Hydraulic

by J. Stephen Guffey, PT

Therapeutic exercise in its many forms has long been a mainstay of physical therapy. Physical therapists are exercise specialists in that we apply various forms of therapeutic exercise for patient rehabilitation. Resistive exercise is one important form of therapeutic exercise.

Historically, we have used three major forms of resistive exercise: isometric, isotonic, and isokinetic. Each type of resistance can lead to facilitation of motor units and, therefore, to gains in force production, but the training effects obtained using each method vary. This variance does not represent particular weaknesses of any of the resistances, but rather illustrates the fact that they are different. Each has specific purposes and uses. Each resistance is excellent in its place but is not the answer to all patient problems. Our job is to select the resistance that will suit the given set of circumstances.

A fourth major type of resistance, based on a hydraulic system, recently has become available to physical therapists. This type of resistance has been relatively underused, perhaps because of the lack of a clear definition of its clinical applications.

The purpose of this article is to bring hydraulic resistance into perspective and to suggest clinical situations and types of dysfunctions that may respond positively to hydraulic resistance. With the necessary information and explanations, clinicians can continue to make the appropriate choice of resistance type for patients. Hydraulic resistance then will find its place as an additional method to treat musculoskeletal and neuromuscular dysfunction.

Muscle contraction and resistance

All four types of resistance are unique and different, but they also possess common ground. No matter what type of resistance is used, the strength of the contraction is based on certain factors: 1) the initial length of muscle fibers, 2) the metabolic condition of those fibers, 3) the number of recruited fibers, and 4) the type of fibers recruited.

The velocity of the muscle contraction is based on how many actomyosin complexes must be formed to move the load and which fiber type is used. If the load is small, then the contraction is rapid; if the load is great, then the contraction is slower. Velocity and force are inversely related. This is true for all patients. We must, however, remember that all patients recruit at different speeds. The composition of fiber types that each patient possesses is genetically determined. Therefore, the type of resistance we use in the rehabilitation of a patient must be specific to the dysfunction *and* to the patient.

Isometric resistance

The amount of iosmetric resistance is always equal to or greater than the amount of force generated. The result is a muscle contraction but no apparent joint-angle excursion. Theoretically, the full force of a muscle contraction can be obtained with isometric resistance. This force is only achieved, however, at one point in the range of motion if maximal effort is made by the patient.

There are several clinical advantages inherent to isometric resistance: 1) it is easy to apply and readily available, 2) it is very inexpensive, 3) it is reasonably easy for the patient to understand, and 4) it has been proven to increase strength. There are also some disadvantages: 1) it can strengthen only one point in the range, 2) there is no specificity of training, and 3) it can result in excessive joint shearing/compressive forces.

Isometrics is used routinely in the clinic. It has proven helpful in resolving edema, assisting in tissue-lengthening efforts, and facilitating rapid strength and tone gains. Isometrics is especially useful postoperatively in patients with restricted ranges and in patients with acute injuries where joint movement might exacerbate the injury. The disadvantages of isometrics can be minimized when the clinician applies the resistance in the appropriate situation.

Isotonic resistance

The amount of isotonic resistance is less than the amount of force generated, and, therefore, joint-angle excursion occurs. The limb moves through some or all of the available range. The resistance value stays the same from a static standpoint, but this is not a static event. Consequently, the patient does not experience the same resistance throughout the range because of the mechanical changes of the joint and soft tissue.

The advantages of isotonic resistance include: 1) it is easy to apply, 2) it has been proven to effect strength gains, 3) the patient understands "lifting weights," and 4) it can be fairly inexpensive.

Resistance

The clinical limitations include: 1) there is no accommodation of resistance throughout the range; 2) the resistance amount is based on the weakest point in the range (only the weakest point is maximally overloaded); 3) substitution is very likely, defeating the purpose; 4) it can be dangerous with the unstable joint; 5) selecting the proper resistance is a trial-and-error process; 6) there is loss of specificity for most activity; and 7) muscle soreness may occur due to the eccentric component.

Isokinetic resistance

Isokinetic resistance is electromechanical in nature. Theoretically, the amount of this resistance is equal to the amount of force generated at any point in the range. A preset velocity is chosen, and, as long as the patient maintains this velocity and contracts with maximum effort, maximum overload is obtained.

The advantages of this resistance are multiple, but perhaps the most important from a clinical standpoint is that the patient who experiences pain can eliminate resistance by stopping his or her effort against the resistance. The patient will not reach the preset velocity and, therefore, will not encounter any resistance.

Although isokinetic resistance is regarded by many clinicians as being the "ultimate" in resistance exercise, it does have its limitations. The basic definition of isokinetic resistance is incorrect. It is impossible for the resistance to be equal to the force generated. This is the definition of *isometric* resistance. Angular motion occurs during the bout of isokinetic resistance exercise.

The equipment is said to accommodate the force generated by the patient, but the velocity of the contraction is preset. It appears that the patient adjusts to the machine and not vice versa.

Isokinetic resistance does not take into account acceleration and deceleration. One of the basic concepts of training and rehabilitations is specificity. Normal human movement is a series of accelerations and decelerations, which does not occur with a preset resistance.

With resistive exercise, the goal is to provide maximum overload. The overload obtained with this resistance is only maximum for the speed selected and the fiber type employed.

The point of commencement of isokinetic resistance is questionable. As the patient accelerates his limb to attain the preset speed of the resistance, he meets with a static lever arm that is set to travel at one speed. The accelerating limb is abruptly halted. The patient can proceed no more rapidly than the velocity set by the operator. This abrupt halt of acceleration is the definition of an *isometric moment*.

