Diversity of Strength Training Methods: A Theoretical Approach

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SUMMARY

THE MOST KNOWN METHODS FOR STRENGTH TRAINING REVOLVE AROUND MUSCLE HYPERTROPHY, WHICH CAN EFFECTIVELY INCREASE MUSCLE MASS. IN THEORY, A METHOD FOCUSING ON ANATOMICAL ADAPTATION MAY BUILD A STRONG MUSCULOSKELETAL STRUCTURE BY STRENGTHENING CONNECTIVE TISSUES AND MUSCLES REQUIRED FOR SUPPORTING, BALANCING, AND STABILIZING THE BODY. STRENGTH TRAINING THROUGH THE USE OF HEAVY LOADS INCREASES THE NUMBER OF MOTOR UNITS RECRUITED. EXPLOSIVE MOVEMENTS MAY FAMILIARIZE THE NEUROMUSCULAR SYSTEM AND ENHANCE THE EFFICIENCY OF THE ACTIVATION FREQUENCY. THIS ARTICLE WILL EXPLORE VARIOUS TRAINING METHODS IN THEORY TO MAXIMIZE ATHLETIC PERFORMANCE.

INTRODUCTION

Although strength training is primarily concerned with muscle hypertrophy, one is often times considered synonymous to the other. Muscle hypertrophy is only one of many factors affecting the production of force. To create force, the nervous system generates impulses, which are transmitted through nervous system conduction routes to the muscles. After a series of reactions, the muscles generate force. To produce movement, force generated by the muscle must have support from the associated bones, tendons, and ligaments. Movement is the product of force generated through the concomitant interaction of both the nervous and the musculoskeletal systems.

It is important to consider the existence of strength training methods outside of hypertrophy, such as anatomical adaptation, which can strengthen and stabilize the musculoskeletal structure. To enhance the efficiency of the interactions between the nervous system and muscular system, the methods of maximum strength and explosive strength are presented and described.

MUSCLE HYPERTROPHY

Force is produced through the mechanism of cross-bridge generation. Cross-bridges are formed when the actin and myosin filaments bind together to produce rotation. Increasing the number of cross-bridges leads to an increase in the cross sections of muscle fibers and muscle force (2,25,48). However, not all factors responsible for hypertrophy are fully understood. The following theory is proposed. According to the supercompensation mechanism, when energy is consumed, the body will replenish the lost energy, after adequate rest, to a level that exceeds its previous value (6). This energy also applies to the synthesis of protein, resulting in an increase in muscle fiber size (53).

To effectively increase muscle mass, one must consume as much energy as possible to exhaust the muscles. Because the work done is equivalent to the energy consumed, a method involving large amounts of work is recommended. When adopting a light load, less energy is applied toward doing work. In comparison with exercises involving heavy loads, sets using medium loads accomplish a larger amount of work. After rest, more energy is supercompensated for protein synthesis and muscle mass increases. Therefore, a medium load, approximately 70–80% of 1 repetition maximum (1RM), represents the appropriate training load for effectively increasing muscle hypertrophy (53). The rest interval between sets is also important, with 50–90 seconds suggested. If the rest interval is too long, the muscle cannot be exhausted or the energy cannot be consumed to the maximum extent. If the rest interval is too short, the intensity is too high to adequately complete the next set (Table 1) (27,44,48,58).

