \$5,000 and half a classroom in Trees Hall, Fu founded the Neuromuscular Research Laboratory (NMRL). Slowly and steadily, NMRL grew, encompassing studies of a variety of athletes, as well as military service members. Three years ago, an entirely new facility dubbed the Neuromuscular Research Laboratory/Warrior Human Performance Research Center (NMRL/WHPRC) opened on Pittsburgh’s South Side.

Today, in the 11,600-square-foot space where lab meets gym, NMRL researchers study just about every physiological aspect of the human form *in medias res*: proprioception, postural stability, strength, range of motion, flexibility, bone and mineral density, you name it. There’s an on-site biochemistry lab, a suite of motion-capture cameras, a transcranial magnetic stimulator. (TMS is a noninvasive way of stimulating specific areas of the brain.) It even has a

swimming flume and an underwater treadmill.

NMRL, which is part of Pitt’s School of Health and Rehabilitation Sciences (SHRS), is interdisciplinary to the hilt. Current collaborators include mathematicians, physiologists, and engineers, as well as School of Medicine faculty. And the list continues to grow.

The lab studies both physical and cognitive performance, how various stressors affect performance, and what can be done to counteract the impact of stressors.

Brad Nindl, an SHRS professor of sports medicine and nutrition, came on board as director when the new facility opened. He calls it his dream job, and this physiology PhD does seem every bit the part. He’s a military guy—a reservist who served for 20 years as an Army Medical Department government scientist, primarily studying biomarkers for fitness and health outcomes.

“And I grew up a coach’s kid—very motivated to be the best athlete I can be,” he says.

In his dad’s day, exercise physiology was central to the study of

human performance. By the '80s, the field had gone “very molecular,” he says, a trend that continued into this century. Throughout the past 15 years, the brain has been increasingly, well, on the brain in terms of the military’s priorities—cognitive readiness and resilience are front-and-center priorities now. And in the past five years, exercise physiology research is complementing our expanding knowledge of health at the micro level, from head to toe. Human performance optimization is now more of a hybrid of both basic and applied science, Nindl says.

In 2015, the United States lifted the ban on women in close ground combat; a year later, the United Kingdom followed. A better understanding of physiological differences between the sexes, particularly in upper-body strength, immediately became crucial to both countries’ militaries and the new crop of service women who wished to join them. Nindl is a coprincipal investigator on a three-year study funded by the U.K. Ministry of Defence. SPARTA, which stands for Soldier Performance and Readiness as Tactical Athletes, will evaluate the efficacy of a variety of physical training regimens

a foot of snow, for x number of miles) and determines appropriate recommendations, given on-the-job constraints, which, of course, are many.

“These guys carry what they need on their backs,” she says. “They have to make choices between carrying food or carrying ammunition or carrying water or other supplies that they need. It’s a compromise.”

Beals is writing a proposal with Alison Morris and Michael Morowitz—director and associate director, respectively, of the School of Medicine’s Center for Medicine and the Microbiome. They want to examine whether probiotic supplements might help undo some of the negative effects of operational stress—or even increase cognitive performance.

Before Chris Connaboy—assistant professor in SHRS, former U.K. military infantry soldier, and Nindl’s coprincipal investigator on the SPARTA study—came to Pitt three years ago, he was in Houston developing a behavioral metric for NASA. The metric measures how human movement is affected by microgravity, stress, changing

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in preparing women for what’s required on the job. “I’ve done a lot of work looking at both men and women and how they adapt,” says Nindl, “and I know that with optimal proper training you can significantly [close physical performance] gaps.”

Taking me on a tour of the NMRL, he stops each of the colleagues in his path for briefings. Like Nindl, they are all PhD faculty members in the Department of Sports Medicine and Nutrition within SHRS.

Shawn Flanagan, an assistant professor, tells me about a project that was just funded by the Department of Defense (DOD). He’s collaborating with Nathan Yates, an associate professor of cell biology and scientific director of Pitt’s Biomedical Mass Spectrometry Center. Working with an army lab near Boston, they’ll be collecting urine samples of enlisted soldiers, in hopes of finding a molecular signature of physiological resilience. They want to learn to identify who is more likely to experience a musculoskeletal injury.

“Urine is interesting. Quantity is not an issue,” Flanagan says. “You [urinate] every day. It’s noninvasive. And it’s naturally integrative, right? I mean, 30 percent of proteins in urine are from plasma, not from the kidney, so you can detect brain-specific proteins, muscle-specific proteins, bone-specific proteins. It’s not just garbage.”

