Isokinetic Muscle Testing: Is It Clinically Useful?

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Abstract

The use of computer-driven muscle-testing devices has become increasingly popular during the past two decades. This expensive equipment allows evaluation of muscles and muscle groups in an isokinetic manner. Isokinetic muscle testing is performed with a constant speed of angular motion but variable resistance. Isokinetic dynamometers have been shown to produce relatively reliable data when testing simple, uniaxial joints, such as the knee, as well as when testing the spine in flexion and extension. Isokinetic strength data are generally not helpful in the diagnosis of orthopaedic abnormalities. Isokinetic testing can be helpful during the rehabilitation of orthopaedic patients, since it allows easy monitoring of progress. It also enables the patient to work on muscle rehabilitation in a controlled manner at higher speeds than are possible with more conventional exercise equipment. An isokinetic rehabilitation program can be easily tailored with concentric and eccentric components that closely resemble muscle actions during occupational and sports activities.

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Orthopaedic surgery has seen an enormous increase in the use of newly developed technology in the past two decades. New implant design, improved surgical equipment, and the use of robotics have all been part of this wave of technological advances in the operating room. Similarly, innovative equipment has also been introduced in the diagnostic and rehabilitative settings. Instrumented muscle testing is one example of such new technology.

Muscle testing for diagnostic or rehabilitative purposes classically was done manually or with weights. Manually, the muscle is usually graded in an isometric fashion on a scale from 0 to 5, with 0 representing complete absence of muscle function and 5 representing normal strength. When weights are used, the muscle or muscle group can be tested in various ways. The measurement can be made by determining the maximum amount of weight that can be lifted or how many submaximal lifts can be performed with smaller weights. These methods are often thought to be relatively crude and, more important, do not seem to duplicate the type of muscle action that is needed during normal activities at work or during sports.

With these limitations in mind, the concept of isokinetic exercise and testing was developed in the 1960s. There are now a number of commercially available isokinetic dynamometers that provide variable but maximal resistance throughout the range of motion, which other types of weightlifting exercise cannot do. These devices are often computer-driven and are purportedly capable of generating objective data on the muscles being tested.

As usual, this technology has come with a hefty price tag. Complete systems often retail for $35,000 or more. In the 1990s it has become apparent that purchase of these expensive new systems cannot be justified unless a clear benefit to patient care can be established. This article will examine the pros and cons of isokinetic muscle testing in a clinical practice.

Isokinetic Exercise

The manner in which muscles are used is usually divided into three categories: isometric, isotonic, and isokinetic. Isometric exercise involves contraction of the muscle without a change in the length of the muscle-tendon unit. Quadriceps setting is an example of isometric exercise. Isotonic exercise involves a muscle contraction without a change in the load placed on the muscle. This

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is associated with a change in the length of the muscle. Exercises using equipment with pulleys, cables, and variable weights, as routinely used in many weight rooms, are examples of this type. Isokinetic exercise involves muscle action that results in movement without a change in angular velocity.[1] Isokinetic exercise involves accommodation of resistance throughout the range of motion, which more closely resembles the normal action of muscle.

Both isotonic and isokinetic exercises can be performed in a concentric or an eccentric mode. A concentric muscle contraction involves shortening. During an eccentric contraction, the muscle lengthens while at the same time it is actively resisting the lengthening. Slowly lowering a weight while resisting some of the force of gravity is an example of exercise in the eccentric mode.

Isokinetic Dynamometers

Isokinetic exercise requires special equipment that maintains a constant velocity with use of a hydraulic system. Most systems are controlled by a computer and associated software. This allows easy readout, manipulation, and storage of the generated data. A few systems are not interfaced with a computer; such systems are meant primarily for exercise and do not allow testing in a rehabilitative setting.

There are two types of dynamometers: active and passive. Passive dynamometers allow free acceleration until the preset angular velocity is attained, at which time resistance is produced by the dynamometer. The newer active dynamometer provides resistance at a preset velocity once the patient meets a preset starting force, which is determined by the therapist. Since the moment arm on which the patient's muscle force acts is known, it can be translated by the computer software into torque (expressed in foot-pounds or newton-meters). The torque generated by the muscle or muscle group being tested can then be plotted against the range of motion. Other variables can be derived from the torque-displacement curve. The highest point of the torque curve is generally defined as peak torque. Work is represented by the area under the curve. The significance of peak torque is generally evaluated by comparing it with either normative values or with values obtained on the uninvolved side. Occasionally, agonist-antagonist ratios are used for evaluation purposes. For instance, hamstring-quadriceps ratios are often used in knee testing.

Most of the currently available systems are designed for either extremity testing or spine testing. Although the extremity systems are most commonly used for knee flexion and extension testing, they can often be adapted for other joints, such as the shoulder and the elbow. Spine-testing equipment is usually designed to measure flexion and extension; occasionally, it measures trunk rotation and lifting.

Some isokinetic systems allow the muscle to be tested or exercised in either a concentric or an eccentric fashion. The early isokinetic dynamometers tested in only the concentric mode. The velocity at which the muscle can be exercised or tested varies significantly from manufacturer to manufacturer but rarely exceeds 500 degrees/sec for the concentric mode and 250 degrees/sec for the eccentric mode.

