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PUBLISHED
 08/28/15

LAST EDITED
 09/01/15

TERRY FOX

TERRY FOX'S PROSTHESIS

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Terry Fox and the Development of Running Prostheses

In 1980, Terry Fox ran 5,373 km during his Marathon of Hope, using a prosthesis designed primarily for walking. His accomplishment motivated researchers to develop prostheses better suited for running.



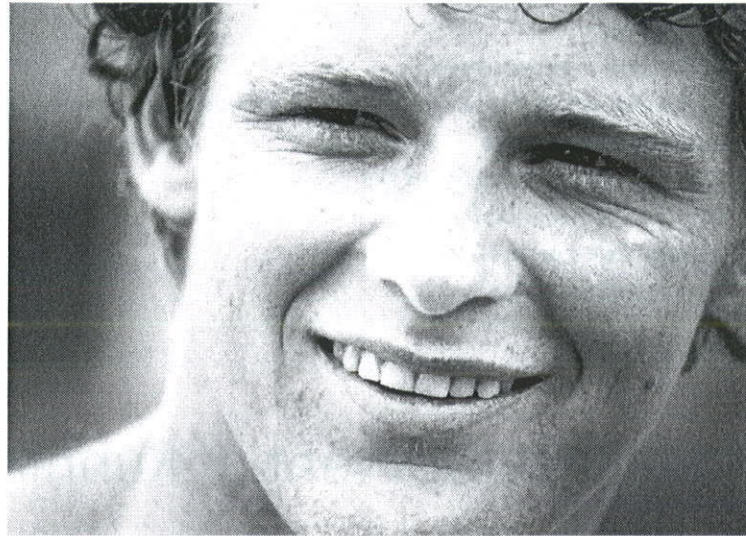
Terry Fox with Prime Minister Pierre Trudeau

Terry Fox met with Prime Minister Pierre Trudeau July 2, 1980. Terry demonstrates how his prosthetic leg works.

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In 1980, Terry Fox ran 5,373 km during his Marathon of Hope, a cross-country run dedicated to raising awareness and money for cancer research. Fox, whose right leg had been amputated in 1977, performed this incredible feat using a **prosthesis designed primarily for walking**. His accomplishment inspired Canadians across the country as well as amputees and para-athletes around the world. It also motivated researchers to develop prostheses better suited for running. Since 1980, developments in materials

manufacturing and computer/bionic technology have led to more comfortable, stable and responsive prostheses, both for recreational and elite athletes.



Terry Fox

Courtesy of Terry Fox Foundation.

TERRY FOX FOUNDATION

Terry Fox

In early March 1977, university student and athlete Terry Fox was diagnosed with osteogenic sarcoma (bone cancer) and told his right leg would have to be amputated above the knee. The night before his surgery, Fox's high school basketball coach gave him an article that would change his future. The article was about Dick Traum, the American amputee who, in 1976, became the first to run the New York Marathon with a prosthesis. Fox later said that Traum's story was the inspiration behind the Marathon of Hope.

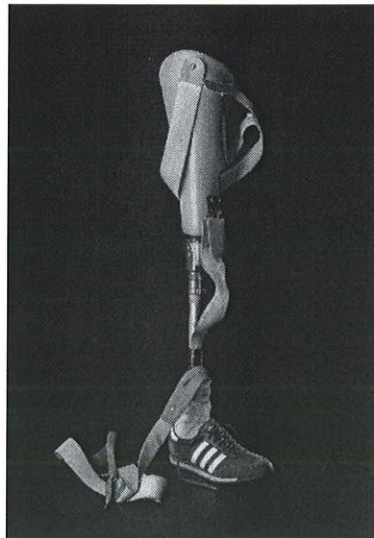
Fox's right leg was amputated 15 cm above the knee. Within weeks, the determined young man was walking. The following year, he joined Rick Hansen's wheelchair basketball team. But his dream of running across Canada remained.



