5. Isokinetic Strength

Theory and Description of Isokinetic Strength Measurement

The concept of isokinetic measurement of strength was originally related by Hislop and Perrine.[1] Characteristics of an isokinetic exertion are constant velocity throughout a predetermined range of motion. Strictly speaking, a means of speed control, and not a load in the usual sense, is applied in isokinetic exertions.[1] However, load and resistance are definitely present in this technique. In this case, the load is a result of the energy absorption process performed by the device to keep the exertion speed constant. The device prevents energy from being dissipated through acceleration in isokinetic exercise. The energy is instead converted into a resistive force, which varies in relation to the efficiency of the skeletal muscle.

Since the speed of motion is held constant in isokinetic exercise, the resistance experienced during a contraction is equivalent to the force applied throughout the range of motion. For this reason, the technique of isokinetic exercise has sometimes been referred to as *accommodating resistance exercise*. This type of exercise allows the muscle to contract at its maximum capability at all points throughout the range of motion. At the extremes of the range of motion of a joint, the muscle has the least mechanical advantage, and the resistance offered by the machine is correspondingly lower. Similarly, as the muscle reaches its optimal mechanical advantage, the resistance of the machine increases proportionally. It must be understood, however, that while isokinetic devices control the speed of the exertion, this does not assure a constant speed of muscle contraction.

The speed of isokinetic contractions is constant during individual exertions; however, it is also possible to compare muscular performance over a wide range of isokinetic velocities. Increasing the isokinetic speed of contraction will place increasing demands on Type II muscle fibers (fast twitch and fast oxidative glycolytic).

Workplace Assessment

It is clear that isometric strength testing cannot substitute for dynamic strength assessment when examining highly dynamic occupational job demands. As most industrial work tasks contain a significant dynamic component, analysis of isokinetic strength capabilities appears to offer some advantage to isometric testing in this regard. However, it must be recognized that isokinetic devices are not entirely realistic compared with free dynamic lifting in which subjects may use rapid acceleration to gain a weight-lifting advantage.

Most isokinetic devices available on the market focus on quantifying strength about isolated joints or body segments, for example, trunk extension and flexion (see Figure 7). This may be useful for rehabilitation or clinical use, but isolated joint testing is generally not appropriate for evaluating an individual's ability to perform occupational lifting tasks. One should not assume, for instance, that isolated trunk extension strength is representative of an individual's ability to perform a lift. In fact, lifting strength may be almost entirely unrelated to trunk muscle strength. Strength of the arms or legs (and not the trunk) may be the limiting factor in an individual's lifting strength. For this reason, machines that measure isokinetic strengths of isolated joints or body segments should not be used as a method of evaluating worker capabilities related to job demands in most instances.

