

Modes and Methods of Resistance Training

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RESISTANCE TRAINING HAS been shown to improve a variety of health and performance variables (38). Improvements in performance can include increased muscular strength, power, and high intensity exercise endurance (21, 30).

Physiological and physical changes can include improved cardiovascular parameters, beneficial endocrine and serum lipid adaptations, increased lean body mass, decreased fat, increased tissue strength and bone strength, and decreased physiological stress (5, 16, 17, 22, 27, 38, 42).

In males, programs using strength training or strength training as an integral part of physical conditioning have been shown to improve performance in ergonomic tasks, such as lifting weighted boxes to different heights (1, 11).

It is known that the choice of training method can make a considerable difference in the outcome of a resistance training program (7, 10, 41). It is probable that the choice of training mode can influence the adaptations to a training program.

This article examines the relative usefulness of various types of

machines and free weights for enhancing performance in increasing maximum strength, power, and high intensity exercise endurance.

The concept of "specificity of exercise" is of primary importance in selecting appropriate equipment for resistance training. Specificity includes bioenergetics and mechanics of training (41, 45). This discussion will be concerned with mechanical specificity.

■ Specificity of Mechanics

Specificity of mechanics refers to the mechanical similarity between a training activity and physical performance. This includes movement patterns, peak force, rate of force development, acceleration, and velocity parameters. The more similar a training exercise is to actual performance, the more likelihood of transfer (3, 6, 18). Mechanical specificity has been extensively studied as it affects strength training exercise. For example:

Explosive Strength and Power

In untrained subjects, heavy weight training can produce beneficial effects and shift the entire force velocity curve toward the right (12, 41). In trained subjects,

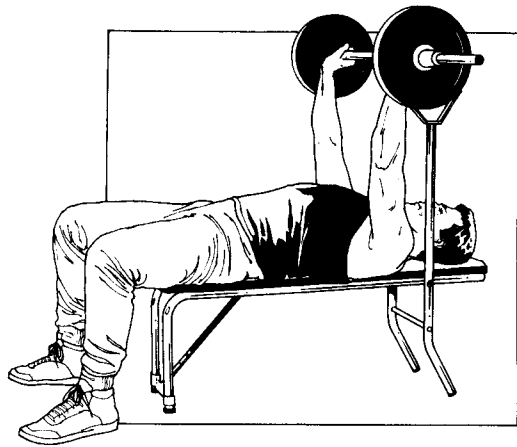
however, evidence suggests that high velocity training may be necessary for making alterations at the high velocity end of the force/velocity curve (12, 41).

Although isometric training can increase the rate of force production and velocity of movement, especially in untrained subjects (3), the isometric training effect on dynamic explosive force production is relatively minor (12). The primary effect of ballistic training appears to be an increased rate of force production and velocity of movement, while traditional heavy weight training primarily increases maximum strength (12, 32).

Furthermore, high power training increases a wide range of athletic performance variables to a greater extent than does traditional heavy weight training, especially in subjects with a reasonable initial level of maximum strength (46).

Some evidence, primarily cross-sectional, suggests that a combination of heavy weight training over a few weeks followed by

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high velocity training or combination training may produce superior gains in strength and power than either type alone (12, 37). A recent longitudinal study (14) indicates that a combination (heavy training followed by combination training) produces better results in maximum strength and athletic performance such as the vertical jump, standing long jump, and 10-yd shuttle run compared to continued high velocity or heavy weight training.

Joint Angle Specificity

It is known from studies of isometrics (2, 20) that strength gains are greatest at the joint angle trained. Use of variable resistance devices results in strength gains that are greatest at the joint angle at which the greatest resistance is applied.

Movement Pattern Specificity

Studies and reviews of the literature have consistently noted that the magnitude of measured increases in strength depends on the similarity between the strength test and the actual training exercise (3, 8, 28, 31–33).

