MedX Medical Machine
....Theory and Operation

MedX Lumbar Extension Machine, left.

Below, MedX Cervical Extension Machine.

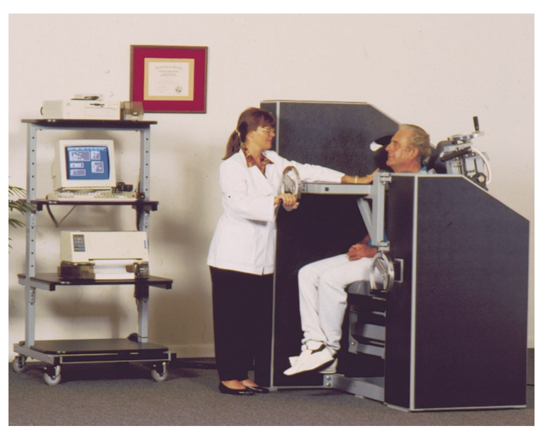
This training manual is intended to equip its student with machine-operation skills and an understanding of MedX theory for effective medical exercise and musculoskeletal rehabilitation. It aims to provide competent clinicians a command of MedX-based technology for treating spinal pathology in both the cervical and lumbar regions.

This educational program is a predecessor of one previously conducted at the University of Florida, Center for Exercise Science, started in 1988 and running continuously through June 2003.

The personnel responsible for this program were students in one or more spinal certification classes at UF, and have worked with MedX technology for more than two decades combined.

Program Objectives

1. To effectively operate MedX-based medical exercise and rehabilitation facilities, directors and clinicians require proficiency in the following:
    A. Skeletal and muscular anatomy, physiology and function of the lumbar and cervical spine.
    B. Identification of machine parts and proper operation of MedX strength testing equipment.
    C. Proper body positioning and stabilization during strength testing/training.
    D. Strength curve interpretation.
    E. Computer (software) operation.
    F. Clinical aspects of strength testing/training.



Proper operation of the equipment is best learned through hands-on instruction by a knowledgeable clinician, company representative, or independent party certified through the University of Florida or the University of California at San Diego. This reference manual complements the hands-on instruction.

Definitions of Commonly Used Terms

Acceleration – the upsloping of an isokinetic strip chart recording when moving from 0°/sec to the preset speed of the machine. Muscular torque is not recording during this period, which can account for 30-50% of joint ROM.

Acute pain – the result of some specific and readily identifiable tissue damage.

All-or-none principle – the fact that either all of the muscle fibers within a motor unit contract or none of them contract.

Atrophy – the reduction in the size of muscle or muscle group (a normal response to disuse or immobilization).

Basal metabolic rate – a minimum level of energy required to sustain the body's vital functions in the waking state.

Calibrate – the process of setting a measurement device equal to a known reference point prior to collecting data.

Chronic pain – decline in symptomatic recovery despite assumed completion of tissue healing following initial trauma. A condition generally becomes chronic 8 to 12 weeks after onset.

Compound trunk function – extension or flexion of the trunk which incorporates primarily the hip extensors (hamstrings and gluteals), and secondarily the lumbar extensors (72°) for a complete movement of 180°.

Concentric muscle contraction – the muscle shortens as it develops tension and overcomes external resistance.

Constant resistance – there is no alteration of the resistive torque throughout the joint's ROM. This is generally achieved through the use of a round pulley.

Correlation coefficient – describes the relationship between two or more variables, and is expressed statistically as 'r'. r can range from +1.0 to –1.0, and is often used to express the reliability of test/retest measurements.

Dampening – a method by which torque overshoot (impact force) is attenuated or eliminated during the computerized reporting of an isokinetic test result.

Deceleration – the downsloping of an isokinetic strip chart recording what occurs toward the end of a joint ROM as a result of proprioceptive protective mechanisms, which slow down a muscular contraction. Decrease in an object's velocity per unit time.

Degrees per second (°/sec) – the unit of measurement used to describe limb velocity during isokinetic testing.

Eccentric muscle contraction – a muscle lengthening while developing tension as a result of the external resistance exceeding the muscular force generated.

Fast twitch muscle fiber – type of skeletal muscle which is characterized by the ability to produce powerful contractions over short time periods. These fibers have very little capillary and mitochondrial densities and low aerobic capacity.

