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INTRODUCTION

When evaluating most athletic training rooms in use today, as well as methods of exercise equipment used, one most likely focuses on the use of free weights and conventional weight machines. However, the use of hydraulic resistive equipment has introduced a new concept in the area of athletic training, and is becoming widely used among trainers worldwide.

Hydraulic resistive exercise equipment was invented in 1969 by a coach from Central Texas. This revolutionary type equipment has been defined by exercise scientists as a form of "isokinetic" resistance, which allows the user to exercise throughout the full range of motion.

In this report, I attempt to show the benefits of hydraulic resistive exercise equipment in the conditioning of athletes in the areas of strength, power, and cardiovascular endurance.

The presentation of this material is aimed toward college students who may or may not be familiar with the different types of exercise equipment.

In preparing for this report, I have consulted several exercise physiology and fitness books which address the different concepts of exercise. I have also interviewed the inventor of the hydraulic exercise equipment.

In the report, definitions of different types of exercise will be explained, as well as explanations on the three most important components necessary in the total dynamic conditioning of the athlete. The latter part of the report will include various research studies conducted on hydraulic resistive exercise equipment.

The Hydraulic Cylinder

Hydraulic resistance is created by manipulating the size of an orifice valve in a fluid-filled hydraulic cylinder. (Fig. 1) The fluid in the cylinder is forced through the valve as the user moves a lever arm by virtue of a muscular contraction against the lever arm. There is no preset speed, and the resistance is simply a product of how rapidly and forcefully the user can move the fluid through the orifice by exerting force against the lever arm. The speed and resistance can be varied by changing the size of the orifice, but the speed and resistance remain specific to the user and not to the machine, no matter what the orifice size may be. The amount of torque generated and the speed at which it is generated will be different for every user at any resistance setting chosen. Hydraulic resistance is user specific (Brentham, Oct. 26, 1992).

Scientific Definition of Hydraulic Exercise

Exercise scientists define hydraulic resistive exercise machines as a form of isokinetic resistance.

According to McArdle,

> Theoretically, isokinetic-type training would make it possible to activate the

COLLECTED DATA

The History of Hydraulic Exercise Equipment

Hydraulic resistive exercise equipment was invented by Jerry D. Brentham, a former Texas high school coach. In 1967, while coaching, Brentham witnessed an accident in the weight room. One of the athletes was leg-pressing multiple weights and his feet slipped. The weights came crashing down upon the athlete. While the weight stack had a safety device to reduce the impact of the weights, the possibility of a serious injury became a concern for Brentham. Immediately he began thinking of a way to build safer exercise equipment. Brentham recalled his work experience as a teenager with a company that specialized in building heavy industrial hydraulic equipment. He decided to pursue the idea of designing exercise equipment using hydraulic cylinders instead of conventional weights. Two years later, in 1969, Brentham introduced the first hydraulic resistive exercise machine (Croft, 1987, p. 51).

> largest number of motor units and consistently overload muscles to achieve their maximum tension-developing or force output capacity at every point in the range of motion, even at the relatively "weaker" joint angles (1991, p. 467).

Exercise scientists have utilized hydraulic resistance equipment in many experimental procedures. Hydraulic resistance exercise has unique properties permitting muscle loading in contrast with conventional weight-based resistance equipment (Peterson, 1987, pp. 1-3).

Strength-Component of Conditioning

The first component of improving athletic skill is *strength*. According to Ralph and Valerie Carnes, strength is defined in sports training as the ability of a muscle or group of muscles to gain strength when force is exerted against a resistance, without regard to time. The muscles generate a force in order to overcome the resistance. Strength is gained by the force one can exert (1983, pp. 149-50).

There are various types or classifications of muscle contractions necessary in order to gain strength. An isometric contraction occurs when the muscle develops maximum force against an immovable object. An isotonic contraction occurs when the resistance or load remains the same and the speed of movement can vary. This type contraction occurs when using free-weights or other weight-stack machines. Therefore, in an isotonic contraction, the greatest weight that can be moved through the normal range of motion is limited by what can be moved at the weakest joint angle. Therefore, the muscle is provided with maximal overload at that point only. An isokinetic contraction is defined as occurring at a fixed velocity. Most isokinetic devices also provide variable or accommodating resistance which implies that the resistance is maximized according to the ability of the muscle to generate tension (McArdle, 1986, pp. 380-81).

