The Physics of Catchers' Knees

by David Kagan

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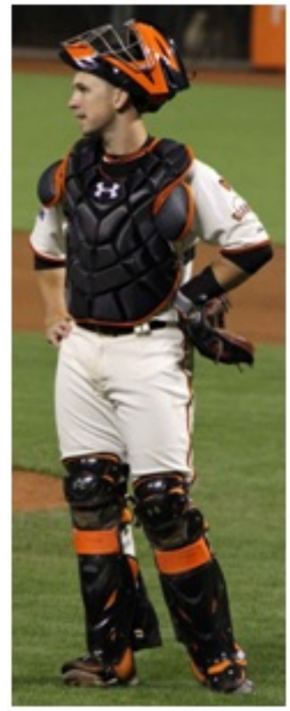
The knee is a complex marvel. (via Alan Turkus)

> "To be a catcher is sort of like being a cowboy, without the romance of the Old West. It's hard, dirty and often dangerous work. And old catchers, like old cowboys, tend to walk a little more gingerly than the rest of us."
>
> — Dan Rather

Deep knee bends for a second or two ten times every evening is probably good for you. However, crouching behind the plate for five to ten seconds about one hundred and fifty times a night can't be healthy.

If we are going to examine this from the perspective of physics, we need to realize that when you are at rest, your knees exert an upward force on the rest of your body to counter the weight of everything above them.

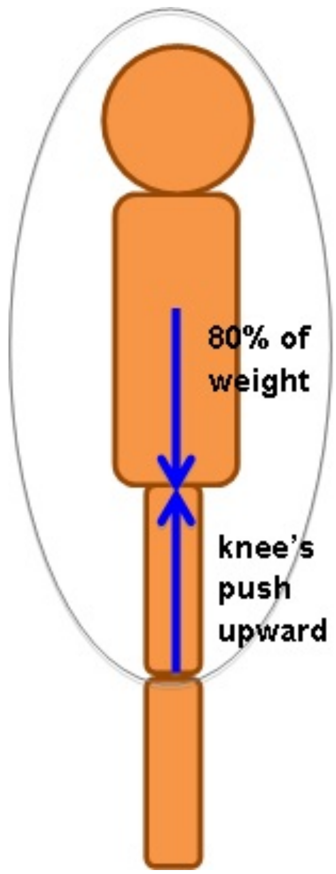
When **Buster Posey** stands up trying to understand why nobody covered third base, his knees support about 80 percent of his weight. So each knee supports about 90 lbs. Remarkably, this also is true when Posey is crouched behind the plate. When he is down waiting for the pitch, something has to keep the upper portion of his body from collapsing into the dirt. What else could it be but his knees?



(via Kimberly Koch)

Initially then, it might seem that catching shouldn't be any more troublesome for the knees than standing. Since that is clearly not the case, we need to investigate more deeply.

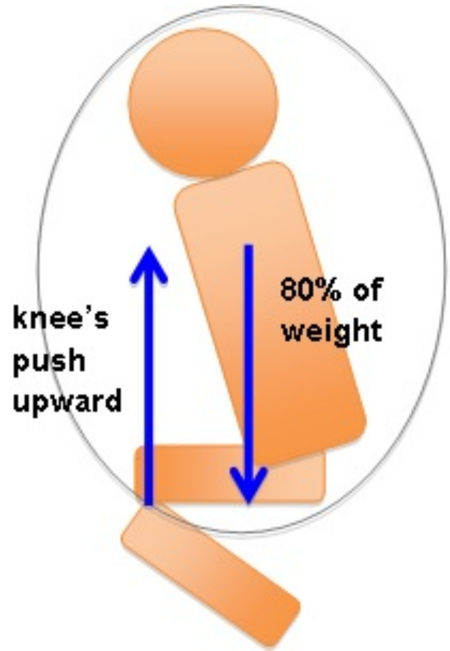
Let's be sure we understand this from the point of view of physics. The first step is to remove all features of the catcher–including his All-Star status–and focus only on a caricature of his body as shown in the figure.



His upper body is isolated by the gray oval. The forces acting on the upper body are 80 percent of his weight pulling down and the knees pushing up. Since the catcher is at rest, at least for the moment, these forces must cancel out. That is, they are the same size, about 180 lbs.

Now, let's look at the situation when the catcher is-–as **Mike Krukow** likes to say–"in the squuuaaaat." The sketch again uses a gray oval to isolate the upper portion of the body. Again the two forces acting are 80 percent of his weight downward and the knees pushing upward. So again, these two forces must be equal when the catcher is at rest.

