The Science of Olympians

By David R. Bassett and Scott A. Conger

Once every four years, people come together from all nations to marvel at the incredible feats of some of the greatest athletes in the world. What is it that allows them to run, jump, and throw two to three times faster and farther than the average person? Is it good genes, or sheer hard training?

Some athletes, like USA cyclist Taylor Phinney, seem to have followed the suggestion of the Swedish physiologist Per Olaf Astrand, who once joked, “If you want to be a champion, then choose your parents wisely.” Phinney’s parents are cycling royalty. His mom, Connie Carpenter-Phinney, won a gold medal in the 1984 Summer Olympics in the women’s road race. His dad, Davis Phinney, was a bronze medalist in the 1984 Olympics and stage winner in the Tour de France.

However, it is not just genes that make an athlete; getting an early start in athletics also seems to benefit future Olympians. A study conducted at the 1976 Summer Games in Montreal found that most of the Olympians surveyed had at least one older sibling. The scientists speculated that trying to keep up with an older brother or sister helped them develop essential motor skills for sport.

Many physical traits of Olympians are evident even as they step onto the athletic stage. Athletes in the power events are taller and have bigger muscles and stronger skeletons, while those in the gravity sports are smaller in size with little body fat. But some of the traits that allow these athletes to achieve incredible things are invisible to the naked eye. Over the years, athletes have participated in research to uncover the secrets of their success, and this has led to new insights into the inner workings of the human body.

Athletes’ hearts are one of many factors that determine their success. Not only do Olympic athletes have enlarged hearts, but echocardiograph and MRI studies have shown that endurance athletes have hearts with larger chambers and normal wall thicknesses, while powerlifters and wrestlers have thicker walls in the heart chambers. The marathon runner’s heart is exposed to a volume overload due to the large volume of blood returning from the exercising muscles. The weightlifter’s heart is exposed to a pressure overload. Studies in which catheters have been place directly into the arteries of powerlifters during a deadlift have recorded pressures as high as 400/225 mmHg, which could cause a stroke in an average individual. However, the heart and blood vessels have a remarkable ability to adapt themselves to the rigorous demands of training and competition.

Olympic endurance athletes not only have high baseline aerobic power, but their bodies also respond well to training. The Heritage Family Study, which began in 1992 and is still ongoing, recruited 742 inactive adults and trained them in precisely the same manner to study variations in the training response. Surprisingly, some individuals did not respond at all to the standardized training load, while others had a 40 percent increase in aerobic fitness. Since the trainability of aerobic fitness ran in families, the authors concluded that genetic factors play a big role in the response to training.

Olympic power athletes show an increase in muscle size and anaerobic enzymes. To better withstand the stresses and strains of competition, the bones of Olympic athletes undergo remodeling. Weight lifters develop robust bones in their arms, vertebrae, and legs, whereas runners have increased bone strength only in their spine and legs. A 2009 study found that runners develop shin bones that are thicker on the front and back, whereas athletes in sports that require lots of quick directional changes have robust shin bones that are uniformly thickened all the way around.

Case Studies of Olympians

Peter Snell from New Zealand was once the world’s most dominant middle-distance runner. He won gold in the 800 meters in 1960 and in the 800 and 1500 meters in 1964, a feat that has rarely been repeated. Built more like a sprinter than a miler, Snell did not look like the typical middle-distance runner. Exercise physiologists at San Diego State University tested Snell in 1965 and found that he had a maximal oxygen uptake of 72 milliliters of oxygen per kilogram per minute. Oddly enough, his lungs failed to saturate his blood with oxygen during maximal exercise, which is usually a sign of pulmonary disease. Scientists were baffled until they figured out that his large athletic heart propelled the blood through the vessels in his lungs so quickly that there wasn’t enough time to saturate the red blood cells with oxygen. Even so, Snell’s aerobic power was great enough to keep pace with his rivals, and his powerful, muscular build allowed him to outsprint them at the finish. In the 1960 Rome Olympics, Snell defeated Roger Moens of Belgium by 0.07 seconds in the men’s 800-meter race (1 minute 46.48 seconds vs 1:46.45). This slender margin of victory is only a third of an eye blink, but it earned Snell a place in the pantheon of Olympic champions.

