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The National Strength and Conditioning Association's Basic Guidelines for the Resistance Training of Athletes

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Overview

1. Progressive overload should be a fundamental characteristic of resistance-training programs directed at the development of neuromuscular capabilities and athletic performance.
2. Resistance-training programs for athletic performance must adhere to the principle of *training specificity* in order to match the demands of the sport to the training program developed for a specific athlete.
3. Resistance-training programs for athletic performance should be periodized in order to optimize the adaptations over long-term training. Periodized training also helps to reduce the potential for overtraining.
4. Multiple-set periodized resistance-training programs are superior to single-set, nonperiodized programs for physical development over long-term training programs.
5. Care must be taken when developing resistance-training programs for younger and older athletes because the volume of exercise and the intensity may have to be altered to meet the recovery demands of each individual.

Preface

THIS PAPER IS INTENDED TO give a concise overview of resistance training, including some basic guidelines for program development and facts about resistance training. These guidelines should be viewed as an extension of other guidelines but with the focus on the training of athletes of all ages (4). Extensive amounts of literature have been published on resistance exercise and training over the past 20 years. The scope of this paper is limited to providing some of the fundamental guidelines and basic facts needed to start a resistance-training program for the young to master athlete. Each athlete will have specific goals, needs, and medical concerns that must be carefully evaluated in the program design by the strength and conditioning specialist. Thus, of primary importance to this whole process is the strength and conditioning specialist, who must use his or her experience, knowledge, and training to properly direct and implement such individualized, sports-specific programs. The effectiveness of any training program is defined by the ability of the strength and conditioning specialist to effectively use scientific principles as the basis for making a multitude of decisions on a day-to-day basis as to the individual progression of a resistance-training program for an athlete.

Introduction

Resistance-training programs have been used for many years as an integral part of a total strength and conditioning program for the enhancement of athletic performance. During the past 2 decades, the effectiveness of carefully planned weight-training programs as a method of improving body development and sports performance has been accepted on the basis of the scientific literature (4, 6, 20, 54, 60, 75, 88, 91). Significant benefits can be gained from the systematic and proper application of resistance-training principles, which are based on scientific investigations. The overload principle remains one of the primary tenets of resistance training; according to the principle, the demands on the neuromuscular system are progressively increased over the training period. Combined with the principles of periodization of training needed to optimize the exercise stimulus, resistance training provides one of the most potent and effective exercise stimuli available for athletes to increase muscular performance capabilities (12, 20, 88). In addition, the associated adaptations to resistance training contribute to improve sport performances and prevent injury. Another primary principle utilized in resistance training is the concept of training specificity (10, 28, 47, 48, 62, 83). The more closely the resistance exercises simulate the actions in a specific sport, the greater the transfer carryover of strength and power to motor performance in that sport.

Resistance training can also affect other physiological systems and performances (22, 59, 72). For example, resistance training may contribute to improve flexibility, provided the exercise is performed through the entire range of motion (4). In addition, normal increases in muscle size (i.e., hypertrophy) with resistance training do not reduce the muscle's endurance. Resistance-training programs do not typically improve maximal oxygen consumption to the extent that other modes of cardiovascular training do (e.g., running, cycling, etc.). However, it has been shown to augment the development of maximal oxygen uptake values and improve running efficiency while not causing any negative effects on the development of maximal oxygen consumption (54). Increasing the cardiorespiratory endurance capabilities of an athlete requires endurance specific training to achieve optimal results. The details of programs used to achieve improvements in maximal oxygen consumption have been well documented over the past 30 years (4).

Basic Adaptations to Progressive Overload Resistance Training

There is a large volume of literature that gives an overview of the process of adaptation to resistance training (43, 51, 56, 57). The rapidity with which overload increases the capacity for the muscle to handle heavier loads indicates that there is a dramatic increase in the neurological activation of motor units during the initial phases of resistance training. Scientific studies have demonstrated that such improvements in strength associated with the first 3–4 weeks of resistance training are primarily due to neurological adaptations (63, 70). In addition, during this time, the quality of muscle protein (e.g., myosin heavy chains and myosin ATPase) also changes rapidly within the first several workouts to allow for more rapid and forceful contractile capabilities (74).

Although the ultimate magnitude of morphological size of a muscle is primarily determined by genetic factors, numerous studies have long established that resistance training leads to muscle hypertrophy (1, 11, 29, 55, 74). Hypertrophy of muscle fibers is observed approximately 8–12 weeks after the initiation of the training program (57, 74, 79). The continued interplay of hypertrophic and neurological adaptations to resistance training continues to interact with long-term training. The impact of long-term training on muscle hypertrophy remains less studied, but the absolute magnitude of gains in muscle size and strength is lower as athletes approach their genetic limits (35, 36, 57, 84). Nevertheless, continued training over an athlete's career contributes to more sophisticated athletic development of the athlete's body in order to attain elite-level performances (35, 39).

