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Volume 22, Number 6, pages 18–30

Roundtable Discussion: Machines Versus Free Weights

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Keywords: free weights; weight machines.

MANY STRENGTH AND CONDITIONING professionals design and implement resistance-training programs that involve both free weights and weight machines. These programs are often designed in an attempt to improve strength, power, and ultimately athletic performance. The benefits of both modalities of resistance training are often discussed by athletes, coaches, athletic trainers, and sport scientists. In these discussions, there are many differing opinions about which modality or combination of modalities produces optimal sports performance gains. The purpose of this roundtable is to discuss several issues related to the use of free-weight and machine modalities in an athletic setting.

■ Question 1: What Are the General Advantages and Disadvantages of Free Weights?

Harman: The general advantages of free weights are that they (a) are often used for exercises that involve a large portion of the body's musculature either directly or for support and stabilization; (b) lend themselves to ballistic or "explosive" exercises; (c) can readily be used to simulate real-world lifting movements; (d) involve ranges of motion and muscle activation patterns similar to those in many sports movements, particularly for the lower body; and (e) are relatively low in cost.

The general disadvantages of free weights are that they (a) can be intimidating to people who lack confidence in their athletic ability; (b) provide little resistance except in the downward direction; (c) require more time than do machines to adjust resistance when plates and collars are used; (d) usually require separate weight plates that may become misplaced, left in places that could create hazards, or fall on users; (e) sometimes require a spotter for safety; (f) are more likely than machines to cause injury if the user is inept or careless; (g) require more knowledge of proper exercise form than do machines; and (h) are not readily used for circuit training because of the time required to change resistance.

Because gravity only pulls downward, for a free weight to provide resistance to a movement, the body must be positioned in such a way that the downward pull of the weight resists the movement. This is not difficult in the case of movements such as combined knee and hip extension, for which exercises such as the squat can be used, or such as combined shoulder transverse plane adduction and elbow extension, for which exercises such as the bench press can be used. However, several other body movements are difficult to exercise with free weights. Some examples are torso transverse rotation, important for throwing and batting sports; hip adduction and abduction, important for sports involving lateral movement; and shoulder frontal plane adduction, important for combative sports such as wrestling and judo and sports in which the body is lifted, such as gymnastics. These and several other movements are more readily exercised using machines than free weights. Even athletes engaging in sports that don't emphasize these movements would likely benefit from such exercises by achieving balance among the various muscle groups.

Wathen: The advantages of free weights (barbells/dumbbells) are that they (a) are versatile, (b) are lower in cost, (c) allow for large variations in user strength, (d) require balance and coordination much like actual sporting events, (e) allow for small incremental adjustments in resistance, (f) allow for multiplanar movements, and (g) are safe when used appropriately.

The disadvantages are that (a) some movements (bench press, squats, etc.) require spotters or special racks; (b) space requirement is larger than a single-station machine; (c) they require balance and coordination; (d) some exercises such as leg curls, knee extensions, leg presses, and calf raises are difficult if not impossible to perform with free weights; and (e) they are psychologically intimidating to some novice trainees.

Carpinelli: There are theoretical advantages and disadvantages to free weights, with no strong scientific evidence to support the superiority of this modality. Perhaps more balance and coordination are required to perform free-weight exercises compared with machine exercises, but there is no evidence that this skill has any significant transfer to other activities. It should be recognized that just as everyone who participates in a sport must practice their skill with the tools required for their sport, powerlifters and Olympic weightlifters must practice their skill with the required tools—free weights. A potential disadvantage with both free weights and machines is that injuries may occur as a result of improper use of either tool. Lombardi and Troxel (6) note that in 1998, weight training accounted for an estimated 60,000 emergency room visits and at least a half-dozen deaths in the United States. The authors propose widespread education and an emphasis on technique rather than the amount of resistance to help eliminate senseless fatalities and minimize the incidence and severity of injuries (6).

Stone: Definition of free weights: barbells, dumbbells, associated benches, medicine balls, body mass—in other words, a freely moving body that does not inhibit the occurrence of normal force/acceleration patterns. Challenges the lifter to control, stabilize, and direct a movement.