Throughout a full range of motion, muscular strength can be increased through maximum contraction of muscle groups, and sustaining a constant speed. Isokinetic resistance has tremendous potential in the development of muscular strength, power, and endurance (Wilmore, 1982, p. 74).

As a general rule, a muscle worked at maximum capacity and overload will increase in strength. The overload or resistance may be applied with standard-type weight machines, immovable bars, or various isokinetic training devices. The important fact is that improvement in strength is generally governed by the intensity of movement and not by method. Progressive resistance weight training (isotonic), isometric training, and isokinetic training are three exercise systems utilized in training muscles to become stronger. These systems rely on the type muscular contractions used during an exercise session. Concentric muscular contractions are performed when the muscle shortens to produce work, such as flexing the elbow to lift a weight. Eccentric muscular contractions happen when the muscle lengthens under force such as lowering the weight to its original position (McArdle, 1981, p. 291).

A comparison study was performed on the advantages and disadvantages of three types of resistance training programs. Isokinetic type training rated excellent in seven of ten categories (Lamb, 1984). (Fig. 2)

The inventor of hydraulic resistance exercise equipment, Jerry D. Brentham, further explains that both concentric and eccentric components in exercise are involved in the raising and lowering of conventional weights. Hydraulic resistance systems provide a bi-directional loading which provides resistance against antagonist muscle groups as the lever arm is returned to the starting point. The term agonist and antagonist are used to describe muscles which generally have opposite movement responsibilities. For example, the biceps flex the elbow while the triceps extend it. The ability to work opposing muscle groups alternately at the same exercise station is an advantage of the concentric only, functional related, accommodating hydraulic resistance systems. This is accomplished with a push:pull movement of the lever arm on the exercise equipment (Oct. 26, 1992).

While hydraulic resistance systems do not permit eccentric loading, which some feel is important, the bi-directional concentric loading with accommodating resistance provided by the hydraulic cylinder is an advantage in time-efficiency. A major problem encountered by novice weight-trainers is the failure to exercise antagonist muscles equally since different exercises are required. The bi-directional loading capabilities of most hydraulic resistance systems help eliminate this problem (Brentham, Oct. 26, 1992).

Frank I. Katch, a noted exercise physiologist and scientist at the University of Massachusetts, states that a distinction can be found between a muscle loaded isotonically and one loaded isokinetically. During conventional weight or free weight lifting (isotonic), the initial resistance of the weights must first be overcome and then the progression of the weight movement can continue. When lifting a weight, the user is limited to the amount of pounds that he or she can lift at the weakest joint angle of a particular exercise. Otherwise, the athlete or user could not move through the full range of motion. Therefore, the maximum force the user can apply is not consistent throughout the full range of motion. In an isokinetic exercise, the user is able to generate a maximum power output at any given point in the range of motion of a particular exercise (Katch, 1983, pp. 195-96).

Power-Component of Conditioning

According to Jack H. Wilmore,

> Strength can be defined as the maximum ability to apply or to resist force. Power is simply the product of strength and speed. While absolute strength is an important component of performance, power is probably even more important for most activities (1982, p. 73).

While defining the importance of *power* in athletic training, Wilmore also emphasizes the importance of power in all athletic sporting events. In order to be successful, the sprinter running the one-hundred yard dash definitely relies on power. The soccer player requires agility, neuromuscular coordination, and skill. The gymnast must have superior flexibility. These qualities are also essential to athletes in many other sports. A football player at any position must be concerned with power, agility, coordination, skill, and flexibility. An athlete is dependent on high levels of power for successful execution of his or her assignment (1982, p. 93).

Isometric and isotonic weight training result in similar gains in strength, but isokinetic type training may have the greatest potential for gaining strength and power (Wilmore, 1982, p. 90).

