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Varying Neural and Hypertrophic Influences in a Strength Program

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THE IDEAL PROTOCOL TO OPTImize muscular strength or hypertrophy remains elusive, particularly for well-trained strength athletes whose adaptive response to training is minimal. This elusiveness can be traced, in part, to unknown qualities about the complex interplay between neural and hypertrophic factors, as well as to a lack of integration of what is known about these factors into strength-training regimens. Although several leading programs, including multiple-set strength training, 1-set-to-failure training, and hypertrophy/bodybuilding-type training, have positive aspects; by nature of their purported mechanisms, they also possess features that constrain their effectiveness for both neural and hypertrophic adaptations. Neural factors are often overlooked in training programs for well-trained persons because they are commonly thought to contribute primarily to initial strength gains and to have little impact on mass gains. Indeed, the stimuli that promote motor control efficiency may not be the same stimuli that promote maximization of hypertrophy (19). However, these simplistic views do not account for indirect or secondary relationships between neural and hypertrophic factors. For example, Kraemer et al. (19) suggested that even in highly trained individuals, a lack of neuromuscular recruitment may lead to incomplete hypertrophy across muscle fibers. Thus, without a firm understanding of neural factors, particularly motor unit behavior, the design of effective resistance-training programs is hindered.

In consideration of these factors, it is important to view strength training as having 2 separate yet interacting components. Training 1 of the components, the nervous system, focuses primarily toward increasing strength. Training the other component, muscle cellular systems, aims at producing hypertrophy. Each type of training is intended to produce adaptations specific to that respective system while having carryover effects that enhance training adaptations in the other system. The purpose of this paper is to present a model for a resistance-training program intended to stress both neural and hypertrophic systems by frequent and specific variations in training protocols and loading parameters. Because of this variation from day to day and week to week and because of carryover effects, individual training sessions need not be extensive. Thus, the program outlined here has the added benefit of enabling training sessions that are relatively short—less than 1 hour —in duration.

Nervous-System Training

Perhaps the most overlooked aspect of strength training is the development of the nervous system. The purpose of nervous-system training is to teach the body to recruit—perhaps even preferentially—high-threshold motor units, improve inter- and intramuscular coordination, increase the motor unit firing rate, and to decrease inhibition or increase excitation from the central nervous system (32). Motor units are recruited and stressed based on a variety of stimuli, and as such, the adaptations made by motor units and by the whole muscle to training varies with the type of training stimuli. According to the size principle, motor units are recruited in order from low to high threshold as force requirements increase (8). This recruitment pattern typically corresponds to a recruitment order of small to large motor units, which is further associated with a fiber-type recruitment order of slow-oxidative glycolytic to fast-oxidative glycolytic to quickly fatigable. However, variations in these orders may exist because of fatigue, contraction type, afferent feedback, training adaptations, and contraction speed (8, 33). Further, muscles compartmentalized by functional, neural, or metabolic similarities may result in varying recruitment patterns across the whole muscle (21). Regardless of size principle variability, when more force is required, additional motor units need to be activated and their firing rates increased in order to produce more force (5). In addition, more force may be created by increasing the absolute number of active motor units across synergistic muscle groups or by a relative net increase in agonist activation by inhibiting antagonist motor units. Clearly, then, fully stressing the motor control system to produce adaptations is a complex process, a process influenced by biomechanical loading parameters, as well as by manipulating psychophysical factors such as arousal/motivation (6, 13) and cognitive strategies (3).

The training variable of most importance when classifying a program as hypertrophic or neural is load intensity. With neural training, the percentage of a 1RM load is very high, which subsequently reduces the number of repetitions per set. Fewer repetitions lead to a decreased time under tension, and thus make more sets necessary to fully fatigue the high-threshold fibers. It has been suggested that if muscle fibers are recruited but not fatigued, they are not trained (27, 32). In addition and because a primary goal in nervous-system training is to promote maximal neural activation, central nervous system (CNS) fatigue needs to be considered. CNS fatigue, whether it be of neurobiological or psychological origin, reduces central drive and thus motor unit recruitment (6). CNS fatigue has been linked to a host of neurochemical changes that may have time courses longer than that of muscle metabolic fatigue (e.g., 2, 6). Hence even if a muscle is metabolically recovered, the nervous system may not be capable of recruiting high-threshold fibers. This notion has prompted some to suggest that high-intensity training requires longer rest intervals between sets to ensure adequate recovery (1).