Because of the high degree of mechanical specificity that free weights offer to designated activities, it is highly probable that training with free weights may have a greater transfer of training effect to athletic and ergonomic tasks

than training with machines (9, 26, 36, 39). This is primarily because movements with free weights can mechanically mimic athletic and ergonomic tasks more effectively than machines. However, few studies have actually compared changes in performance using different modes of training. For example:

■ Machines vs. Free Weights

Transfer of Training Effects: Maximum Strength Gains

Short-term studies using specific strength tests (strength was measured on the different types of apparatuses used in training) have consistently indicated that free weights produce superior strength gains (4, 15, 40, 44). These studies indicate that, when measuring 1-RM, free-weight training transfers to machine testing better than machine training transfers to free-weight testing.

Studies in which the strength testing was not specific (strength was measured on an apparatus different from that used in training) have not shown strength gain differences (24, 34, 35). In the studies by Saunders (34) and Silvester et al. (35), training was dynamic and strength testing was isometric, which likely attenuates any strength gains or differences.

Furthermore, dynamic tests of strength in which the testing device is supposedly nonspecific in fact can favor either free weight or machine training. This is because the dynamic testing device must be either free weights or a machine.

In the study by Messier and Dill (24) comparing Nautilus and free-weight training, tests of leg strength were performed on a Cybex II isokinetic leg extension device, an open kinetic chain exercise. The Nautilus group used leg extensions as one of the training exercises. Free weight training was carried out using the squat, a closed kinetic chain exercise, and no leg extensions were performed. Thus the Nautilus group likely had an advantage in testing because part of their training was biomechanically similar to the testing device.

Although training differences may be attenuated by using a “nonspecific device” to measure strength, these studies do demonstrate a transfer of training effect for strength gains.

Isokinetic Devices. Although previously believed by many clinicians and exercise scientists to be a superior method of training, there is considerable scientific evidence that isokinetic training does not offer advantages over other forms of resistance training, and in most instances may even be inferior to other forms of training.

Isokinetic refers to an exercise using a constant angular velocity of a machine lever arm on which a body segment applies force. Theoretically, an isokinetic device will accommodate force production and maintain a constant velocity; thus a maximum force effort can be made through the complete range of motion. However, there are no commercially available devices that produce an isokinetic movement throughout

a complete range of motion, especially at fast speeds (41).

This lack of complete isokinetic range of motion is due to acceleration at the beginning and deceleration at the end of the range of motion.

Studies and reviews comparing isokinetic and other resistance training modes indicate a high degree of strength specificity (12, 25). In fact, strength and power gains as a result of free weight training or variable resistance training are not always demonstrable when measured on isokinetic devices (8).

It may be argued that a freely moving object or device will allow muscle contractions to occur that are more similar to natural motions since movement is rarely performed at a constant velocity through a full range of motion (19, 41). A recent comparison of "isotonic" (freely moving leg extension device) versus isokinetic training indicates that isotonic training produces better strength and power gains (19).

Transfer of Training Effects: Functional Effects

Few studies dealing with modes of training have investigated the carryover to aspects of performance other than strength, such as sprinting or jumping, and none have investigated the effects on ergonomic tasks.

A few studies have compared free weights and variable resistance machines as to their effects on the vertical jump and vertical jump power indices (15, 35, 40, 43, 44). Three studies (35, 40, 43) found that free weights produce superior results while two studies (15, 44) found statistically equal results.

No studies have indicated that machine training produces better results compared to free weights

in gains in vertical jump. While these studies generally indicate the superiority of free weights in producing a transfer-of-training effect, they are not definitive.

Problems With Comparing Adaptations of Various Modes

It is difficult to compare training adaptations of various modes of resistance exercise. Several confounding factors become evident. As previously pointed out, testing specificity can be a major problem.

Work Equalization. It is exceptionally difficult to equalize work even when set-and-repetition combinations are the same. This is partly because machines use various combinations of methods for producing resistance such as springs, elastic bands, levers, hydraulics, pulleys of different shapes, and weight stacks. Additionally, it is doubtful that training protocols with equal workloads are typically chosen in practice. The training protocols chosen are those that are believed to produce desired results.

Often the machine manufacturers recommend set-and-rep combinations that may differ from that commonly used (e.g., one set to failure). Thus many studies used different set-and-rep combinations among comparison groups, for example the study by Stone et al. (40).