A variety of cellular adaptations occur with resistance-training programs. These include increased anaerobic enzyme concentrations, stored energy substrates (e.g., glycogen and phosphagens), increased myofibrillar protein content (i.e., increased actin and myosin proteins), and increased noncontractile muscle proteins (29, 36, 55, 74, 78, 80–82). In addition, important changes occur within the central and peripheral nervous system to help in the activation of motor units to produce specific force and power requirements (36, 70, 72). Furthermore, a variety of changes occur in other physiological systems (e.g., endocrine, immune, and cardiovascular systems) that support the neuromuscular adaptations to a resistance-training program (22, 59, 70). All of these composite adaptations support the neuromuscular improvements in force, velocity, and power capabilities in the body consequent to resistance training.

Factors in Program Design

The overload principle is based on the concept that the athlete must habitually adapt to the demands of greater physiological challenges to the neuromuscular system. This will result in the need for the physiological system to respond and adapt in a specific manner based upon the exercise stimulus (12, 20, 75, 88). Thus, the physiological stress or loading of the muscle or muscles must be progressively increased over time for gains to occur (22, 75, 88). To accomplish an overload of the neuromuscular system, four factors should be considered in designing a resistance-training program. These factors include load, repetitions, sets, and frequency. The load is a measurable amount of resistance; a repetition is the number of times that the load is administered; a set is the completion of a number of repetitions; and the frequency is the number of training sessions per given time (e.g., 1 or more times a day or a certain number of times in a 1-week interval). Total volume is defined as the load times the number of repetitions times the number of sets (20) or more classically by the number of repetitions times the sets (75).

The total volume of a workout must be taken into account when planning resistance-training programs because too much volume for too long of a duration is one of the key factors in the development of an overtraining syndrome. A primary factor in overtraining is trying to do too much, too quickly (52). Periods of reduced volume can be used as an effective means to provide for recovery of the neuromuscular system and to help avoid overtraining specific muscle groups or the whole body.

Finally, periodization of the training program is vital to effectively implement the overload principle. The planned periods of rest and reduced volume and intensity over a training cycle help to avoid overtraining (20, 52, 75). As resistance training has evolved over the last 20 years, it has become difficult to design effective training protocols without considering specificity of exercise, periodization, as well as the wide variety of equipment available for to use in a resistance-training program.

■ Specificity of Training

Specificity of exercise relates appropriate resistance training of athletes to sport activity. Although athletes may enhance speed and power with non-sport-specific programs (65), to optimize athletic performance, the specificity principle should be followed. The principle allows one to match the appropriate metabolic and biomechanical characteristics of the training program to the sport activity, thereby training the appropriate metabolic systems as well as duplicating joint velocity and angular movement associated with sport activity.

The specificity of training is vital for the transfer of the stimulated adaptations created by the resistance exercise workouts to needs of the sport skill for enhanced performance. Most resistance-training programs effect general improvements in muscular strength and size. However, the specific characteristics of muscle force required for enhanced sport performance requires that greater care be taken in the sports-specific program design. For example, although improvements to increase 1-repetition maximum (1RM) strength are common to all programs that use heavy resistance, the improvement of force at very rapid speeds depends upon training at high velocities (33). Thus, improvement of a 1RM using conventional slow-velocity, heavy-resistance training does not assure the improvement of force development in ballistic sport movements (e.g., shot put, jump, forearm shiver).

The primary characteristics of the neuromuscular system that can be developed are related to the maximal force, power or rate of force production, muscle size, and local muscular endurance. Resistance-training programs must be specific to the goals of the program and to the specific characteristics of the neuromuscular system being trained.

■ Periodization of Resistance Training

One of the most important developments in the technology of sports training has been the advancement of concepts related to periodization of training. Periodization is the systematic process of planned variations in a strength-training program over a training cycle (20, 21, 75, 88). A significant amount of literature has been published over the past 2 decades. The majority suggests that the utilization of this concept has been shown to be vital for the optimization of the training adaptations in athletes (19, 53). One of the primary advantages of this training approach is to avoid overtraining. Thus, built within the program is time needed for physical and mental recovery of athletes. Finally, this type of training plan encourages peaking for athletic performances and allows for continued long-term gains in a resistance-training program. Typically, the larger muscle group exercises are periodized, but all exercises can be varied for intensity and volume (20, 72, 75, 88).