Because of the length of the rest intervals, a practical option is to use the agonist–antagonist method of training; that is, performing back-to-back sets for opposing muscle groups. This allows an individual to increase the number of different exercises while maintaining the proper work-to-rest ratio for a particular exercise. In addition, performing a contraction of the antagonist muscle has been shown to increase force output of the agonist in subsequent contractions (17, 27). The large number of sets performed per exercise in neural training may limit the number of exercise types that can be executed per session for a given muscle group. A limited number of exercises with many sets is recommended over many different exercises with few sets because a large number of repetitions may bring about additional neural changes. Repetition is a key element in motor learning (16), and thus a large number of sets with a single exercise may facilitate motor learning adaptations to a particular movement and training intensity (4). To avoid training only a limited number of muscle groups because of the use of only a few different exercises, it is recommended that compound or multijoint exercises be used (e.g., squats or deadlifts).

Training to increase muscle mass rather than strength is generally done by using loads of lower intensity and performing more repetitions (19). However, brief training cycles using higher intensities may enhance the hypertrophic response if training intensity is later reduced to allow adequate rest (11, 12). There are several possible reasons why inserting a neural-training cycle during hypertrophic training may be of benefit. First, if mass gains are made during high-intensity periods, they may be primarily due to contractile protein hypertrophy as opposed to noncontractile protein (e.g., collagen) hypertrophy, which has been shown to accompany high-repetition work (22, 32). Second, maximizing motor unit recruitment through high-intensity neural work for 1 or 2 mesocycles (2–6 weeks) may enable previously underutilized muscle fibers to be trained (14, 19). Moreover, other systems that support hypertrophy, such as the endocrine system, are influenced by neuromuscular stimulation (19). Third, neural adaptations may allow the use of heavier loads at a given number of repetitions, thereby increasing the hypertrophic stimuli (10).

■ Hypertrophy Training

The primary goal of hypertrophy training is to produce a stimulus that promotes an increase in muscle mass as an adaptive response. Although not fully understood, it has been suggested that mechanical damage leads to protein catabolism, which then leads to a supercompensation of muscle protein synthesis during the recovery period (19). Training programs to promote mass gains tend to be more muscle fatiguing. However, the relationship between muscle fatigue and hypertrophy is not well known. It is plausible that this fatigue may result in metabolic or hormonal changes (19) or may create more mechanical stress and damage to the muscle. Regardless of the mechanism, an increase in muscle size may not always be accompanied by a proportionate increase in strength, perhaps because of an increase in the noncontractile proteins as opposed to the actin and myosin filaments.

As with neural training, several training components need to be manipulated to promote hypertrophy. Foremost is a lower intensity in hypertrophic training compared with neural training. A lower intensity allows the number of repetitions to fall to between 6–12 per set and increases the time under tension per set. The number of sets performed per exercise to bring about muscular fatigue is typically less than that in neural training because of the increased number of repetitions. In addition, rest intervals between sets may be shorter: 45–120 seconds appears to be adequate (1, 9). Also, more exercises may be chosen for a given body part depending on the size of the muscle mass being trained.

To summarize, indications show that both volume and intensity variations should be inserted into a year-round training program in order to promote the greatest adaptations in both neural and hypertrophic systems. Regardless of whether or not individuals may respond differently to work volume and intensity (10), if a particular regimen stops producing results, it is necessary to adopt an alternative method (30). Planned variations in the program may circumvent plateaus, as well as take advantage of potential carryover effects between neural and hypertrophy training.