Fatigue Response Test (FRT) – An isometric test, followed immediately by a set of dynamic exercise, followed immediately by another isometric test. The shape of both curves should be very similar, although the post-exercise test should produce lower torque.

Flexibility – the looseness or suppleness of the muscles, tendons, ligaments and joint.

Impact force – a force produced against the limb as a result of the braking action (servo-mechanism) of an isokinetic machine. Such forces are recorded as torque overshoot on an undampened isokinetic report and are potentially harmful to the joint system being tested.

Inroad – the loss of isometric strength, generally as a result of an acute bout of dynamic exercise (fatigue response test).

Isoinertial – a term synonymous with isotonic.

Isokinetic resistance – (‘iso’ = same, ‘kinetic’ = speed) in theory, a maximal muscular contraction performed at a constant angular limb velocity. There is no set resistance to meet. Any force applied against the equipment results in an equal reaction force. The reaction force mirrors the force applied to the equipment through the range-of-movement. However, because of accleration/deceleration and torque overshoot, the term ‘isokinetic’ is a misnomer.

Isometric contraction (static) - (‘iso’ = same, ‘metric’ = length) a muscular contraction where no change in the length of the muscle takes place. This can be performed against an immovable object such as a wall, a barbell, or a weight machine loaded beyond the maximal concentric strength of an individual.

Isotonic contraction - (‘iso’ = same, ‘tonic’ = tension) in theory a muscular contraction in which the muscle exerts a constant tension against an external resistance that does not vary. The term ‘isotonic’ is a misnomer because the amount of force that a muscle must generate to overcome a fixed external resistance will change due to the biomechanical arrangement of the bones, joints, and muscles at each joint angle (change in leverage).

Law of levers – Reistance X Resistance Arm = Force X Force Arm.

Learning effect – the process of becoming familiar (efficient) with a movement as a result of performing that activity. This can include psychological and physiological adaptations. Relatively permanent improvement in behavior as a result of practice or experience.

Mean – an average of scores.

Mechanical work – energy output expressed as a force (F) acting through a vertical distance (D). Work = F X D.

Metabolism – the sum of all the biochemical reactions that occur within an organism.

Motor unit – an alpha motor neuron and all of the muscle fibers it stimulates. The functional unit of muscular activity under neural control.

Muscle function – the ability of a muscle to generate force.

Muscle hypertrophy – a normal response to exercise training and is characterized by an increase in the size (cross-sectional area) of the individual muscle fibers.

Objective measurement – one in which the evaluator's personal opinions cannot bias the test results.

One repetition maximum (1 RM) – the maximum amount of weight an individual can lift through their full ROM one time (common form of isotonic testing).

Psychosocial function – how an individual views himself/herself and how he/she interacts with others.

Range-of-motion (ROM) – a joint's capacity to move from one position to another. ROM is dependent upon the structure of the bones comprising the joint, the length of the muscle ligament, the elasticity of the tendinous tissue, and the distribution of body fat.

Reliability – repeatability (consistency) of test measurements.

Servo-mechanism – the part of an isokinetic machine that functions to brake an accelerating limb.

Slow twitch muscle fiber – type of skeletal muscle that is characterized by low-force production that can be maintained over long periods of time. These fibers have very high capillary and mitochondrial densities and can sustain endurance activities.

Spinal stenosis – a narrowing of the spinal canal producing compression of the cauda equina (nerve root).

Spondylolysis – fatigue fracture of the vertebrae.

Standard deviation (S.D.) – an estimate of the variability or spread of the data; variability of scores from the mean.

Standard error of the estimate (SEE) – a description of the variation between the relationship of two or more variables.

Subjective measurement – one in which the evaluator's personal opinions can bias the rest results.

Synergistic muscle activity – stabilizing muscular activity which serves to steady a movement during contraction thus preventing unwanted movements and helping the target muscle group to function more efficiently (e.g. free weight lifting).

Torque – a force acting upon a lever (moment) to cause rotation about a fixed axis (Torque = Force X Distance).

Torque overshoot – testing artifact produced by the servo-mechanism of an isokinetic machine when it brakes an accelerating limb in an attempt to maintain a preset speed of movement.

Validity – accuracy of a measurement; (ie. The device measuring what it is supposed to measure). Validity = calibration.

Variability – a statistical description of the speed of the data; deviation from the mean (e.g. S.D., S.E.E).

