The Isokinetic Concept of Exercise

HELEN J. HISLOP, Ph.D., and JAMES J. PERRINE

SPECIFICITY IN exercise refers to creating training demands to develop those particular aspects of neuromuscular performance most needed for a given task. This concept loses its vagueness when muscular performance is analyzed in terms of its physical parameters: force, work, power, and endurance.

The force output of a muscle as well as the torque it generates at the joint is a function of the tension that contracting muscle can develop. This is the parameter most usually referred to when the term strength is used.

"Work" is defined as the action of a force over a specific distance in space. In biomechanics, work refers to the product of muscular force exerted through specific ranges of movement.

"Power" refers to the rate of doing work. Applied to muscular performance, it is the work output of muscles at specific speeds of contraction.

Dr. Hislop is Research Consultant, Department of Physical Therapy, Institute of Rehabilitation Medicine, New York, N.Y. 10016.

Mr. Perrine is a Consultant Engineer.

"Endurance" refers to the capacity to extend the power output over specific intervals of time.

As with muscular performance, the mechanics of a resistive exercise system can be classified by the physical parameters involved: resistance, distance moved, speed of movement, and the number of repetitions (or the time duration) of the bout. There is a clear parallel between these exercise parameters and the parameters of muscular performance (force, etc.). However, the degree of specificity attainable through exercise will be determined by the inherent mechanics of the exercise system used. The important factor is whether the exercise system parameters (resistance, etc.) can be manipulated to meet the training needs, or whether they are uncontrollable or basically unsuitable.

Until the present time, only two concepts of resistive exercise have been understood: isotonic and isometric. Isotonic exercise involves muscular contractions against a mechanical system providing a constant load. The body segment moves against this constant load

through a range of movement, as when lifting a weight or overcoming a brake resistance.

Isometric exercise denotes muscular contractions against a load which is basically immovable or is simply too much to overcome. The muscle can develop near-maximum tension, but its length remains constant and no perceptible joint movement is allowed.

The conventional techniques of resistive exercise employed by the physical therapist and others have incorporated either or both of these two concepts.

The purpose of this paper is to present the principles of a third concept of resistive exercise: isokinetic. Significant differences between an isokinetic contraction and the other two types result from the control of speed in contrast to controlling either resistance or distance moved. The technique of exercise through isokinetic contractions may be referred to as accommodating resistance exercise.

BIOMECHANICAL PRINCIPLES IN CONVENTIONAL EXERCISE

Resistance and Load

Resistance is always a force which, when acting in opposition to a contracting muscle, will cause tension to develop in the muscle.

"Load" refers either to the physical agent which is the source of resistance or it refers to the act of applying the resistance.

Isotonic Exercise. In conventional isotonic exercise, weights are moved through a range of motion. The resistance offered to the moving body segment (skeletal lever) remains constant during the entire motion (Fig. 1A). However, the resistance to the muscle is not constant (Fig. 1B) because of the modifying effects of the lever system through which it must pass.

The resistance has its greatest mechanical advantage on the muscle at the extremes of range. Here the lever system is most extended or flexed, and consequently the load on the muscle is greatest at these points. Conversely, closer to mid-range where the lever is most efficient (and therefore fixed resistance has least effect), the load on the muscle is proportionally less. In effect, then, the tension demand placed on the muscle in isotonic exercise is maximum only during a small portion of any range of motion. Consequently, the total work done is significantly less than maximum capacity.

The clinical value of isotonic exercise, therefore, is limited by its inability to impose maximal tension and work demands on a muscle throughout its range of action, because the therapist must select a weight which accommodates the weakest point in the range so that the patient may accomplish a complete motion.

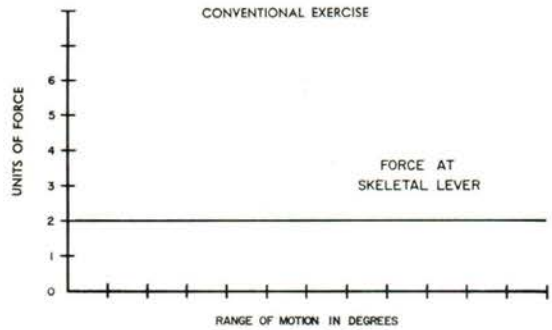

FIG. 1A. During conventional isotonic exercise, resistance offered to the skeletal lever remains constant.

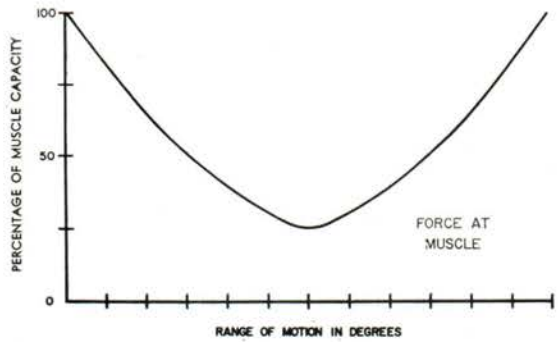

FIG. 1B. In isotonic exercise, resistance to the muscle varies because of the modifying effects of the lever system. Resistance has its greatest mechanical advantage on the muscle at the extremes of range and consequently the load is greatest at these points. Closer to mid-range the lever is most efficient and therefore the load on the muscle is proportionately less. Demands placed on the muscle are maximum only at the extremes of the range.

Isometric Exercise. Isometric exercise occurs whenever the resistance acting on the skeletal lever is of sufficient magnitude to prevent motion. The relatively large resistance permits the muscle to develop maximum loading—but in only one position with no physical work being performed. The clinical value of isometric exercise is limited to the extent that the demands it places on the neuromuscular system parallel the individual's needs.