In 1975, twenty of the best long-distance runners in the world came together at the Institute for Aerobics Research in Dallas. Maximal treadmill tests revealed that their maximal oxygen uptakes were nearly twice as high as that of the average man. They had low levels of body fat and high proportions of slow twitch fibers. Steve Prefontaine had the highest maximal oxygen uptake of all the runners (84 milliliters of oxygen per kilogram per minute), while Frank Shorter had the lowest (71 milliliters of oxygen per kilogram per minute). However, Shorter was more economical than the others, requiring less oxygen to run at a given speed, and he was able to maintain a high percentage of his maximal oxygen uptake for extended periods of time. This allowed him to cruise to a first-place finish in the marathon in the 1972 Munich Olympics.

Prefontaine, the American record holder in several running events, was known for his finishing kick and could unleash a 54-second lap at the end of a race. A higher percentage of fast-twitch muscle fibers in his legs allowed him to excel at 5- and 10-kilometer races. At age twenty-one, Prefontaine gave it his all against a stellar field in the finals of the men's 5,000-meter race at the 1972 Munich Olympics, but came up just short of a medal, finishing fourth.

Mark Spitz, the nine-time Olympic champion in swimming and star of the 1972 Munich Olympics, was tested in the swim flume at the US Olympic Training Center. Similar to a swimmer's treadmill, this device uses a propeller or a pump to generate a current, allowing a swimmer to swim in place. In 1992, Spitz attempted a comeback from retirement at the age of forty. "I was tested in the flume in the United States at the Olympic Training Center, and based on the data that they had I had the most efficient stroke in the world ever tested, even to current athletes," he said in 1992.

The US swimmers going to Rio this August, like Michael Phelps and Ryan Lochte, are bigger, stronger, and faster than Spitz. Phelps stands six feet four inches, with an even longer arm span, and weighs 195 pounds. He has an unusually long torso and relatively short legs. "This allows me to plane in the water," says Phelps. Another competitive edge is his ability to hyperextend his knees, giving him a greater range of motion on his kick. Missy Franklin, at six feet two inches and 165 pounds, is bigger than Spitz was. She currently holds the world record in the 200-meter backstroke and will represent the USA in that event in Rio.

Colin Jackson, a Welsh sprinter and hurdler who was a silver medalist in the 1988 Seoul Olympics, set a world record of 12.91 seconds in the 110-meter high hurdles in 1993. In 2013, a BBC film crew followed him to the Ball State University Human Performance Laboratory in Muncie, Indiana. There scientists removed small samples of his thigh muscles so they could study them in the laboratory. "Man, that's a good bit of mincemeat there!" he exclaimed when shown the muscle samples. The results showed that three-quarters of Jackson's muscle fibers were of the fast-twitch variety, but the most surprising finding was that 25 percent of his fibers were super-fast twitch fibers, which are very rare. By performing analyses on single muscle fibers the width of a human hair, the researchers found that his super-fast twitch fibers were six times as powerful as regular fast-twitch fibers and twelve times more powerful than slow-twitch fibers. Thus, Jackson is well suited for explosive power. Since fiber type is determined mainly by genetics, Jackson's success is due, at least in part, to his parents. Said Jackson, "There's lots of issues that ultimately make you who you are. And I kind of ended up pretty lucky, didn't I? I had the right building blocks, I was placed (fortunately) in the right environment, and so ultimately, given the right opportunities, delivered the right performances."

The Ball State researchers also performed muscle biopsies on Jackson after he did a weight workout consisting of four sets of seven maximal squats with a two-minute rest between sets. After the workout, the gene that produces myostatin, a hormone that inhibits muscle growth, was suppressed. The FN14 gene that codes for muscle growth was turned on, increasing its expression by 500-fold in the super-fast twitch fibers. This world sprint champion is blessed with muscles that respond very well to a training stimulus.

Environmental Studies

On occasion, the Olympic Games have served as a laboratory for natural experiments. The 1968 Olympic Games in Mexico City, held at an elevation of 7,380 feet, posed a true environmental challenge. In Mexico City, the sprint running races were 1 to 3 percent faster than at the 1964 Olympic Games in Tokyo, 100 feet above sea level. This difference resulted from the decreased air resistance at altitude, and the fact that sprinters power their muscles with non-oxidative pathways in their muscles. However, due to the shortage of oxygen in Mexico City, the endurance runners were left gasping for breath, and their performances were 2 to 6 percent slower than in Tokyo. The exception was in the men's 1500-meter finals, when Kip Keino, a police officer from Kenya, ran three seconds faster than the gold medal winning time in Tokyo.