Requirements for Valid Testing

Accurately testing torque generated by the muscles that extend the spine requires eliminating or accommodating several factors that would otherwise nullify validity of the results. More than a dozen years of research and development were dedicated to what has resulted in today's MedX Medical Lumbar Extension and Medical Cervical Extension machines. Most of the time was spent in trial-and-error experimentation identifying — and ultimately gaining control over — these factors.

Today's clinician, unaware of the painstaking past, may fail to recognize the significance of one or more of the measures necessary for assessing or eliminating artifacts that skew test data. This results in compromising MedX medical machine technology and shortchanging the patient. Attention to detail and appreciation of seemingly insignificant directives matter more than you may realize.

Developing equipment capable of performing meaningful tests of strength, range of motion and muscular endurance signified a breakthrough in treatment of musculoskeletal dysfunction. MedX revolutionized rehab of the spine by incorporating the features highlighted on the following pages into its machine designs and operation procedures.

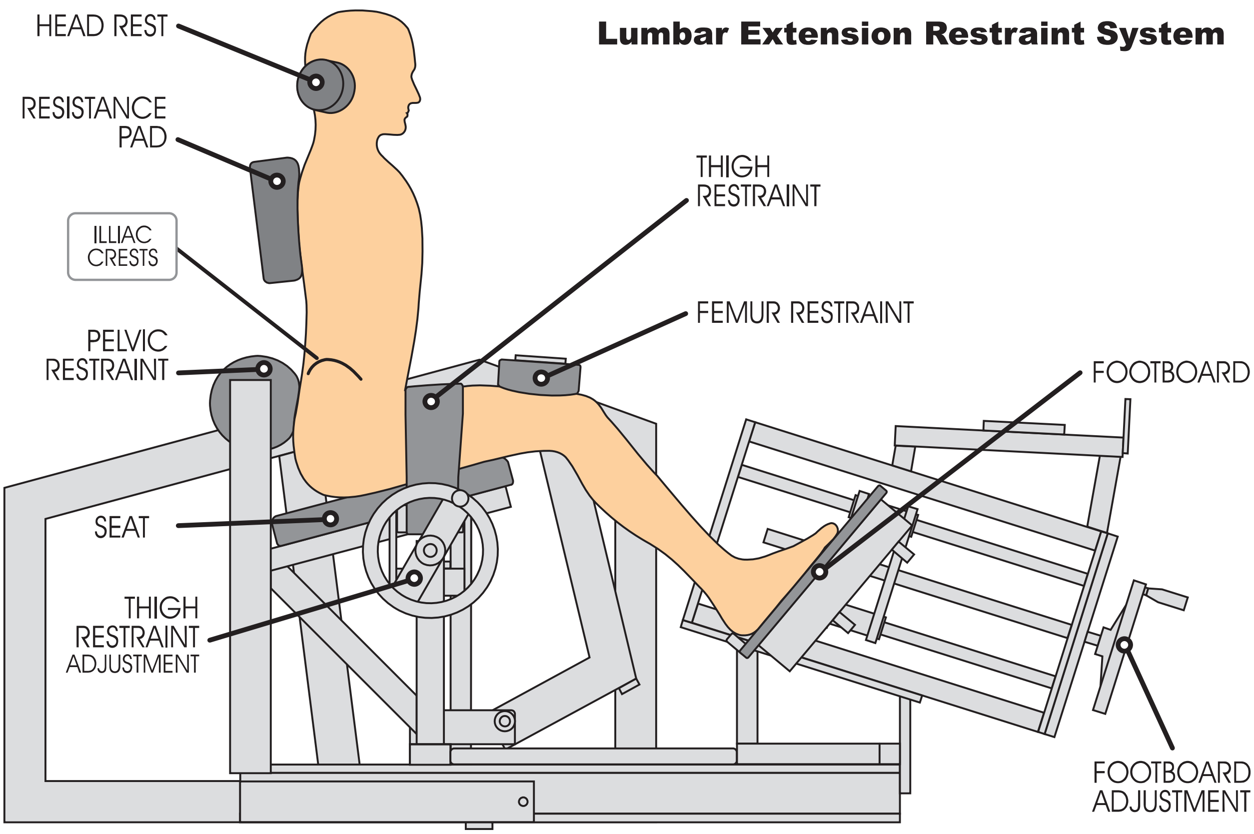
The benefits of this experience are provided in this reference training manual. Please consider carefully all requirements and suggestions.