To exhaust the muscle, no more than 3 muscle groups should be trained in a given session using ideally 2–5 exercises. After completing the exercises for 1 muscle group, the next muscle group should be trained accordingly. This method emphasizes training 2–3 groups of muscles with

KEY WORDS:
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Table 1 Muscle hypertrophy training profile	
Training parameters	**Work**
Objective	Exhausting muscle to increase muscle mass
Load	70–80% of 1RM
Repetitions	8–12
Exercises	2–5 exercises for each muscle group
Sets of each exercise	3–4
Rest interval	
Set interval	50–90 s
Session interval	48–72 h
Execution speed	Moderate
Frequency	5–6 d
Training duration	At least 10 wk

1RM, 1 repetition maximum.

a series of movements in 1 session (44,48). The training frequency is a split routine, with 2 examples being the 4-1 and 6-1 routines (21,44,58). The 4-1 routine involves 4 consecutive training days and 1 resting day, with the same cycle repeated for the next 5 days. For instance, the first day may be composed of exercises involving the chest, biceps, and abdominals, whereas the quadriceps and calves are trained on the second day. The latissimus dorsi, triceps, and abdominals are trained again on the third day, and, finally, exercises for the gluteals/hamstrings and shoulders are suggested for the fourth day (Table 2). The preceding schedule will allow for a nearly all the major muscles of the body to be trained within a span of 4 days.

Another split routine is the 6-1 style, designed to train the same muscles twice every 6 days with 1 day of rest. The 6-1 routine is suggested for advanced individuals (Table 3). To provide variation in training and to accommodate athletes of different levels, alternative split routines have also been proposed (7,48). Regardless of the training regimen followed, each routine allows for at least 48 hours of recovery time for each muscle (48).

ANATOMICAL ADAPTATION

Anatomical adaptation emphasizes strengthening all anatomical aspects of the musculoskeletal system. One of the aims is the strengthening of connective tissues. In many cases, programs emphasize muscle mass and ignore the connective tissues, which form the support structure that muscle is built upon. As a result, it is also the region where injuries most commonly occur (21).

Table 2 Example of a 4-1 split routine				
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Chest	Quadriceps	Latissimus dorsi	Gluteals/Hamstrings	Rest
Biceps	Calves	Triceps	Shoulders	
Abdominals		Abdominals		

If the connective tissues and the muscles for stabilizing and balancing the anatomy structure are weak, the result is an unstable musculoskeletal system (21). It is analogous to constructing a house without first building a strong firm base and frame (1). Strengthening the musculoskeletal framework is a critical prerequisite for developing muscle force. Anatomical adaptation consists of 5 subareas: (a) strengthening the connective tissues, (b) building stable joints, (c) developing core muscles, (d) balancing the muscle forces, and (e) developing the stabilizer musculature.

STRENGTHENING THE CONNECTIVE TISSUES

Connective tissue includes bones, ligaments, fascia, cartilage, and tendons. These units are considered as a single unit in this article on the basis of their shared roles as a supporting base, connection structure, and in the conveyance of force. When connective tissues are stressed (through body motion or weight bearing), their structures and force-bearing capacities are strengthened and serve as a critical component in the prevention of sports injuries (47,59). The maximal strength of connective tissues is maintained well above the voluntary force capabilities of associated muscles. Concentric forces responding to mechanical forces might threaten the condition of the support structure formed by connective tissue if an appropriate paradigm of strength training is not adopted (21).

The appropriate choice of load magnitudes and volume to be applied for strengthening tissues continue to be debated, with many of the results being rather controversial (13,11,16, 46,50,49,52,57). Although heavy load is recommended by Tsuzuku et al. (51), training constantly with high-intensity loads may decrease bone mineral density (36). Furthermore, compared with muscle, the connective tissue takes more time to develop force and morphological adaptations (10,13,52). If heavier loads are adopted, the adaptation rate of muscle force is faster

Table 3
Example of a 6-1 split routine

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Legs	Chest	Back	Legs	Chest	Back	Rest
Abdominals	Shoulders	Trapezius	Abdominals	Shoulders	Trapezius	
	Triceps	Biceps		Triceps	Biceps	

than that of connective tissue force (6,5,21,46). Large increases in muscle size and strength may occur too rapidly to allow for adequate connective tissue adaptation, leading to a loss of balance between muscles and connective tissue (33,34). This imbalance occurs when the muscle forces exceed a specific critical level, placing the bone or connective tissue at risk for damage.