In 1981, Stone and colleagues (77) in the United States developed a model for strength and power sports by modifying the classic periodization program that was created by coaches in the former Soviet Union and Eastern European countries (87, 91). This approach broke a training program down into 5 mesocycles.

The model called the initial phase of training the *hypertrophy phase*, which emphasizes high volume and low resistance. The major goal of this part of the training cycle was to increase adaptation to resistance exercise and to increase muscle tissue mass. This is followed by the *strength and power phases*. The major goal of these phases was to stimulate increases in maximal strength and power, respectively. The *peaking phase* that follows the strength and power phases was designed to peak strength and power for a particular competition. The model was directed at preparing strength and power athletes for competition; however, the concepts could be modified for a variety of athletes. The decrease in volume across the training cycle was mirrored by a compensatory increase in the resistance or load used in the training. An *active-rest phase* followed the peaking phase. The goal of this phase was to allow recovery and was accomplished by either the use of limited, low-volume, low-intensity resistance training or by having the athletes perform other types of limited physical activity. The importance of this part of the training cycle was to allow for physiological and mental recovery from the training phases that preceded it. After the active-rest mesocycle the entire macrocycle was repeated.

It has been found that even greater gains in strength and power could be accomplished with more than 1 training cycle per year (20, 75). Again, typically, 3 complete training cycles are used in a year. The concept of variation is a vital factor that helps to explain the advantage of performing the entire set of training phases 3 times in a single year. Ultimately, the essence of periodization is the variation in load, volume, rest periods, and exercises done in a consistent manner over time.

■ Linear and Nonlinear Methods of Periodized Resistance Training

One can vary the program either within a week or over a number of training cycles. This is called linear or nonlinear periodization models. Each can be effective, but both involve variation over the training cycle. The linear model is the most classic model of periodization. As mentioned before, with more frequent completion of an entire training cycle within a year, greater gains appear possible because of increased variation. Conversely, many athletes have started to use a less traditional model of nonlinear periodization in which more dramatic changes occur within a weeklong training cycle. Such a method of periodization appears to better fit sport programs that have very long seasons and multiple competitions (e.g., wrestling, tennis, and basketball) and are not conducive to the deliberate build-up to a peaking phase.

The linear model of periodization varies the intensity over several weeks (or microcycles) of training. For example, the intensity over a a 16-week program might be as follows: weeks 1–4, light; weeks 5–8, moderate; weeks 9–12, heavy; and weeks 13–16, very heavy/power. Usually, the number of weeks used for a particular intensity load is called a microcycle, and their length ranges from 2–4 weeks. Again, the cycle ends with an active-rest phase prior to starting another complete training cycle or an in-season program.

A nonlinear periodization model varies the intensity and volume over the week, for example, Monday, light; Tuesday, heavy; Wednesday, rest; Thursday, power; and Friday, moderate. This goes on for a given training period (usually 8–12 weeks), and then competition is started or an active-rest phase is undertaken for 1–3 weeks. Upon completion of the active-rest phase, a new 8–12 week cycle begins that is based upon the athlete's new goals and needs. After the last cycle or at the end of a training period, competitions are usually scheduled because athletes are then at their peaks for that period of training.

One can also enter into an in-season program in which the athlete lifts once or twice a week to maintain gains. Many times, the nonlinear method of variation is used so that training can continue through the season. This is especially important for sports with long seasons (e.g., tennis, wrestling, basketball, and hockey). Typically, during the in-season programs, the frequency of training is reduced, and the volume of exercise is also modulated in relation to the amount of competition and volume of sport practice. The key element of this type of training is the variation and ability to allow rest after a training or competition period. Strength can be maintained easier than it can be gained, so periods of active rest allow the athlete to stay active but not necessarily participate in resistance training (66).

The length of active rest is related to the amount of training the athlete has and where it is taken in the yearly cycle. Usually, active rest periods range from 1–4 weeks in adults, with the less experienced taking the shorter, 1–2 week breaks before a new cycle of training begins. Children, like older adults, may need more time to recover. It is important that programs be individualized and that adults do not just impose a generalized training program on a child.

Empirical evidence suggests that variation in exercises for the same muscle group causes greater increases in strength and power than no variation in exercises. This does not mean that the exercises performed must be changed every single training session or that all exercises must be changed when one change is made. However, changes in exercises may be made every 2 to 3 weeks or some exercises varied on an every-other-training-session basis (e.g., 2 somewhat different training sessions performed alternately). Still, certain core exercises should be maintained through the training program so that progress in the major lifts can be made continuously (66).