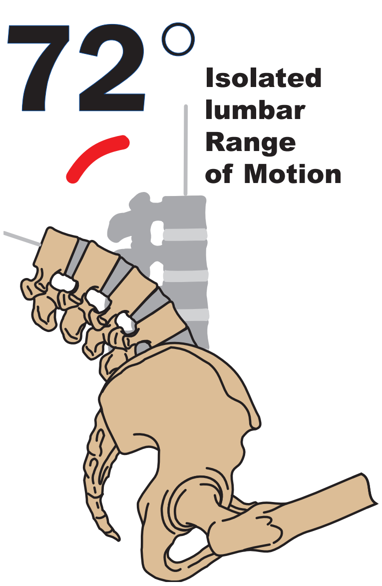
1-A. Pelvic Stabilization/Immobilization

(Lumbar Extension)

An elaborate pelvic restraint mechanism is built into the Lumbar Extension Machine. Its appropriate application is easily identified visually — if the tubular pads compressed against the patient's pelvis rotate on their own axis, the hip and thigh muscles are producing measured torque. Tighten the restraints until the pads fail to rotate when the patient flexes and extends through the range of movement. (See "104-Point Checklist" for further information)

Lumbar Extension Restraint System





The lumbar extensors muscles are isolated in the following manner:

1. Force imposed against the bottom of the feet is transmitted by the lower legs to the femurs at an angle of approximately 45 degrees.

2. Large pads located above the lower thighs limit upward movement of the knees.

3 . A heavy belt prevents upward movement of the upper thighs and pelvis.

4. A round pad prevents movement of the pelvis in the direction of extension.

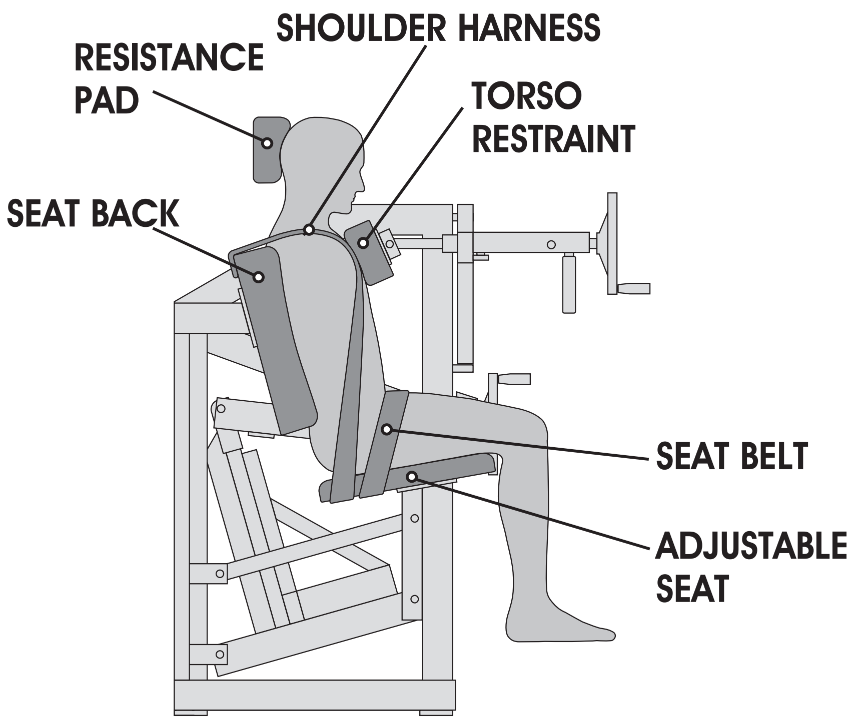
Properly restrained in this machine, the pelvis cannot rotate. It is the clinician's duty to check for pad rotation, and tighten restraints until it does not occur. Without total restraint of the pelvis, force from the muscles of the hips and thighs would contribute to torque readings, making it impossible to determine the true force-production capability of spinal muscles as well as range of isolated lumbar-spinal movement.

1-B. Torso Stabilization and Trapezius Restriction

(Cervical Extension)

To keep the cervical extensor muscles from receiving assistance from the trapezius muscles, a shoulder harness is applied over the patient's collarbone. This works in unison with upper chest padding and seat belt to anchor the torso, and thus isolate the cervical extensor muscles.