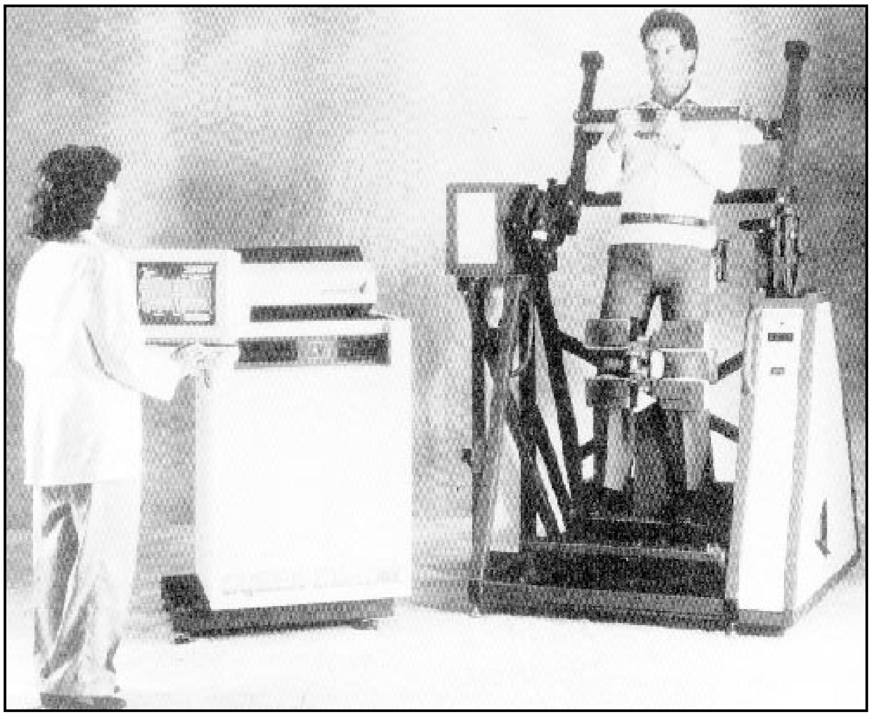

Figure 7*—Many isokinetic devices are designed to evaluate isolated joint muscle strengths. Such devices can be of great benefit in a clinical setting, but may not be as conducive to workplace assessment procedures.* (Cybex Medical, Division of Henley HealthCare, Inc., Sugarland, Texas.) [Photo courtesy of Henley HealthCare.]

Published Data

Several investigators have used dynamic isokinetic lifting devices designed to measure whole-body lifting strength.[2-5] These devices typically consist of a handle connected by a rope to a winch, which rotates at a specified constant velocity when the handle is pulled (Figure 8). The amount of force generated by the subject is thus evaluated over a specified range of motion, and the peak or average force generated during the test is recorded. As detailed below, some investigators have been able to demonstrate that the results of certain isokinetic strength tests (for example, an isokinetic exertion from floor to chest height) appear to be correlated with the amount of weight individuals were willing to lift for infrequently performed tasks.[2]

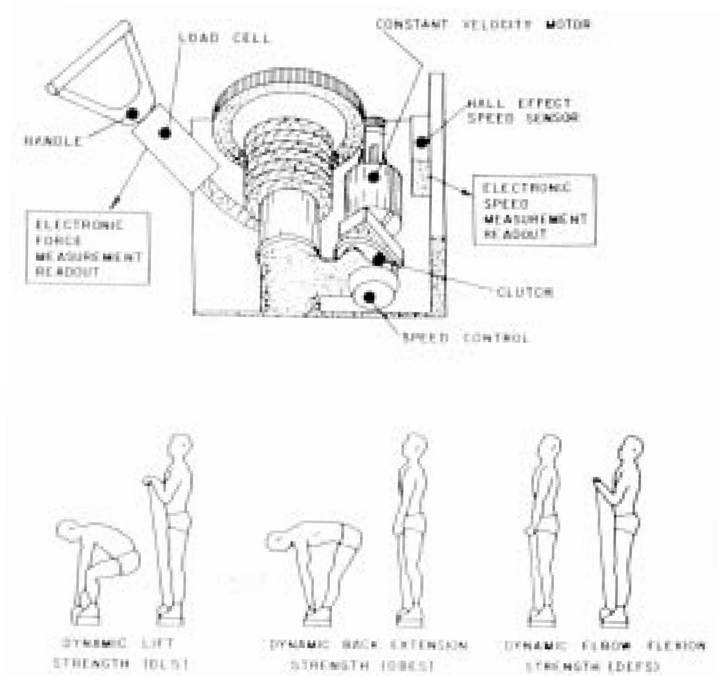

Figure 8*—An isokinetic whole-body strength measurement system. This device allows the experimenter to assess various muscular strengths (such as those shown) at a constant velocity.* (From **Kamon, E., and Pytel, J.L.:** Dynamic Strength Test as a Predictor for Maximal and Acceptable Lifting. *Ergonomics 24(9):663–672* (1981). Reprinted with permission of Taylor and Francis Ltd.)