To stimulate adaptation to connective tissues and to maintain a balanced force between tendons and muscles, a light load (30–60% of 1RM) is suggested (5). Furthermore, due to the enhanced sensitivity of young bones to mechanical forces (35,36), this method is suggested for beginning adolescent athletes. According to the principle of progression, connective tissue should be progressively overloaded (12) to avoid any imbalance between muscle and connective tissue. Beginning athletes should use a light load for the majority of their training. Only after they become more advanced, should heavier loads be progressively used.

BUILDING STABLE JOINTS

Although some stabilizers may also help in stabilizing the joint, our main concern is in building strength in the joint not just the stabilizer. For instance, in terms of the anatomy of a shoulder joint, the rotator cuff holds the humerus and the joint together. Other muscles surrounding the shoulder joint, such as the flexor, extensor, abductor, adductor, horizontal abductor, and horizontal adductor, also aid in holding the joint stable at different angles (22,26,40). Joint structure needs to be strengthened not only for joint movements that take place in sports but also for other angular joint movements (58).

Sports that focus on loading a particular muscle group over a long period might make the associated joint unstable. For example, if a lifter is practicing a snatch, the motion on the shoulder joint is primarily shoulder flexion. If an athlete repeats this motion, which results in significant work on the shoulder flexors, the muscle might become too strong compared with the other muscles around the joint, creating a muscle strength imbalance. To develop general strength, an athlete (especially a beginner) should multilaterally strengthen the muscles surrounding the joint to build a stable joint before focusing only on particular muscles (6).

BALANCING THE MUSCLE FORCES

Muscle balance is vital for force development and prevention of sports injuries. There are a number of types of muscle balance that should be considered, such as the balance between left and right lateral, upper and lower body, and agonist and antagonist muscles.

If one leg is apparently stronger than the other, when running, as the more powerful leg pushes off, the weak leg lands and receives a comparatively stronger impact, increasing the risk for injury (55). When the difference in force is beyond 10%, or, when measured in thigh circumference, is more than 3 centimeters, the weak leg should be strengthened to balance the forces between 2 legs (58,4).

The force produced by the upper and lower body should be balanced as well. When the upper body is capable of producing more force than the lower body, the force required to initiate a movement will lack power due to the relative weakness of the lower body. If the upper body is weaker, a powerful start may be initiated with the stronger lower body, but the force transmitted through the upper body may decrease noticeably. Furthermore, when running, the strong lower extremities deliver a force toward the earth, which, in turn, returns an equally powerful reactive force back into the legs. Simultaneously, a strengthened arm swing directs additional force toward the earth, which is similarly returned toward the runner. Thus, a more powerful body force is expected. Therefore, the strength of the upper and lower body should be equally emphasized.

Athletes may also be injury prone due to the imbalance between agonist and antagonist muscles. For instance, while the force of a leg extension is produced by the quadriceps, the hamstring controls the reducing force of the tibia. If the hamstring is weak and is required to control a strong quadriceps force beyond the limit of its tolerance, injury is possible (54,58). The force between agonist and antagonistic muscles should remain within specific ratios to reduce the risk of injury (3,9,21). Performance in various sports will result in a variety of relative muscle imbalances. Resistance training should be performed early in an athlete's development to prevent the occurrence of muscle imbalances (55).

DEVELOPING CORE MUSCLES

The core muscles are the muscles connecting the pelvis and lumbar vertebrae and those surrounding the lumbar vertebrae (14). The center of gravity of the body is within this area, which is located between the upper and lower trunk (14,26). A strong midsection is a fundamental building block of spine stability (1). The midsection also helps absorb impact, especially when landing from heights. Strong core muscles stabilize our body. Furthermore, the core muscle is also in the power zone, which initiates force (39). It plays the role of initiating power generation and transmission of force to other parts of our body. If this area is strong and stable, the body has a platform from which to drive (14).