There are several marked advantages of free weights compared with machines:

1. Free weights are typically cheaper and thus have greater cost effectiveness. For example, well-made Olympic-style barbells can be purchased in the United States for well under $1,000 for a 400-lb. set. If the cost of outfitting a major training facility with typical machines (each one performs essentially 1 function) were used to purchase barbells, dumbbells, and associated benches, then this would allow substantially more people to train simultaneously at the same cost (or less).
2. Most machines have limited adaptability—that is, the machine will only allow performance of the exercise (with few variations) for which it is designed. This is not a problem with free weights, in which exercises can be created to fit the activity (i.e., greater degree of mechanical specificity).
3. Although some manufacturers have attempted to improve adjustment factors, most machines do not have sufficient adjustment capability to be able to fit all sizes or populations. Even cursory observation of athletes or nonathletes reveals differences in height, weight, limb length, and so on that will affect the way in which many, particularly variable-resistance, devices are able to effectively apply resistance. For example, most machines are made to fit adults, not children. An advantage of free weights is that one size fits all. In this context, "variable-resistance" machines do not adequately apply resistance in relation to human strength curves, particularly on an individual basis (10).
4. Metabolic aspects of exercise and training can be very important to both athletes and nonathletes. Large–muscle mass exercises require more energy than smaller muscle mass exercises. Body mass and body composition can be greatly influenced by total energy expenditure; thus, large–muscle mass exercises are more likely to influence body composition and metabolic adaptations (for review, see Stone et al., ref. 31). A greater variety of large–muscle mass exercises can be performed with free weights as compared with the case of typical machines. In this context, free weights can be advantageous in terms of providing time-efficient training sessions. One large–muscle mass, multijoint exercise such as the squat press can exercise as many muscle groups as can 4–8 small, isolated or small–muscle mass exercises, thus saving time.
5. The development of training protocols in which the exercises have a high degree of mechanical specificity (with appropriate training design) is the major advantage of free weights. This is particularly true for developing speed and power. Mechanical specificity includes force characteristics

(i.e., magnitude of force, rate of force development, velocity, power), as well as movement patterns. There is little doubt that free weights can satisfy these aspects of specificity better than can typical machines. (See Stone et al., ref. 30, for a more detailed discussion).

6. Review of the literature and careful observation indicate that skillful free-weight movements can augment motor control and general coordinative abilities (12, 15, 27, 29). These "coordinative abilities" can include the following:
   - Orientation and differentiation
   - Reactive ability
   - Rhythm and balance
   - Combinatory abilities
7. Space limitations can be a disadvantage for free weights (and most machines). For example, space can be limited in confined quarters, such as aboard ships, submarines, space vehicles, and so on. In many cases, specifically constructed machines, sometimes using springs or elastic bands, can take up less space.

■ Question 2: What Are the General Advantages and Disadvantages of Machines?

Harman: The general advantages of resistance exercise machines are that they (a) do not usually intimidate novice users; (b) can be designed to provide resistance in any direction; (c) usually provide a quick and easy means of changing resistance; (d) are generally self-contained, not requiring add-on weights that might be misplaced; (e) do not generally require a spotter for safety; (f) are less likely than free weights to cause serious injury to a user who is inept or careless; (g) require little knowledge of proper exercise form; and (h) may be organized in a circuit to provide a fast and convenient way to exercise all major muscle groups.

The disadvantages of resistance exercise machines are that they generally (a) provide for sequential training of isolated muscle groups rather than training major muscle groups in unison, (b) do not lend themselves to ballistic or "explosive" exercises, (c) do not simulate real-world lifting movements, (d) do not simulate complex muscle activation patterns characteristic of sports, and (e) are relatively high in cost.

Wathen: The advantages of machines are they (a) require no spotters, (b) generally are easy and safe to use, and (c) usually allow for gradual increments in resistance. Machine stations generally take up little space and may be less intimidating to some novice trainers. Some exercises, such as the leg curl, leg press, and knee extension are more easily performed with the use of machines. Machines do not require balance, which is both a desirable and undesirable trait depending on the health status of the trainee.

The disadvantages of machines are (a) increased cost, (b) inflexibility (generally, only 1 movement/exercise can be performed per machine), (c) difficulty of some units to provide a wide variety of resistances and fit a wide variety of body sizes. Some units are difficult to figure out how to use without assistance. Additionally, most units only allow movements in 1 plane of motion and do not require balance. Ballistic movements such as the Olympic lifts and their modifications (power cleans, overhead squats) are often impossible to perform on machines. Additionally, when movements are performed in a ballistic fashion, damage may be done to some machines. Finally, machines generally require more maintenance.

