MUSCLE MATTER

Even athletes aren't spared the decline of muscle mass that accompanies aging

BY SALLY POBOJEWSKI • PHOTOS BY MARIE FROST

John Faulkner, Ph.D., is living proof that a lifetime of physical activity can deliver big benefits at an advanced age. Faulkner is a professor of molecular and integrative physiology and biomedical engineering at the U-M Medical School. Now 83 years old, he manages a well-funded research program, supervises four graduate students and teaches muscle physiology to residents and graduate students. Many of his original graduate students have retired, but Faulkner just keeps on going.

When genes for athletic ability were handed out, Faulkner must have been at the head of the line. He played football and basketball in college and has the broad shoulders and quick step of a man who works at staying fit. Every day for 47 years, Faulkner has been riding a bicycle to and from his office. He also plays tennis and works out regularly at the Central Campus Recreation Building.

His only concession to aging was giving up running. "I have a total knee replacement, so I can't run anymore," he says. "I ran marathons until my early 60s and used to downhill ski, but it really beat up my knees, so I had to stop."

At one time nearly six feet tall, Faulkner has shrunk to five-feet, nine-inches with age. He sports a neat grey mustache, a wide smile and laugh lines around his brown eyes. It may take him a bit longer to get up from a chair than it used to, and most of his thick black hair has long since disappeared, but his colleagues say he has more energy, passion for his work, and enthusiasm for life than many people half his age.

Throughout a long and diverse career as a coach, teacher and scientist, Faulkner has been fascinated with muscle, especially the effects of aging and exercise on skeletal muscle.

Research by Faulkner and other scientists has shown that the decline in muscle

mass and strength everyone experiences with aging is caused largely by the loss of individual muscle fibers. Between ages 50 and 80, we lose almost half the number of muscle fibers we had in our 20s, according to Faulkner. Even conditioned athletes are not immune.

"No matter how hard you train, there's a significant decline in muscle mass with age," he says. "So staying active and building muscle mass when you're young is important, because the number of muscle fibers you end up with at 70 depends on the number you start out with at 20."

Understanding what happens to muscle as we get older is a topic of more than mere academic interest. With growing numbers of aging baby boomers, sedentary adolescents and obese adults, the American health-care system could face an explosion in the number of frail elderly people who need 24-hour care, simply because their muscles have atrophied to the point where they can no longer stand or walk — or even get out of a chair — without assistance.

Physicians call this muscle-wasting condition sarcopenia, and it's the health-care crisis no one talks about — according to Joseph Metzger, Ph.D., a professor of physiology and one of Faulkner's research collaborators. "When physicians, scientists and public health experts think about morbidity and mortality associated with aging, they think about heart disease, cancer and Alzheimer's disease," Metzger says. "No one thinks much about muscle weakness and the impact of frailty and falls."

The news isn't all bad. U-M researchers are developing and testing new exercise protocols designed to help elderly people safely preserve and strengthen the muscle fibers they have left. The big problem is how to motivate everyone, young and old, to get off the couch and start moving before it's too late. Because after a certain age, once a muscle fiber is gone, it's gone for good.

Muscle mechanics

Our bodies contain a lot of skeletal muscle; it makes up 30 to 40 percent of total body mass. Unlike cardiac muscle or smooth muscle, skeletal muscles are attached to the skeleton and are under our voluntary control. As soon as you hear a ringing telephone, for example, biochemical signals travel from the brain, down the spinal cord and through motor neurons to stimulate the muscles in your arm and hand to reach for the phone.

Muscle fibers are the basic building blocks of skeletal muscle. Hundreds of muscle fibers are bundled together to make a small muscle in the hand, while hundreds of thousands of fibers make the large, weight-bearing muscles in the thighs.

Under a microscope, skeletal muscle fibers look like long cylinders with alternating light and dark stripes. The dark stripes are thick filaments of a protein called myosin, and the light stripes are thin filaments of a protein called actin. ➤

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When triggered by nerve impulses, filaments of myosin and actin slide across each other, making the muscle fiber contract.

Under the control of the brain's central nervous system, skeletal muscles can "learn" to contract in a specific order with great precision. This is what makes it possible for us to dance a waltz, ride a bicycle or hit a baseball.