The upper and lower skeleton are connected by lumbar vertebrae, which endure a higher pressure without the aid of surrounding muscles like the rectus abdominis, external and internal obliques, and erector spinae. A significant number of individuals suffer from lower back pain. This may be attributed to decreased supporting force arising from weak muscle support. The resulting uneven pressure on the intervertebral disc of lumbar vertebrae causes the nucleus pulposus to be pressed outward, stretching the posterior longitudinal ligament and culminating in the gradual compression of the pain-sensitive cells. Stronger muscles in this area might prevent the occurrence of imbalance surrounding the lumbar vertebrae and may create higher intra-abdominal pressure, providing more protection for the lumbar vertebrae and reducing pressure on the intervertebral disc (21,58). When detraining, the abdominals are prone to weakness. For this weakened muscle, more attention is needed (56).

DEVELOPING THE STABILIZERS

When an agonist muscle contracts, the stabilizer acts like a base to hold the mover. If the base is strong and firm, the force produced by the agonist is more efficient. Without a strong stabilizer, the agonist can be likened to a tree without deep and firm roots, and force development is hampered. For a given motion, the agonist is located at the distal end of the body, whereas the stabilizer is located at the proximal end. For example, the shoulders are immobilized during elbow flexion, and the abdominals serve as stabilizers during the throwing motion. Stabilizers also contract isometrically, immobilizing one part of the limb and allowing the other part to move (22,26).

There are 2 aims of anatomical adaptation: (a) to strengthen the connective tissues and (b) to train the muscles to balance and stabilize the musculoskeletal system. From the discussion above, we can conclude that the muscle forces serve to strengthen the tissues, stabilize the joints, be a balancer between muscles, build the core muscles and develop the stabilizers. The relevant muscles are not only limited to agonists but also include antagonists and synergists. From the perspective of the motion axis, these muscles include flexors, extensors, adductors, abductors, and rotators. Training the muscles suggested here are fundamental to the further development of maximum strength and power.

Exercise programs should be designed to work the multijoint and large muscles first. This is followed by exercises training the lesser joints and smaller muscles and ending with the final exercises targeting the abdominals and lower back muscles. Furthermore, exercises for the upper and lower body are arranged in an alternating fashion as are the exercises targeting agonist and antagonist muscles (3,5). For training these muscles, the magnitudes of the proposed loads are low. Because the synergists or rotators are usually not as strong as agonists, extensors, or flexors, heavy loads are not suitable. Additionally, according to the principle of progression, a light load comes before a heavy load in the periodization of strength training. To build the foundation for further training, a load of 30–60% of the 1RM is suggested.

MAXIMUM STRENGTH

Maximum strength can help enhance the capacity for explosive force and endurance, which are essential factors in attaining peak performance (15,29, 30,37). If maximal strength has not been developed, the capacity of the muscle has not been completely explored. In the human nervous system, motor units of high activation threshold are usually inhibited. When heavy resistance is applied for the purpose of developing maximum strength, inhibition is decreased. This, in turn, allows for the activation of motor units with high thresholds, stimulating contraction of the fast-twitch motor units. Training for hypertrophy with medium resistance induces adaptation to higher forces by adding more protein within the motor units, and training for maximum force under heavy load can activate more motor units to contract.

The adaptation to heavy resistance may promote the efficiency of the nervous system by recruiting additional fast-twitch motor units. The heavy load training is a form of high-intensity training designed to counteract inhibition that prevents muscles from exerting more force than the connective tissues can tolerate (7). When the inhibition is released, so is this barrier. Therefore, strong connective tissue and stable musculoskeletal structure is a result of anatomical adaptation, which should be required for the purpose of reducing the risk of sports injury. Maximal strength is executed concentrically, eccentrically, and isometrically. The rest interval between sets or between sessions should be complete to have enough capacity for the next set or session.