However, there is a distinct difference between the two situations. When Posey is standing, his weight is directly above his knees. When he is catching, most of his weight is behind his knees. If fact, his weight is concentrated directly above his feet so he doesn't tip.

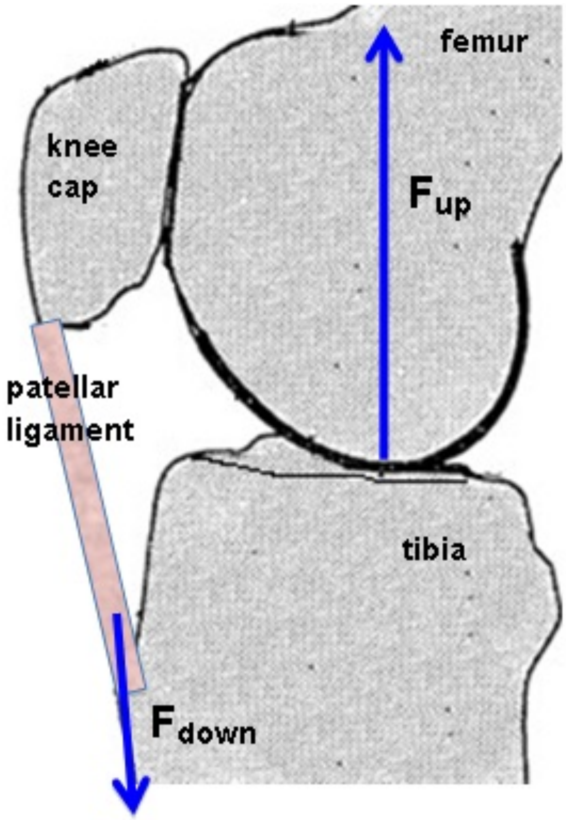


Another way to think about it in the standing case is, the force exerted by the knees is directly in line with the weight of the upper body. In the crouch, the forces are equal but not aligned.

Engineers call two equal but non-aligned forces a "couple." I've often wondered if this is due to the poor quality of the relationships engineers have with their spouses. Anyway, the key point is, couples create rotations.

Try it yourself with that pencil in front of you. Exert equal but oppositely directed forces on opposite ends. Rotation! Wait a second. The pencil rotates but Buster remains still as he goes through the signs.

Exactly! The total force exerted by the knees must equal 80 percent of the weight, but there must be a combination of forces in each knee to insure that upper body doesn't rotate. We need to look more carefully at the knee joint.



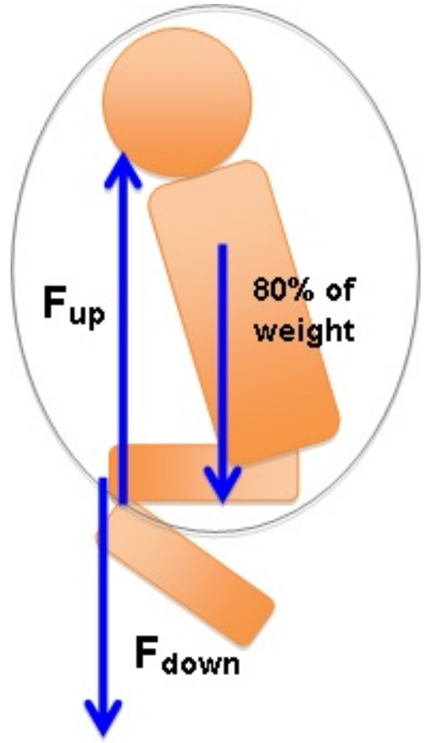
The knee joint is an amazingly complex collection of ligaments, tendons, cartilage, and several other words I don't really understand. One of the best descriptions I have found **was on YouTube**. That's the beauty of physics. I can say something about what's going on without understanding very much…I don't think that came out quite right.

Anyway, back to the details of the knee joint. I trust if I mess anything up too badly our readers with expertise here will help clear things up.

The sketch shows the knee slightly bent. While there are probably many forces exerted by all the various parts of the knee acting on the upper portion of the body, the primary two are shown.

The upward force is due to the bigger bone in the lower leg (tibia) pushing upward on the big bone in the upper leg (femur). The downward force is the tibia pulling down on a ligament (patellar ligament), which wraps over the kneecap (patella) and pulls on the femur.