Speed

In conventional resistance exercise, speed (or the rate of movement of the body segment) has not been specifically controlled and only rarely has it been measured.

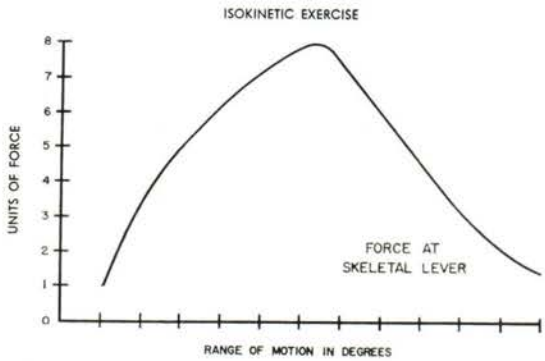

FIG. 2A. Force output at the skeletal lever during isokinetic exercise. At the extremes of range the muscle has its least mechanical advantage and resistance is least. Toward mid-range, where the mechanical advantage is greatest, the resistance increases proportionately.

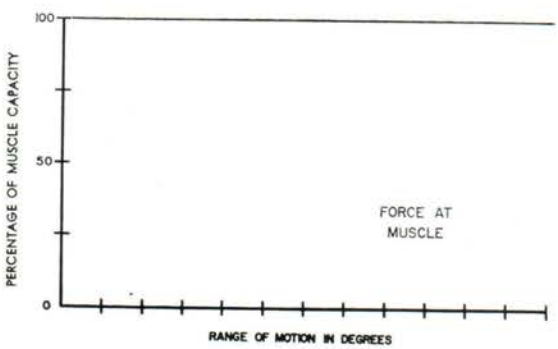

FIG. 2B. During isokinetic exercise the reistance accommodates the external force at the skeletal lever so that the muscle maintains maximum output throughout the full range of motion.

In isotonic exercise, because resistance is constant, the speed of the body segment will vary with the force applied. As a result, there is an inverse relationship between force and speed so that, in practice, if one is to be increased the other necessarily decreases. Because of this situation, isotonic exercise is limited in the demand it can place on the power capacity of a muscle.

If isometric exercise is viewed with regard to speed, it may be considered as a technique of controlling speed at zero.

ISOKINETIC EXERCISE

The unique factor in the concept of isokinetic exercise is control of the speed of muscular performance. In order to achieve this kind of performance, it is necessary to provide an external means of holding the speed of body movements to constant rates irrespective of the magnitude of forces generated by the participating muscles. At the same time, an isokinetic device provides suitable mechanical means of receiving the full muscular force potential of a body segment throughout a range of motion, but without permitting acceleration to occur.

Resistance and Load

Although, strictly speaking, a means of speed control, and not a load in the usual sense, is applied in isokinetic exercise, load and resistance are definitely present and available in relatively unlimited amounts.

Actually the *load* acting in isokinetic exercise cannot be traced to a familiar agent such as gravity or friction, but is the result of the mechanical process of energy absorption which an isokinetic device performs in order to keep the exercise speed constant.

In conventional exercise, energy is only partially absorbed and the remainder is dissipated with accelerations in the exercise motion.

In isokinetic exercise, energy cannot be dissipated by acceleration because this is mechanically prevented by the device. Because the energy is not dissipated anywhere in the process, it completely converts to a resisting force which is always proportional to the magnitude of the input (muscular force). Thus it varies in relation to the efficiency of the skeletal leverage.

In effect, the resistance can accommodate all factors causing force variations through a range of motion. Figure 2A illustrates the condition at the skeletal lever during an isokinetic contraction. At the extremes of the range of motion where the muscle has its least mechanical advantage, the resistance offered is least. As the motion approaches the point in the range where the mechanical advantage is greatest, the resistance increases proportionately. With resistance accommodating the

varying force at the skeletal lever (external force), the muscle is able to maintain a state of maximum contraction through its full shortening range (Fig. 2B). This situation permits a maximum demand to be placed on the work capacity of a muscle.

Speed

In addition to the benefits of holding speed constant in exercise, the isokinetic concept provides the opportunity to manipulate the rate of speed selected so as to establish specific exercise conditions with regard to muscle power output. Once an isokinetic device is set at a specific operating speed, it permits and demands muscular contractions at that speed. If the speed is set at the highest rate at which a muscle can contract and still demonstrate its maximum work performance, then the maximum muscle power output will be achieved. Progressively higher rates of speed set over the course of an exercise program will place increasingly greater demands specifically on the contractile speed of the muscle. Alternately, the speed can be maintained at a calculated (functional) rate until work capacity reaches some optimum level at that rate of contraction. In either case, power output is improved.

Increased demands in the area of endurance capacity can be made by maintaining a maximum power output with increasingly longer bouts of exercise.

SUMMARY

The concept and mechanical principles of a new system of exercise have been presented which offer a greater control of loading. Isokinetic exercise represents the first practical control of speed without sacrificing force. The parameters of muscular performance (force, work, power, and endurance) are defined and applied to isotonic, isometric, and isokinetic exercise. The exercise parameters (resistance or load, distance moved, speed, and number of repetitions or time duration) are similarly discussed.

Improvement in performance capacity in response to operating against a relatively high demand (stressing) system is a well-known physiological phenomenon. Although this is often called overloading, a more accurate description is loading to full capacity.

Isokinetic exercise permits greater demands to be placed on muscular performance than have heretofore been possible. This method, in turn, offers a means of developing greater power and endurance through loading the muscle to capacity throughout the range of motion.