EXPLOSIVE STRENGTH

Like maximum strength training, explosive strength also promotes activation efficiency, but in a different way. The former is designed to recruit more motor units, and the latter is designed to achieve higher activation frequency. When force-resisting loads increase, the activation frequencies linearly increase. Based on electromyography, the activation frequency is 50–60 Hz given maximum force. When it increases beyond this range, there does not seem to be any enhancement of force. However, it aids in increasing the muscle action velocity. When an explosive movement of high intensity is performed, the frequency may reach as high as 80–120 Hz (18,43).

Maximum force requires more time to recruit additional muscle fibers. Type I slow twitch motor units are recruited first, followed by type IIx motor units, with type IIa motor units recruited last. This mechanism is known as the size principle (24,28,31). However, to complete an explosive movement as soon as possible, instead of recruiting the slow twitch motor units, the neuron might select the fast twitch motor units to act first. The motor units with high activation thresholds are activated before the motor units with low activation thresholds. This phenomenon is called selective recruitment (17,23,45). In other words, using heavy load may create adaptation due to the size principle, whereas explosive strength training may create adaptation due to selective recruitment (21).

From the aspect of muscular coordination, the purpose of heavy load training is to explore the capacity of a muscle group as much as possible to induce maximum force. Known as intramuscular coordination, control of the nervous system is coordinated by reducing the inhibitors to optimal coordination between inhibition and excitation within a muscle group. To accomplish fast and explosive movement, explosive strength training induces the adaptation of conveying force among muscles smoothly to reach the state of intermuscular coordination. When the muscles are coordinated with one another, they gain the ability to coordinate specific sequences in which various muscles are involved in performing a movement, and the athletes learn to relax the antagonistic muscle so that unnecessary contractions do not affect the force of the prime agonist. Meanwhile, the force among muscles could be transmitted efficiently, resulting in less energy consumed (5).

Unlike slow strength training, where the intensity of 1 repetition is determined by the load, explosive strength is determined not only by load but also by velocity. Due to the different combination spectrum of load and velocity, the formation of a variety of training methods is feasible. The possible training methods include explosive method with heavy load, the ballistic method, the explosive method with a medium load, plyometric drills, and speed-resisted training (Table 4).

To overcome inertia as soon as possible, explosive training with heavy resistance is designed to speed up the rate of force development and shorten the action time between the nervous system and its associated contraction muscle. Although movement velocity may not be fast with a heavy load (Table 5), the action velocity inside the neuromuscular system is fast (44,58).

When traditional weight training is practiced, movements must be stopped at the end of the range of motion. This uses deceleration, thus negatively affecting movement velocity. It appears that the lighter the resistance, the greater the deceleration (20). To overcome this problem, the ballistic method is suggested. When executing the movement, immediately before the start of the movement, the pattern of the movement is preprogrammed. Potential energy is then released without hesitation, resulting in the implement being lifted into the air with high speed and acceleration (38,55). The rate of force development focuses on fast muscle action or the quick start of internal strength (force). Ballistic training emphasizes fast acceleration and high movement velocity, explosive strength with medium load, and highlights force and velocity simultaneously. It is designed to induce the largest power response, promoting the enhancement of power capacity (5,21).

So far, the natural patterns of human body movement have not been emphasized. This is the purpose of the plyometric drills. The plyometric drill uses the stretch-shortening cycle, which begins with muscles stretching and then acting concentrically (32). First, the muscle is stretched to store elastic energy and to induce a stretch reflex. Subsequently, the potential energy and reflex are released to increase force as the muscle is shortened. The elastic and reactive properties of the neuromuscular system are used for maximum force production. When the stretch phase has a small amplitude but high velocity and no delay exists between the stretching and shortening phases, the enhancement of performance due to the stretch-shortening cycle is maximized (8,19,42).