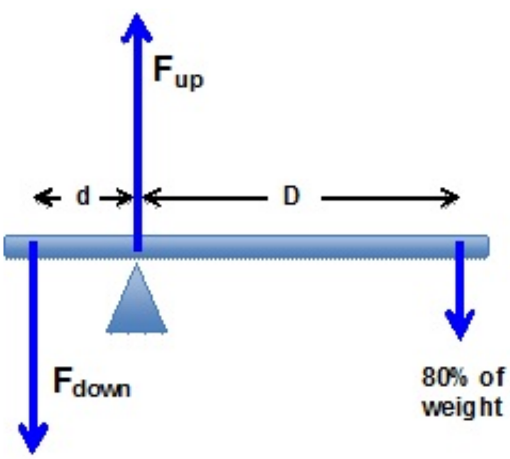
Now that all the jargon is over, the three forces on the upper part of the body are shown in the sketch. These forces must balance so that Buster doesn't move up or down, and they must keep him from tipping over, as well.



You can think of these forces as forming a see-saw. The upward force is the one at the center about which the see-saw pivots. The downward force is the heavy kid who needs to be near the pivot to balance the lighter kid that is further away. This lighter kid in this analogy is the 80 percent of the weight.

Look what's happened now! The upward force must be much bigger than 80 percent of the weight because it must also balance out the downward force.

How much bigger? Let's look at the see-saw.



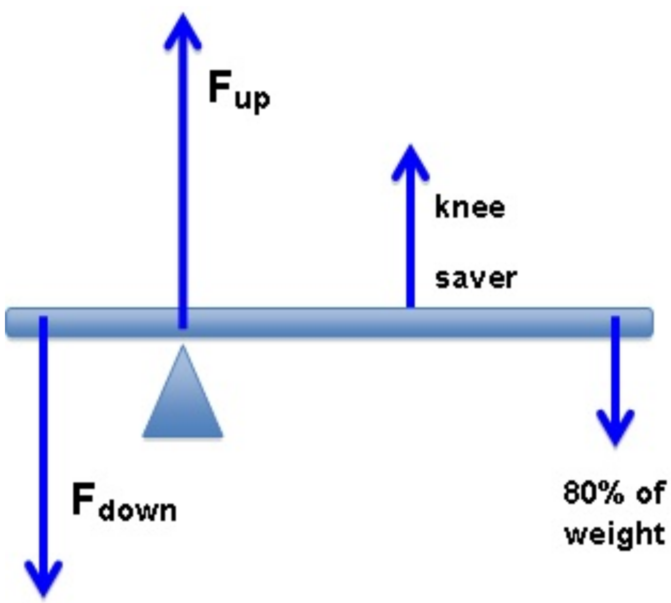
In physics we call it the "Law of Levers," but it might as well be the "Law of See-Saws." The rule is that the product of the distance and the force on one side must equal the product of distance and force on the other. So,

> d Fdown = D (80 percent of the weight).

Looking at my own scrawny legs, I would guess that d is about an inch and D is around six inches. The math gives a downward force of around 1080 lbs. (540 lbs. each) for Mr. Posey. Since the upward force is the sum of the downward force and 80 percent of the weight, the force that Buster's tibia is pushing against his femur has gone up from a measly 180 lbs. when standing to about 1260 lbs. (630 lbs. for each knee) in the squat.

Fortunately, there is some padding between the tibia and the femur called the "meniscus." You might have heard that word before in reference to knee injuries. The meniscus must be able to withstand the 1260 lbs. of compression force. In addition, it must deal with the friction caused by the rotation of the femur across the tibia each time Buster goes into or out of his squat.

The beating inflicted upon the meniscus and other pieces of soft tissue in the knee is substantial. Hence the invention of "Knee Savers"–you know, those triangular pads attached to the back of the lower legs that prudent catchers wear.



Since we now understand how the forces work in a see-saw, we can add the upward force on the upper body from the Knee Saver as shown above. There are many ways to think about how this additional force reduces the upward force the tibia exerts on the femur, reducing the pressure on the meniscus.

You can think about the force from the Knee Saver canceling part of the weight of the upper body, thereby reducing the size of the downward force and, as a result, the upward force.

Another way to think about the Knee Saver force is that it supplies additional counter-clockwise rotation on the see-saw, reducing the need for the counter-clockwise rotation from the downward force, thus reducing the downward force and thereby reducing the upward force, as well.

Finally, you could just look at the Knee Saver force as providing some of the upward force so the upward force at the knee can now be smaller. No matter how you look at it, the Knee Saver is appropriately named, as it reduces pressure on the meniscus.

Returning to the cowboy theme, **Johnny Bench** summarized the lot of a catcher by saying, "A catcher and his body are like the outlaw and his horse. He's got to ride that nag till it drops."

References & Resources

- Thanks to Chris McSharry for his thoughtful comments on the anatomy of the knee.
- In addition, Melissa Mache got me started on this article with a helpful conversation.

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