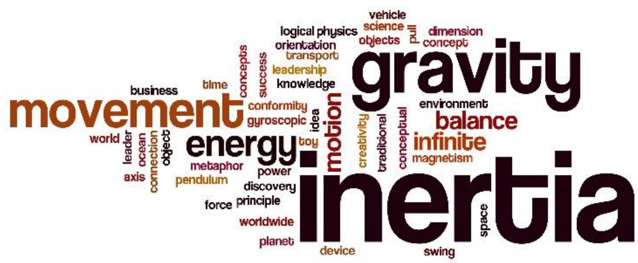
WHY DOES THE TYPE OF RESISTANCE MATTER?

> "All motion is governed by the laws of physics, independent of the exercise being performed or the exercise being used, however the degree to which the governance affects the associated kinetics, kinematics (force, power, velocity, acceleration, etc.) and muscle activity is dependent on the resistance type" – Dr. David Frost

In order to comprehend the mechanical differences between Keiser's Pneumatic Resistance and a mass-based resistance (free weights, weight stacks, the human body, etc.) we have to travel back to elementary science class and investigate some of the basic laws of physics. Each type of resistance has specific inherent qualities based on the mechanical laws of physics and it is these qualities that influence the specific adaptations expected from different types of resistance training.

The Role of Inertia

First, we must understand what inertia is and what challenges it presents to resistance training. Inertia is a property of matter outlined in Newton's First Law of Motion, otherwise known as the Law of Inertia. Inertia is simply the tendency of a body to resist movement unless acted upon by an unbalanced force.



Inertia is different from the gravitational force that pulls an object down to earth. The measure of the force created by gravitational pull on a mass is its weight. When we step on a scale or place an object on a scale, we are measuring the gravitational force created by an object in pounds or kilograms.

The effects of inertia can be observed by witnessing the resistance to movement of a large object suspended in the air. The act of suspending the object overcomes the gravitational force created by the earth's gravitational pull, subsequently reducing the weight of the object to zero. If you walked up to a suspended car and tried to push or pull it, the resistance to movement is attributed to the object's inertia. The more mass an object has, the higher its inertia and, subsequently, the harder it is to move. All mediums used to create force via mass are said to be high inertia and governed by Newton's First Law of Motion.

Keiser Pneumatic Resistance is said to be low inertia because only the piston and linkage system are governed by Newton's First Law. The resistive forces employed by Keiser's Pneumatics are generated by exploiting the potential energy of compressed air. A small 2½ inch diameter pneumatic cylinder can produce over 500 pounds of force, but with only 3 pounds of actual moving weight. It is only that 3 pounds that are subjected to Newton's Laws of Motion. This is the secret to the very pure, very consistent, and very controllable resistance of Keiser's Pneumatic Technology.

Mass-Based Resistances = High Inertia

Pneumatic-Based Resistances = Low Inertia

A Pound Is Not Always a Pound

Sir Isaac Newton proved that a pound is not always a pound. When looking at a gravitational resistance (whether in the form of a barbell, dumbbell, or a weight stack) one assumes it represents a particular weight. It does, but only when it is at rest or moving at a constant speed (no acceleration). Once in motion, the changes in speed of movement cause this weight to change. Sir Isaac Newton demonstrated this in his Second Law of Motion, The Law of Acceleration. This law states that the changing force is proportional to the mass or weight one is lifting multiplied by the acceleration (rate of change of speed). The faster you try to accelerate a mass, the more force is required to move the object. Everyone is familiar with this formula for Force:

Force = Mass x Acceleration

It can be much easier to comprehend this concept by utilizing this formula:

Force = Mass x Gravity + Mass x Acceleration

The "mass x gravity" segment represents the force created by the gravitational pull of the object to the earth, while the "mass x acceleration" segment represents the acceleration of the object. Regardless of the movement velocity, the "mass x gravity" stays constant, while any desired increase in acceleration will elicit a greater force that is proportional to the mass or weight lifted.

The Force and Muscle Activation Killer – Momentum

Momentum plays a critical role when discussing a gravitational-based resistance. Momentum is simply the product of mass and velocity.

Momentum = Mass x Velocity

You need to move to have momentum. If two objects are travelling with the same velocity, the object with the larger mass will have greater momentum.

Mass-Based Resistance = Great Momentum

Pneumatic Resistance = Trivial Momentum

When using a massed-based resistance, momentum builds as the object accelerates. A key concept to remember is that an object with momentum is harder to stop and an object with higher mass will be even harder to stop because of greater momentum. This is the reason that trains can take miles to come to a full stop. An additional consequence of momentum is its direct correlation to a reduction in force application and muscle activation.

