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Physics pushes peak performance

In light of the recent Olympic and upcoming Paralympic Summer Games in Paris, we take a closer look at the physics of sports and how it helps athletes improve their performance.

When preparing for highly competitive sports events, such as the Olympic or Paralympic Games, athletes also turn to physics to optimize their training and performance. A prime example that highlights three key ingredients for maximizing success in sports — movement, equipment, technique — is boccia, one of the two Paralympic disciplines without an Olympic counterpart. The goal in boccia is to bring a ball as closely as possible to a white ball, which is thrown first. Depending on the class of the match, athletes in wheelchairs play the ball with their hands or feet (pictured) and compete with or without assistance from either a dedicated sports assistant or a selection of different tools.

The study of movement alone already involves many physical aspects at different scales, including the molecular motors that drive muscle contraction, the dynamic properties of muscles and the role of elasticity when throwing at high velocities. An article recently published in *Nature Physics* discusses the potential role of hydraulic effects in the dynamics of contracting muscle fibres. Its authors report a multiscale model that describes muscle as an active fluid-filled sponge and show that active hydraulics limit the rate of spontaneous muscle contractions[1].

Inspired by the performance of unshod endurance runners, a comparative study between barefoot runners and shod runners highlighted differences in how the foot lands on the ground. For example, there is a smaller collision force and thus reduced impact-related injury risk when habitually running without shoes[2]. Modelling makes it possible to estimate how the properties of shoes affect running performance, which might help identify their optimal materials[3].

Both materials science and engineering play a major role in sports. For example, the right pair of shoes, highly optimized prosthetic devices or racing wheelchairs can enhance a runner's abilities in Olympic or Paralympic track events. At the 2023 Berlin Marathon, the winner of the women's division undercut the previous record by over two minutes while wearing a brand new racing shoe model, which refuelled the debate on the role of high-tech equipment in sports. After the 2008 Olympic Games, a full-body swimsuit was determined to have provided an unfair advantage to its wearers because it added buoyancy in the water while reducing drag; this model and other variants were thus banned in 2010.

One of the most recently introduced disciplines at the Olympic Games is skateboarding, and here, too, materials make a difference to performance. Wood is a great material for decks owing to its ability to reduce impact, and today's polyurethane wheels have a better grip and are more durable than the wheels of early boards, which were fabricated from steel or clay. As Daryl Chrzan put it, "materials science […] saved skateboarding from being a fad." One of the most iconic tricks, the 900, which involves two and a half turns in mid-air, seems to defy the laws of gravity. But it doesn't: when starting the spin, the skater makes themselves smaller and angular momentum conservation then allows them to spin faster and complete more turns before gravity takes over.

When watching the Olympic and Paralympic discipline track cycling, the sight of the athletes' bikes moving up the steepening velodrome's wall with increasing speed while continuing to tilt might give spectators the impression that the athletes are not subject to the laws of physics. But it all comes down to the centripetal force keeping the cyclists on the track. Understanding the forces, energy and work at play can improve techniqe and thus performance and also prevent injuries.

A basic understanding of these physical concepts is helpful for amateurs, but professional athletes can draw from studies with more complexity. For example, measurements of the flows around mannequins revealed the role of drag in track cycling[4], and mathematical modelling predicted the optimal pacing strategy for coming in first[5]. Beyond speed-focused sports, modelling could potentially be used to put together routines, for example, in the Olympic acrobatic or artistic gymnastics competitions, to make the best use of the athlete's abilities.

The principles of physics underlying certain moves have given the athletes performing them an almost unbeatable advantage. In badminton, the recently introduced spin serve, where the player adds spin to the shuttlecock, has been banned until the end of the Paris Summer Paralympic Games. Like other illegal serves, this move is nearly impossible to return.

Another example of a hard-to-beat move stems from American football (admittedly not an Olympic discipline). In the Philadelphia Eagles' signature move, the tush push, the quarterback is pushed over a yard or less, often across the goal line to score. The National Football League has considered banning this particular play, but this will not be the case for the 2024 season. Neil deGrasse Tyson has explained why it is almost always successful.

Physics, and other scientific disciplines, can give athletes the edge they need to succeed.

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