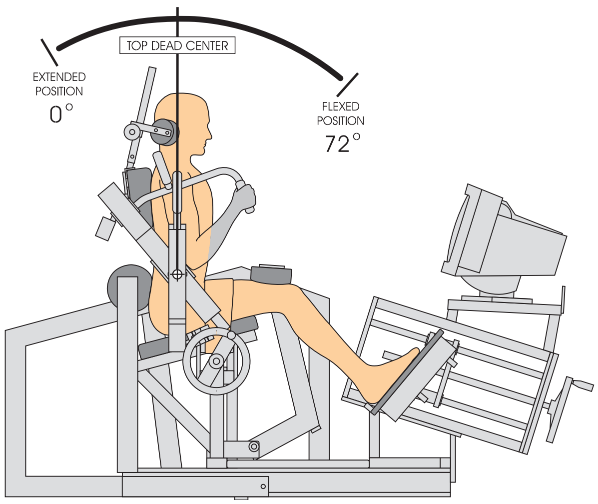
Cerivcal Extension Restraint System

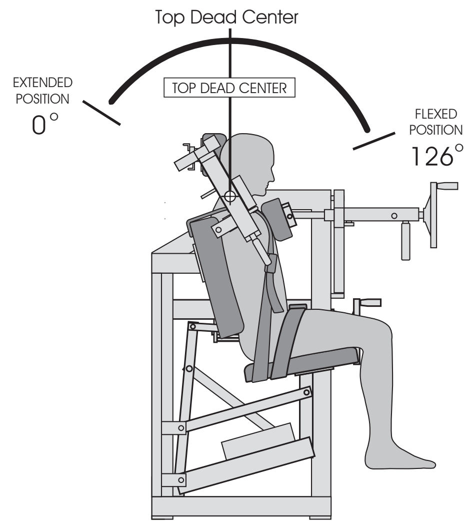


Restraint for cervical extension isolation is provided by a system that anchors the shoulders and torso. Vertical adjustment of the seat is provided to bring the effective axis of the neck into coaxial alignment with the axis of the machine. However, due to the spine's multi-hinge nature, the effective axis of the neck changes as it extends. Compensation for this change is provided by the resistance pad's freedom to rotate on its own axis. While this automatically compensates for any alignment shifting of the neck axis with the machine axis, movement of the pad should be very slight. Marked rotation of the pad as a patient moves from flexion to extension signifies need to adjust the vertical position (seat height). The seat should be cranked up or down until very little rotation of the pad is produced by full-range extension of the cervical spine.

2. Torso, Head and Aparatus Counterweight

To compensate for torque produced by gravity acting upon the mass of the head, arms, and torso, a counterweight must be positioned accurately to offset this force. Both the Lumbar and Cervical machines provide such a counterweight and it must be set appropriately for each testing or exercise session. On the Cervical Extension, every part of the machine that moves, apart from the weight stack, is also counterweighted.





1. Determine Top Dead Center

Before setting the counterweight, determine the centerline of torso mass (lumbar) and head mass (cervical). The counterweight is connected in an opposite direction; when the top dead center line is straigh up, the counterweight must be straight down; it’s 180 degrees out of phase with the patient’s midline of mass. The counterweight is connected to the resistance arm by a lock lever (which the therapist is holding at right). A bubble level indicator is also incorporated into the design to assure accuracy.

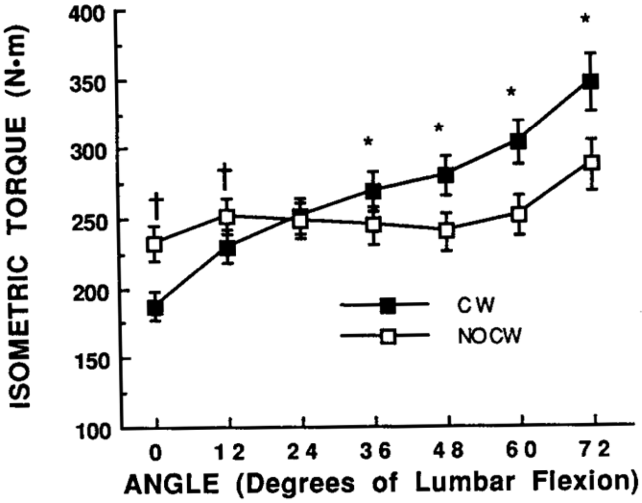
2. Set Couterweight

With the subject relaxed in the extended position, the counterweight is adjusted by turning this crank until balance is achieved; the weight of the body is balanced by the torque from the counterweight acting in an opposite direction. The computer monitors this operation, signalling when balanced.

