Strength Training and Science

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16. December 2020

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1 Introduction

In the fitness- and training industry we see a broad spectrum of approaches to strength training. Some are tuned in to increase strength whilst others are more prone to develop muscle mass. And even within the specialties, we see a great variety of methods and focus. It can confuse and misguide trainees, athletes, and even coaches. What is strength? Is it the capacity to lift extremely heavy loads, to achieve records in long jump, or is it to possess an extremely muscular physic? More importantly, how can we be specific in our training approach to reach certain goals?

Most of us have, to our surprise, seen individuals show great strength with a seemingly modest physique. In the following, we look at the physiology and the changes in the musculoskeletal system as a result of specific strength training. For athletes, it is crucial to choose the right training method to be amongst the best in their sports. The level of knowledge within training has, guided by research, developed a lot and is in continuous development. Most likely specificity in training is the main reason for the spectacular results we see world-class athletes produce in many sports. An optimized training approach, which keeps raising the bar. Based on the theory we look at the transformation of human tissues exposed to specific types of strength training. And I will explain terms frequently used in strength training.

1.1 Synopsis

How does the outcome and nature of the qualities of strength and muscle mass depend on the load, number of repetitions, number of sets, and the speed at which the exercise is carried out, and what is the scientific explanation to support it?

And secondly; What considerations should be made when planning an exercise program for tennis players, bodybuilders, and elderly people?

2 Method

In answering the synopsis, I will use literature and review research papers covering this topic. It is important to understand the theoretical foundation upon which strength training rests on. From a theoretical point of view, I will define strength and other terms and briefly describe the various tissues responsible for strength. As my starting point, I use the book “Science and Practice of Strength Training” by Vladimir M. Zatsiorsky and William J. Kraemer covering the theoretical section.

2.1 Included

Within this scope, we will look at muscles, ligaments, tendons, and the nervous system and describe the impact different training approaches have on those tissues.

2.2 Not included

Mobility, nutrition, hormone status, and genetic, even though it plays a great role in strength training, falls outside the scope of this study.

3 Theory

3.1 Definition of strength

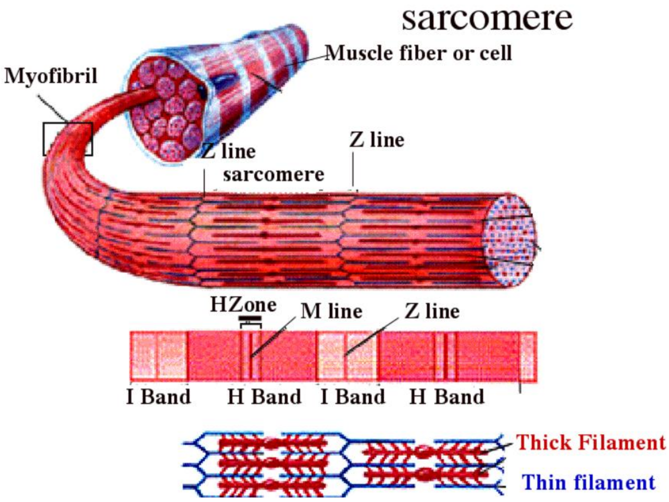
Muscular strength can be defined as the ability to overcome or counteract external resistance by muscular effort. Or expressed as the ability to generate maximum maximorum external force, Fmm. Concentric and eccentric strength is terms used respectively when a muscle is developing strength in shortening and lengthening of the muscle fibers. To measure the intensity in strength training, the standard “repetition maximum (RM)” is used. It refers to the maximum load that can be lifted a given number of repetitions until failure. An example would be 8 RM – this is the load that can be lifted in a single set only eight times (1).

3.2 Specific strength

Two factors or systems are important for generating maximal force. One is related to the capacity of the individual muscles to create maximal force (muscle fore potential (peripheral) factors). The other system of importance is the central nervous system, which is responsible for the activation and coordination of muscle activity (neural (central) factor) (1).