Reliability of Isokinetic Data

Any type of measuring equipment must produce reliable, reproducible data to be useful in patient care. In normal subjects, knee flexion-extension torque measurements have been shown to be relatively reliable if certain factors are taken into account.[2,3] For example, the type of equipment used and the positioning of the extremity relative to the lever arm can be associated with a large degree of variability in the generated data. Comparisons between different systems and different patients are therefore very difficult. Within one patient tested with one particular system, the data appear to be relatively reproducible. This is particularly true when simple uniaxial joints, such as the knee, are tested. Testing of multiaxial joints like the shoulder is often associated with a high degree of variability, largely due to the difficulty in consistently aligning the axis of the joint with the axis of the dynamometer.

To decrease the variability, the patient should generally be given an initial test session before the actual measurement. Once the patient is familiar with the equipment, the results tend to be more reproducible. A similar learning effect has been found in spine testing. Relatively reliable torque values have been found in trunk flexion-extension testing of normal subjects.[4]

Isokinetic Testing as a Diagnostic Tool

Although reliability is a criterion for any measuring device used in medicine, it is the ability to discriminate between normal and abnormal that makes some of our medical equipment indispensable. When isokinetic dynamometers were first marketed, there was a wave of enthusiasm because it was thought that they could objectively measure muscle abnormalities, such as weakness and imbalance. Since muscle weakness was (and still is) considered to be a major etiologic factor in many orthopaedic disorders and injuries, it appeared that isokinetic devices would be useful for both diagnosis and treatment. Although there have been many attempts to associate abnormal isokinetic measurements with certain orthopaedic abnormalities, the overall results have been relatively disappointing.

Many studies have been conducted using patients with knee problems, since the flexion-extension torque values are relatively easy to measure with acceptable reliability. Anterior knee pain was initially reported to be associated with significantly decreased torque values in an eccentric mode.[5] However, later studies revealed that a significant portion of healthy subjects without a history of anterior knee pain had similar deficits without the development of anterior knee pain.[6] An abnormally shaped torque curve can be found in patients with patellofemoral pain following anterior cruciate ligament (ACL) reconstruction using patellar tendon autograft.[7] This is generally thought to result from pain inhibition, and the abnormal muscle performance is not considered to be necessarily the cause of the pain.

Isokinetic testing has also been used extensively in the knee with a ligament injury. Studies by Seto et al[8] and Almekinders et al[9] suggest that improved isokinetic test values for hamstring and quadriceps strength are associated with improved functional scores in knees with an ACL reconstruction. It is not clear from these studies, however, whether the isokinetic test values and functional scores are actually causally related or whether they are both end products of a successful ligament reconstruction. Isokinetic test values in unreconstructed ACL-deficient knees have also been studied in relation to functional outcome.[10] Hamstring-quadriceps torque ratios in injured knees that are similar to those in normal knees have been associated with better outcome scores. Again, it is not clear whether this is truly a cause-and-effect relationship or merely a reflection that an ACL deficiency is well tolerated. Longitudinal studies are needed to clarify this issue.

Many other studies have been able to show isokinetic-strength deficits following arthroscopic meniscectomy,[11] medial collateral ligament injuries, and ACL injuries.[12] However, most of these studies have been unable to show the clinical significance of these deficits, although the authors invariably recommend correction of the deficits through isokinetic exercise. Further research is needed to determine whether these deficits are a cause of problems such as persistent pain, recurrent injury, and decreased function. In one study of osteoarthritic knees,[13] isokinetic torque data had little predictive value in relation to functional outcome. In addition, there was little advantage in obtaining isokinetic data rather than static isometric values.

Isokinetic testing has also been used widely in spinal disorders. Chronic low back pain has often been ascribed to muscle weakness and imbalance. Most studies indicate that patients with low back pain tend to have lower torque values than asymptomatic control subjects.[4,14] Unfortunately, the variability is large in both patients and control subjects. Therefore, isokinetic data in this setting are usually not helpful in distinguishing clearly between normal and abnormal subjects. Although isokinetic values can be improved in patients with low back pain, it is not at all clear whether this is associated with an improved clinical outcome. Finally, studies have been unable to show that isokinetic strength differences in asymptomatic subjects are associated with an increased risk of back injury or pain.[15]

Isokinetic testing at times has been advocated to identify patients who more or less consciously fail to put their full effort into their rehabilitation program. It was thought that in malingering patients the torque curve would be abnormal in such a way that they could be discriminated from patients with true physical weakness. Unfortunately, there is no good evidence that supports this assumption for either spine or extremity testing.[4,16] Torque data can vary widely in normal subjects, and abnormal torque curves are common in both normal and patient populations. The most common reason for low torque values in patients is actual or perceived pain during the testing. However, no definitive conclusion about whether the pain is real or merely due to apprehension can be drawn from the data.