Faulkner uses care with the word "contraction," because it implies that muscles always get shorter when they are activated and attempt to contract. Actually, when a muscle is activated, it reacts in one of three ways. The muscle can get shorter, remain the same length or get longer, depending on the interaction between the force of the contraction and the load on the muscle. These three types are known as shortening, isometric and lengthening contractions.

To understand the difference, Faulkner suggests trying this simple experiment in muscle physiology: Balance a coffee cup on the palm of your hand and lift it off a table. While you lift the cup, note how the biceps muscle in your upper arm gets shorter to generate more force than the weight of the cup. If you generate an amount of muscle force equal to the weight of the cup (an isometric contraction), the cup will stay level. Now ease up on the amount of force your muscle is generating, so you can lower the cup below the level of the table, and feel how the muscle lengthens as it attempts to contract.

Lengthening contractions, especially when force on the muscle is high — from activities like running downhill, lowering a heavy object or catching yourself when you fall — are more likely to injure muscle, according to Faulkner. Muscle injuries do not occur during shortening contractions (lifting a weight) or during isometric contractions (pushing against a wall).

Because they can injure muscle, lengthening contractions can be dangerous, especially for frail, older people. "Young people can and do injure their muscles frequently, but young muscle can regenerate by growing new muscle fibers to heal the damage," Faulkner says. "An elderly person can't regenerate new muscle fibers as easily as young people, so the same level of injury can be permanent."

In recent research, Faulkner discovered that the mechanism of muscle fiber atrophy in older mice and older people appears to be associated with a loss of motor units. A motor unit is a group of muscle fibers controlled by a single motor neuron that projects from a nerve cell in the spinal cord. Without stimulation from the nervous system, muscle fibers lose their ability to contract and the entire motor unit may atrophy and die.

"In humans, rats and mice, we see a loss in the number of motor units with aging," says Faulkner, but the mechanism responsible for the loss is unknown. "The big question we're working on is whether the nerve dies first or the muscle fibers die first. Right now, nobody knows the answer to that question."

At an age when most scientists are cashing their retirement annuity checks, Faulkner is eager to find the answer to this chicken-and-egg question. He and his colleagues are starting a new research project with Eva Feldman, M.D., Ph.D., who is the Russell N. DeJong Professor of Neurology, to determine the basic mechanism behind the degeneration of motor units.

Photo: Courtesy John Faulkner

Faulkner collects data as a runner participates in a maximum oxygen intake test on a treadmill at an altitude of 14,000 feet. During the summer of 1966, Faulkner and colleagues ran tests on three groups of runners training at different altitudes on Mt. Evans in Colorado. The data were published in the *Journal of Applied Physiology*, Vol. 24, No. 5, May 1968.

The mysteries of muscle

In 1960, Faulkner came to the U-M School of Education to establish a human exercise physiology laboratory and teach human physiology to physical education students. That's where he rekindled his friendship with Horace Davenport, Ph.D., the legendary chair of the Department of Physiology who had served on Faulkner's doctoral committee. In 1965, Davenport invited Faulkner to join the Medical School faculty, an appointment he holds to this day. Since then, Faulkner's wisdom, experience and gentle sense of humor have influenced generations of Medical School students and faculty.

"John was a big reason I came to Michigan, so I have a warm place in my heart for him," says Metzger, who has worked with Faulkner since joining the U-M faculty in 1991. "He's a great colleague and a great mentor. I think John is a better scientist now than he was 40 years ago. He's like a fine wine — he really gets better with age."

Susan Brooks, Ph.D., an associate professor of molecular and integrative physiology in the Medical School, has worked with Faulkner since 1985 when she came to the U-M as a graduate student. She is one of 49 former graduate students and post-doctoral fellows who began their scientific careers in Faulkner's laboratory.

Her research has contributed to understanding that muscle injuries have two phases. The initial injury is mechanical and occurs when a lengthening contraction tears structures, both within and between sections of muscle fibers. But the real damage comes later when signals from damaged fibers trigger an inflammatory response, with associated pain and swelling, which can destroy entire sections of muscle. In young animals, this inflammatory reaction seems somehow to make the muscle stronger after it heals. But since the mechanical damage and secondary inflammation are more severe in older animals, what makes young muscle strong can permanently injure old muscle.

