Weight vs. Mass

There is often confusion about the terms ‘weight’ and ‘mass’. This is a short description of these two terms.

Weight is a force. It is the amount of pulling force that gravity exerts on an object. What is really interesting is that the amount of force acting on an object causes that object to accelerate at -9.8 m/s/s if that is the only force acting on the object. Since weight is a force, it has units of Newtons (SI units). However, most of us are more used to units of ‘pounds’ or ‘lbs’ because we all step on a scale and see ‘weight’ in ‘lbs.’

The equation for weight looks like this:

$F_{Weight} = mg$

Where ‘g’ is -9.8 m/s/s and represents the acceleration due to the force of gravity and ‘m’ represents the object’s mass (in kg). This equation actually gives us some insight in that the force of gravity is a negative force (since ‘g’ is negative). But, word on the street, we always talk about ‘weight’ being positive. Let’s continue to explore this.

Mass is a measure of an object’s inertia. Inertia is a mechanical term used to describe an object’s resistance to change motion. That means that the more inertia an object has, the harder it is to get going (from a stopped position) and the harder it is to stop the object from moving. We already know this … can you imagine kicking a soccer ball vs. kicking a bowling ball?! Of course we would not kick a bowling ball … it has too much inertia (too much resistance to change motion) and it would take too much force to change the motion (and the foot would likely be injured!).

To determine the mass of the object, we would simply take the object’s weight and divide by the acceleration due to the force of gravity. The equation looks like this: $m = F_{Weight}/g$. But we see a problem here that this gives a negative value for mass if we use -9.8 m/s/s for ‘g’.

How do we measure weight? We put the object on a scale. Mathematically, when an object is on a scale (see the picture below), we have two forces acting on the object: 1) Gravity pulling down and 2) the ground pushing up (we call that the Ground Reaction Force). For this discussion of weight vs. mass, I’ll refer to this force as F_{scale}. Since the object is not moving, velocity is 0 m/s and is constant. Therefore, acceleration is zero ($a = \Delta v/\Delta t$). Knowing that, we can now apply Newton’s 2nd Law ($\Sigma F = ma$):

$\Sigma F = ma$

$F_{scale} + (-F_{Gravity}) = ma$

Since acceleration of the person is zero (i.e., the person is not moving), then a = 0 m/s/s

$F_{GRF} + (-F_{scale}) = 0$ N

$F_{GRF} = F_{scale}$

So, in order to figure out how much force gravity is acting on an object, we 'weigh' it because the reaction force will equal the force of gravity when the object is not accelerating. When we do this, we say 'weight' is positive (e.g., someone weighs 180 lbs) … but, technically, we are talking about the Ground Reaction Force (vs. the Force of gravity pulling on the object).

Remember, the force of gravity is 'negative' (since it is pulling down on the object) and the acceleration due to the force of gravity is also negative. Therefore, mass is calculated as $m = F_{Gravity}/g$ … and now when we use -9.8 m/s/s for 'g', the equation yields a positive value for 'm'.

It is important to remember that weight is a negative force representing the force due to gravity acting on the person. When we factor 'gravity' in our equations, we use a negative force. But in everyday language, when we talk about how much an object weighs, we do not specify the direction of the force.

Back to mass … it is clearly related to weight of the object in that the more weight an object has, the more mass it has. That is a good concept to hold on to … but it is important to know that mass of an object is the same regardless of the force of gravity. That is, an object on earth will have a specific weight but that same object on the moon will weigh less. That is because the force of gravity on the moon is less than that on earth. Gravitational force is a function of the mass of two objects and how far apart they are from each other. In this example, the two objects would be the person standing on the earth (person, earth) vs. the person standing on the moon (person, moon). Since the earth has more mass than the moon, the force due to gravity on the earth is greater than the force due to gravity on the moon. However (and this is really important) the mass of the person is the same on earth or the moon.

Some of the confusion between weight and mass comes from the scales we use. Most of the scales will give units as either 'lbs' or 'kg' … which gives us the sense these are both units for force. This kg and lbs are not the same units. However, since the force of gravity and the acceleration due to the force of gravity are both constant, the mass of the object will be directly proportional to the weight … that means converting between lbs and kg is really easy. However, as a Biomechanist, it is important to talk about weight as a force (in N or lbs) and mass (in kg) as a measure of inertia.

The units of mass that we will use are 'kilograms' or 'kg'. This works when we use Newtons as the units of force. If we use 'pounds' for force units, then we end up having a different set of units for mass … the 'slug'. That can get a bit confusing … so we will always use 'Newtons' for force, 'kg' for mass.

If we have a measure of weight in pounds, we can convert to Newtons by multiplying the number by 4.4 (i.e., there are 4.4 Newtons for every lb).