Isokinetic Exercises as a Rehabilitative Tool

Most orthopaedic injuries and surgical procedures are associated with muscle atrophy and weakness. It is a well-accepted practice to recommend rehabilitative exercises in an attempt to reverse postinjury atrophy. Return to work or sports prior to reversal of muscle atrophy has been associated with an increased rate of reinjury.

Isokinetic exercise has been advocated as an ideal rehabilitative tool in this setting since it allows exercise at high speeds in both concentric and eccentric modes.[1] Isometric exercise is still used early in the postinjury period since it avoids all joint motion. However, although isometric exercise is relatively safe around a recently injured joint, it can improve only limited aspects of muscle performance. Isotonic exercise allows joint motion, but the speed is not controlled, and the variable resistance of the lever arm is dependent on gravitational forces. In isokinetic exercise, the speed is controlled, and the resistance is dependent on muscle performance throughout the range. This allows submaximal exercise below the level of pain.

The control over the speed of exercise was thought to allow the patient to perform more sport- or work-specific exercises. Unfortunately, the angular motions of joints during daily activities and particularly during sports still tend to exceed the maximum speed that can be attained on most isokinetic devices. In addition, no consistent relationship has been found between isokinetic performance and athletic performance.[17] Thus, the purported superiority of isokinetic exercises over the more traditional isometric and isotonic exercises in this respect remains to be proved in a scientific manner.

It is certainly possible to obtain excellent rehabilitation results using more traditional forms of rehabilitative exercises. In addition, many therapists and their patients still need to resort to isometric and isotonic exercise in the early postoperative period following joint reconstruction. Pain and swelling can be aggravated by isokinetic exercise, and isometric exercise without joint motion is often more comfortable for the patient. Isotonic exercise in the early postoperative period can be helpful since it can force the patient to work with low resistance, whereas in isokinetic exercise the resistance is effort-dependent. Eager, motivated patients can cause significant joint pain and swelling by putting forth more effort than appropriate at a given stage of rehabilitation.

Isokinetic evaluation has allowed the therapist to more easily follow the progress of individual patients (Fig. 1) and to tailor rehabilitation programs based on the deficits present during isokinetic testing. Most isokinetic devices can also be used in the early postinjury period in an isometric or isotonic fashion, with data acquisition also in that mode. Later during the rehabilitation period, the patient can progress to an isokinetic mode at increasing speeds. This allows a more gradual transition to normal activities. Some devices allow both open- and closed-chain isokinetic exercises. Closed-chain exercises are thought to be more protective of the joints by eliminating some of the shear forces present in open-chain exercises. The patient can then progress to eccentric exercises, which tend to generate higher forces in the muscle-tendon units.

Use of isokinetic testing and exercise can be a good tool to motivate patients to persist in or increase their efforts. Most isokinetic devices have clear, colorful readouts on the monitor during the testing, which are very user-friendly. The patients can often run their own exercise sessions and see the improvement they have made during a session or compared with previous sessions.

In sum, isokinetic devices tend to be very versatile rehabilitative tools, although it remains to be proved that they affect the ultimate outcome if used during rehabilitation.

Summary

Although isokinetic testing and isokinetic exercise are widely used, there are still many unanswered questions regarding their usefulness. The ability of isokinetic testing to conclusively identify muscle weakness as an etiologic factor in several orthopaedic conditions is still uncertain. However, one should not conclude that muscle weakness is not an etiologic factor in these conditions. The more likely explanation is that isokinetic testing equipment does not test solely the muscle itself. The torque values generated during an isokinetic testing session are the product of many different factors, only one of which is true muscle performance. Others, such as the presence of pain, the quality of pretesting instructions, and psychosocial and behavioral factors, can influence the results to varying degrees. In spite of these limitations, isokinetic evaluation has allowed orthopaedic surgeons a different look at what patients can do with their muscles. It is possible that, with continued research and improvement of testing conditions, valid predictions can be made from isokinetic test results regarding orthopaedic pathology.

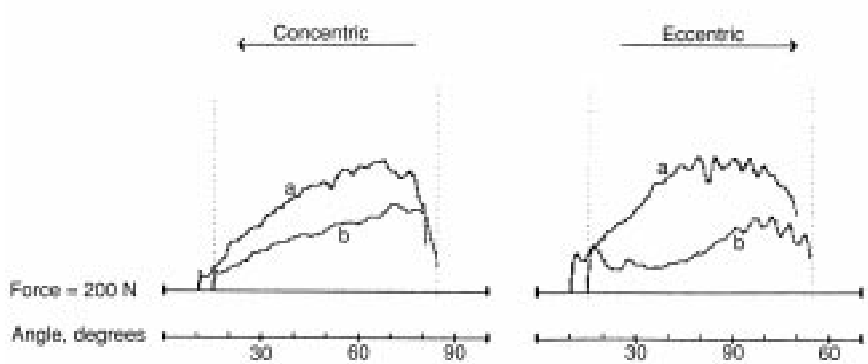

Fig. 1 Isokinetic torque curves of the quadriceps muscle 6 months (a) and 12 months (b) after reconstruction of the ACL and the medial collateral ligament. Note the initial deficits, especially in the eccentric mode, and the subsequent improvement.

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