Terry Fox's Prosthesis

In 1979, Terry Fox started marathon training, using a prosthetic leg made for walking. Prosthetic legs at the time were cumbersome and heavy, designed for walking, not running — a far cry from the lightweight, running-specific versions worn today by elite para-athletes.

In a sound leg, running involves the following actions: the quadriceps muscles (front of the thigh) move the leg forward, bending the hip and straightening the knee; the hamstrings (back of the thigh) then act as a brake to stop the swinging lower leg and straighten the hip; the knee is allowed to bend a bit to absorb the shock of the foot hitting the ground and the quadriceps straightens the leg again as the body moves over the foot; the hip muscles also help the quadriceps and hamstrings to move the leg. Calf muscles then contract to lift the body (heel) to allow the other leg to swing through and also help drive the body forward; like the quadriceps, they also help to absorb the impact of hitting the ground. For an above-knee amputee like Fox, the hip muscle had to perform the work that would otherwise have been done by the quadriceps and hamstrings. The artificial knee also had to stay straight in full extension while the leg was bearing weight or the leg would buckle.



Terry Fox's Prosthesis (1980)

The prosthesis worn by Terry Fox during the Marathon of Hope. (Courtesy of Canadian Museum of History, photo Steven Darby, IMG2015-0001-0015-Dm.)

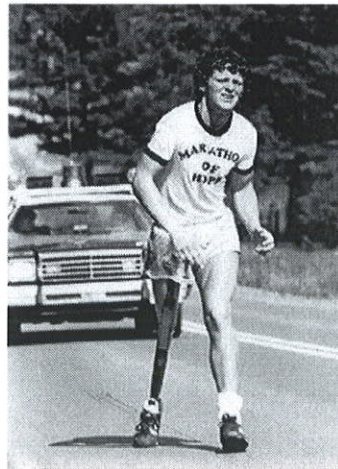
CANADIAN MUSEUM OF HISTORY

The prosthesis Fox used for the Marathon of Hope was designed by British Columbia prosthetist Ben Speicher. Speicher adapted the conventional walking prosthesis, using a steel knee joint that operated much like a hinge (the Otto Bock 3R17). The leg was attached by suction and a series of belts; an elastic strap

was added to help extend the leg forward. At about 4 kg, the prosthesis was heavy compared to the lightweight running prostheses used today.

One of the biggest problems for an amputee runner like Fox was that a conventional prosthesis was not designed to absorb the impact generated at heel strike by running. Runners can hit the ground with up to four times the force of their body weight—about two times the force compared to someone walking. That force is normally absorbed with knee flexion, and by the quadriceps and calf muscles. In an able-bodied runner, the foot also helps to absorb shock and return some energy to the body. Fox's prosthetic foot, which was made of wood and rubber, could not perform either function. Fox's prosthetic leg was not designed to absorb the impact of running. He and Speicher experimented with a pogo stick design, using a motorcycle shock absorber, but they didn't like the result and ended up abandoning it prior to the marathon.

Another problem facing Fox was something known as a slow "swing-through." Runners normally use their quadriceps to quickly propel their lower legs forward, before the heel strikes the ground. For an above-knee amputee, that task has to be performed by the hip muscles. With a conventional prosthesis, the swing time was slow and active knee flexion impossible. An amputee runner therefore had to wait for the leg to swing forward to full extension before weight could be applied, allowing him to vault over the straightened leg. Although Fox's prosthesis incorporated a strong elastic strap to speed up the swing-through phase, it was still very slow. This resulted in his "hop and skip" style of running—hopping on his sound leg while he waited for his prosthetic leg to swing through. This hop not only allowed time for the prosthesis to extend, but also helped cushion the blow to his residual limb in its rigid prosthetic socket. The technique was hard on the body, particularly on the hip joint of his sound left leg.



The Courage of Terry Fox

Although the prosthesis was uncomfortable, its simple design meant that it was relatively easy to repair. In July 1980, Frank Cicchillo, a master mechanic at Slessor Motors in Newmarket, Ontario, repaired Fox's leg using parts from the rear suspension of a 1978 Chevy Malibu. The following month, while Fox was running to Sault Ste. Marie, the spring broke; luckily, a welder was able to quickly repair it, and Fox continued his run.