3.3 Muscle force potential

Skeletal muscles consist of muscle fibers, made up of many myofibrils, which again consist of longitudinal repeated units of sarcomeres. Those units include thin filaments consisting of actin and myosin. According to the sliding filament theory, shortening of the sarcomere occurs as a result of the active relative sliding of the actin filaments between the myosin filaments. The maximal force production is depending on the total number of cross-bridge links. Sarcomeres in a myofibril work in series. Force production of a muscle fiber is limited by the number of myofibrils working in parallel, thus to determine the muscle potential in a muscle we have to look at the cross-sectional area or the filament area density (1).



3.4 Hypertrophy

Strength exercise can increase filament area density – the capacity of a muscle to produce force depends on the number of muscle fibers (hyperplasia) and the cross-sectional area of the fibers (fiber hypertrophy).

An increase in muscle mass and strength is mainly, close to 100 percent, a result of fiber hypertrophy. Strength training will not have any significant impact on the amount of muscle fibers. That being said; individuals born with a large number of fibers will have greater potential in weight lifting and bodybuilding competitions.

There exist two types of muscle hypertrophy, sarcoplasmic and myofibrillar hypertrophy.

Strength training with heavy resistance will lead to a mix of both – enhancement of both force production and muscle mass.

By being more specific in our approach to training parameters, we can favor one quality over the other. Athletes should be exposed to training that ensures and favors myofibrillar hypertrophy, while bodybuilders would choose a different setup (1).

3.4.1 Sarcoplasmic hypertrophy

Sarcoplasmic hypertrophy is hypertrophy without a gain in strength. The filament area decreases, while the cross-sectional area, due to the growth of sarcoplasm (semifluid intrafibrillar substance), increases (1).

3.4.2 Myofibrillar hypertrophy

Myofibrillar hypertrophy is characterized by the growth of the contractile protein actin and myosin, hence the gain in strength (1).

3.5 Metabolism of protein

3.5.1 Energetic theory of muscle hypertrophy

There are many theories about the process, which initiates the build-up of increased mass and force production. One theory, that is more likely to be valid than others, is the energetic theory of muscle hypertrophy.

It is based on the idea, that the muscles during heavy resistance work outcomes in deficit of energy used for muscle work and synthesis of muscle protein. Most of the energy is used for muscle work.

As a result, protein degradation and the presence of catabolites increase during training. During the resting period – the time between training sessions – the synthesis of protein increases. The process of degradation and synthesis of protein is called super-compensation of protein and considered similar to what happens with muscle glycogen as a consequence of endurance training (1).

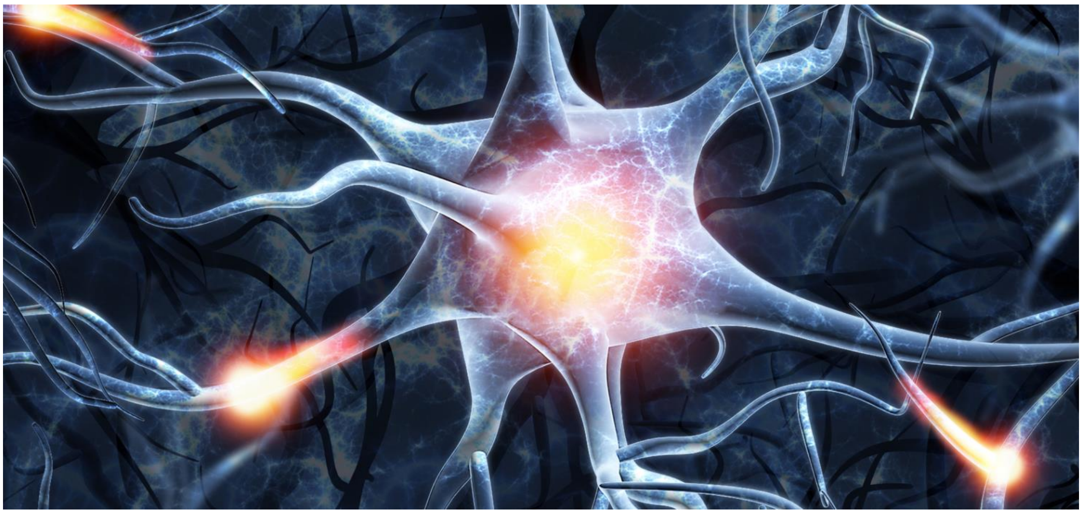
3.5.2 Muscle fiber types

In general, we have two types of muscle fibers; type 1- slow-twitch fibers and type II – fast-twitch fibers. They respond differently to strength training. Type 1 fibers rely more on preventing the amount of myofibrillar protein degradation, while type II rely more on increasing protein synthesis. As we can see; training parameters seem to be worth some consideration when planning an ideal program for a specific goal (1).