Examples of Basic Periodization Program Designs

Linear Model

For the linear model, it should be noted that the weekly microcycle fluctuations occur such that the repetition maximum–level (RM) training is generally done on 1 day, and subsequent training in the same week for the same activity is done at a moderate (5–10% less than RM day) or light (10–30% less than RM day) level with the same volume. It is not necessary to train at RM level every training session.

Preparatory Training. A higher volume, lower intensity training program of 4–6 weeks should be undertaken to teach exercise techniques, gain initial adaptation to resistance exercise stress, and prepare the body for the initiation of the first training cycle. Loads are typically very light (e.g., 15- to 20-repetition maximums). This phase is especially important for beginners and may or may not be used with experienced lifters.

Hypertrophy/Endurance Phase. Choose a cycle length from 2 to 4 weeks. This phase formally starts a training cycle because the number of exercises and initial adaptation should be in place from the prior base cycle. Perform 3–5 sets of each exercise at an intensity that allows between 8–12 repetitions (50–75% of 1RM). This will create a high-volume, low-intensity stimulus. A 1–2 minute rest period can be used between sets and exercises.

Strength Phase. Using the same length cycles of 2–4 weeks, perform exercises that allow only 3–5 sets of 5–6 repetitions with intensity at 80–88% of 1RM. A 3- to 5-minute rest period is used between sets and exercises.

Power Phase. Using the same length cycle of 2–4 weeks, now perform exercises that allow only 2–4 repetitions for 3 to 5 sets of an exercise at 90–95% of 1RM. Also include exercise choices that allow the use of explosive exercises with these loads. In addition, one can include plyometric power exercises (e.g., with medicine balls) to begin to develop the power component in the training program of experienced lifters. A 2-to 3-minute rest period between sets is recommended to allow for adequate recovery.

Transition (Optional) and Competition Phase. Using a 2–3 week phase, the athlete uses a resistance that allows only 1–3 repetitions. The athlete performs 3 to 4 sets of each exercise. A 3- to 5-minute rest period is used between sets and exercises. These phases allow for the peaking of strength and power abilities, especially in sports where maximal, 1RM strength and power are important to the sport performance.

Active Rest Phase. At this point, the athlete moves into the competitive season after a week of active rest or formally undertakes a 1- to 3-week active rest phase before repeating the protocol from the hypertrophy phase again.

Nonlinear Model

Base Training. A higher volume, lower intensity training program of 4 to 6 weeks should be undertaken to teach exercise techniques, gain initial adaptation to resistance exercise stress, and prepare the body for the initiation of the first training cycle. Loads are typically very light (e.g., 15 to 20 RM). This phase is especially important for beginners and may or may not be used with experienced lifters.

Nonlinear Periodization. This nonlinear method can use the same time period as a linear model (e.g., 12–16 weeks). The different training sessions are cycled within the 7-day (or more) microcycle training range. Typically, a 1-week microcycle is used. For example, loading schemes could be similar to the linear model. Here, we use a 4–day training cycle.

- Monday: *Light day.* Perform 2–4 sets of each exercise at an intensity that allows between 10–15 repetitions. A 1- to 2-minute rest period can be used between sets and exercises.
- Tuesday: *Power day.* Use loads that allow only 2–4 repetitions for 3 to 4 sets of an exercise at 30–60% of 1RM performed at higher velocity of movement or at a 2–4 RM level. Include exercise choices that allow the use of explosive exercises with these loads. In addition, one can include plyometric power exercises (e.g., with medicine ball) to develop the power component in the training program of experienced lifters. A 2- to 3-minute rest period between sets is recommended to allow for adequate recovery.
- Wednesday: *Active rest.*
- Thursday: *Moderate day.* Perform 2 to 4 sets of each exercise with a load that allows 8–10 repetitions with loads 5–10% lower than heavy-day training. A 1- to 2-minute rest period is used between sets and exercises.
- Friday: *Heavy day.* Perform 3 to 4 sets of each exercise with a load that allows only 3–6 repetitions. A 3- to 5-minute rest period is used between

sets and exercises.

- Saturday and Sunday: *Active rest days.*

With the nonlinear program, one can vary the program over the week in whatever manner makes the most sense for the athlete. A 2- or 3-workout cycle can also be used. The different types of workout stresses can be alternated over a 14-day cycle as well, as giving this type of program a great deal of flexibility in its design to meet the needs of various athletes. The effectiveness of periodization results from systematic variation, which allows the athlete to have adequate recovery in activity levels, volume of exercise, and loading. At the end of a training cycle, one enters into an in-season program (usually with reduced frequency per week) using the same method of intensity variation but with a reduced number of exercises or sets to create a lower volume of training that is compatible with the demands of the sport.