Brooks and post-doctoral fellow Tim Koh found that controlled passive stretches and isometric contractions made mouse muscle more resistant to damage from lengthening contractions. She wants to use what they've learned to develop exercise programs older people can use to safely maintain or increase the size of the muscle fibers they have left.

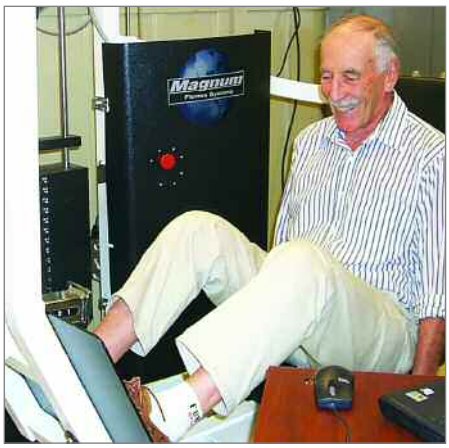

Photo: James Ashton-Miller

Faulkner is the first "older" subject to perform leg extensor lengthening contractions on a novel motorized leg muscle training device at the U-M Biomechanics Research Laboratory in November 2004.

"What excites me is the possibility of developing non-damaging kinds of protocols for the elderly person who wants to get involved in an exercise program," says Brooks. "Passive stretch protocols may serve as a stepping stone, allowing them to increase the rigor and intensity of exercise over time."

To increase muscle mass, athletic trainers know it's important to include lengthening contractions as part of a progressive resistance exercise program. Lengthening contractions build muscle mass by increasing the size and strength of fibers in the muscle. Because lengthening contractions also increase the risk of muscle injury, however, they have always been considered too dangerous for older people.

But recently, new exercise protocols that incorporate lengthening contractions have been developed and are being tested on elderly research subjects. "This kind of training has tremendous potential for older people," Faulkner says. "You can get a 10 to 15 percent improvement with shortening contractions alone, but with these new protocols you can get 30 to 40 percent improvement. It's a huge difference, but you have to be really careful."

Faulkner is collaborating with James Ashton-Miller, Ph.D., a U-M professor of biomechanical engineering, and Neil Alexander, M.D., a professor of gerontology, on a clinical study to test one of these new exercise regimens on people in their 70s. The study uses a leg-press exercise machine attached to a programmable motor that regulates the machine's speed and the amount of force required to complete a 12-week progressive exercise protocol of lengthening and shortening contractions.

When researchers in Faulkner's laboratory analyzed the strength of individual muscle fibers obtained from muscle biopsies of people using the device, the results were encouraging. They compared muscle fibers from people using lengthening contractions with fibers from people using a traditional exercise protocol. After 12 weeks, muscle fibers from the group using lengthening contractions were 35 percent stronger and they had no injuries.

"Our exercise protocol focuses on building strength and power in muscles involved in hip flexion and leg extension, because people with muscle weakness around the hips and knees are most likely to fall," says Ashton-Miller.

Faulkner is the study's "experimental rabbit," according to Ashton-Miller. Whenever the exercise apparatus is modified or the protocol changes, Faulkner is the first person to try it out. He is now eagerly waiting for the arrival of the third generation training device. "I can't wait to get on it," he says.

It would be unrealistic to think that everyone in their 80s can match John Faulkner's level of fitness and activity. But U-M scientists emphasize that exercise, even simple walking, can help nearly everyone improve muscle strength. "Doing something is better than doing nothing," says Ashton-Miller.

Tomorrow, John Faulkner will continue to probe the mysteries of muscle. There will be new graduate students to train and more papers to write. This summer, he's flying to Scotland to attend a retirement party for an old friend and former running partner.

But for now, at the end of a chilly, spring day in Ann Arbor, Faulkner heads for the bike rack in front of the Biomedical Science Research Building. He slips on black gloves, zips up an electric blue windbreaker with black stripes, and fastens Velcro straps around his pant legs. Then he climbs on his 1981 Peugeot mountain bike and heads across campus on the first leg of the four-mile commute home.

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