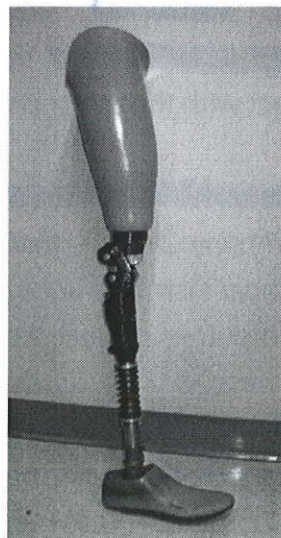
Sadly, it was not long before Fox was forced to abandon the Marathon of Hope. He retired from the run on 1 September 1980 near Thunder Bay after the cancer returned, this time in his lungs. He died the following year, on 28 June 1981.

Research Inspiration — the Terry Fox Running Prosthesis

Terry Fox's cross-country run inspired millions of Canadians, across all walks of life. This included researchers. In July 1980, while Fox was running through Ontario, The War Amputations of Canada asked Guy Martel, head of the prosthetics and orthotics department at Chedoke-McMaster Hospital (Hamilton), to meet with Fox to review his prosthetic needs. During their discussion on 14 July, Fox told Martel about his prosthetic variations, including the trial with prosthetist Ben Speicher of a spring-loaded mechanism. He repeatedly expressed frustration that he could not run better with his current prosthesis.

Unfortunately, Fox died before Martel could develop a better running prosthesis. However, in February 1982, Martel and his team received a \$17,000 research grant from The War Amps of Canada to build an improved running prosthesis. The research team (Martel, Hubert de Bruin, head of biomedical engineering, and mechanical technologist Edwin Iler) eventually developed and tested a lighter leg which used a commercial carbon graphite polycentric-axis knee joint, a standard foot, an improved version of Terry's failed spring-loaded mechanism and a pneumatic shock absorber. The spring shaft compressed upon heel strike, reducing the impact to the residual limb. The heel-strike compression also shortened the leg slightly, lowering the runner's centre of gravity. At toe-off, the compressed spring released its stored energy, which helped propel the prosthesis and the runner forward. The improvements would have made it easier for Fox to run, and would have eliminated the need for the hop-skip style of running that he used.

In May 1984, the Terry Fox Inspired Running Prosthesis was unveiled at The Warm Amps Child Amputee Program (CHAMP) Seminar in Burlington, Ontario.



Terry Fox Running Prosthesis 1984

The Terry Fox Running Prosthesis was developed by a research team at Chedoke-McMaster Hospital from 1982 to 1984. The prosthesis was inspired by Terry Fox and funded by the War Amps of Canada. (Courtesy of Hubert

de Bruin.)
HUBERT DE BRUIN

Modern Prostheses

Lower-limb prostheses have improved significantly since 1980, owing in large part to the availability of carbon fibre composite materials. These materials, which had originally been developed for the aerospace industry, have allowed engineers to create prostheses that are lighter, stronger and more durable. Developments in computer-aided technology have also improved control and responsiveness of prosthetic knees.

Since the 1980s, companies such as Össur and Ottobock have continued to develop prosthetic feet and knees for amputees who want to remain active. In 1997, Ottobock — the German-based company that developed the knee joint used by Fox — released the C-Leg, the first knee to include a microprocessor-controlled hydraulic knee joint. Icelandic-based company Össur has also developed microprocessor knees — in 2004, it launched the Rheo Knee, which uses artificial intelligence and magnetic fluid to adapt to changes in the user's gait as well as changes in the environment.

Since then, microprocessor-aided prosthetic technology has developed significantly. For example, the current versions of the C-Leg (the C-Leg 4) and the Rheo (Rheo 3) use gyroscope sensors to better understand user intent and provide improved stability and safety. Össur also produces the Symbionic Leg — the world's first commercially available bionic knee and ankle system — and the Power Knee, the first device to provide powered lift, thus replacing normal muscle function.