■ Equipment Utilization

Most training facilities will have a variety of different exercise machines as well as free weights. A well-balanced program will benefit from the appropriate use of many different types of equipment to take advantage of the benefits some equipment can provide over others. However, some forms of training (e.g., isokinetic) are more appropriate for speed training than for development of muscle hypertrophy (67). Ultimately, each piece of resistance-training equipment must be used correctly to be both safe and effective. Multijoint exercises are most effective if performed with dumbbells or barbells (e.g., Olympic-style bar and plates). However, when learning exercise techniques, one can start with a very light resistance, such as only a bar or even, in some cases a long wooden stick. Increases in load should not occur until proper exercise technique has been accomplished. As progression in both the exercises and the loading occurs, constant supervision of proper exercise technique is vital to reduce, if not eliminate, injury. Proper technique is vital for all exercises, whether a simple, single-joint machine lift or a complex explosive lift, like a power clean. With motor learning, an initial neurological adaptation of proprioceptive mechanisms and interjoint neural communication must be trained with technique practice. Resistance machines are best suited for isolated muscle and single-joint movements because they focus the exercise stimulus on that specific muscle or muscle group.

In addition, the use of many pieces of equipment that have been around for many years has been rediscovered; these items are now used in modern strength and conditioning programs (e.g., medicine balls for upper-body power training). For example, performing speed repetitions as fast as possible with light weights (e.g., 30–45% of 1RM) in exercises in which the bar is held on to and must be decelerated at the end of the joint's range of motion (e.g., bench press) to protect the joint does not produce power or speed training but rather teaches the body how to decelerate, or slow down (64). If the load can be released into the air (i.e., the bar can be let go at the end of the range of motion), the negative effects are eliminated. Here is a situation in which the medicine ball became a rediscovered tool for upper-body power and plyometrics. Each piece of equipment must be evaluated as to its advantages and disadvantages as a tool for creating a specific exercise stimulus in a conditioning program.

■ Single Versus Multiset Programs

Not all exercises need to have the same number of sets performed in a resistance-training workout (20). In fact, few programs perform the same number of sets in all exercises in a single workout. Thus, many times, the arguments surrounding the concept of one versus more than one set become related to the context of its use (e.g., highly trained, limited training time, power training, etc.). In reality, the number of sets is part of the exercise volume equation. It is likely that the volume of exercise helps to create the exercise stimulus needed to elicit a specific physiological adaptation (20).

Resistance training has been reported to increase muscular strength in virtually all studies that have examined this modality. The magnitude of strength increase is dependent upon the program used (20), training status (39), genetic endowment (84), the compatibility of other modes of exercise (i.e., endurance training, plyometrics) performed simultaneously with weight training (41, 42, 55), nutritional status (50), and recovery (34). A primary objective of program design is to manipulate acute training variables in order to maximize strength and power performances. Acute program variables that may affect the magnitude of strength gain are the load (intensity) used, number of sets and repetitions, exercise selection and order, rest periods (between sets, exercises, and repetitions), and training frequency (20, 66, 75).

The number of sets performed per exercise has become a topic of interest among coaches, trainers, lifters, and sport scientists over the past several years. The efficacy of both single- and multiple-set protocols has been a controversial issue. Multiple-set protocols (e.g., 3–6 sets) have been shown to produce significant increases in muscular strength for individuals ranging from the untrained to elite strength and power athletes (6, 20). Athletes may benefit from single-set protocols during the initial 6–12 training sessions or during the initial 10 weeks of training (20, 68). However, it appears that multiple-set protocols are superior thereafter for continued improvement (49, 53). Although successful weightlifters, power lifters, and bodybuilders train predominantly with multiple-set programs (35, 37, 57, 82), proponents of single-set protocols argue that similar effects can be achieved using significantly less volume and time (9, 89). To date, there are no scientific data available to support this claim in advanced athletes. In fact, the majority of scientific studies examining resistance-training adaptations suggest that multiple sets, especially periodized programs, are superior for optimal strength gains in advanced athletes (6, 49).

Theoretically, both single- and multiple-set protocols present advantages and disadvantages. Single-set protocols may be advantageous for individuals with limited available training time during maintenance training and for those individuals beginning a resistance-training program (88). Single-set programs permit performance of a greater number of exercises during a training session (45) while minimizing the risk of overtraining. A single-set program is also the recommended minimal standard for starting a resistance-training program in healthy adults (88). The disadvantages with single-set protocols are that they limit training progression (i.e., the lack of variety in set structure or rest periods between sets), potentially limit high-intensity endurance (4, 89), and may not provide the optimal threshold volume or optimal muscle fiber recruitment to produce further improvements in muscle strength and size over long-term training.