Plyometric drills targeting the lower extremities include jumping in place, hopping, bounding, box drills, landing, and drop jumps, all of which should be

Table 4
Methods of explosive strength training

Training style	Objectives	Loads
Ballistic	Emphasizing movement velocity	Light or very light load
Emphasis on speed and load simultaneously	Enhancing power (work/time)	30–80% of 1RM (medium load)
Rate of force development	Promoting action velocity, and overcoming the inertia quickly	85–100% of 1RM (high load)
Stretch-shortening cycle	Using elastic energy and stretch reflex	Plyometric drills from different heights
Speed-resisted training	Pattern of main sport movement resisted	Specific sport movement with increased resistance

1RM, 1 repetition maximum.

Table 5 Training parameters for rate of force development		
Training parameters	**Zatsiorsky (58)**	**Schmidtbleicher (44)**
Objective	Enhancing muscle action velocity	Enhancing muscle action velocity
Sets	3	3, 1, 1, 1, +1
Load	90% of 1RM	90, 95, 97, 100% of 1RM
Repetitions per set	3	1, 2, 3, 4, +5
Rest between sets	5 min	3–5 min
Execution speed	Explosive	
Training frequency per week	2–4 times	2–4 times
Duration	6–8 wk	

1RM, 1 repetition maximum.

arranged progressively and systematically (5,41). There is a possibility of confusion between the ballistic method and plyometric drills because both the movements are implemented for fast velocity and high acceleration. The difference being that the plyometric drill has to be implemented in a ballistic manner, but the ballistic training is not necessary for the stretch-shortening cycle method. The ballistic method can be practiced in a solely concentric way, whereas the plyometric drill emphasizes a quick switch between eccentric and concentric phases.

Explosive training should simulate the movements inherent to various sports. Speed-resisted training simulates sports movements with increased resistance. Examples include practicing shot put movements with 8- or 9-kg implements, wearing a load-bearing vest when running, uphill or higher-gear cycling, running uphill, and using a parachute in running drills. The extra resistance should not be too heavy to avoid changing the sport's technique because of an addition of vertical force (58).

CONCLUSIONS

For strength training, instead of focusing solely on muscle, insight into the coordination of the neuromuscular and musculoskeletal systems allows us to see the whole picture of strength, leading to the integration of the 4 kinds of strength training described (Table 6). The most basic and fundamental method is anatomical adaptation. Light resistance with high repetitions and circuit weight training are recommended. The aim is to strengthen the connective tissues and muscles, which help to keep the musculoskeletal system stable, balanced, and firm. This method is not only suitable for improving the musculoskeletal system but it also creates the foundation for further development toward maximum strength and power for the beginning athlete. Without this process of adaptation, the risk of injury would be higher and might hamper the advancement achieved through high-intensity training.

The purpose of hypertrophy training is to induce adaptation toward increasing the number of cross-bridges in the muscle, where medium resistance can effectively increase muscle mass. Although the hypertrophy method is designed to increase the size of myofibrils within a motor unit, heavy resistance is designed to recruit more motor units–especially the fast twitch motor units–to induce maximum force. For recruiting more muscle fibers, inhibition and excitation should be combined to reach a state of intramuscular coordination.

Explosive strength training is used to recruit specific muscle groups as soon as possible to enhance activation frequency. This training method also requires coordination between muscles to accomplish intermuscular coordination. Strength training is not only useful for increasing muscle mass but also for efficient nervous system activation and strengthening the musculoskeletal system.

Table 6 Methods of strength training			
Adaptations	**Mechanism**	**Exercise intensity**	**Methods**
Anatomic adaptation	Balancing and strengthening the musculoskeletal system	Light load with moderate speed	Circuit weight training
Hypertrophy	Increase number of cross-bridge within a motor unit	Medium load with moderate speed	Split routines
Maximum strength	Promoting recruitment efficiency and intramuscular coordination	High load with moderate speed	Concentric, eccentric, and isometric ways
Explosive strength	Enhancing activation frequency and intermuscular coordination	Explosive way under different loads	As listed in Table 4

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