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The science behind strength training

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Abstract

Strength training is a type of physical exercise specializing in the use of resistance to induce muscular contraction which builds the anaerobic endurance, size of skeletal muscles and strength. Sports with strength training as the central object are body building, weight lifting, power lifting, shot put, discus, hammer, javelin throw and wrestling etc. Since strength is an important component of motor fitness or performance related fitness, almost all sports use strength training as a part of their training regimen. The players of lawn tennis, rugby, rowing, hockey, soccer, judo, basketball, volleyball and all athletes are involved strength training in their periodisation of training. The terms weight training and resistance training are also called strength training and used synonymously by coaches and trainers for the development of strength. Resistance training is any exercise that causes the muscles to contract against an external resistance with the expectation of an increase in strength, tone, mass and muscular endurance. The external resistance can be dumbbells, free weights, rubber bands, your own body weight etc. Weight training is also performed through barbell with weight plates, single station weight machines, multi gym, dumbbells etc. The athlete should follow the basic law and principle of strength training before starting strength training. He must understand the types of muscle contractions and how muscles work together at the time of joint movement. This is the main objectives of this topic.

Keywords: strength, resistance, isometric, isotonic, isokinetic, power, and weight training

Introduction

Strength training is a method of improving muscular strength by gradually increasing the ability to resist force through free weights, machines and players' own body weight. Strength training is also called resistance and weight training. Resistance or weight training was once considered inappropriate for athletes except for weight lifters, power lifters, body builders and throwers. Women were not advised to do weight training exercises. Researchers and coaches have discovered the benefits of strength training for all sports and it has since become more popular globally. Finally, in late 1980s and early 1990s health professionals began to recognize the importance of resistance training for overall health and fitness. Most athletes including female, now incorporate strength and power training as important components of their training schedule. Resistance training is an important part of the exercise programme for those who seek health related benefits of fitness. Strength training programme differs for each sport. Even the resistance exercise training schedule for power sports like body building, power lifting and weight lifting also differ. Body builders need more hypertrophy and muscles definition where as power lifters require maximum strength and weight lifter needs more explosive strength. This entire training programme for the three different sports is complex in nature but strength is the ultimate goal. Since, strength training is complex in nature; one must have basic knowledge about muscles fiber, motor units, principles and laws of strength training. There are various types of strength training exercises for our upper body and lower body parts. All these exercises are selected and designed for specific purposes called types of strength training, like circuit training, super set system, antagonist super set system, maximum load method, isokinetic method, slow or super slow system etc. As per the requirement of types of strength for different sports, the coaches design various exercises for their athlete's strength training programme. This paper focuses on physiological aspects of muscle fibers, motor units, muscles contraction, principles and laws of strength training.

Strength its meaning and types

Strength is the ability to overcome the resistance. Strength comes in many forms and more

complex in nature. It is classified into various categories.

(a) Maximal strength refers to the maximum amount of weight that a person can lift one time. For example a weightlifter lift 60 kg in his front press or 130 kg in his back squat, so his maximum shoulder and leg strength will be 60kg and 130 kg respectively which is his 100 percentage. Off course to reach 60 kg in his front press he might have start his first set from 50% of his maximum strength (60 kg) that is 30 kg/5Rep, second set 60% that is 36kg/4 Rep, third set 70% that is 42kg/3Rep, fourth set 80% that is 48kg/2 Rep, fifth set 90% that is 54kg/1Rep and finally in his sixth set 60 kg with one Rep which is his maximum shoulder strength (100% intensity). Similarly he might have started with 50% in his back squat and finally reach in his last set 130 kg with one rep and complete. So, his maximum leg strength is 130 kg (100% intensity). It reflects the heaviest load an athlete can lift in one attempt, expressed as 100 percent of maximum or one repetition maximum (1RM). It is highly important to know one's maximum strength of shoulder, leg, back etc. in strength training it is the basis for calculating loads for every strength phase or strength training schedule.