Combination of Protocols. Some studies have used combinations of free weights and machines in comparing protocols to machine exercise (23). Care must also be taken in properly describing the training protocols. For example, in the study by Boyer (4), using women, the "free weight" lower body training program was actually carried out using a leg sled. A leg sled is not a true free weight device since its movement

is a single fixed plane and results in guided and restricted movements.

Subject Number and Study Length. The subject number in many comparative studies is relatively small. For example, a study by Wathen and Shutes (44) indicated that significance favoring free weights in the vertical jump would have been reached if the subject number had been higher ($n = 8$ per group).

A major problem with any type of training study is its length. No study comparing training modes has lasted longer than 12 weeks. Another important consideration is the training status of the subjects. Only three studies in the scientific literature used previously trained subjects (40, 43, 44). Finally, few studies have used women. Obviously much more comprehensive study needs to be carried out.

Practical Considerations

Advantages and disadvantages of various modes of training (9, 13, 36, 39, 41) can include the following:

1. The advantage of free weights is primarily their ability to develop training protocols containing a high degree of mechanical specificity. An important consideration is that with free weights the pattern of intra- and inter-muscular activation used (i.e., exercise selection) can be more similar to the movement requirements of a specific task than is usually obtained through machine exercise.

Use of free weights allows proprioceptive and kinesthetic feedback to occur in a manner similar to that in athletic performance. This is possible because with free weights, movement can take place in all three planes and

is not being guided or otherwise restricted.

It should be noted that machines can limit movement or exercise selection in several ways, for example:

(a) Typically only one or two exercises can be performed on a machine, thus many machines are required for a complete training session. Free weights allow many exercises to be performed with minimum equipment.

(b) Machines typically allow little mechanical exercise variation (e.g., changes in hand or foot spacing) while free weights allow unlimited variations.

(c) Most machines typically permit movement in a single plane (rotation of a lever arm about a fixed axis) while free weights require balance and therefore permit exercise in multiple planes as occur in athletic and ergonomic movements.

(d) Some machines (variable resistance and isokinetic devices) restrict normal acceleration and velocity patterns that can change normal proprioception and kinesthetic feedback. For example, the design of variable resistance machines attempts to match human strength curves with the resistance supplied by the machine. However, due both to individual differences and to limitations in machine design, matching resistance and strength curves has not been accomplished.

2. Metabolic considerations are also important. Large-muscle-mass exercises require more energy than small-muscle-mass exercises (38, 42). Because body mass and body composition are strongly influenced by energy expenditure, large-muscle-mass exercises are more likely to effect body composition (and metabolic) changes (38). Large-muscle-mass exercises are

Points to Consider

1. Free weights allow one to develop mechanically specific training protocols.
2. Large-muscle-mass exercises are more easily accomplished with free weights. Because these exercises require more energy, they are more likely to lead to positive changes in body composition.
3. Spotters are needed during free weight exercises and some machine exercises.
4. Time can be saved by employing a few large-muscle-mass/multijoint exercises rather than many isolated muscle-mass exercises.
5. It takes time and effort to learn the technique of some free-weight movements but it's time well spent.
6. Machines may or may not save time. The time spent training is largely determined by the length of rest periods between sets, whether working with machines or free weights.
7. Free weights allow a wider range of incremental weight increases (from 0.5 to 45 kg).
8. Machines can make it easier to isolate specific parts of small muscle masses, which can be important in rehabilitation or injury prevention.
9. There is no supporting evidence that machines are any safer than free weights.
10. When storage space is limited, machines can be a better option, especially those with springs and elastic bands.
11. In terms of cost, machines are usually more expensive.
12. In terms of equipping a training facility, free weights can allow more people to be trained at the same time.