Kim Beals, an SHRS associate professor who studies diet as a means of injury prevention and performance optimization, has worked with every branch of Special Operations forces in the U.S. military. She studies nutrition (the given fuel demands of, say, walking, in snowshoes, up the side of a mountain, through

physiological states, and anything else you might encounter on a mission to Mars. He realized concussions, and what they do to human performance, were an important next frontier for him; but he had zero background in this area.

He wanted to learn from the best.

“And it’s Pitt. It’s just fantastic,” he says.

From discussions with his new Pitt colleagues (notably, Anthony Kontos and Michael “Micky” Collins, PhDs who are, respectively, research director and director of the Sports Medicine Concussion Program), Connaboy learned that once you’ve had a concussion, you’re more than twice as likely to have another. Further, you’re twice as likely to have a lower-limb musculoskeletal injury.

Using his newly developed behavioral metric, Connaboy and NMRL doctoral student Shawn Eagle looked at dozens of people with a history of concussion and compared them to controls. He found that the former had trouble with what is called perception-action coupling.

“It’s the ability to accurately assess your action boundaries,” he explains, to successfully coordinate and time your actions even as your environment changes. It’s putting yourself in the right place at the right time.

He adds that there are ways to retrain for and rehabilitate this skill. “But we need to know it’s compromised first”—preferably, before the person goes back on the job, onto the field, or into combat theatre and winds up with a musculoskeletal injury, another concussion, or worse. ■

# Sleepless Fights

This is probably because they sacrifice speed to maintain accuracy, she says, and the patterns of

Anyone who's ever pulled an all-nighter knows that, come morning, flying off the handle is pretty much your new default mode. Sleep and emotional well-being are inexorably linked—and often, so are sleep disorders and mood disorders. Interestingly, in studies of people who have both, researchers consistently find that when the treatment plan starts with fixing the sleep problems first, the severity of the mood disorder lessens all on its own, whether it be PTSD, depression, anxiety, or suicidality. Even cravings for alcohol decrease when sleep improves.

Anne Germain, PhD professor of psychiatry, psychology, and clinical and translational science, is among the scientists who've shown this robust and remarkable phenomenon. Working with service members and veterans for more than a decade, she's found that sleep therapy is a solid step toward symptom relief.

And now, Germain hopes to convince much broader scientific circles that sleep is integral not just to what we feel but to everything we do.

It's well documented that if you assign a sleep-deprived person a computer-based task day after drowsy day, performance suffers. The first to go is vigilance, the ability to detect and attend to cues in the environment. Motor performance and working memory follow, as well as emotional reaction. The latter can err either on the snappy and overreactive side, or the blunted and numbed. And when emotional reaction is off base, that, in turn, messes up a person's decision-making.

Good luck explaining this to the chronically sleepless, though.

Across the board, Germain says, people quickly develop a perception that they're adjusting to sleeplessness and are doing just fine, thank you very much. We've all been there, "and effectively, we are completely wrong," she says. "Even after a night or two of insufficient sleep, you see this pattern come up. Performance is decreased." That effect doesn't go away as your sleep drought drags on.

And, she adds, all this self-delusion can be terribly risky.

"We're no longer a good judge of our behavior. What we [in sleep medicine] tell people is that if you've been awake for 24 hours, it's the equivalent of being over the limit for blood alcohol when you're driving."

So what saves our military service members, essentially out in harm's way and drunk from sleeplessness? In a word, Germain says: training. They know what to do when a given threat befalls them because practice makes perfect. In her experience, soldiers might tend to get a bit slower at performing various tasks in the throes of sleep deprivation, but not significantly less accurate.

brain circuitry that support the best course of action are deeply ingrained.

Sleep is replete with million-dollar questions for the military. At the top of the list: Is there a way to make five hours of sleep as restorative and beneficial as eight?

Germain and colleagues are exploring this and other questions. She and the Neuromuscular Research Laboratory's (NMRL) Brad Nindl are coprincipal investigators in a large, multi-institutional, multifaceted study of neurocognitive and physical performance in simulated military tasks, complete with the typical stressors of the job: caloric restriction, physical exertion, and sleep loss. The study, which launched in January with funding from the Department of Defense, will follow 80 service members for six-day stretches through marksmanship exercises at a reserve center in Coraopolis, tactical mobility exercises in the UPMC Lemieux Sports Complex in Cranberry, and sleep studies in Germain's Oakland lab.

Amy Haufler, a coinvestigator at the Johns Hopkins Applied Physics Laboratory, will apply an adaptive decision-making test of her own design. The NMRL's Chris Connaboy will apply his NASA-tested, NASA-approved behavioral metric, which Germain calls "an amazing, testable model" for deciphering exactly what abilities loss of sleep degrades first.