Multiple-set programs may be advantageous for the training of athletes because they provide for a greater means of training variation, progression, and adequate volume to elicit improvements beyond the novice stage (13, 61, 74, 76). Disadvantages with multiple-set programs include the increased risk of overtraining (if volume and intensity are not correctly prescribed) and longer workout duration, particularly if several muscle groups are trained during a single session.

Using a single-set protocol as a starting point to begin a program has been shown to be effective; however, multiple-set protocols that vary sets, load, and repetitions have a greater effect on strength gains than do single sets (19). Furthermore, periodized training creates even more of a differential in the training adaptations (53). Although it is beyond the scope of this paper to suggest a multiple-set protocol to meet the needs of every athlete and strength professional, the following minimal guidelines are recommended for the enhancement of athletic performance through resistance training.

■ Basic Recommendations

- Training should occur at least 3 days a week, with a minimum of 24 hours' rest between training sessions.
- Programs should be designed so that all of the major muscle groups are targeted during training sessions.
- Program design should take into account appropriate muscle balance across joints, as well as both the upper- and lower-body muscle groups.
- Training should be periodized so that variation of volume and intensity occurs.
- Plan recovery periods to help avoid any overtraining symptoms.
- Generally, no more than 2 exercises should be performed per body part; however, different exercises per body part may be used throughout the week.
- Specific large–muscle group exercises should be limited to 2 times per week (e.g., parallel squat performed on Mondays and Fridays).
- Warm-up sets should be used that involve a very light resistance.
- Adequate recovery should be allowed for muscle groups during a training week (e.g., split programs or split-body part programs can be used depending upon the program goals).
- Large-muscle group exercises should be performed first in a workout.
- Rest between sets depends upon the goals of the training program. If maximal strength is the goal, then a longer rest period is desirable (e.g., 2–3 minutes). If skeletal muscle hypertrophy is the primary goal, then short rest periods may be desirable (<1 minute).
- Using a 4-day-per-week training protocol, one can divide the selected lifts into two groups: (a) chest and shoulders and (b) back and legs. This arrangement is most often used by experienced lifters and is the basis for many collegiate programs.
- A well-balanced program will make use of multijoint and Olympic-style lifts with free

weights as well as isolated movements on resistance machines to promote targeted muscle hypertrophy.

Because one program will not benefit all athletes, programs should be developed that allow for the integration of existing knowledge in exercise science with the practical requirements of administering a strength and conditioning program. The program should be focused, challenging, and enhance the potential for long-term adherence to the program. Ultimately, each program should be individualized to best meet the needs of the athlete and his or her sport.

■ Resistance Training for Children

Even with the large number of children participating in youth sports, many are not conditioning their bodies for the physical demands and rigors of the sport. If a child is capable of participating in a youth sport, she or he is capable of participating in a resistance-training program designed to condition the body to meet the demands of the sport and help prevent sport-related injuries. It was previously believed that resistance training-induced strength gains during preadolescence (defined as a period of time before the development of secondary sex characteristics) were not possible because of insufficient concentrations of circulating androgens (2). However, current findings clearly indicate that children can significantly increase their strength above and beyond what is accounted for by growth and maturation, provided that the resistance-training program is of sufficient duration and intensity (8, 14, 16, 58, 71). Strength gains of roughly 40% have been observed in children following short-term (8–12 weeks) resistance-training programs, although gains of up to 74% have been reported (15). Further, positive changes in motor fitness skills, sports performance, and selected health-related measures have also been observed in resistance-trained youths (8, 14, 58). Interestingly, preliminary evidence indicates that resistance training may also increase a child's resistance to sports-related injuries (5).

One of the traditional concerns associated with youth resistance training is the potential for injury to the epiphyseal plate or growth cartilage. Although epiphyseal plate fractures have been reported in young weight trainers, most of these injuries involved improper lifting techniques or the performance of heavy, overhead lifts in unsupervised settings. An epiphyseal plate fracture has not been reported in any prospective youth resistance-training study that was appropriately designed and competently supervised. If children are taught how to resistance train properly (e.g., adequate warm-up, correct technique, and a gradual progression of training loads) and if close and competent adult supervision is present, it seems that the risk of an epiphyseal plate fracture while strength training is minimal. In general, it appears that the risks associated with youth resistance training are not any greater than those in other sports and recreational activities in which children regularly participate (40). However, the potential for a serious injury is possible if youth guidelines and safety precautions are not followed.

The goal of youth resistance-training programs should not be limited to increasing muscular strength but should also include teaching children about their bodies, promoting injury prevention strategies, and providing a stimulating program that gives children a more positive attitude toward resistance training and exercise in general.