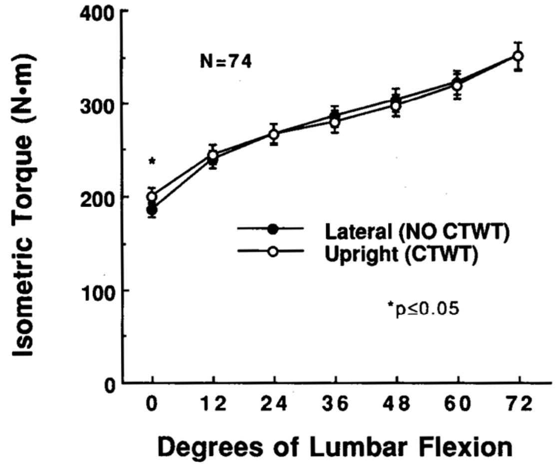
3. Record Settings

The goniometer (angle detector) on the right side of the machine indicates position of top-dead-center, and a digital position indicator on the counterweight shows position of the counterweight in which proper counterweighting was provided. Both of these readings should be entered into the computer record for future use with the particular patient. Barring meaningful changes in bodyweight, the top-dead-center setting and counterweight position will never change.

The Importance of Counterweighting



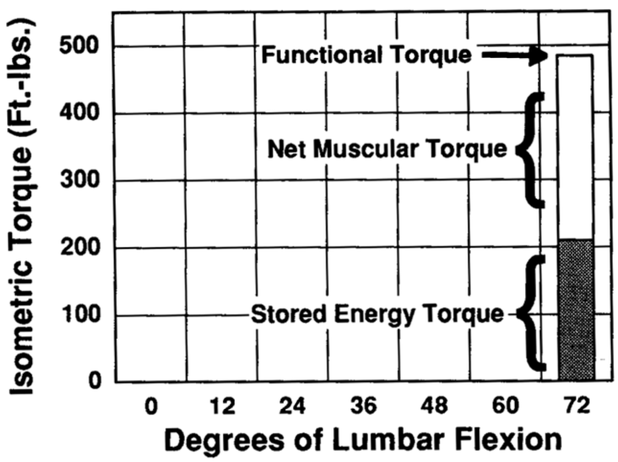
A group of 34 subjects was tested for isolated lumbar extension strength with counterweighting (CW) and again without a counterweight (NOCW). This graph demonstrates that the typical angle of top dead center is 24 degrees. From 72 degrees of flexion to 24, patients have to lift their torso weight, which is why the NOCW torque readings are lower in that range. Most subjects go "over the top" around 24 degrees, which means their torso weight is now assisting; conversely, a counterweight nullifies this assistance. (Presented at the Orthopaedic Rehabilitation Association Conference, San Antonio, TX, 1990)

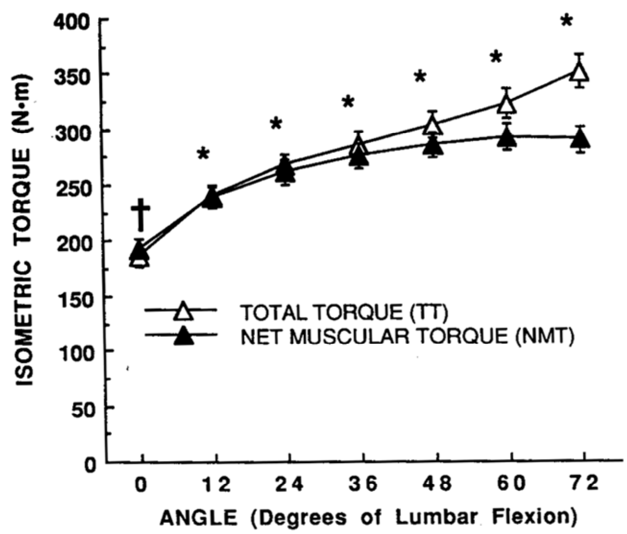


This chart shows the isometric torque values for lumbar extension strength testing in the sagittal plane with upper-body mass counterweighted (CTWT) and in the transverse plane without the need for counterweighting (NO CTWT). Notice that the values are essentially identical. (From Pollock M, Graves J, Leggett S, et al; Med Sci Sports Exerc 1991; 23 (suppl):66.)