Carpinelli: There are theoretical advantages and disadvantages to machines but no strong scientific evidence to show any advantage over free weights. For example, if variable-resistance machines more effectively overload the muscles throughout the range of motion, they may stimulate a greater increase in muscular size and strength compared with the case of free weights. However, there is no evidence to support this assertion.

Stone: Definition of machine: device that applies resistance in a guided or restricted manner. Smaller challenge, compared with the case of free weights, for stabilization, control, and directed movement.

1. In some specific small–muscle mass exercises in which joint segments "close in on themselves," such as arm curls, some machines may offer resistance through a greater range of motion compared to any one free-weight exercise. This may be an advantage in hypertrophy development with some machines.
2. It is often argued that machines are safer than free weights. However, there is no evidence for this assumption (22). In the author's experience, there are as many or more injuries occurring with machines as free weights. Often, these injuries result from poor technique or from poor technique coupled with poor training programs, regardless of the mode of exercise.

■ Question 3: Discuss Briefly Your Interpretation of the Literature Regarding Strength Gains Using Free Weights or Machines

Harman: The literature has shown major strength gains from the use of exercise machines as well as from free weights (4, 6, 11, 14, 25–27). The muscle doesn't "know" whether a machine or a free weight is providing the resistance. Thus, there is little reason for either free weights or machines to produce greater strength gains for individual muscles, assuming equal resistance is applied. A study comparing the free-weight bench press to the machine bench press (17) showed a high degree of similarity in muscle electrical activity during the 2 exercises. Any difference in strength gain is likely due to a difference in the training protocol, such as intensity, volume, rest periods, and so on. Differences in measured training effect between free weights and machines can often be attributed to the degree of similarity or difference between the training exercises and the strength tests. The concept of specificity of training states that the closer the strength test is to the training exercise with regard to muscles involved, ranges of motion, speed of movement, and pattern of resistance, the more likely the training will improve test performance. That is true not only because the exercise is likely to stimulate growth of muscle fibers directly involved in the movement but because development of strength is due in large part to the establishment of neural firing patterns (23).

Wathen: Depending upon the testing method used to quantify strength, the laws of specificity are very applicable (14). For example, if you test a 1-RM bench press with free weights, you are likely to test better if you train with free weights. If you test a 1-RM leg press, you are likely to get better if you train with the leg press. There is some evidence that more carryover is likely with free weights than machines when training and testing in both modes (4, 16, 17). Generally, strength can be developed with all types of resistance equipment if a proper progressive-resistance program is employed.

Carpinelli: Free weights and machines have seldom been compared, but when they have been compared, neither modality has shown any overall superiority. For example, Silvester and colleagues (10) conducted 2 experiments. Experiment 1 had 3 groups that trained 3 times a week for 13 weeks. One group performed 1 set of 4–12 repetitions to fatigue on a Nautilus Compound Leg machine, which is comprised of 2 exercises: the knee extension and leg press. Another group performed 2 sets of 7–10 repetitions to fatigue on a Universal Leg Press machine. A third group executed the free-weight squat for 3 sets of 6 repetitions. The authors stated, "The analysis of the strength measures established that there were no significant differences (P < 0.05) between the groups for any of the [strength] variables. It appeared that vertical jumping ability was improved to a greater extent by training with free-weights and the Universal apparatus than by training with the Nautilus device. However, the differences are relatively small, and in view of the similarity of the strength gains, the practical application of the finding is unclear" (10, p. 32).

In experiment 2, Silvester and colleagues (10) trained 4 groups 3 times per week for 8 weeks. Two groups performed free-weight barbell curls; either 1 set of 8–12 repetitions to fatigue or 3 sets of 6 repetitions with 80% 1-RM; 2 groups used the Nautilus Omni Biceps machine, performing 1 of the 2 aforementioned protocols. All 4 groups had a significant increase in strength, with no significant difference among the groups. Silvester and colleagues concluded, "The finding that there were no significant differences in strength gains for any of the groups at any angle implies that variable resistance and free-weights were equally effective at developing strength throughout the complete range of motion. The importance of the present findings is that it does not seem to matter which method of strength training one chooses" (10, p. 32). The absence of any supporting evidence suggests that when used properly, free weights and machines produce similar results in a healthy, athletic population.