Pytel and Kamon[2] analyzed various types of isokinetic strength in relation to maximal dynamic lifting capacity in their initial study. These investigators developed three isokinetic strength techniques and compared them to actual lifting capabilities of their subjects, consisting of 10 male and 10 female subjects. Each of the isokinetic exertions were performed at two speeds: .73 meters/second and .97 meters/second. Figure 8 illustrates the three isokinetic exercises evaluated in this study, which were named Dynamic Lift Strength (DLS), Dynamic Back Extension Strength (DBES), and Dynamic Elbow Flexion Strength (DEFS). These were compared with two tests that evaluated actual lifting capacity. The Maximal Dynamic Lift (MDL) was the amount that a subject estimated was the maximum he or she could safely lift from the floor to a level 113 cm above the floor. The Maximal Acceptable Lift was defined as the weight subjects felt they could lift safely at a rate of six lifts per minute for a regular work day.

Results of this investigation are provided in Table VI. The investigators found that the DLS (measured at .73 m/sec), in combination with the gender of the subject, was highly correlated with the MDL selected by the subject (R^2 = .941). Isokinetic tests performed at .97 m/sec did not correlate as well. Strength values obtained at this speed were consistently lower than those obtained at the slower isokinetic velocity, a finding regularly reported in tests of isokinetic strength.

Table VI

Means and Standard Deviations of the Maximal Dynamic Lift (MDL) and Peak Forces for the Dynamic Lift Strength (DLS), Dynamic Back Extension Strength (DBES), and the Dynamic Elbow Flexion Strength (DEFS) Performed at Two Speeds.[2]

Test	Speed (m/sec)	Strength (N)	
		Women (n = 10)	Men (n = 10)
MDL		250 ± 54	544 ± 109
DLS	.73	379 ± 95	601 ± 129
DBES	.73	315 ± 87	540 ± 101
DEFS	.73	167 ± 33	323 ± 55
DLS	.97	260 ± 99	398 ± 113
DBES	.97	210 ± 95	339 ± 102
DEFS	.97	120 ± 38	233 ± 39

Other investigators have taken the same type of device and devised methods of mounting it in different orientations to evaluate isokinetic strength in a variety of orientations.[3,5] Various handles attached to the end of the rope have been used to evaluate tasks such as short distance carrying or pulling in the horizontal, vertical, or transverse planes. The variations described above have been used to measure isokinetic lifting strengths using horizontal exertions at heights of 81 cm and 152 cm in a sample of male and female university students. These subjects were instructed to exert as hard as possible without jerking. Table VII provides data on the isokinetic strength of male and female students in both vertical and horizontal planes.

Table VII

Means and standard deviations for isokinetic strengths (N) of males and females in the vertical and horizontal planes.[5] Isokinetic tests include dynamic lift strength (DLS), dynamic elbow flexion strength (DEFS), and horizontal isokinetic strengths at 81 cm (DS81) and 152 cm (DS152).

Test	Strength	
	Females	Males
DLS	632 ± 251	1083 ± 297
DEFS	269 ± 132	741 ± 327
DS81	223 ± 122	344 ± 93
DS152	312 ± 156	594 ± 172

Evaluation According to Physical Assessment Criteria

Is Isokinetic Strength Testing Safe to Administer?

Given proper procedures and supervision, isokinetic musculoskeletal testing appears to be a reasonably safe method of evaluating muscular strength and endurance. Certain risks associated with use of free weights, weight machines, and other isotonic methods of assessing strength are not present in isokinetic testing. In addition, since the resistance or load experienced by the subject is directly related to the force the subject voluntarily applies, risk of injury due to overloading of the musculature would decrease, because the subject can control his or her own effort. However, it should be noted that some investigators have reported that lower velocity isokinetic exertions may be painful.[6,7]

Certain precautions have been suggested to reduce injury risk in performance of isokinetic musculoskeletal evaluations:

1. Warm-up and stretching of the involved muscle groups.
2. Performance of 5 to 10 submaximal trial repetitions to assess proper alignment, subject comfort, and subject familiarization with the test requirements.
3. Postexercise stretching.
4. Ice/compression/elevation any time postexercise effusion or swelling occurs.