3. Nonmuscular Torque Assessment

In addition to torque produced by the force of muscular contraction there are three sources of nonmuscular torque (gravity, friction, and stored energy). These sources of force-producing tension must be measured by the machine's computer and eventually deducted from torque measurement of the muscular contraction.





Stored Energy

Stored energy, one of the test options in the machine software, is determined by having the patient positioned at the testing angle but totally relaxed. Flip the force/angle switch to record a measurement. It will capture a force reading of the compressed tissue in the front and the stretched tissue in the rear of the patient's torso. The bar graph displayed on the monitor indicates the level of nonmuscular torque produced in that position. A large man, totally relaxed in the fully-flexed position, may produce more than 300 foot-pounds of nonmuscular torque which will overstate the true level of strength to an enormous degree.

Functional Strength

Having measured and recorded nonmuscular torque, the actual strength test begins by having the patient gradually produce muscular force in the direction of extension of the lumbar spine. As the level of effort increases, the monitor shows a rising bar graph of torque. Upon reaching a maximum level of effort, the patient should maintain that level for approximately two seconds, and then slowly relax. Muscular force should be increased and reduced slowly, without jerking. The maximum level of measured torque is functional strength in that position.

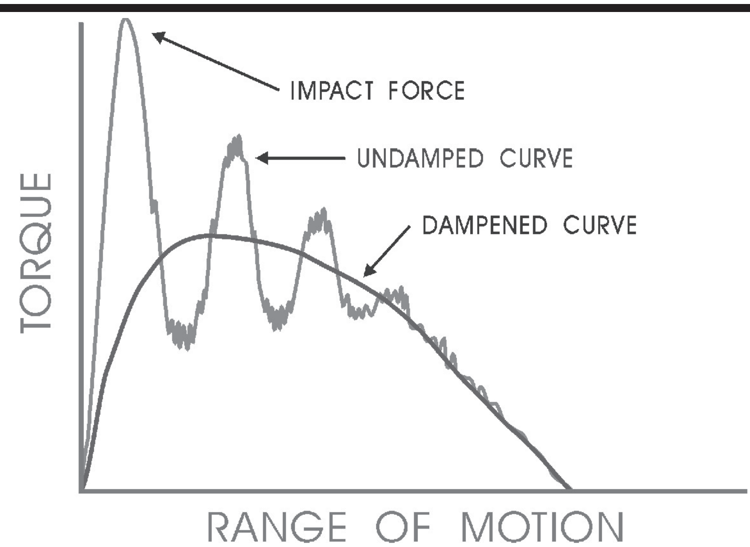
Net Muscular Torque

When nonmuscular torque is subtracted, the remainder is the true level of muscular strength, or net muscular torque (NMT). This is the amount of force actually produced by the muscles.

4. Isometric Testing Method

Accurate testing requires an isometric contraction with the generated force measured by a strain gauge. Static testing avoids the inherent difficulties of dynamic testing procedures. All dynamic procedures produce error in test results from several unavoidable sources: impact forces, friction and stored energy (torque produced by stretching and compressing soft tissues). Dynamic testing may also allow insufficient motor unit recruitment and spans of acceleration/deceleration may not allow for full ROM measurement. On MedX equipment, a succession of isometric contractions are performed along a series of standardized angular positions. These torque readings are then computed into a strength curve.

The graph at right was adapted from Murray, D. Optimal Filtering of Constant Velocity Torque Data. *Med Sci Sports Excer:* 18, 1986. It compares the impact force and the undamped and dampened curves during dynamic repetition testing on isokinetic-type equipment.