■ Adaptation/Accommodation and Training Variation

A training program needs variation in exercise protocols in order to avoid staleness and ensure continued progress (9), which may be particularly important for persons of advanced training status (11). Adaptation or accommodation may result in fewer motor units performing a given task (4), making a number of protocol changes necessary to maintain an appropriately rigorous stimulus (16). Both quantitative and qualitative features may be varied to promote continued adaptation. Psychophysiological systems may quickly adapt to quantitative training variables such as intensity, sets, and repetitions, and therefore they must be changed periodically to provide an adequate training stimulus (20). Qualitative factors such as exercise type are also quickly adapted to and must be similarly changed. Recognizing when these changes need to take place is difficult because the amount of time it takes to accommodate training variables is dependent on the individual's training status, type of training, and motivational factors (19). Of course, the accommodation time may vary for each training variable.

There are other important aspects of training that are often overlooked but should be considered when varying training protocols, especially for trained individuals. These aspects include but are not limited to variability in movement patterns, training, supporting and stabilizing muscles, exercise selection, time under tension, duration and frequency of training.

Variability in Movement Patterns

Changing the biomechanics of the exercise, such as the angle of the body in relation to the load, hand and foot positions, and bar pathway, can introduce new challenges to the nervous system even if the exercise performed is quite similar (8, 16, 27). Moreover, different types of movement may cause different muscle compartments or synergistic muscles to become more or less active (21, 24). In these cases, the nervous system is forced to reorganize the contraction patterns or tap into different motor unit pools that may further promote strength or mass gains (25).

Training Supporting/Stabilizer Muscles

It is often assumed that plateaus in training progression are due to a limited adaptive response from the prime movers. However, stabilizer and support muscle adaptations are important for strength increases (26), and thus stabilizer muscle inadequacy may prevent increases in intensity (29). Weak or neurally untrained stabilizers may be overloaded quickly and send inhibitory sensory signals, resulting in a decreased neural drive to the prime movers. It is foreseeable that specific work for the stabilizer or neutralizer muscles may subsequently enable higher-intensity training for the prime movers.

Exercise Selection

If the total number of different exercises is relatively small, then the goal of maximizing motor unit recruitment may not be met. To overcome this problem, compound or multijoint movements during neural training cycles may be used. It is also important to vary exercise selection regularly, possibly changing the exercise types every 4–8 workouts for a given body part (16). All muscles should be trained continually; however, different movements may be chosen in order to allow the nervous system to recover from doing a particular exercise. For example, not performing a squat or bench press on occasion is permissible if the muscles used in those lifts are trained with other exercises. In addition, varying concentric, eccentric, and even isometric contraction modes leads to specific neural adaptations (15).

Time Under Tension

The length of time a muscle is under tension is a function of the number of repetitions and the speed of movement or time to perform the lift. Most individuals inadvertently regulate time under tension with the number of repetitions performed. It may not matter, however, how many repetitions are done, but rather the time under tension. The time, or tempo, typically has 3 phases; eccentric, pause (isometric), and concentric. Each phase can be represented in terms of seconds taken to complete each portion of the lift. For example, a 5-0-1 tempo indicates that a lift takes 5 seconds in the eccentric phase, 0 seconds in the pause, and 1 second in the concentric phase. Tempos can be varied, yet it has been recommended that the total duration of the set should not exceed 70 seconds (31). Sets lasting longer than this time are probably not loaded sufficiently to bring about adequate strength or hypertrophy development and may be focused more toward muscular endurance.