In addition, subjects should wear tennis or running shoes during isokinetic muscle testing when performing standing exertions.

The American Academy of Orthopaedic Surgeons has established guidelines to meet when testing dynamic muscle performance.[8] The following summarize the guidelines developed by the AAOS Human Performance Testing Task Force:

1. Equipment must be determined safe for both the subject and the tester.
2. The reliability and validity of the equipment should be documented.
3. Equipment should be designed to ensure freedom of movement with sub-

ject comfort, and isolation of the motion should be achieved via proper stabilization techniques.

4. Training and education in correct use of the equipment should be available.

Does Isokinetic Strength Testing Give Reliable, Quantitative Values?

Several studies have reported on the reliability of values obtained using isokinetic devices. Results have generally indicated high reliability for isokinetic equipment. In a study examining the isokinetic movement of the knee extensors using a CYBEX II dynamometer, Johnson and Siegel[9] found reliability coefficients ranged from .93–.99. Furthermore, these authors reported that reliability appears to be affected more by testing over days than when comparing different trials performed on the same day. Pipes and Wilmore[10] reported test reliability in isokinetic exertions of a similar magnitude (r = .92–.99) in tests of bench press strength and leg press strength. Moffroid et al.[11] performed a test of reliability for torque measurements at various velocities with a CYBEX device and found that peak torque was reliably measured (r = .999) at velocities ranging from 4 to 12 rpm. Intratest, intertest, and intertester reliability of isokinetic strength measurements were examined in a study quantifying strength in children using a CYBEX dynamometer.[12] The authors concluded that none of these sources of measurement error were a significant source of inaccuracy.

While good reliability for the CYBEX dynamometer has been reported, some authors have expressed concern about a torque "overshoot" artifact that may appear in CYBEX torque measurements.[13] This artifact is evidenced as an initial prominent spike in the torque output curve, which is then followed by a series of progressively diminishing secondary oscillations. The cause of this phenomenon appears to be a result of "overspeeding" of the dynamometer's input lever during a free acceleration period before its resistance mechanism is engaged. The authors concluded that the prominent initial spikes represent inertial forces and should not be confused with actual muscle tension development. Proper signal damping procedures may suppress this "overshoot"; however, damping should not be used when absolute torque values are required.

Many other isokinetic devices have been developed since the introduction of the CYBEX in 1980. Most of these devices have demonstrated reliability similar to the CYBEX. Klopfer and Greij[6] analyzed the reliability of torque production on the Biodex B-200 at high isokinetic velocities (300 deg/s–450 deg/s) and found that coefficients of correlation ranged from .95–.97, reflecting a high degree of reliability of the test equipment. Other authors reported reliability of between .94 and .99 with the same equipment.[14] A study analyzing the reliability of the Kinetic Communicator (KINCOM) device reported intraclass correlation coefficients of .94–.99.[15] Reliability of the Lido isokinetic system appears somewhat lower than the others reported here, ranging from .83–.94.[16] The reliability of the Mini-Gym (the isokinetic device best suited to analysis of occupational tasks) does not appear to have been reported in the literature.

The foregoing data suggest that isokinetic strength testing equipment generally exhibits a high degree of reliability. However, it should be noted that results obtained using one system may not be comparable to results collected on other systems. Several studies have attempted to compare results between systems, and all have found significant differences. Torque values may vary as much as 10%–15% between different systems.[17,18] These discrepancies indicate that data collected on different devices cannot be compared, and normative data generated on one system cannot be used on other systems.

Is Isokinetic Strength Testing Practical?