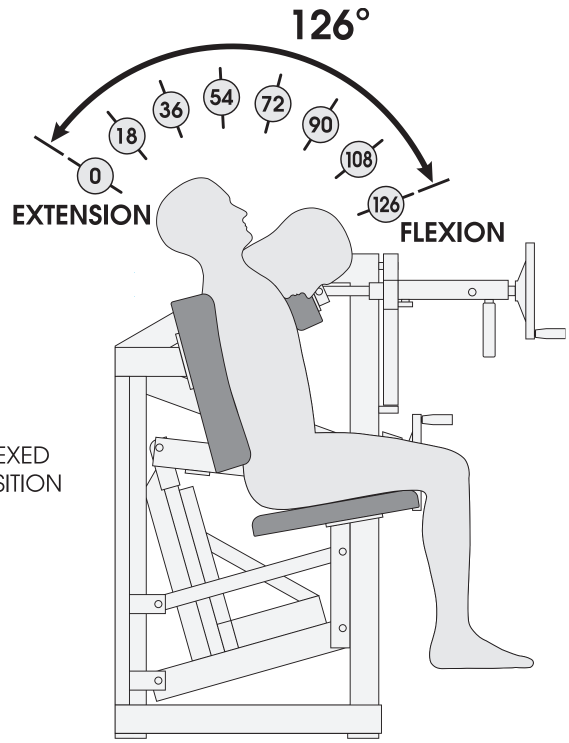
At the time of its introduction, MedX jolted orthodoxy by proclaiming “isokinetic” testing devices as unreliable. Several independent research studies were also pointing out inadequacies. Researchers who examined a Biodex Isokinetic device reported:

> “Because isokinetic devices test dynamic rather than static movements, clinicians may have assumed that these devices provide more meaningful (i.e., more functional) measurements than do strain gauges or cable tensiometers...The evidence in the athletic literature suggests that this is not the case. Relative to rehabilitation, there is no evidence to support the argument that dynamic testing is a better predictor of functional capacity than static testing....Future research may demonstrate some predictive use of isokinetic measurements, but at present, any suggestion that functional performance may be determined from isokinetic testing is conjecture.”
>
> – Mayhew, T., and Rothstein, J. Measurement of muscle performance with instruments. In Rothstein, J. (ed.) Measurement in Physical Therapy, 1985.

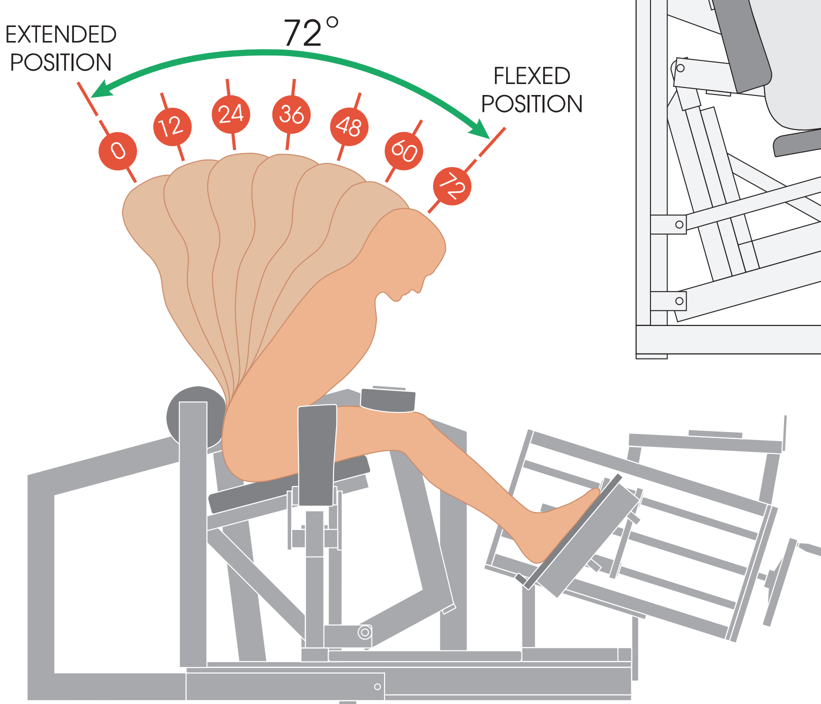
MedX pioneered static testing.

5. Repeatable Angular Positions

Due to leverage and biomechanical factors, strength output varies from one position to another throughout any full-range movement. Thus it is necessary to determine the relative positions of the involved body parts; true changes in strength can be determined only when the tests are conducted in known positions.



*On the **Cervical Extension** (above), normal range of movement is 126 degrees, and testing can be conducted in any of 43 positions, in increments of 3 degrees. Given a subject with full-range movement, testing is normally conducted in eight positions, in increments of 18 degrees throughout the full range.*



***Lumbar Extension** tests can be performed in any or all of twenty-five positions, with three-degree increments between adjacent test positions; thus it is possible to test within one and one-half degrees of any desired position. Typically, however, static tests are conducted in each of seven positions, at intervals of 12 degrees within 72 degrees of isolated lumbar-spinal movement.*