Running-Specific Prostheses

In 1984, American inventor Van Phillips developed the Flex-Foot, a prosthetic foot that would revolutionize running for amputees. The Flex-Foot brand of foot and lower-limb prostheses are lightweight (made of carbon graphite) and store kinetic energy, much like a spring. That energy is released at toe-off, helping to propel the runner forward. Now known commonly as "blades," the feet also help absorb the shock of impact, and improve knee stability upon contact with the ground.

The Flex-Foot was first used in elite competition at the 1988 Paralympic Games. Since then, variations of the Flex-Foot — now made by Icelandic-based company Össur — have been used by most elite runners. For example, controversial South African runner Oscar Pistorius, known by many as "Blade Runner," used the Flex-Foot Cheetah. Trans-tibial (below-knee) amputees benefit particularly from this technology.

While the Cheetah is designed for short-distance runners, the company also produces the Flex-Run Foot for longer distances. In 2005, American Sarah Reinertsen became the first female amputee to complete the Ironman triathlon, using Össur's Flex-Run Foot combined with the Total Knee 2100. Canadian runner Rick Ball, who became the first single-leg amputee to run a marathon in under three hours, wears a similar system.



Sarah Reinertsen

Sarah Reinertsen uses an Össur prosthesis when running. She was the first female amputee to complete the Ironman triathlon. Courtesy Jason Adams, Össur Canada.

As of 2015, the only running prostheses specifically designed for above-knee amputees is the Ottobock 3S80 Fitness Prosthesis, while Össur is preparing to launch a line of knee joints specific to different running distances.

If Terry Fox were running today, he would likely use either the Ottobock 3S80 or Össur's Total Knee 2100 in combination with the Flex-Run prosthetic foot. In comparison, the modern prosthetics are vastly superior in terms of socket fit, responsiveness and stability. They are also significantly lighter: whereas Fox's leg weighed around 4 kg, a running prosthesis using Ottobock's 3S80 weighs around 2 kg.

Impact and Availability

Advances in prosthetic technology have allowed more people with disabilities to remain active; they have also significantly enhanced the performance of elite para-athletes. In 2015, for example, new world records were set in the 100m women's sprint in both the T42 (single above-knee amputation) and the T43 (double below-knee amputation) categories. Yet running prostheses are expensive, costing tens of thousands of dollars. Like other types of assistive technology, their high cost raises concerns about availability, particularly for athletes from developing countries. (See Paralympic Games: Technological Innovation).

Advantage Controversy

When Terry Fox was running his Marathon of Hope in 1980, no one would have argued that his prosthetic leg gave him an advantage over able-bodied athletes. In the 21st century, however, there is a lively debate about the advantages of modern running prostheses for athletes with lower-limb amputations, compared to able-bodied athletes.

In 2007, the International Association of Athletics Federations (IAAF) ruled that double-amputee Oscar Pistorius could not compete in able-bodied competitions, because his prosthetic “blades” gave him an unfair advantage. However, the decision was overturned — Pistorius won a silver medal as part of the 4 X 400m relay team at the 2011 World Championships in Athletics, and competed in the 400m dash and the 4 X 400m relay at the 2012 Olympic Summer Games.

The concern about Pistorius was that his two Flex-Foot Cheetah prostheses gave him an unfair advantage (including energy return and shorter swing-through times). Although the debate continues about the potential advantages of modern prostheses, particularly for double amputees, the case for single-leg amputees is clearer: as single-leg amputees must synchronize the stride velocity of their prosthetic and sound legs, they can only run as fast as their slowest limb.

In the end, the accomplishments of Terry Fox, Steve Fonyo and Rick Ball (like those of other para-athletes) are due primarily to sheer determination and inner, as well as outer, strength.



Terry Fox Running

Terry Fox in northern Ontario on August 13, 1980 during his marathon cross-country run to raise money for cancer research.

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Acknowledgments

Our thanks to Geoffrey Hall (Custom Prosthetic Services), Jason Adams (Össur Canada) and Mark Agro (President, Ottobock Canada) for their advice and assistance.