Several issues may impact the practicality of using isokinetic devices to examine an individual's muscular capabilities. Not the least of these is the significant cost of purchasing an isokinetic measurement system. Many of the systems discussed in this section cost tens of thousands of dollars, which may render such systems impractical for many applications. Another important issue related to practicality for job-specific strength assessment is the ability of these devices to easily simulate a variety of occupational tasks. Although certain isokinetic devices have been specifically designed to mimic lifting tasks,[2] many are designed simply for quantifying of strength of isolated muscle groups in a clinical setting without regard to accurate simulation of work tasks.

Is Isokinetic Strength Testing Related to Specific Job Requirements?

The answer to this question depends upon the type of isokinetic device and how it is used. As discussed previously, isokinetic machines that test isolated muscle groups do not meet this criterion if the job requires use of many muscle groups or body segments. On the other hand, the Mini-Gym can be used to evaluate the dynamic strength necessary to perform many types of occupational tasks, and results of strength tests using this device appear to be related to lifting capacity, at least under certain conditions.[2] However, many industrial tasks are clearly too complicated to be evaluated using current isokinetic technologies. Great care must be taken to ensure that isokinetic strength measurements are appropriate for analysis of strength requirements associated with specific occupational tasks.

Does Isokinetic Strength Testing Predict Risk of Future Injury or Illness?

A recent prospective epidemiological investigation analyzed whether isokinetic lifting strength could predict who would be at risk of occupational low-back pain.[19] Subjects were required to perform maximal whole-body lifting exertions using an isokinetic linear lift task device, and were then followed for 2 years to evaluate whether this measure of strength predicted who would experience LBP. Results of this study indicated that isokinetic lifting strength was a poor predictor of subsequent LBP or injury. It should be noted, however, that no attempt was made in this study to compare job strength requirements to individual strength capabilities. Whether isokinetic strength tests can be used to predict future LBP when a careful comparison of job demands and individual strength capacity is made has yet to be determined.

Summary

Isokinetic strength assessment is a technique of assessing dynamic muscle function where the velocity of motion is constant. Numerous isokinetic devices are available on the market, most of which focus on quantifying strength about isolated joints or body segments. Devices that perform isolated joint assessment are typically quite expensive and may be well-suited to clinical and rehabilitative use. However, such devices may be limited in their ability to assess occupational demands at the workplace. This is because isolated joint or segment strengths may be unrelated to a person's ability to perform a specified occupational task. For example, the ability to perform a lifting task may be unrelated to isokinetic trunk strength; rather, the ability to perform such a task may be limited by strength capabilities of other muscle groups (such as those of the arms or legs).

A different sort of isokinetic device has been used by some to measure whole-body lifting strength. These devices typically have a handle connected by a rope to a winch, which rotates at a specified isokinetic velocity when the handle is pulled. Good correlations have been reported between isokinetic lifting strength (typically a lift from floor to chest height) and psychophysical lifting results of tasks having similar vertical displacement. However, while validity of whole-body isokinetic strength has been demonstrated for relatively simple lifting tasks, the more complex lifting tasks often seen in industry are not well simulated using current isokinetic apparatus.

Isokinetic muscle testing appears to be a relatively safe and highly reliable technique of assessing dynamic muscle function. The practicality of using isokinetic systems may depend heavily on their substantial cost. The limitations of assessing job-specific strength demands by such systems has been noted above. When assessing isokinetic strength, one must always bear in mind that this mode of contraction is not quite physiologic, that is, isokinetic movements are not used in everyday human motion. The ability of isokinetic muscle testing to predict risk of future injury or illness has not yet been demonstrated. Thus far, prospective studies have shown that generic isokinetic strength tests (like generic static strength tests) do not predict those who might experience low back pain. Whether isokinetic strength tests can be used to predict injury or illness when careful comparisons of job demands and individual strength capabilities are performed has not yet been investigated.

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