3.6 Relative strength and absolute strength.

The terms relative and absolute strength are interesting perspectives in sports. Absolute strength is an expression of maximum strength without squinting at bodyweight, while relative strength must be seen in the context of body weight in relation to strength. For Olympic super-heavy weightlifters or shot putters absolute strength is ideal, whereas, for athletes, who are moving their body alone without a heavy implement, relative strength is important (1).

3.7 Neural central factors



Muscular strength is depending on both intramuscular and intermuscular coordination, respectively to what extent can individual fibers in a muscle be activated (intramuscular coordination), and secondly; the activation of several muscle groups (intermuscular coordination) (1).

3.7.1 Intramuscular coordination

Based on motor units (MU's), the nervous system has several measures to adjust muscle force production. Gradation of total muscle by activation and deactivation of individual MU (recruitment). Changing the firing rate (rate coding) of MU and lastly synchronization by activation of the MU in a synchronized way. As an analog to the muscle fibers, the MU is classified as slow-twitch (ST) and fast-twitch fibers (FT). The FT is further divided into IIA and IIX. It is not possible for muscle fibers to convert from type IIA into type IIX muscle fibers.

Each fiber within a motor unit contracts according to the"all or none" law. This principle states that when a motor unit receives a stimulus of sufficient intensity to bring forth a response, all the muscle fibers within the unit will contract at the same time, and to the maximum possible extent. The force production gradation though can change through changes in the firing rate.

FT and ST produce the same force per unit, but FT motor units are covering larger cross-sections and thereby produce greater force per unit. High-level athletes in strength and power sports have a high percentage of FT fibers, while athletes within endurance sports possess a higher percentage of type I fibers.

Recruitment of the MU is determined by the size of the MU – small MU with the lowest threshold is recruited first. Larger motoneurons FT have the highest threshold, thus recruited last. Not all individuals can pass the highest threshold and get access to the fastest muscle fibers in the body. Phycological factors such as willpower and the consequences of failing are very important in that sense. The order in which the MU is recruited is relatively fixed in a specific motion, but if the movement pattern is changed, it is possible to change the threshold for the same muscle. This implies that training a muscle with heavy resistance, training in different patterns will potentially lead to a more fully development of that particular muscle. For bodybuilders it is recommendable, but for elite athletes, it is a different story. An increase in muscle mass can have a negative effect on their performance.

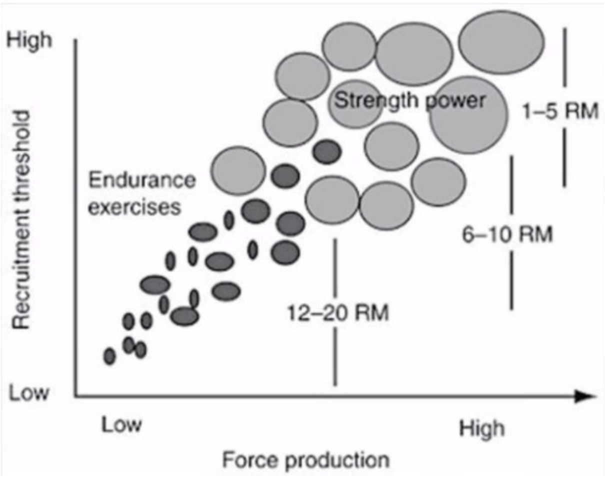


Figure 3.7.1 Force production in relation to recruitment threshold. The largest MU's requires a higher threshold triggered by higher load (size principle). The figure illustrates that by changing the load (RM) we can activate a wide spectrum of MU's.

Activation of small muscle most MU’s is recruited at a level of force less than 50 % of Fmm. In larger proximal muscle with force between 80-100 % of Fmm, the firing rate is responsible for almost the total increase in force development.

