Significant forces can be placed on the body through the act of manual material handling. These forces can be of a level that will lead to sprains, strains, and other types of back problems. Lifting loads as light as 30 lbs. from floor level can lead to forces on the base of the spine (L5/S1 disk) that are associated with an increased risk of injury. Loads of 100 lbs. lifted at floor level can give rise to compressive forces at the L5/S1 disk that are on the order of 1,500 lbs. It’s no surprise that three-quarters of a ton of pressure on the disks in the low back can give rise to an eight-fold increase in the risk of back pain!

The purpose of this document is to introduce you to the concept of biomechanics and explain how the application of biomechanical principles can reduce the risk of injury in your workplace.

**THE BODY AS A MECHANICAL SYSTEM**

The bones of the body can be thought of as levers acted upon by the muscles in order to move the body or move objects. We apply the principles of physics to determine how much strength is required by the muscles and how much force acts on the joints. As an example, let’s consider the force required by the biceps, the muscle in the upper arm, in order to lift a 10 lb. load in the hand. Figure 1, Biomechanics of the Elbow, depicts the load in the hand, the forearm, and the bicep muscles.

The load in the hand tends to rotate the forearm downward, as does the weight of the forearm. In physics terms, the load in the hands is said to create a “moment” about the elbow joint. The moment is calculated by multiplying the weight by the “moment arm”, which is the distance between the elbow joint and the load in the hands. In order for the forearm to at least stay stationary, the moments rotating the forearms down (the weight in the hand and the weight of the forearm) have to be exactly balanced by the moment rotating the forearm up, which is created by the contraction of the biceps muscle. For a 10 lb. weight in the hands, the biceps have to create approximately 80 lbs. The eight-fold factor between the load in the hands and the force required by the biceps is due to the fact that the biceps act on the forearm much closer to the elbow joint and, therefore, has a much shorter moment arm than does the load in the hand.
The same principles can be applied in order to calculate the strength required about all the joints in the body and the compressive force acting on the L5/S1 disk.

The L5/S1 disk is of particular interest to us for two reasons. First, this is the site of a large percentage of the injuries related to manual handling. Second, and not coincidentally, the forces acting on the L5/S1 disk are not the highest of all the areas of the spine, since this area is the farthest way from the load in the hands. Stated in biomechanical terms, in general, the moment arm is the largest for the L5/S1 disk.

As with the biceps, tremendous force requirement is on the muscles of the low back are developed by seemingly moderate loads in the hands. For instance, a 10 lb. load in the hands can give rise to a low back muscle force requirement of 623 lbs.

The muscles of the low back compress the disk between the L5 and S1 vertebra, as do the weight of the torso and the weight of the load in the hands. It is not uncommon for the compression on the disk due to these factors to be ten to fifteen times the weight of the load in the hands. As an example, a biomechanical evaluation of the task of lifting 100 lbs. in the posture shown in Figure 2, Stoop Lift - Far, indicates that the compressive force on the L5/S1 disk is 1,521 lbs. for an average-size male. Previous research indicates that the risk of low back pain increases three-fold for tasks where the L5/S1 compressive force is greater than 1,000 lbs. The risk increases eight-fold for tasks where the compressive force is greater than 1,500 lbs.

**DESIGN IMPLICATIONS**

There is a number of basic design and work practice guidelines that can be understood from a new perspective if we consider the biomechanical implications.

**Keep the Load Close**

We have all heard that the safest way to lift is to keep the load close to the body. There is a very good reason for this if we consider the biomechanics. Keeping the load close to the body reduces the moment arm between the load and the L5/S1 disc. Using our example of lifting 100 lbs., the compressive force drops from 1,521 to 1,251 lbs. by just bringing the load closer (see Figure 3, Stoop Lift – Close). This decreases the risk injury from eight-fold to three-fold.
**Keep the Torso Upright**

We have also heard that we should keep the torso as upright as possible when lifting. In part, this causes us to keep the load in closer to the body, but it has another very important biomechanical impact. By keeping the torso upright, we reduce the moment arm to the center of gravity of the torso. Since the torso weighs approximately 100 lbs. in a typical male, minimizing the moment arm can have a significant impact on the force required in the muscles of the low back and the compression on the L5/S1 disk. If we could bring the 100 lb. load close to the body by keeping the torso upright (see Figure 4, Squat Lift), the compressive force is reduced from 1,521 to 799 lbs.

The analysis also reveals that the limiting factor for being able to do the task is strength about the knees rather than the back. This is not surprising in that people do not have adequate quadricep strength to be able to lift from this posture. These results emphasize the importance of good general fitness as well as proper training in lifting technique.

**Avoid Lifting at Floor Level**

Lifting at floor level creates two problems. First, it is difficult to keep the load close to the body. Therefore, we tend to have a long moment arm to the load. Second, it is difficult to keep the torso upright when lifting at floor level, so we tend to have a long moment arm to the center of gravity of the torso. By lifting at knuckle height, for instance, we can keep the moment arms to the load and the center of gravity of the torso much smaller (see Figure 5, Erect Lift). With our 100 lb. load at knuckle height, the compressive force falls from 1,521 lbs. to 337 lbs. This compressive force is well below the 1,000 lb. threshold associated with a three-fold increase in risk of injury.

**Minimize the Weight of the Load**

The weight of the load has a major impact on the compressive forces acting on the L5/S1 disk. We mentioned earlier that there can be a ten-to-fifteen-fold multiplier effect between the load in the hands of the compressive force acting on the L5/S1 joint. Obviously, if we can reduce the load in the hands, we will reduce the compressive force in the low back. For instance, if we reduce the load in the hands from 100 lbs. to 10 lbs. and keep the same posture as shown in Figure 2, the compressive force drops to 623 lbs.
The weight in the hands, though, may be of minor importance if we are in a full-stoop posture. In such a case, the weight of the torso times its moment arm can be enough by itself to cause injury to the low back. This is why it is possible to injure oneself while picking up something as light as a piece of paper, if it is done with a poor technique. When a biomechanical analysis is performed for lifting 10 lbs. in the posture shown in Figure 4, the compressive force drops from 623 lbs. to 347 lbs. Once again, the quadricep strength is the limiting factor. If the 10-lb. load is lifted at knuckle height as shown in Figure 5, the compressive force drops 98 lbs.

**SUMMARY**

Biomechanical evaluation of the tasks in your workplace may allow you to identify situations that have a high risk of injury. This type of evaluation will also allow you to evaluate design or work practice alternatives in order to identify an effective solution before investing in the change. Bringing the load close, keeping the torso erect, lifting near knuckle height, and reducing the magnitude of the load are all examples of changes that will help reduce the risk of injury.