A Little Extra Weight Goes a Long Way FREE

Steven K. Blau

Physics Today **56** (1), 15 (2003);
https://doi.org/10.1063/1.1554125

A Little Extra Weight Goes a Long Way

Some form of the long jump was featured in the ancient Olympics after it was introduced in 708 BC as part of the pentathlon. But as vase paintings such as the one shown in the top photograph attest, there was an intriguing difference between the way ancient athletes performed their jumps and the way modern ones do: Ancient Olympians took off holding halteres, or jumping weights. The weights, made of stone or lead, improved the jumpers' performance.

One key to understanding that improvement is the relation between the jumpers' feet and center of mass. Before the takeoff, an athlete holds the halteres extended backward, then swings them forward. At takeoff, the jumper's arms are extended up and out, and so the center of mass of a weighted jumper is further forward and higher than it would be without halteres. As the jumper prepares to land, the halteres are swung down and backward so that, on landing, the feet of the weighted jumper are more forward of the center of mass than they are for modern, unweighted athletes. Because the initial position and velocity of the center of mass determine its subsequent trajectory, halteres improve the jump distance, provided that their extra weight does not excessively diminish the takeoff speed.

BRITISH MUSEUM

ALBERTO E. MINETTI

ALBERTO E. MINETTI

Now, Alberto Minetti and Luca Ardigó of Manchester Metropolitan University in England have analyzed the effect of loading athletes with jumping weights. Assuming an unchanged takeoff speed, they estimated that carrying a 3-kg weight in each hand would allow an athlete to enjoy a 6% increase in jump distance. They also explored, both with human subjects and computer simulations, how halteres do affect takeoff speed.[1]

Minetti and Ardigó asked subjects to jump vertically, with and without halteres. The posture and muscle action associated with a vertical jump are very similar to those of a standing long jump, but jumping vertically is a more familiar skill, and one easier to coordinate with swinging weights. Thus, vertical jumps were more practical to test than the horizontal sort. They were also easier to simulate on a computer.

The Manchester experiment determined that takeoff speed actually increased by 5–7% when jumpers were loaded with halteres weighing from 2 to 9 kg each. That mass range corresponds well with the range of archaeological specimens, three of which are pictured above. Within the 2–9 kg range, the speed was essentially constant, given experimental uncertainties. The greater takeoff speed achieved by loaded jumpers led to increases in distances beyond those generated by using the halteres to shift the position of the feet relative to the center of mass.

As Minetti explains it, halteres can lead to an increased takeoff speed because moderately loaded muscles exert greater force than unloaded muscles, while still contracting at reasonable rates. Thus, loaded muscles can generate increased power.

Minetti and Ardigó's experimental results were generally consistent with the results of their computer simulation. In their model, a jumper was built from a shank, a thigh, a trunk, and an elbowless arm. Joints at the knee and shoulder were able to generate torques. The model included physiological measurements relating muscle forces to contraction distances and speeds, and relating joint torques to angular displacements and speeds. When holding a pair of 3-kg halteres, the virtual jumper increased takeoff speed by 2%. Minetti and Ardigó suggest that the simplicity of the model, in particular its lack of elastic structures such as tendons and ligaments, could be responsible for the discrepancies between simulation and experiment.

Few details are known about how jumping events in the ancient Olympiads were conducted or judged, according to David Gilman Romano of the University of Pennsylvania's department of classical studies and Museum of Archaeology and Anthropology. Written testimonies stipulate that the foot had to land "properly," and that the halteres were an aid to proper landing. But it is not known if there was a penalty for slipping backward, or for allowing the halteres to touch the ground. Some historians have argued that Olympic athletes could throw the halteres backward before landing, further increasing their jump distance. Some vase paintings indicate that ancient Olympic long jumps commenced from a standing position. Others, though, show athletes taking off on one foot. The depictions of one-footed takeoffs and accounts of better than 50-foot jumps suggest to some scholars that athletes got a running start and that the ancient Olympic long jump was akin to the modern triple jump. Given the nearly 1200-year span of the ancient Olympic games, it could be that the long jump was run differently in various Olympiads. The ancient Greeks, unfortunately, did not leave us definitive rulebooks.

Steven K. Blau

Reference

1. A. E. Minetti, L. P. Ardigó, *Nature* **420**, 141 (2002).