Under normal circumstances, the MU's are working asynchronously to produce smooth and accurate movements. Elite power and strength athletes though seem to be able to activate MU’s synchronously during maximal voluntary muscle work. Synchronicity will enhance the trainees to adapt to a more targeted and efficient movement pattern in their sports (1).

3.7.2 Intermuscular activation

Every exercise requires a great deal of coordination of many different muscle groups, which is the primary reason for athletes to train in patterns. It is not efficient to train single muscles in isolation and it should be limited only as a supplement to normal training.

Explosive strength (rate of force development) and the force in stretch-shortening muscle actions are independent components of motor function (1).

3.8 Strength training methods

There are three terms used to describe the methods of strength training:

- Maximal effort method
- Repeated or submaximal effort method
- Dynamic effort method (1)

3.8.1 Maximal effort method

This method is known to be superior for improving intra- and intermuscular coordination. The maximal number of MU’s are activated, when the load is close to maximal, and the repetitions are from 1-3 (fig 3.7.1). A disadvantage with the maximal effort method is the high risk of injuries. The method should only be used by trained athletes. Because of the small number of repetitions in each set, the mechanical work, and the ability to induce hypertrophy are low (1).

3.8.2 Repeated or submaximal effort method

Repeated and submaximal methods are mainly used for hypertrophy and differ only in the number of repetitions. The repeated effort method extends the number of repetitions to failure, whereas the submaximal effort method includes the intermediate number of repetitions before failure. Both methods are almost equal in enhancing hypertrophy. By changing the parameters for the exercise, for example, shortening the time intervals between sets, a submaximal method is as effective as working to failure. As we have seen from the theory, there is a whole range of MU’s, from the smaller and slower to the largest and fastest. Training for hypertrophy affects mainly the middle portion of MU’s, with intermediate qualities. As indicated in figure 3.7.1, we can expand or broaden the corridor of MU’s subjected to training, by changing the parameters for the training; the number of repetitions, and the load (1).

3.9 Explosive strength and power (dynamic effort)

Explosive strength, defined as the ability to produce maximal force in minimal time, is crucial for elite athletes' performances. As noted earlier explosive strength is linked to the rate of force development (RFD). In athletics such as shot put, long jump, and sprint the time of the motion is very short. The time available is too short to produce Fmm. The difference between Fmm and Fm is called the explosive-strength deficit (ESD). To increase the explosive strength there are two options; increase the Fmm (maximal effort method) or reduce ESD. Which way to go depends on the level of the athlete. A beginner will most likely benefit by increasing Fmm, while a more experienced athlete should focus on decreasing the ESD (dynamic effort method). The experienced athlete will in most cases if they are properly trained, not be able to increase Fmm to a level, which can improve their performance in sport. In this case, increasing the rate of force can yield good results and should be the primary focus area for the experienced athlete.

Power is another term used in training and elite athlete performances. Power is defined as P=F(D/t) = F(V). We can see from the equation, that power increases with a decrease in time. Since F and V are inversely related, the optimal relation between them has to be established, thus maximum power is defined as Pmm=1/3Vmm(1/2Fmm) = 1/6(VmmFmm). As an example, the power output in shot putting exceeds the power output in a heavy squat. Reversely the force produced in a heavy squat, due to the increased time available, is much greater compared to shot put.

To increase explosive strength, there are two options; we can increase the load to 80-90 % of 1 RM with very few repetitions enhancing the strength part (maximum effort method) or we can focus on speed, RFD, trained with plyometric training, jumping or throwing, without or with a light load, 30-45% of 1 RM (dynamic effort method) (1).

3.10 Plyometrics – reversible muscle action

Plyometrics, a term often used in training athletes, can be translated as a stretch-shortening cycle – eccentric and concentric contraction of muscles. Movements often consist of both concentric and eccentric actions. Jumping is a result of just that; lengthening of muscles and immediately after shortening of the same muscles. The muscles and tendons get winded up and result in greater force development and power. As an extra advantage, the energy expenditure decreases. There are four reasons for the increase in force. In the moment of transition between lengthening and shortening, the force is developed in isometric conditions and the impact from high velocity is avoided. As mentioned earlier, when the velocity decreases, the force increases. Time for force development increases which means, as we have seen, that we can produce force closer to Fmm. Muscle and tendon elasticity and reflex action are of importance in reversible muscle action (1).