When introducing children to resistance training, it is always better to underestimate their physical abilities and gradually increase the volume and intensity of training than to overshoot their abilities and potentially risk an injury. There is no minimum age requirement for participation in a youth resistance-training program; however, all participants should have the emotional maturity to accept and follow directions and should understand the risks and benefits associated with resistance training. A medical examination is recommended for children with known or suspected health problems; however, it is not mandatory for apparently healthy children.

A variety of resistance-training programs have been developed for children, and different types of equipment have been safely and effectively used in these programs (14, 58). Although extra pads and boards can be used to modify some types of adult equipment, child-size resistance-training equipment is now available and has proven to be a viable alternative to adult-sized machines. Free weights, elastic tubing, and body weight-resisted exercises can also be used. Although youth resistance training has the potential to be a pleasurable and valuable experience, it should be only one part of a total conditioning program that also includes cardiorespiratory, flexibility, and agility exercises.

Typically, children should participate in a periodized program using loads that will allow a 6- to 12-repetition range. In addition, programs are typically lower in volume and may be performed using a lower frequency (2–3 days per week) but can adhere to many of the same principles as adult resistance-training programs. It is important that youth resistance exercise-training programs do not attempt to just implement adult programs because the physiological stress will be inappropriate (14, 58).

■ Resistance Training for Older Master Athletes

We are still learning about the prescription of resistance exercise for older adults. To date, no data exist on the impact of resistance training of master athletes who have a prior training base to work from. Thus, as with many of the other studies in the resistance-training literature, extrapolations to the athlete's particular situation must be made from the case of subjects who start a program untrained. Currently, there is a great deal of interest in the recovery time course for resistance-training workouts in the older individual. It has been hypothesized that it may be longer for untrained adults over the age of 60 when compared with their younger counterparts because a loss of or diminished physiological capacity for adaptational strategies (e.g., lower hormone concentrations, loss of Type II fibers; see Refs. 30–33). It appears that recovery from heavy workouts is a special concern. Older athletes may require longer recovery periods from a heavy training session or fewer heavy sessions in a training cycle to optimize recovery. Nevertheless, the importance of resistance training for older populations has been established as an important conditioning component (3, 30, 31, 32, 33, 44, 69).

It is clear that older individuals can respond to a resistance-training program. Significant gains in musculoskeletal strength and functional capabilities (e.g., mobility) have been observed, even in individuals over 90 years of age who have participated in resistance-training programs of sufficient intensity (e.g., 3 sets of 8 repetitions at 80% of the 1RM) and duration (more than 2 months; see Refs. 17, 18). For older adults, these improvements not only enhance exercise performance but can also help improve quality of life and make activities of living more enjoyable. Furthermore, because there is a strong association between muscle weakness and the risk of falling and fractures (73), exercise interventions designed to improve muscle function in older populations have important public health implications. The importance of these factors in master athletes becomes even more crucial for carryover to sports performance.

The decline in the muscle's force generating capabilities should not necessarily be considered an inevitable consequence of aging but rather a consequence that can be modified with resistance training. Although adaptations to resistance training have most frequently been observed in younger men and women, research indicates that older men and women show similar or greater strength gains when compared with younger individuals (3, 69). Given an adequate training stimulus, elderly subjects have more than doubled knee extensor strength, have tripled knee flexor strength, and have significantly increased total muscle area (23). It has also been observed that increasing muscle strength in frail, institutionalized nonagenarians improves balance, gait speed, and spontaneous activity (81, 82). Clearly, elderly men and women retain the capacity to make many adaptations to progressive resistance training that are positive and have significant and clinically relevant changes in muscle strength and functional abilities.

With advancing age, there are significant changes in body composition that can lead to the development of physical functional impairments in the elderly. Most notably, the decline in lean body mass and muscle strength over the decades of life result in functional changes that are associated with an increased tendency for falls, fractures, and loss of independence (46). Between the second and seventh decade of life, there is an approximate 30% decline in muscle strength and a 40% decrease in muscle mass (69). The functional consequences of the decline in muscle mass and strength are significant because the rate and magnitude of change will influence the age at which a person may become functionally dependent (e.g., unable to rise from a chair without assistance) or reach a threshold of disability. Furthermore, the loss of muscle mass in the elderly reduces the ability of the muscles to generate power (i.e., exert force rapidly) that is closely associated with functional abilities (7). Because muscle actions related to stair-climbing speed or the prevention of injury from falls require rapid power development, the decline in muscle power may be even more significant than the loss of muscle strength. This is especially of concern to master athletes, for whom power is a primary feature. Recent studies have demonstrated that the development of power may not be as easy in older adults as thought (31, 32). Although strength gains are observed, the magnitude of power capabilities, even with periodized training, lag behind in active and healthy men over the age of 60. This lack of a training effect may be due to a loss of type II fibers, to neural deficiencies, or to the amount of training time needed to stimulate adaptation

(54). This is an important topic of current research, and it has dramatic implications for the master athlete. At this point, no special recommendations on power development in the elderly can be made differentially from prescription paradigms for younger athletes.