(b) Relative Strength refers to the ability to work against one's body weight. Relative strength is associated with weight lifting and power lifting sports. For example a 60 kg weightlifter lifts a total 280kg (both snatch and clean and Jerk) his relative strength will be $280 \div 60 = 4.66$. Where as a 100kg body weight weightlifter lifted a total of 350kg (150kg+ 200kg) and his relative strength will be $350 \div 100 = 3.5$. If we will compare the relative strength of both the lifter the 60 kg lifter's relative strength is more.

(c) Eccentric strength, or "Yielding" strength, is the ability of a muscle to develop force while it is lengthening. This form of strength is essential to success in power tasks such as jumping, cutting, or changing direction.

(d) Strength endurance is the ability to sustain muscle force production at a high level over a period of time. A body builder performing a bicep curl exercise 20 times (Rep) with a 20 kg bar is the example of strength endurance exercise. This is also called muscles endurance.

(e) Power is defined as the rate of performing work. It is the product of force and velocity. Maximal muscle power generally referred to as power that is the explosive aspect of strength and speed of movement.

$$\text{Power} = \text{Force} \times \text{Distance/time}$$

Where Force = Strength and distance/time = speed

Types of muscle contraction

Skeletal muscles are responsible for both contraction and relaxation. A muscles contract when it is stimulated and contraction stops it relaxes. The sportsman in different sports involved in weight training exercises and depending upon their training schedule and equipments muscles contraction occur. There are three types of muscles contraction which is isometric, isotonic and isokinetic.

Isometric is a muscle contraction in which no movement occurs. The length of the muscle remains constant under tension. For example, if an athlete pushes against a wall, tension will be created in the muscles without changing the length of it.

Isotonic is a muscle contraction that pulls on the bones and produces movement. Most types of lifting would be considered isotonic. It is of two types one is concentric and second is eccentric. In concentric contraction the muscles

shortens its length. For example, in bicep curl exercise with dumbbell or barbell, the bicep muscle shorten. In leg extension exercise, quadriceps contract concentrically. Eccentric contraction is the reverse process of a concentric action. During a bicep curl, the eccentric contraction occurs when the arm extended fully and come to the starting position. Similarly, in after leg extension movement, eccentric contraction occurs when knee joint bend and come to starting position.

Isokinetic is a type of contraction which maintains constant velocity throughout the range of motion. Isokinetic work out needs special equipments that designed to allow a constant velocity of contraction regardless the load. Mini gym, cybex are the best example of isokinetic equipments which is very expensive. When athlete performed exercise in this equipment, both concentric and eccentric contraction occurs and the machine provides a resistance that is equal to the force generated by the athlete. That means equal amount of force is applied in each repetition. The main benefits of this exercise are it allows the muscles to work maximally throughout the entire movements.

How muscles work together

The skeletal muscles do not contract independently of one another; but they contract together with a different role. Prime movers or agonist and synergists are muscles that work together as a team, cooperating to perform a movement. The synergists are the muscles that provide assistance to agonist or prime movers. Antagonists acts in opposition to agonists during the movements. For example in our bicep curl movements (elbow flexion), bicep is the agonist, triceps muscle is antagonist and trapezes are the synergist. Stabilizers or fixators are usually small muscles that contracts isometrically to anchor or steady a bone so that prime movers have a firm base support for the movement. A stabilizer may be a muscle in the same limb or other parts of the body at the time of a joint movement. For example, in a pitcher curls exercise (elbow flexion where upper arm or triceps rested on a firm support) the shoulder and abdomen muscles contract as iso-metrically and act as stabilizer in the bicep curl movements.