3.10.1 Muscle and tendon elasticity

The elasticity of a muscle and tendon is stored and recoil like a spring in the concentric phase. The muscles, when active, get stiff and it requires a great deal of force to stretch it. High-end elite athletes can produce force to a degree where the muscles get stiffer than the tendon. For most people, it is the reverse. Now the muscles are stiffer, and the energy is stored mainly in the tendon, acting as a spring.

The nervous system controls the reversible muscle action via the myotatic reflex and the Golgi tendon reflex. The myotatic reflex, also named muscle spindles, is located in the muscles and prevents excessive stretch of a muscle by increasing the muscle spindle discharge. It leads to an increased discharge of the alpha-motoneurons and a reflex contraction of the stretched muscle (length feedback). The Golgi tendon reflex, when activated by sharply increased muscle tension, is sensitive to forces and inhibits muscle action. The efferent signal to the muscle is a combination of those two reflexes. For athletes, it is important to keep the muscle force exertion by inhibiting the effect of the Golgi tendon reflex. This can only be trained by specific training such as drop jump (1).

3.11 Rest and timing in training

Proper restitution and timing in training is a crucial part of effective programming in training. Not just for elite athletes, but also for exercises in general. It has an effect on gains and at the same time be of importance in regard to avoiding injuries. Many trainers, especially within elite sports design medium-term planning (periodization) with a range of 1 year. The planning is then again broken into minor units, macrocycles (preparation, competition, and transition periods), mesocycles (4 weeks), and microcycles, where microcycles are one training session. In the following, I will look at the general principles and considerations of rest and timing, rather than explaining in more detail the individual cycles (1).

3.11.1 Rest

The requirements for rest between training sessions is mainly depending on the workload in the first session. After training with a high workload, it can take up to 48-72 hours to recover. Too many training days in a row with a high workload using the same muscle groups may lead to severe exhaustion, fatigue, and potential injuries. Fatigue from different types of muscular work is specific in the sense that if a trainee is unable to perform an exercise with proper quality, he can still perform another exercise to the required level. It is of utmost importance to respect rest as an equally important factor as training. In fact, with resistance training, when we emphasize neural condition – both intra- and intermuscular – the trainee, for maximum result, should be as fresh as possible.

The rest in between the sets is also important to ensure good results. Heavy resistance training for strength with few repetitions requires 4-5 minutes of rest between sets and for hypertrophy 1-2 minutes between sets. The restitution time is utilized to train other exercises not involving the same pattern or muscles (1).

3.11.2 Timing of exercise sequence, intensity, and variation

For optimizing the training result it is also important to plan the sequence and intensity of the exercises used in the microcycle. As a general rule, it is recommended to

- Include main sports exercises before assistance exercises (exercises which are basic strength exercises, but not one of the primary movement patterns in the sport).
- Use dynamic power type exercises before slow exercises like squats.
- Train larger muscle groups before smaller ones.
- Exercises with maximum training weight should be practiced at the beginning of the training

In a mesocycle, it is recommended to keep the same exercises through the whole period, but for the benefit of variability, the load changes from microcycle to microcycle. Furthermore, the trainee should perform a given exercise at least twice a week to get the best possible physiological adaptation.

After 4 weeks (mesocycle) it is recommendable to change the exercises to avoid accommodation, which is characterized by slow or no gains in strength (1).