A variety of resistance-training programs have proven to be safe and effective for older populations (3, 17, 18, 23, 30, 31, 32, 33, 44, 69, 73). Because large muscle groups are utilized in dynamic sport activities and for load carrying and climbing stairs in daily life, it is particularly important to address these specific needs. Although weight machines are useful, they may not address some of the functional balance requirements of everyday activities and sports. When appropriate, free-weight exercises should be incorporated into the program in order to improve balance and coordination. It is particularly important for older populations to breathe properly during the performance of each repetition to avoid the Valsalva effect. Ultimately, for the master athlete, resistance-training programs can follow similar guidelines as younger adults, but care should be taken as to the volume of exercise and the number of heavy training sessions because recovery is a primary concern. Current research has started to address the problem of power development in older men and women, and it is premature in our study of this problem to make any definitive recommendations except to state that power is probably the most vital component to the older individual, including the master athlete. Similar to the case in children, resistance exercise protocols for older athletes need to mirror the same principles of resistance training used by younger athletes, but again, careful attention must be paid to toleration of the program, total volume utilized, and the number of heavy training sessions in a cycle.

■ Overtraining

Although physical adaptations are best brought about by increases in training volume and intensity, at certain points in a training program, more is not better. The detailed discussion of the many aspects of overtraining (i.e., decreased physical performance) as both a physical and psychological phenomenon is beyond the scope of this paper, and the reader is referred to other detailed reviews on the topic (24, 52, 85). Nevertheless, the toleration and recovery from resistance exercise stress is a crucial factor that must be monitored carefully in every resistance-training program. The study of overtraining in resistance exercise has received much less attention because significantly fewer studies have been reported. From these studies, it is clear that what many have found to be markers of overtraining in endurance exercise are not always representative of overtraining in resistance training.

It appears that the two primary types of overtraining in resistance exercise are too high an intensity and too large a volume (24, 52, 85). Yet each has been difficult to study (25). In some programs, periods of overwork are used, followed by rest or reduced training to gain the benefits of a rebound or supercompensation in physical strength and power (24). The time course of such protocols remains elusive and highly individual. Many overtraining syndromes are a function of the rate of progression, or in other words, attempting to do too much too soon, before the body's physiological adaptations can cope with the stress. This typically results in extreme soreness or injury.

There are two overtraining scenarios that lifters may fall into: (a) overtraining a muscle group and (b) overtraining the body. Both are common, and many lifters may experience both. Overtraining is most often a result of increasing the volume of the program at too rapid of a pace. In addition, some lifters may maintain training for too many days at high intensity and not vary their load or take a rest. It has been shown that taking 1 or 2 days of rest in the weekly training cycle (25, 26) can effectively reduce intensity overtraining. Effective program design will include increasing and decreasing the total volume of the workout and using the concepts of periodization to plan changes in volume, intensity, and recovery. Difficulties in dealing with overtraining and the symptoms that may develop are that there is no 100% accurate measurement for the onset of overtraining and that generally once symptoms develop, overtraining is certain, and strength gains have stopped (24, 27). In addition, symptoms of overtraining are different for aerobic and anaerobic training, and with athletes, a combination of symptoms many times results. Once symptoms have developed, the most effective cure is rest (90).

General symptoms of a general overtraining model include the following:

- A plateau followed by decrease of strength gains.
- Increased resting diastolic (bottom number) blood pressure.
- Increased resting heart rate (by 5 to 10 beats per minute).
- Sleep disturbances.
- Decrease in lean body mass (when not dieting).
- Decreased appetite.
- A cold that just won't go away.
- Persistent flu-like symptoms.

- Loss of interest in the training program.
- Feelings of fatigue upon rising in the morning.
- Excessive muscle soreness.

Summary

A systematic resistance-training program that applies the principles of overload, specificity, and periodization will enhance the physical development of an athlete and positively affect sports performance. Resistance training also plays an important role in injury prevention by strengthening support structures, such as tendons, ligaments, and bones. The many permutations that a periodized resistance-training program can take on are numerous, based upon the sport's demands and the needs of the individual. Thus, basic program guidelines act as a starting point and can never document the multitude of manipulations needed to be made by the certified strength and conditioning specialist to address individual circumstances. Ultimately, resistance training can benefit both men and women athletes of all ages. ▲

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