Collateral Damage to the Human Body

Now that we know a pound is not always a pound, we need to investigate how this phenomenon affects the human body. For this, we go right back to Sir Isaac Newton. Newton's Third Law of Motion, The Law of Reaction, states that for every action there is an equal and opposite reaction. More specifically, in every interaction, the magnitude of the forces on the first object equals the magnitude of the forces on the second object. Additionally, the direction of the force on the first object is opposite to the direction of the force on the second object. Regardless of the numerical weight associated with a resistance, the shock loads that are placed on the human body are the actual forces generated to overcome the impeding resistance.

When you initiate a movement using Keiser Pneumatics you are only loaded with the forces associated with the numeric resistance. When you initiate a movement with a mass-based resistance you are shock-loaded with both the numerical forces associated with the object and the additional inertial forces needed to accelerate the load. The initiation of the majority of movements happen during the transition from the eccentric to concentric phases where our joints and soft tissue are most susceptible to injury. This notion is magnified in certain exercises like the back squat, where you have shock forces in addition to shearing forces placed on the knee joint.

Let us now look at an actual demonstration to compare the different inherent qualities of a mass-based and pneumatic-based resistance.

THE FOLLOWING GRAPHS DEPICT DATA FROM AN ACTUAL DEMONSTRATION

To illustrate the difference between a mass-based resistance and a pneumatic resistance, a special machine was built with two independent exercise arms contacting the user's lower legs. One connected to a weight stack while the other to Keiser's Pneumatics. The machine was designed so that the two systems provide the same variable resistance curve utilizing a four second concentric phase and a four second eccentric phase. Force sensors, attached to each pad in contact with the user's legs, provide data to a computer. The computer then graphs the exact force being applied to the legs by each system as the user extends his or her legs throughout the range of motion.

FIGURE 1

This graph shows a four second concentric phase and four second eccentric phase. The gold line shows the force the weight stack is producing and the red line shows the force the pneumatic cylinder is producing. At this speed, the two resistances are producing almost identical forces due to almost no acceleration. Using the Force = Mass x Gravity and Mass x Acceleration formula for the mass-based resistance, the force curve is very similar due to acceleration being virtually zero at a four second rep. The variable resistance curve also holds true for both systems.

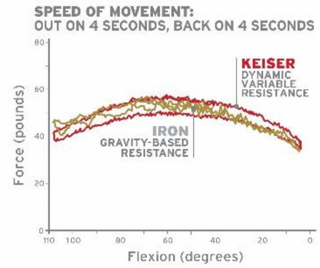


FIGURE 2

The graph depicts what begins to happen as the training speed is increased to a two second concentric phase and two second eccentric phase. There is a slight increase in force for the weight stack at the beginning to get the weight moving, and a slight drop off towards full extension as the momentum tends to carry the weight. The Keiser forces do not appear to change. The systems seem very similar at this speed. This increase in force at the beginning of the concentric phase is related to the increase in acceleration needed to complete a two second rep. The variable resistance curve holds true for both resistances, although the mass-based resistance is slightly deformed.

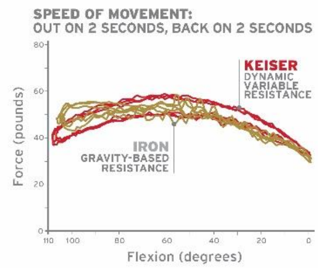


FIGURE 3

This graph shows a more dramatic change when the training speeds are increased to a one second concentric phase and one second eccentric phase. Note the 70% increase in resistance with the weight stack during the beginning of the exercise, by just going one second faster. Unfortunately, these high spikes in resistance most often come at a point in the range of motion that can result in the greatest harm to joints and connective tissue. As the reps get faster, more force is needed to accelerate the mass. The variable resistance force curve completely breaks down with a one second repetition.

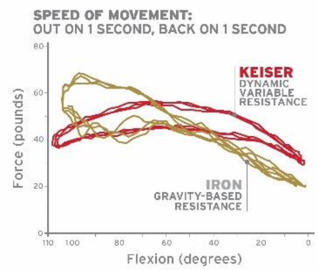


FIGURE 4

As you can see in this graph, the mass-based resistance significantly spikes when the speed is increased to a half second concentric phase and half second eccentric phase. This velocity results in a near doubling of force at the beginning of the concentric phase and near zero resistance at full extension. This data highlights Newton's Laws of Motion. As the leg begins to extend in the first part of the stroke, more force is required to accelerate the weight stack to the desired speed. Momentum then takes over and in the last half of the positive stroke the resistance drops as the weight stack slows to a stop. As the leg nears the starting position, a greater force must be exerted to slow or decelerate the weight to a stop. The faster the speed of movement, the greater the acceleration and force. Throughout these changes in training speed, you can see the resistance provided by Keiser's Pneumatic Technology remains consistent, opening up an array of training options not possible with traditional, mass-based resistances. In short, Keiser is very hard on muscle and very easy on joints and connective tissue.