Training variable	Muscle hypertrophy	Strength (neural factors)
Intent	To activate and exhaust working muscles	To recruit the maximal number of motor units with optimal discharge frequency
Intensity (RM)	From 5-7 to 10-12	1-5
Rest intervals between sets	Short (1-2 min)	Long (3-5 min)
Rest intervals between workouts emphasizing the same muscle groups	Long (48-72 h)	Short (24-48 h)
Exercises in a workout	Three or fewer muscle groups (split system)	Many muscle groups
Exercise alternation in a workout	Flushing: exercises for the same muscle group may alternate; exercises for various groups do not alternate	Recommended to alternate in a workout
Training volume (load, repetitions, and sets	**Large (4-5 times)**	**Small (4-5 times)**

Table 3.11.1 Training Protocols to induce Muscle Hypertrophy or Muscle Strength (Neural Factors) in Science and Practice of Strength Training

3.12 Consistency in training

Periods without training will be followed by a quite substantial loss of muscular and neurological qualities achieved in the previous training cycles. For some sports with tournaments most of the year, ex. tennis players, it can be difficult to live up to general training recommendations. They have to prioritize which tournaments are the most important and plan training cycles accordingly.

Four factors are responsible for the time course of detraining:

- Duration of the immediately preceding period of training (period of accumulation)
    - The longer the period of training, the longer the period of detraining. Athletes with a long preseason and a relatively short competition period will not lose their gains in strength.
- Training experience of the trainee
    - Experienced athletes with a long history of training seem to regain their capacity, especially their motor abilities, much faster than less experienced athletes or trainees.
- Targeted motor abilities
    - There are differences in how fast individuals lose their specific qualities. Anaerobic capacity drops very fast after a period of detraining, whereas aerobic or muscular strength lasts longer. The ability to retain the strength gained in previous training can be stretched out by implementing mesocycles containing small loads in periods of detraining.
- Amount of specific training loads during detraining mesocycles
    - Continued training with heavy loads at a certain level, will make the trainee able to retain or lose the motor abilities at a slower rate (1)

4 Specific training for individual groups

As we have seen in the description above, there are several things to consider when planning a training program. Athletes and bodybuilders as an example will have different requirements in their training programs. And even amongst athletes, we differentiate in our selection of training exercises. In the following, I will argue for general considerations for training athletes, bodybuilders, and elderly people.

4.1 Tennis player

Analyzing a tennis player in a match will give the observer an idea about the requirements that are needed in top tennis. Hitting the ball requires good strength and speed in the upper body as well as in the lower body. Certainly not maximum strength, but a force where the speed of the player's movement triggers a high power in the racket or in the legs. Change of direction, acceleration as well as de-acceleration are also a large part of the work requirements that must be set for the tennis player. Bodyweight is also important; the relative strength is the optimal goal.

From the review, we can concretize in large terms the methods we need to focus on in the planning of strength training for a tennis player. The training must include a mix of maximal effort methods and dynamic effort exercises based on the same movements that the tennis player performs in his sport.

The exercises must have an explosive starting point, where the number of repetitions ranges from 1-3 with 90 % of 1 RM. The requirement for the nervous systems ability to coordinate (intra- and intermuscular coordination) is paramount, and we are outside the field of hypertrophy. The aim is to get maximal recruitment of MU’s and increase RFD.

Training involving reverse muscle action (lengthening/shortening of the muscle) will also be relevant to increase the power of the player. Both acceleration and de-acceleration, hitting the ball are all examples of just that. Moving the arm back, stopping the motion, and instantly forcing the arm forward is a good description of reverse muscle action. Exercises like vertical jumping (unilateral and bilateral), lateral jumping, use of a sled, drop jump, throwing with a medicine ball are all useful in that perspective (dynamic effort method). We are increasing the RFD and at the same time enhancing the loading of the tendons.

Separate training of core stability and assistive exercises that can increase the improvement of the primary movement patterns and qualities and decrease the risk of injuries, should also be part of the training program and should, at least for the assisted exercises, be placed at the end of the program.

Goal	**Explosive strength and power**	**Strengthening and to some extend hypertrophy of muscles which assist enhancement of explosive strength and power**
Method	Maximum effort (ME) and dynamic effort (DE)	Submaximal effort (SE)
Intensity	ME: 1-3 90 % of 1 RM and DE: 6 30-45 % of 1 RM	10-12 RM - 1-2 rep less than failure
Exercise type	ME: Squats, split squats, deadlifts, bench press, and loaded chin-up. DE: Jump squats, box jump bilateral and unilateral with or without drop jump, Medic ball throw in different positions imitating movements in tennis, half push-up fast, etc.	General strengthening of the whole body, especially shoulders, back, core, hips, and legs. These exercises can be settled in blocks to optimize time efficiency. For example, the upper body works in conjunction with ME of the lower body.
Rest intervals between sets	4-5 minutes	1-2
Rest intervals between workouts Emphasizing same muscle groups	24-48 hours	48-72
Training volume	Low: High load, low rep, and relative few sets	Medium: Moderate load, many reps not to failure, and a moderate number of sets.