Stone: Although both machines and free weights produce strength gains, to a large extent, the magnitude of gains in maximum strength as a result of resistance training depends upon the similarity between the strength tests and the training exercise. This aspect of mechanical specificity has been noted in longitudinal studies (1, 13, 21) and in reviews of the literature (23–25, 29).

Reasonable adherence to testing specificity can be very important in attempting to ascertain gains in maximum strength. Lack of adherence may explain why several studies failed to show differences between groups. For example, in studies by Saunders (22) and Silvester et al. (28), training was dynamic and testing was isometric, which likely masks or reduces any gains in maximum strength and may then reduce observable differences between groups (36). Indeed, the rationale behind using a nonspecific test for maximum strength is that such a test would not favor either mode of training. However, a supposedly nonspecific device often favors either a free weight or a machine. This results from the fact that in dynamic testing, the testing device must be either a free weight or a machine. For example, in the study by Messier and Dill (20) comparing Nautilus training to free-weight training, tests of leg strength were performed on a Cybex II semi-isokinetic leg extension device. This leg extension device is used for open–kinetic chain exercise. The machine (Nautilus) group used leg extensions (open–kinetic chain exercises) in training; however, the free-weight group used squats (closed–kinetic chain exercises) and no leg extensions in training. Thus, the machine group may have had an advantage in testing because part of their training was mechanically more similar to the testing mode.

Although differences between groups using different modes of training can be masked or reduced by using a nonspecific measurement, some transfer (in other words, carryover) between devices may be expected (18, 36). However, it is likely that the effect size must be quite large in order to show differences. Interestingly, most of the available peer-reviewed, published data indicate that maximum strength (1RM) gained as a result of free-weight training can transfer to machine testing better than can the converse (6, 24, 26). This concept of greater carryover is supported by 2 unpublished observations from our laboratories (8, 15). The exact reasons for this observation are unknown.

Several problems with some of these studies preclude any definitive conclusions concerning comparison between devices. These problems range from lack of specific testing (see above), use of different protocols, and too few subjects. Perhaps the most important problems deal with the study length; there are no long-term (i.e., years) studies and training status (24). However, there is a suggestion that 1-RM measures of strength carry over from training on free weights to machines better than training on machines carries over to free weights.

■ Question 4: Discuss Briefly Your Interpretation of the Literature Regarding the Carryover of Strength Gains Achieved From Machines to Sports Performance

Harman: Because free weights are so widely recognized as effective in improving sports performance, there have been relatively few studies of athletic strength training in which only machine exercise was performed. Because most studies of the effects of resistance training on sports performance have used either free weights alone or combined programs of free weights and machines, it is difficult to isolate the effects of the machines alone. However, there is evidence that resistance exercise machines can improve sports performance. For example, hip sled exercise produced improvements in both vertical jump distance and leg power (29). Training on machines has also improved the 40-yard dash, softball and baseball throw, shotput, and vertical jump (2, 16, 19). Circuit training both with and without machines has been widely used in athletic-training programs supervised by professional coaches in sports such as swimming, track and field, and baseball (20–22).

Wathen: Numerous studies indicate that gaining strength will result in improved performance in a number of performance areas, such as running speed (4, 6, 13); endurance; throwing (9, 11, 13); serving; striking velocity; and head speed produced with bats (12), clubs, and racquets. Although some studies indicate little improvement in performance with strength gains, most do indicate such improvement. Any mode used to increase strength specific to the muscles involved in a movement should result in improvements in performance, machines included. It is important to note that no amount of improvement in strength will replace skill training for overall improvements in performance.

Carpinelli: I will answer questions 4 and 5 concurrently.

Stone: I will answer questions 4 and 5 together.

■ Question 5: Discuss Briefly Your Interpretation of the Literature Regarding the Carryover of Strength Gains Achieved From Free Weights to Sports Performance

Harman: There is ample evidence in the scientific literature that training with free weights can improve sports performance (28). A few examples of improvements in sports performance as a result of free-weight training include increases in sprint speed (5), running economy (13), throwing velocity (10, 18), and swimming speed (3, 12). Because of specificity of training, the greatest benefits of free-weight training occur with the lifting sports, such as powerlifting and Olympic-style weightlifting, and in sports requiring high lean body mass and the ability to exert pushing force against high resistance, such as U.S. and Canadian football. Free-weight exercise can also be effective in improving vertical jumping ability because body posture and direction of push are similar in the vertical jump and exercises such as the squat and power clean. In comparisons of the effectiveness of the squat to machine exercise, the squat has generally proven superior (2, 8, 24). Specialized free-weight exercises such as the jump squat have proven even more effective than the squat for improving jumping ability among experienced athletes (30).