Isokinetic resistance does not consider fatigue in any constructive fashion. When the patient can no longer maintain the preset velocity, he loses resistance.

Despite these shortcomings, thousands of patients have been treated with isokinetic resistance with success. The testing and rehabilitation protocols used are well established. The resistance is accommodating throughout most of the range. And in the hands of a skilled clinician, some inferences can be drawn as to the type of pathology present when the device is used for testing. Isokinetics has a place in the rehabilitation of musculoskeletal dysfunction. It is not, however, the answer for all situations.

Hydraulic resistance

Hydraulic resistance is created by manipulating the size of an aperture in a fluid-filled hydraulic cylinder. The fluid in the cylinder is forced through the aperture as the patient moves a lever arm by virtue of a muscular contraction against the lever arm. There is no preset speed. The resistance is simply a product of how rapidly and forcefully the patient can move the fluid through the aperture by exerting force against the lever arm. The speed (and, therefore, the resistance) can be varied by changing the size of the aperture, but the speed and resistance remain specific to the patient and not to the machine, no matter what the aperture size may be. The amount of torque generated and the speed at which it is generated will be different for every patient at any resistance setting chosen. Hydraulic resistance is patient specific.

The resistance is totally accommodating throughout the full range of motion. If the patient ceases to exert force, he or she has no load to handle eccentrically. Maximum overload can be obtained at any speed. As long as maximum effort is given, the patient does not lose overload. Fatigue cannot eliminate resistance.

As with the aforementioned resistances, hydraulic resistance has its place in the treatment of musculoskeletal and neuromuscular disorders. Because of its unique biomechanical design, hydraulic resistance may avoid some of the limitations of the other types of resistance.

Normal human movement

Human movement is a sum result of acceleration and deceleration. When we rehabilitate patients, we must design treatment accordingly. Anyone who has treated patients with orthopedic dysfunctions has experienced the problem of patients who do well in a controlled clinical setting, only to return later from the "real world" with resumed symptoms. Our patients do not live and work in controlled clinical settings. Hydraulic resistance allows the patient to meet the stressor at the same velocity as he or she meets it in the world. That is, hydraulic resistance considers acceleration and deceleration—normal human movement. Patients exercise at their own speed, not at the machine's speed. They therefore generate the amount of resistance that they are capable of handling. No guesswork is involved. This is the definition of one of the most basic and important concepts of training—specificity.

Isometric moment eliminated

Those who rehabilitate patients with knee pathology are probably aware of the discussion concerning shearing forces at the knee during isokinetic exercise. Many therapists feel that patients with anterior-glide instability are at risk using isokinetic exercise. If the earlier "acceleration to preset speed" arguments are accepted, then it becomes easy to see the translatory forces placed on the joint at the isometric moments inherent to isokinetic resistance. Because hydraulic resistance does not involve any preset speed that must be attained, the likelihood of isometric moment is greatly decreased.

Fatigue

The patient in the average clinic has lost strength and endurance and fatigues rather quickly. If we use isometrics, we do little to enhance endurance throughout the range of motion. If we use isotonics, we risk substitution (which would decrease the effectiveness of the treatment), injury and muscle soreness caused by eccentric contractions, and the possibility of injury as the patient fatigues and can no longer handle the load. If we use isokinetics, we train only those fibers used to maintain the preset speed.

With hydraulic resistance, every resistance setting is an endurance setting. As the patient fatigues, the resistance decreases because no speed was preset. We have set the stage for total-fiber rehabilitation. The resistance will accommodate the elite athlete who fatigues slowly or the deconditioned patient who fatigues rapidly.

Fluid dynamics

Human joints operate on a fluid principle (synovial fluid). Changing viscosities of that fluid help to regulate the speed and timing of the joint angular motion. Hydraulic resistance uses a similar principle. An electromechanical system cannot be expected to give the smooth, even resistance afforded from a fluid system.

Patients with low performance

It is not unusual for a sedentary patient to have difficulty keeping pace with the preset speeds of isokinetics. We are then left with the slower speeds only, and no training of faster contractions can be performed. This cuts down on the effectiveness and specificity of training. Often we resort to isotonics in these cases. We then must deal with the shortcomings of isotonic resistance. With hydraulic resistance, the patient can exercise with maximal overload at whatever speed he or she can sustain. He or she is not required to keep pace with a machine.

Learning

Some patients may have difficulty learning the concepts of isokinetic resistance. The isolated joint movements are foreign, and the effort of keeping pace with the device requires training. In the work we have done with hydraulic resistance, patients have had no difficulty in understanding their task and performing it accurately.

Patients with neurological involvement

Patients with an upper motor neuron lesion will follow a certain pattern with regard to tone. When confronted with a quick or "phasic" stretch to the muscle fiber, the tone will increase to abnormally high levels. A more sustained or "tonic" stretch tends to reduce or normalize tone.

With isometric resistance, this tonic stretch can be achieved at only one point in the range. With isotonic resistance, the changing biomechanical advantages throughout the range result in many phasic stretches. With isokinetics, the abrupt halt of normal acceleration results in a phasic stretch. Furthermore, most neurologically involved patients cannot attain or sustain the preset speeds of isokinetic resistance.

Hydraulic resistance remains tonic throughout the range. There is no preset speed to attain. There is no abrupt halt of acceleration. The changes in biomechanical advantages are accommodated.

Using our resistance choices

No form of resistance will meet the needs of every patient. This is why we have several types of resistances from which to choose. Hydraulic resistance should be considered as a viable form of resistance when treating musculoskeletal and neuromuscular dysfunction. Not taking advantage of this tool would give our patients less than they deserve. ☐

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