Thinking about Biomechanics

LEVERS: FROM CROWBARS TO BONES

This is the fifth article in a regular series in which Steve Stanley of Siliconcoach explores various aspects of biomechanics.

Have you ever stood around the barbeque staring at the steak cooking over the open flames and wondered if muscles basically just pull, how do we move around and why we aren't lumps of twitching steaks ourselves.

With the barbeque season approaching I am anticipating a lot people will be thinking about this, so I thought I would shed some light on the topic. I will cover bones and their role as internal levers and also cover tools humans use as external levers, some of which humans have been using with varying degrees of success for hundreds of thousands of years.

A lever is a simple mechanical system that enables us to maximize our human limitations; made up of an *axis of rotation, a resistance* and an *applied force*.

You can arrange these components to increase your speed and range of motion capabilities, or use a different arrangement to increase your force generation capabilities. However, as with most things in nature, there is always a trade-off. For example, if you use levers to increase your speed and range of motion, you decrease your ability to increase force, and vice versa.

There are three classes of levers as outlined below. Once you understand this classification system you will begin to understand the relationship between the fulcrum (axis), the resistance and the applied force. With this understanding, you can then start to use levers to your advantage.

First Class

The axis is between the applied force (F) and the resistance (R).

If the force arm (distance from the force to the axis) is longer than the resistance arm then the system favours force output (e.g. a crowbar).

If the force arm is shorter than the resistance arm then the system favours speed and range of motion (e.g. a catapult).

Second Class

Both the applied force (F) and the resistance (R) are on the same side of the axis (fulcrum).

The applied force is further from the axis than the resistance.

A second class favours force output at the expense of speed and range of motion. A wheel barrow is a good example of a second class lever.

Third Class

Both the applied force (F) and the resistance (R) are on the same side of the axis (fulcrum).

The applied force closer to the axis than the resistance.

A third class favours speed and range of motion at the expense of force output. The elbow flexors and joint is a good example of a third class lever.

Note: It does not matter if the 'F' or 'R' arrows are above or below the lever, it is their direction and where they attach that is important.

How are levers used to increase performance? Let's look at your internal levers first. Once you have stopped growing, your bones are pretty much fixed in length. Similarly, with your muscle insertion points, the distance from the insertion point to the joint axis (a lever) is genetically determined. Before you've finished growing, these lever lengths as well as your muscle strength are changing, but not at the same rate. These changes put increased demands on your motor control system as it attempts to learn and coordinate movements in a constantly evolving system. The result can be periods of coordination difficulties during the growing phase.

Rather than looking at just one bone (lever) in isolation, let's look at a series of internal levers linked like a chain; the arm for example. With linked levers, you can change the position of the levers to optimise for either speed or force. Think about lifting a heavy weight, you position your levers so the object in your hands is close to your body, you can't move it very fast but you *can* move it. Opposite to this is throwing a ball. Here the object in your hand isn't heavy so you can position your levers so the object in your hand is further away from your body. Now you can move it at a much greater speed through a much greater range.

When it comes to external levers there is a bit more flexibility because you can design tools for specific needs. For example, implements you hold in your hands that increase release speed such as a club, a racquet and a bat. These implements extend the distance from the axis of rotation (usually your body) to the ball thereby amplifying the speed you can generate using just the hand. The trade off is you need more control as the errors are also amplified.

Crowbars are implements that increase your force generation capabilities as the fulcrum is very close to the heavy object we want to move. With the crowbar, to get a very small movement in the end under the object, you have to move the free end of the crowbar a long way.

Cyclists use levers to make the most efficient use of their limited power. If the focus is on the front chain rings of the bike, the crank length distance (from the bottom bracket to the pedal) is fixed; however, the distance from the bottom bracket to the outer edges if chain rings are not. Here, the cyclist can choose between a shorter lever (small gear) to one or two bigger levers (large gear).

In summary, although your internal levers (bones and muscle attachments) are pretty much fixed in length, you can position a series of levers (body segments) in positions that either increase the overall effective lever arm to advantage speed and range of motion; or arrange the levers close to the central axis to advantage strength. You can use equipment to increase your effective lever length, but you must be strong and skilled enough to generate the extra forces required and to minimise positional errors that are magnified with an external lever.

Bibliography

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