One problem with trying to compare the effectiveness of free weights and machines is that most training studies have used a combination of free weights and machines. That is because such a mix of equipment is characteristic of most sport and recreational weight-training facilities. The fact is that most serious weight trainers use a combination of free weights and machines. It is rare to find an athletic weight room equipped with only barbells and dumbbells, without even a pull-down machine, leg press machine, or knee extension machine. Resistance-training programs that include both free weights and machines have repeatedly proven effective for sports training (7, 9, 15).

Wathen: There is some evidence that resistance-training movements that more closely approximate the sport performance have more improvement value (1, 7, 15). For example, Augustsson et al. (3) indicated that free-weight squat training has more impact on vertical jump performance than does a program of isokinetic knee extension and hip adduction. There are few studies in this area, and most are equivocal, but more evidence points to specificity of muscle action type and movement pattern favoring dynamic free-weight movements that closely approximate the sport movement (5, 7, 15). After all, most sports performance is dynamic, multijoint, multiplanar, requires balance, and deals with both eccentric and concentric actions (3, 10). Sounds like free weights. We see empirically that Olympic weight-lifters are among the quickest, most powerful, and flexible Olympic athletes. They train ballistically with jump-like movements while holding free weights (8). Sounds like a plan to improve strength, power, quickness, reaction time, and flexibility, traits that most athletes in power sports require.

Carpinelli: There appears to be a bias in the Strength and Conditioning Journal favoring free weights over machines. The bias is evidenced by the statements regarding the superiority of free weights over machines that go unchallenged by the reviewers and editors of the journal.

For example, in the early issues of the NSCA Journal, there is a two-part article written by Garhammer (part I) and Stone (part II) that makes very strong assertions—without any supporting scientific evidence—for the superiority of free weights. In part I, Garhammer (4) claims that the transfer of strength and power will be more beneficial if the strength program is based on free-weight multijoint exercises, and he asserts that there are neuromuscular similarities between free-weight exercises and athletic movements that make the transfer of strength easy. Garhammer does not cite any training study to support his opinion. He claims (4) that bodybuilding coaches and gym operators express their preference for free weights over machines, and he cites a book by O'Shea (7), which expresses O'Shea's unsubstantiated bias for free weights. O'Shea continues to advocate the superiority of free weights over machines in his current book (8) and in his recent article in the Strength and Conditioning Journal (9), with no supporting scientific evidence.

Garhammer (4) claims that as an athlete moves through the range of motion in which the optimal internal leverage produces the greatest internal torque, the barbell perfectly accommodates the increased internal (muscular) torque by accelerating at a greater rate. The barbell does not accommodate. It responds to a larger force with a greater acceleration. A greater applied force will produce a greater acceleration to a given mass, but the greater momentum makes the repetition less intense. During the execution of some multijoint free-weight exercises, such as the squat, military press, and bench press, greater torque can be generated during the last third of the concentric muscle action, as compared with the middle third—the sticking zone. If an athlete attempts to accelerate the barbell throughout the range of motion, the greater acceleration in the first third of the repetition produces greater barbell momentum. The momentum helps the athlete through the sticking zone and makes that part of the repetition easier and the last third of the repetition—where he is the strongest—the easiest. Out of the 21 references cited by Garhammer (4), there is not a single peer-reviewed strength-training study comparing free weights and machines. It is merely an article expressing Garhammer's opinion.

In part II, Stone (12) claims that free weights produce superior results compared with machines and asserts that his opinions are supported by research. Among the 39 references cited is the previously discussed article by Garhammer (4) and only 2 studies that compared free weights and machines: Stone and colleagues (11) and Wathen (13). Stone and colleagues (11) compared Nautilus and free-weight strength training performed 3 times per week for 5 weeks. Although Stone and colleagues claim that the squat demonstrated the only significant difference between groups (out of 17 exercises), they did not report any pre- to posttraining data or the percentage change in strength for the squat or any of the other exercises. Their concluding statement, "This study indicates that free weight training is superior to Nautilus in producing changes in variables which may influence athletic success during short term training" (11, p. 160), is not supported by the data reported in their study. Free-weight advocates continue to cite this study, which was not published in a peer-reviewed journal—and was never replicated.