Types of muscle fiber, motor unit and resistance training

All muscle fibers in our body are not alike. A single skeletal muscle contains fibers having different speeds of shortening and strength: Slow twitch, or type I fibers, and fast twitch or type II fibers. Type II fibers are further classified into two: Fast twitch type IIa (type IIa) and fast twitch type IIx (type IIx). Since there is a difference in between type I and type II fibers, there are two different functions are associated with related to exercise. In general, type I muscle fibers have a high label of aerobic endurance. Aerobic means in presence of oxygen. Type I fibers are very efficient at producing ATP from the oxidation of carbohydrate and fat. Type II muscle fibers, on the other hand, have relatively poor aerobic endurance. Thus are better suited to perform anaerobically (without oxygen). Type IIa fibers play a major in high intensity exercise. Type IIx fibers are activated when the force demanded of the muscles is high.

A motor unit is made up of a single motor neuron and it connected to a number of muscle fibers. The motor neuron appears to determine whether the fibers are type I or type II. The motor neuron in a type I motor unit has a smaller cell body where as motor neuron in a type II motor unit has a larger cell body. Small motor units (Type I motor unit)

contain slow-twitch fibers while large motor units (type II motor units) contain fast-twitch fibers. Type II motor unit generate more force because they have larger fibers and more muscle fibers per motor unit than do the type I motor unit. Motor unit recruitment happens when strength is required; nerves assist with the action. The number and type of motor units recruited are dependent upon the amount of strength required. So, strength is not the solely a property of muscles rather it is a property of motor unit. Motor unit recruitment, stimulation frequency, and neural factors are also quite important to strength gain. This is most important aspect of strength training so far as exercise physiology is concerned.

Three basic laws of strength training

Law 1- Develop joint flexibility before developing muscle strength.

Good flexibility aids in the elasticity of the muscles and provides a wider range of motion in the joints. It also reduces injuries. Most of the weight training exercises involved whole range of motion. Think about the weight training exercise of back squat, front press or dead lift where full range of joint movement takes place around knee, shoulder and trunk respectively. After performing weight training exercises they must do stretching exercises. .

Law 2- Develop tendon, ligaments and joint before developing muscle strength.

The tendon and ligaments are both support in resistance training. In initial training period, if load will be more both tendon and ligament will not able to adopt load properly and in consequence injury (strain and Sprain) will occur. The rate of gain muscles strength always related with the rate at which tendon and ligament can adopt higher tension. This is also called anatomical adaptation of the weight or resistance training. In anatomical adaptation phase (light weight training with moderate repletion) which will activate all the muscles, ligaments and tendons of the body so they will better cope with the heavy loads of subsequent training phase. Secondly it prevents injuries through progressive adaptation to heavy loads. The anatomical adaptation phase need 6-12 weeks to progressively adapt their muscles, ligaments and tendon for entry level body builders, throwers and other athletes. After that they must follow principle of progression of load.

Law 3- Develop core group of muscles before developing limbs

The main core muscles of our body's are abdomen and low back muscles (erector spine). The body builders, weightlifters and power lifters must give prime importance to core muscles in their initial stage of training. That does not mean after initial phase of training they will give less importance to core group. A poorly developed trunk represents a weak support system of body framework. Both abdominal and low back muscles play important role in many exercises and sports movements. So weakness in this area can severely limit the action and effectiveness of sports performance. The bicep, triceps, pectorals muscles can be develop easily. So, before develop arm and lower extremities muscles group they must give importance to core muscles.

Language of strength training

- **Intensity** in weight training says about hardness of the exercise. How hard the exercise is? Generally it is based on the amount of weight or load you lift. For example, a lifter performs 150kg in his back squat (one rep) which is

his maximum strength, and then we called it 100 percent intensity. When the intensity of the exercise will more the reps will be less.