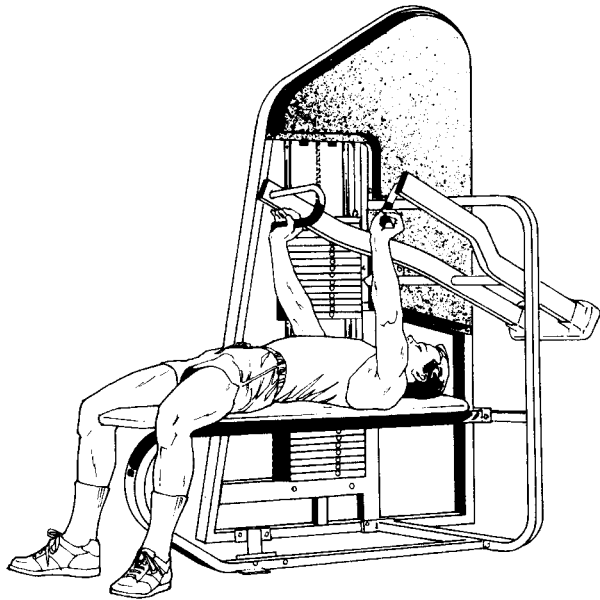
much more easily accomplished with free weights.

3. The use of spotters is necessary for some free weight exercises and occasionally in some machine exercises. Spotters are needed to catch the weight if a repetition is missed, and to provide feedback about proper technique and to provide encouragement.

4. Large-muscle-mass/multijoint exercises can result in more efficient training. One large-muscle-mass exercise (e.g., power snatches) can exercise as many as 4 to 6 small-muscle-mass exercises. Time can be saved by employing a few large-muscle-mass exercises rather than many small- or isolated muscle-mass exercises.

5. Learning the technique of some multijoint free weight movements may require extra time and effort. However, the cost-to-benefit ratio of learning a new skill is worth the effort.

6. Time may be a factor in some training situations. However, it is a common misconception that machines always save time. If the rest period between sets is very short (<30 sec), then moving a pin into a weight stack may be an advantage. In most training situations, especially priority training, the rest time between sets is typically a function of the volume load and usually lasts about 2 to 3.5 min. Because of the relatively long rest periods, changing weights is not a problem.



7. While moving a pin is easier than changing weights on a bar, typical weight stack machines offer increments of 7.5 to 12.5 kg. Some machine companies offer smaller extra weights that can be added to the weight stack, but most do not. And most gyms do not have these smaller add-on weights available.

Furthermore, devices that employ springs and elastic bands for resistance do not typically provide bands offering small increments (the increments are usually approx. 5 kg). With typical free weights the incremental jumps can be made from approximately 0.5 to 45 kg. This wider range of weight increments allows easier progression and more accurate resistance loading, especially if percentages of maximum are used in training programs.

8. With machines it is quite easy to isolate specific small muscle groups and employ single-joint exercises. In some cases machines may isolate small muscle masses or stress specific parts of small muscle masses more efficiently or easier than with free

weights. Training isolated muscle groups or single joints may be important in a body building program, initial rehabilitation, or as part of an injury prevention program.

9. Although it is commonly believed that machines are safer than free weights, there is no evidence to support this belief (29).

10. While space is not always a problem in health clubs, YMCAs, or colleges, it can be in some cases. Storage space in homes is limited. In a military setting, space is often at a premium, for

example aboard ships. Transportation and storage of equipment occasionally dictates the type of equipment that can be used. In many cases machines, especially those using springs and elastic bands, take up less space.

11. Equipment cost is often the determining factor in the selection of equipment. Machines are usually more expensive than free weights. Considering the cost of multistation and single-exercise machines, free weight equipment can be used to train the same number of people for less money. In terms of equipping a training facility, free weight equipment can also allow more people to be trained at the same time for the same cost.

■ Conclusions

Although more research is needed to establish the effects of various modes of training on athletic and ergonomic performance, the current evidence suggests that for most activities, training with complex, multijoint exercises using free weights can produce better results than training with ma-

chines. This is because free weights allow movements that are more mechanically similar to those occurring naturally. Considering the evidence that specificity of exercise results in a greater "transfer of training effect," free weights should produce a more effective training transfer.

Thus the majority of resistance exercises in a training program should be free weight exercises with the emphasis on mechanical specificity. Machines can be used as an adjunct to training and, depending upon the sport, they can be used to a greater or lesser extent during various phases of the training period or if there is a need to isolate specific muscle groups. ▲

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