One of the study's aims is to identify biomarkers of how well individuals tolerate stress, using predictive analytics, bioinformatics, and machine learning. And in the sleep lab, Germain will look for predictors of performance, as well: brain signatures like wave patterns or duration times for sleep's distinct phases. If she can find such signatures, it might be possible to augment them, she notes, in one of two ways:

There's "the messier approach," as she calls it. "Very short-acting medications that could be used to optimize the efficiency of sleep, in terms of its restorative power. Currently we don't have medications like that," so they would have to be developed.

Then there's the neater approach: Labs across the country (including that of Pitt's Fabio Ferrarelli) are beginning to show success in influencing the sleeping brain using transcranial magnetic stimulation. TMS is currently used to diagnose conditions like stroke, and to treat major depressive disorder.

And then, there are approaches that are neater still: sound and light stimulation during sleep. "Even when your eyes are closed, [you] can still detect light," says Germain. Best of all, these nonmedication approaches are rapidly reversible, do not cause grogginess, and have no known side effects. ■

# Your Move

Scientists have long known of a correlation between slowing gait and cognitive decline. In 2017, Andrea Rosso, assistant professor of epidemiology in the Graduate School of Public Health, published a study finally identifying losses in a particular brain region—the right hippocampus—as a common link to both. For 14 years, she had a cohort of 70-some-things volunteer for imaging studies, mental acuity tests, and a timed 18-foot stroll down the hallway.

Rosso found that the simplest and most low-tech test—just a stopwatch, some tape on the floor, and a few minutes every year or so—was enough to flag the earliest sign of trouble.

Our movements tell a story.

And there are more ways of capturing and quantifying our movements all the time. Wearable technology offers real-time monitoring in granular detail that was never before possible, explains Nathan Urban, Pitt’s vice provost for Graduate Studies and Strategic Initiatives, codirector of the Center for the Neural Basis of Cognition, and professor and vice chair of neurobiology. (The new Apple Watch, released in December, can even take your EKG, he notes.)

There’s lab-based tech, too, like in all those behind-the-scenes reels you’ve seen of actors covered in dots as they defend Middle-earth. (Pitt’s Neuromuscular Research Laboratory has a similar setup, minus the green screen.) Urban points out that emerging camera-based motion technologies—no dots required—are on the market as well, and Pitt’s new Center for Research Computing has hardware that’s the perfect fit. He notes that two years ago, Pitt made substantial investments in integrating data and technology into academic pursuits across disciplines, just as it opened a new School of Computing and Information.

Urban is hatching plans to make these technologies widely available to researchers throughout the University. While Pitt raises funds to bring its new Human Performance Center from master plan to reality, he’s talking to potential partners and funders, building up resources, and launching pilot projects, some of which bring in machine-learning and robotics expertise

from Carnegie Mellon University (Urban’s former academic home). His vision: Space for both human- and animal-motion models. Space for data analysis. Whole fleets of wearables that are widely available to researchers studying disease screening, disease progression, how well a given treatment is aiding in disease or injury recovery, and more.

And all of this will be right in the big fat middle of hundreds of college athletes, bodily “super users” whose everyday doings present a potential firehose of data. Pitt scientists

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can ask questions like: Do they have a trick? Are elite performers doing something different—mechanically, molecularly, whatever—that makes them run farther or faster or with less fatigue? What should the Panthers be doing on the day before the game? Is it better to prep and practice more or to sleep longer?

Urban acknowledges that wearable tech presents a number of ethical questions. (For starters: Who can access the data? How will the data be used?) He and his colleagues are in discussions with bioethics experts to prepare for what lies ahead.

This won’t be a one-way street, though. The researchers will have something to give back to their study volunteers, right then, in the moment: data. And those data can have real dividends for health.

Here’s what I mean. Urban, for example, tells me he’s been prescribed physical therapy for back pain.

“I will say that continuing to do your exercises when the pain is no longer quite as severe is hard,” he says.

“But, if you have a way of assessing whether someone is doing exercises correctly, and providing feedback, I think it would be much more likely that someone would continue,” he says. If you can tell them their range of motion is improving, or they’re getting stronger, or performing better than they did last week, “that exact kind of feedback could be very, very important for ensuring that people are compliant.”

You do something, you get something, which influences your behavior. This is basic psychology-textbook reinforcement.

And there you are, invested and encouraged by your own self-efficacy. Working as your own personal agent of change. Controlling your own behavior and outcomes.

Bettering your own personal best. ■