In the other study cited by Stone (12), Wathen (13) trained football players using either free-weight squats (5 sets of from 3 to 8 repetitions) or a MINI-GYM Leaper (5 sets of 20 repetitions) 3 times per week for 8 weeks. Although Wathen claims that the group who performed barbell squats showed a statistically significant increase in vertical jump compared with the Leaper group, he did not report any pre- to posttraining data or percentage change for the vertical jump, performance on the Leaper, or the changes in strength in the squat or in any of the other 7 exercises. The Leaper does not provide resistance for eccentric muscle actions, and several studies have shown that training protocols that employ a combination of concentric and eccentric muscle actions to enhance muscular strength and size are superior to those using only concentric muscle actions (1–3, 5). It is no surprise that a free-weight squat is superior to the Leaper. Conventional strength-training machines manufactured by Nautilus, MedX, Hammer, and so on provide resistance for both concentric and eccentric muscle actions. Additionally, and perhaps more important, there is no evidence to suggest that an increase in vertical jump will transfer to improvement in any sport activity.

Wathen and Shutes (14) followed up on the aforementioned study (13) by comparing the Leaper (2 groups: low repetitions and high repetitions) to free-weight squats (sets, repetitions, intensity, and frequency not reported by the authors) after 8 weeks of training. The group performing—and inherently practicing—free-weight squats showed a significantly greater increase in squat strength compared with the 2 Leaper groups. However, none of the groups improved in vertical jump or 40-yard dash. Neither Wathen's studies (13, 14) nor the study by Stone and colleagues (11) shows any evidence of a transfer of strength to sport activity.

Wathen: Addressing Dr. Carpinelli's comments, I would like to state that Athletic Training was a peer-reviewed journal in 1979 (the year reference 11 in his list was published) and continues to be refereed. The 1980 (his reference 13) study that I authored was published in the NSCA Journal, which was not a peer-reviewed journal at that time. The editor published the study, leaving out the pretest data and the data on the lifts used in the program without my permission.

Stone: The major contributing factor to the superiority of free weights compared with machines is the ability of free weights to mimic and overload most athletic (and daily task) movements. Because of this aspect, there can be a greater transfer of training effect.

I will use the vertical jump as an example. The vertical jump is often chosen as an indicator of athletic performance because (a) it is easy to measure; (b) the vertical jump is a primary component of many sports (basketball, volleyball, and so on); (c) there are reasonable associations and correlations between the vertical jump and other "explosive" exercises—for example, sprinters jump higher and sprint faster than distance runners (16); (d) the vertical and related jumps (or the vertical jump's components, including velocity and power output) have been associated with performance ability in numerous specific sports (2, 4, 29, 33).

With few exceptions (35), free weights have consistently produced superior results in vertical-jump gains across short-term–training periods (3, 5, 28, 32, 34).

From the standpoint of specificity, there are a number of kinetic and kinematic parameters, which must be appropriately overloaded to stimulate gains in performance. One of the most studied and contemplated performance aspects of specificity is the vertical jump and its relationship to weightlifting movements and weightlifting training. Indeed, improved weightlifting performance as a result of training has been associated with increased vertical-jump height and associated power output among novices (29). Furthermore, weightlifters have superior weighted and unweighted vertical-jump heights and power outputs compared with other athletes (19). Part of the reason for these superior performance characteristics are likely related to the mode and methods used by weightlifters in training. Although adaptations to training are always multifactorial, one likely contributing factor is the degree of mechanical specificity that can be observed between weightlifting movements (i.e., the snatch, clean and jerk, and derivatives) and the vertical jump (11, 14). These factors include a combination of high power output, high rates of force development, and movement patterns that cannot be easily duplicated by machine use.

Other assumptions that cannot be supported when examined closely have been made concerning the use of free weights and machines. For example, it is often assumed that throwing motions requiring twisting (trunk rotation) cannot be made and trained appropriately with free weights and that machines are necessary for this type of training. However, this idea may be related more to lack of experience with free-weight training than the actual mechanics of free weights or machines. First, it should be remembered that most throwing movements are made in a standing or upright position. For many years, throwers have simulated these upright positions using weighted balls and implements; additionally, walking twists and weighted–hammer thrower exercises have been used successfully to overload upright trunk rotation. Furthermore, with the use of benches or pommel horses, a variety of positional exercises using both weights and balls can stress trunk rotation from a variety of angles that cannot be attained with most machines.