As with other loading parameters, tempo should be changed often to present a new and challenging situation. For example, slow-speed contractions have been shown to enable an increased force output (7, 27). Increased force at low speeds is a property of the muscle's velocity–tension relationship and may also take advantage of decreased inhibition from the Golgi tendon organ (7). On the other hand, a rapid tempo or intended rapid tempo may result in different motor unit recruitment adaptations (3, 18). Variations in tempo may also provide specific stimuli to the different contraction modes. For example, a slow eccentric phase in relation to the concentric phase may help exhaust eccentric strength. Inserting isometric stops during the eccentric lowering may further serve to exhaust isometric strength and as a result, promote muscle mass gains (28). Pausing prior to the concentric phase has been shown to reduce the recoil force generated by the eccentric phase, making the concentric contraction more difficult (32). These examples represent only a few of the speed patterns that may be used to keep workouts both physically and mentally challenging and interesting.

■ Duration and Frequency of Training

It has been suggested that regardless of the training goal, a workout should not last longer than 1 hour (32). Long training sessions have been associated with decreased intensity of effort, decreased levels of motivation, and even changes in immune response (20). There are some exceptions to this rule: a "stress microcycle," in which an excessive volume of work is done, may be used occasionally if adequate recovery is provided afterward (11). The frequency of training should be based on the individual's ability to recover, which will vary depending on the individual's training status, workout intensity, dietary intake, and sleep habits. Typically training is too frequent, and thus changes in the exercise protocol are often to decrease the frequency. It may be important to consider having periods in which relatively easy work, or no work, is done for two to four 1-week periods during the training year. These rest weeks are inserted in order to realize the training effect of the previous cycle (16) and to prevent loss of effectiveness. Overcoming or avoiding a loss of effectiveness are rooted in having planned variations in the program and making an effort to recognize adaptations or maladaptations.

■ Plan of Action

Success in training is best achieved when a direct plan of action exists, leading one to a particular goal. Training can be broken down into individual workout sessions, microcycles (grouping of several training days), mesocycles (typically several microcycles—approximately 2–6 weeks), and macrocycles. Macrocycles can be considered the entire training year. Goals formed around a mesocycle, rather than a macrocycle, plan are likely sufficient for most people. Within a mesocycle a series of microcycles can be planned and individual sessions prepared accordingly. All workouts should be recorded in a training journal in order to monitor progress. Ideally an individual should set goals for themselves prior to the training sessions. Goal

Table 1
Outline of Loading Parameters Used To Construct the Strength and Hypertrophy Regimen

Phase	Exercises per muscle group	Exercise type	Sets per exercise	Reps	Tempo	Rest interval
Hypertrophy	2–3	Multijoint, single joint, bilateral, unilateral	3–5	8–12	Moderate (3–6 s/rep)	60–120 s
Neural	1–2	Multijoint only (e.g., squats, deadlifts, military and bench press, rows, dips)	6–12	3–5	Slow (3–10 s/rep)	180–300 s (with use of agonist/ antagonist method)

Note: The loading parameters are to be systematically used within each 3–4 week mesocycle, after which the phase is changed. Regardless of the phase, all training sessions are limited to 60 minutes. The agonist/antagonist method is used during neural training to allow more work to be done within the 60-minute session, while maintaining proper work-to-rest scheduling. Training is conducted on 3 or 4 days per week depending on recovery. All sessions are planned in a journal prior to exercising, and the performance is recorded. Specific exercises are varied throughout each mesocycle phase.

setting is well recognized to enhance motivation, provide direction, and, consequently, promote adherence (23).

A Sample Program

These principles can be used to design a resistance-training program for a well-trained individual. An example of such a program is shown in Table 1. The program is marked by planned microcycle and mesocyle variations to produce appropriate neural and hypertrophic stimuli and enable carryover effects of the adaptive responses. Sets, repetitions, tempo, rest intervals, and exercise type all are varied to produce the appropriate stimuli. This program is intended to be followed for 3–4 days per week, and to last no longer than 1 hour per day.

Conclusions

We feel that it is possible for trained athletes to get significant gains in strength or power, even in a relatively short training time per week. For athletes who are also working on practicing their sport, extraneous time spent in the weight room is time wasted or may lead to overtraining. By focusing training on varying both neural and hypertrophic training stimuli and by taking advantage of training carryover effects, training can be both effective and time-efficient.▲

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