In that race, Keino defeated twenty-one-year-old Kansas runner Jim Ryun, the world record holder in the mile, who had been a favorite to win. One year before the Olympics, Ryun had been invited to Alamosa, Colorado, to train with Jack Daniels, a sport scientist and running coach. Ryun didn't realize how much of a difference altitude would make. He recalled, "At that time most people, myself included, thought it was mostly a psychological problem." Ryun's first mile time trial at altitude was run in 4 minutes 29 seconds, a full 38 seconds slower than his sea-level best. That was a wake-up call that he needed to do some serious altitude training prior to the Olympics. But in the end, Keino's lifetime exposure to Kenya's elevation (7,000 feet) was a factor in his win over Ryun, who had only a year of altitude training to prepare for the games.

The 1984 Olympics, held in Los Angeles, posed an extreme environmental challenge for athletes due to the hot conditions. In the first women's Olympic marathon, the fivefoot-two-inch, 100-pound American Joan Benoit pulled away from the pack at the 2.5-mile mark and went on to win in 2:24:52. Gabriela Anderson-Schiess from Switzerland was not so lucky; she succumbed to heat exhaustion and staggered around the track after entering the Olympic Stadium. The crowd gasped as she lost her sense of posture and her body seized up. The event sparked new interest in medical guidelines for hot weather marathons and treatment of heat illnesses. More importantly, the first women's Olympic marathon shattered myths and preconceptions about what women could accomplish in the field of athletics.

<u>New View of Aging</u>
In 2015, researchers from Denmark reported on a forty-year-old rower who increased his maximal oxygen uptake during the first five years of his career (up to 78 milliliters of oxygen per kilogram per minute), and then maintained it over a twenty-year period. During this time period, his maximal heart rate decreased from 182 to 162 beats per minute. But he made up for it with an increase in his oxygen pulse, which is an indicator of the volume of blood the heart can pump with each beat. Kent Bostick, an American track cyclist, is another case of successful aging: He earned an Olympic berth in 1996 at the age of forty-two. He recently completed a hundred-mile bike ride in 3 hours and 57 minutes at the age of sixty. Athletes like these are causing scientists to rethink conventional views on aging.

Spartan lifestyles and hard physical training may have health benefits for Olympians. In 2012, the *British Medical Journal* published the first large-scale study on the longevity of Olympic athletes. The authors examined more than fifteen thousand Olympians from nine country groups (United States, Germany, Nordic countries, Russia, United Kingdom, France, Italy, Canada, and Australia/New Zealand) who won medals between 1896 and 2010. They concluded that Olympic medalists live about three years longer than men and women in the general population. Medalists in endurance sports have a greater survival advantage than those in the power sports. It is not certain whether the increase in the medalists' longevity is the result of superior genetics, physical training, or an overall healthier lifestyle, but it is probably all three.

In addition to teaching us about the physiology of the human body, Olympic athletes can also teach us about the resilience of the human spirit. The history of the summer Olympics is filled with tales of underdogs who were given little chance to win but who achieved hard-fought victories. Billy Mills seized gold in the men's 10,000-meter race in the 1964 Tokyo Olympics, where he set a personal record by 50 seconds. Bob Beamon's "leap of the century" in Mexico City, where he broke the world long jump record by almost two feet, defies scientific explanation. Gymnast Kerri Strug was the last vaulter in the 1992 Olympics and needed a 9.6 for the team to win the gymnastics team all-around competition. She received a 9.1 on her first attempt and injured her ankle. Strug completed her second attempt by landing on one leg and got a 9.7 to clinch the team gold.

Only a small percentage of the Olympic athletes who compete in Rio de Janeiro will come away with a medal, but all of them will meet fellow competitors from around the world who will push them to perform at their best. In the words of the founder of the modern Olympic Games, Baron Pierre de Coubertain, “The important thing in life is not the triumph but the struggle; the essential thing is not to have conquered but to have fought well.”

David Bassett is professor and head of the Department of Kinesiology, Recreation, and Sport Studies at the University of Tennessee, Knoxville. Scott Conger is an assistant professor in the Department of Kinesiology at Boise State University. They have developed a course called Physiology of Athletes: Exploring the Limits of Human Performance.