■ Question 6: In What Populations Are Free Weights More Appropriate?

Harman: Free weights are appropriate for anyone who is not intimidated by them. Almost everyone has the physical coordination to handle free weights safely, so the issue is whether or not the trainee has the confidence to use them. People who are initially afraid of free weights can usually overcome their fear with proper instruction. Free weights are particularly important for training the muscles of the body to work in unison, especially in lifting or in other activities in which gravitational resistance is a major factor, such as sprinting and jumping. Barbell training has been shown to be more effective than machine training for improvement of the vertical jump (1).

To ask in what populations free weights are more appropriate implies that there are populations in which free weights should be used to the exclusion of machines. As important as free weights are for training the body as a whole, they should not be used to the exclusion of machines because of their inability to provide resistance in other than the downward direction. For example, frontal-plane shoulder adduction is commonly exercised using a pull-down machine. Although the movement can also be performed using the pull-up exercise, that limits resistance to body weight or greater. In contrast, resistance to the movement with less than body weight is readily achieved using either a pull-down machine or a pull-up machine that provides assistance via weight plates or other mechanism to help lift the body.

Wathen: All populations who are capable of weight-bearing exercise. Most resistance-training programs will have a combination of free weight and machine exercises. As mentioned earlier in this discussion, some exercises are more efficiently performed on free weights and some better with machines. The mode of exercise chosen will often dictated by the goals (strength, power, or joint stability) of the individual.

Stone: The important aspect here is "primary" exercises. Training exercises should be primarily carried out with free weights. Although a few machine exercises may be advantageous, most of the exercises should be performed with free weights for all populations. Exceptions are not usually population oriented but rather situation oriented, for example, where space may be at a premium (i.e., a submarine—crews have used elastic bands, which take up less space then either free weights or most machines).

■ Question 7: In What Populations Are Machines More Appropriate?

Harman: A machine can be designed to provide resistance in any direction and with any resistance pattern using cams or other mechanism of variable resistance. Machines are therefore appropriate for anyone involved in resistance training and should probably be used to some extent by all trainees. In addition, exercise machine circuits may be useful for training a relatively large group of athletes in a limited amount of time because it is much faster to change the resistance on a machine than on a barbell. However, the advantages of machines should not be taken to mean that machines should be used instead of free weights. Because free weights have the advantage of simulating real-world activities and calling upon muscles of the body to work in unison, virtually all resistance exercisers should be encouraged to use free weights. Even the elderly or those confined to wheelchairs can safely exercise with light dumbbells.

The question of whether either machines or free weights should be used to the exclusion of the other form of resistance exercise is a nonissue for virtually all strength coaches, a vast majority of whom use a combination of both. Rather than trying to determine which form of exercise is more appropriate, it is best to identify how both forms of exercise can be most effectively integrated into a comprehensive training program.

Wathen: All populations at some time during their training may benefit from using machines in their training programs.

Carpinelli: Most trainers and trainees have opinions about which type of equipment they prefer for different populations. However, unless those opinions can be supported with strength-training studies, they remain opinions. Strength-training protocols that are based on the sciences of physiology, kinesiology, and biomechanics and that are executed at an appropriate training intensity should transcend any theoretical differences in modalities. The absence of substantial evidence suggests that when used properly, free weights and machines produce similar results.

Stone: As the primary mode of training, none.

It has been assumed that populations comprising the elderly or those with certain disease states, such as arthritis, cannot use free weights because of pain during weight bearing or other limitations. However, this is an assumption that has not been adequately tested. In fact, evidence suggests that using free weights can be a safe and effective method of enhancing performance in these populations. For example, Brill et al. (7) successfully used a free-weight program with an elderly population (73–91 years) in promoting beneficial adaptations in several functional performance measures (such as balance, stair climbing, etc.). No adverse effects were noted.

It is likely that not being able to perform a particular exercise is more a function of individual physical and psychological characteristics that may be coupled with specific disease states or injuries, rather than characteristics of a population. These individual problems can easily be recognized by competent strength training personnel, and program adaptations can be made accordingly. ▲

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