- Volume in weight training is how much work you do, such as the number of reps you perform in an exercise.
- Sets are a group of repetitions of a specific exercise. Each set should be followed by a period of rest before another is performed.
- Reps are repetitions used to describe the number of consecutive times you perform an exercise.
- Hypertrophy means increase in muscles size. Hypertrophy is two types one is transient and second is chronic. Transient hypertrophy is the increased muscle size that develops after a weight training programme. This results mainly from fluid accumulation in the interstitial and intercellular space of the muscles which last for a short time. The fluid returns to blood within hours after exercise. Chronic hypertrophy refers to the increase in muscle size that occurs with long term resistance training. This reflects actual structural changes in the individual muscle fiber (fiber hypertrophy) in the number of muscle fibers (fiber hyperplasia).
- **Muscle definition (MD):** This term is used in body building (Best Physique) training programme. MD is a training phase using specific training methods, where the objective is to burn fat and in the process further improves muscle striation and vascularization.
- **Low load:** It means pertaining to loads up to 49 percent of 1RM.
- **Medium load:** It means pertaining to loads between 50 and 89 percent of 1RM
- **Maximum load:** It refers to a load of 90 to 100 percent of 1RM.
- **Super maximum load:** a load that exceeds 100 percent of 1rm. These weights are used by experienced weight lifters to improve their maximum strength.

Principles of strength training

(a) Work capacity training

This is the most basic level of training for strength development which is called "work capacity". Every coach or Physical education teacher must adopt this in their preparatory phase. This phase consist of developing various physical qualities like (i) Core strength, (ii) Joint mobility, (iii) strength endurance, (iv) Anaerobic capacity (v) Body composition. We must consider these factors before start strength training in case of a group of school athletes (11 to 14 years of age) or a group of untrained older athletes. As we have already discuss three basic laws of weight training. The training intensity and volume should be very less. The Set and Rep must be calculated properly.

(b) Principle of progression of load

According to this principle the training load should be gradually increase as per their adaptation of the load. All of sudden they must not start with maximum load in their training schedule. In resistance training, the load should be gradually increased for a better performance. Otherwise the performance will deteriorate due to over load. This is also called step load or pyramid type load. Gradually athletes body's adaption capacity will improve.

(c) Principle of reversibility

According to principle of reversibility, training benefits are lost if resistance training is either discontinued or reduced

abruptly. To avoid this training programme should continued and maintained though out their periodisation.

(d) Principle of hard and easy

According to the principle of hard and easy, one or two days of hard training (maximum load) should be followed by one day of easy training (moderate or low load), allowing the body and mind to fully recover before the next hard day of training.

(e) Principle of individuality

Athletes are not equal with the same ability to respond or adapt to resistance training. A group of weight lifters having 60 kg body weight categories are different so far as their structure, body function and maximum strength though their body weight is same. The coach should take individual attention so far as training load is concerned.

(f) Principle of periodisation

In resistance training, periodisation is the gradual cycling of specificity, intensity and volume of training to achieve peak level of performance in completion. Whole year (macro cycle) is divided in to preparatory, competition and transitional periods with various meso and micro cycles. In body building training, this meso and micro cycles are confined with hypertrophy, mixed training, maximum strength and muscles definition.

Resistance training needs to be analysis

Except weight lifting, power lifting and body building, the coaches of all other sports should analysis following points before prescribing a resistance training programme for their athletes.

- (a) What major muscles group needs to be trained?
- (b) What type of training is required?
- (c) Which exercises will be selected and performed?
- (d) What will be the order of exercises in which they will be performed?
- (e) What will be the number of sets and reps of each exercise?
- (f) What will be rest periods between each sets?
- (g) What will be the intensity and volume of the training?
- (h) What preventive major will be taken to avoid injury?

All these points are very important to analysis before start a resistance training programme for different sportsman.

Conclusion

In this paper, I have considered the role of resistance training in increasing muscular strength and improving performance. The laws, principles and role of motor unit in strength training which is highly important have been discussed. We come to know how muscle strength is gained through both muscular hypertrophy and neural adaptation. Resistance training equipments are very expensive so far as isokinetic training is concerned. Strength training can benefit almost everyone, regardless of age, gender or athletic involvement. Most athletes in all sports can benefit from resistance training if an appropriate programme is designed for them. To ensure the success of the programme, it should be assessed periodically. The training regimen with intensity and volume of load, sets with repetitions should be adjusted as required to avoid injury and negative effects.

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