Scientific Research on Hydraulic Equipment

S. R. Peterson conducted a study designed to measure high-speed resistance circuit training and aerobic power. Twenty-seven well-trained males were the subjects for this study, and all were affiliated with junior-varsity or varsity athletic programs at the college level. The study group exercised and trained four times weekly over a five week period on six stations of hydraulic exercise equipment. The first fifteen sessions were conducted on two circuits of training and the remaining six sessions consisted of three circuits on variable hydraulic resistance equipment. Heart rates were closely monitored and recorded at the end of each weekly session. The ability of the subjects to work at high speed movements, with accommodating resistance in both directions, and the potential for recruitment of large muscle groups, may all contribute to increasing the heart rate during the exercise sessions. Petersen concluded that during the exercise sessions and the relief intervals, the heart rate was significantly elevated over other tests conducted previously on conventional weight-based resistance exercise. Thus, the use of hydraulic resistive exercise equipment appears to enhance aerobic power in previously trained athletes (1988, pp.339-43).

A study was conducted using a combination of free weights and hydraulic resistive machines. Coaches agree that high-intensity training is necessary to gain dynamic strength and dynamic strength will result in the athlete reaching his or her potential for size, speed, and power. High intensity training allows the athlete to train at a maximum rate of speed during every repetition. In order to accomplish this, the resistance must allow the athlete to exert maximum effort throughout the full range of motion. When the athlete's force output increases, the resistance and speed must increase simultaneously. Combining free weights and hydraulic resistive equipment has revealed several advantages: 1) Before movement begins, excellent resistance is provided by the weights, 2) the force required during the middle movement of an exercise is greater, overcoming the coasting effect of the free weights, 3) the peak forces are greater during acceleration in an exercise, and 4) at the end of the exercise there is an eccentric loading because of the weights causing the reflex phenomenon (Telle, 1985, pp. 66-68).

Cardiovascular Endurance - An Important Component

Cardiorespiratory endurance must be the major component of any conditioning program. While muscular endurance is extremely important and is related to muscular strength, athletes who perform at a high level must also concentrate on developing cardiorespiratory endurance. Weight training techniques and facilities should develop a system of training which would include equipment designed to promote cardiorespiratory endurance (Wilmore, 1981, p. 111).

In years past, strength was considered the most important aspect of physical fitness. It is now known that strength plus speed produces power. Most sports are power sports, and the athlete must have both strength and power to excel. And in order to perform at an upper level the athlete must have a high degree of endurance (Wilmore, 1981, pp. 125-26).

Research on Cardiovascular Fitness

In 1985, Frank I. Katch, Patty S. Freedson, and Carole A. Jones did research to evaluate the acute heart rate response to hydraulic resistance exercise. Twenty male subjects who were untrained college students at the University of Massachusetts, completed three twenty-second bouts of shoulder, chest, and leg exercise on a three-station hydraulic machine over a two-day period. Twenty seconds rest between bouts and five minutes rest between exercise modes was allowed. The students were encouraged to perform the exercises at maximum effort. Each subject was asked to complete the maximum number of repetitions during the twenty-second time period. Average oxygen consumption for the three exercise modes was 52.8% of the maximal oxygen consumption determined during a cycle ergometer test. Furthermore, the averaged heart rates were 84.6% of the maximum heart rate. These authors concluded,

> The magnitude of the average heart rate and metabolic response patterns with maximal effort hydraulic exercise is in the range recommended by the American College of Sports Medicine to promote improvements in cardiovascular fitness (pp. 168-172).

A study was conducted in Canada to assess the cardiovascular fitness of subjects using the hydraulic circuit training. Thirty-two untrained men were voluntary subjects in the study. They were divided into four groups--one group was used as a non-exercising control group, one trained on a dynamic training cycle, and the other two groups trained on nine-stations of hydraulic resistive exercise equipment. One of the hydraulic circuit groups was assigned to exercise at the maximum number of repetitions possible during the prescribed time, while the other hydraulic circuit group exercised at seventy to eighty-five per cent of maximum repetitions possible. The training groups exercised three times a week over a nine-week period. Tests were conducted at the end of the training period. The three training groups recorded significant improvements in cardiovascular fitness (Haennel, 1989, pp. 605-11).

CONCLUSION

Summary of Findings

The hydraulic resistance exercise equipment is a revolutionary method of training. The concept of this resistance was developed primarily because of a need for safer methods in training athletes. After its development, the exercise scientists discovered unique properties in this form of isokinetic exercise.

Interpretation of Findings

Based on my findings, it appears that any weight training system would benefit by hydraulic resistance exercise equipment. This unique and distinctive method of training is beneficial in improving athletic performance and for total conditioning in the areas of strength, power, and cardiovascular endurance.

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