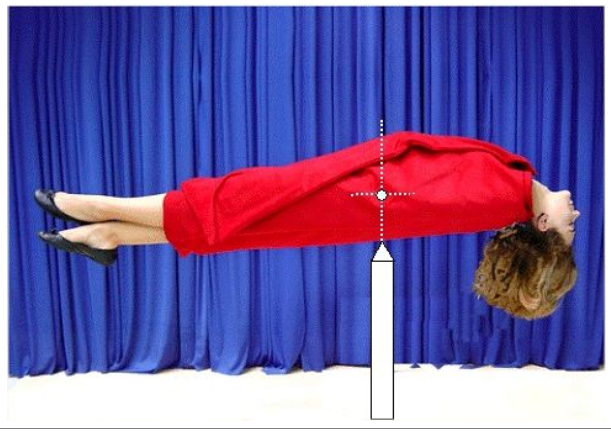
12.3.2 Center of Mass

For starters test yourself if you know the meaning of "**center of mass**" (***COM***), also known as "**center of gravity**". Where would you look for your personal center of mass? And how? I'll tell you how you could do it. It's not easy, though You need to exercise a lot so you can perfectly stiffen your body. You should be able to do this:

First step in determining your center of mass
Here you can see how it could be done

- If you do it as shown above, you will actually feek a torque working on your stiff body that invariably would rotate you and bring your lower end down. You need some magic to counter its effects. Your friendly neighborhood magician might be able to help you here. But to make life easier, I allow you to abandon magic and to use a second chair right under your feet.
  Stay rigid and now have a column with a pointed tip put right under your body somewhere in the middle. If you put the tip right below your center of mass you will not tilt in one way or the other if the chairs are removed and you can rest in peace until the beer gets too warm. The vertical line from the tip through your body runs through your center of mass.
  This may take some practicing and possibly some drugs to keep you stiff



Second step in determining your center of mass

- In a third step you do the experiment sideways, rotating 90^{o}. The line from the tip through your body runs through your center of mass once more, and your center of mass is where the lines from the two experiments intersect inside your body.

This can be a fun thing to do as long as it's not *your* center of mass your buddies try to find. Finding the center of mass of your (straight) sword or any longish straight object that is not too heavy can be done in a much easier way, though. Rest the object on a finger of your left and right hand, starting on the outside. Move your fingers together, easily sliding along the object. The center of mass is right between your two fingers when they eventually meet.
This is shown below

Finding the center of mass of a straight sword

- Easy enough. Whichever way you pick, the result is always the same: If an object is held right at its center of mass (or exactly below it), it does not *rotate*. It just stays in place without any movement.
  No movement means there is no *net* force, and no rotation means there is no *net* torque.

The crucial word is *net*

We most definitely have forces in the pictures above! The legs are pulled down by gravity, and so is the head and just about everything else. We also have torques. The weight of the head times the distance to the lever point provides for a substantial torque; same for the feet and so on.
However, if we add all the forces and torques, including the force that the tip exerts upwards on the body, the *net* result is exactly zero in both cases.

- Of course there is a strict physical / mathematical definition of what constitutes a center of mass and how you calculate it - consult the science module if you want to know. Here we focus on the essentials. All you need to know is:

1. If an object has some symmetry (like your typical straight double-edged sword, where the left half is the mirror image of the right half), the center of mass will be in the symmetry plane (in the middle of the blade)
2. For a straight sword, the center of mass is closer to the heavier end. Sort of trivial, but:
3. For a curved sword, the center of mass might be *outside* the sword. Below is a case where it is exactly at the edge. Change the mass distribution a bit (e.g. by taking off the hand guard at the hilt) and the center of mass is outside the blade.

A tegha (kind of oversized tulwar) resting on the rubber end of a pencil

4. If you drop your sword, the center of mass will move down towards the earth (you knew that). The sword will not rotate if their is no friction (supplying forces). Since the air does supply some friction, some rotation might take place but we forget about that here.
5. If you want to produce specific motion patterns of your sword, i.e. make the center of mass move in a certain way *and* make the sword rotate, for example doing what that Samurai does, you can ask a physicist to calculate the force and torques you need to apply with your hands. She will tell you that this would be a very complicated job to do and suggest to do something easier and more fun instead.

Now you can begin to see the problem I'm facing here. Most people can make all kinds of fancy movements with a sword, a tennis racket or a hockey stick without any problems whatsoever. And they never waste a single thought on the complex physics involved! They just do it. Your muscles produce movements of major parts of you plus rotations in your wrists, elbows and shoulders in am exceedingly complex pattern of forces and torques. Unbelievably difficult to calculate (or simulate; our present day robots would not yet make great sword fighters).
How am I supposed to teach you just the basics of what is involved? Without equations? You would need vector calculus if not tensor algebra to deal with this stuff, so it would be hopeless anyway. So why bother?

- Because there are limits of what your body / brain combination can do in the "auto" mode. And your "natural" reaction on how to hit something with the longish object you are wielding in order to achieve some desired effect (score a goal in hockey, send your tennis opponent into a remote corner, check your enemy...) might not be the best way to "swing".
  Getting to know the limits and finding out the best ways for swinging your stick necessitates to look into the physics, unfortunately. And that, as remarked before, is not something easily done.