Table 4.1 Considerations planning a strength training program for an elite tennis player.

4.2 Bodybuilder

For a bodybuilder, visual expression is the main concern. Symmetry and full development of individual muscles is the goal. Strength is less important, but as the review shows, strength and muscle mass go somewhere hand in hand. It is not possible to completely rule out one quality in relation to the other. But as science states; we can favourize one over the other.

Training for maximum extend of muscle fatigue and break down of proteins followed by a relatively long rest period is the recipe for creating a complete and massive physique. The number of sets per muscle group can go as high as 20 sets depending on the load. The higher the load, the more rest time between sets. Two or a maximum of three muscle groups per training session. As the reader will probably notice, a training session containing three muscle groups with 20 sets per.

muscle group and 2 min rest between sets last up to two hours. Most bodybuilders choose a split program over three days, where two muscle groups are trained per. day. An example could be shoulders, arms, and abdominal muscles on day 1, legs on day 2, chest and back on day 3 followed by a rest day. The program ensures training of the individual muscles two times a week and at least 72 hours between each muscle group.

We have seen that hypertrophy can be established in two ways; sarcoplasmic and myofibrillar hypertrophy. A bodybuilder will have to focus on both qualities to get maximum growth of the cross-sectional area. From the theory, we have learned that repetitions from 1-5 rep will lead to the greatest increase in strength and minimum hypertrophy. Bodybuilders, for the most part, will set the amount of repetition in the range of 5-7 or 8-10. For reaching their goals, they do not have to possess extreme strength to get maximum muscle growth. Remember; an increase in muscle mass or cross-sectional area is the goal (muscle force potential). The central factors (intra- and intermuscular coordination) are to some extend important to activate FT muscle fibers, but for Olympic weightlifters, it is of more importance to get access to the absolute fastest fibers. Specific movement pattern is less important, thus including machines as a measure in training is not a limiting factor for building muscle mass.

To achieve a complete physique as a bodybuilder it is important to train the same muscle with a variety of exercises with different angles and patterns. It will ensure the maximal enhancement of growth in each muscle.

Goal	**Hypertrophy**
Method	Repeated effort method (RE)
Intensity	5-7 or 10-12
Exercise type	A combination of free weights and machines for the whole body. A big variety of exercises for the same muscle, which ensures a more complete and bigger muscle mass
Rest intervals between sets	1-2 minutes
Rest intervals between workouts Emphasizing same muscle groups	48-72 hours
Training volume	Large: 5-6 days a week, up till 20 set pr. Muscle group

Table 4.2 Considerations planning a strength training program for a bodybuilder.

4.3 Strength training of elderly people

During aging, our physiology goes through dramatic changes functionally. A decrease in strength, speed, and agility is just some of the experiences we are facing. There are multiple courses for the degeneration of human physiology. In the following, I will briefly explain what happens with some of the tissues responsible for our biomechanics.

4.3.1 Degeneration biomechanics

Younger people resemble articular cartilage while the adult interface resembles fibrocartilaginous tissue. There are marked differences in collagen fiber orientation that become more pronounced with age (2).

Structural properties of ligaments in relation to linear stiffness, ultimate load, and energy absorbed decrease significantly with specimen age (3).

With increasing age, the force-generating capacity (strength) in the muscles is reduced (4,5). The loss of strength in older people is primarily linked to the result of muscle atrophy and alterations in the percentage of contractile tissue within the muscle (5-7) rather than deficits in muscle activation (motor unit (MU) recruitment and firing rates) (8-9).

Muscle fiber number and size in skeletal muscle cross-sectional area (CSA) decreases with age (5, 6, 7). Sarcopenia is the term used to describe a reduction in fiber size, fiber number, or a combination of the two. A reduction in the total number of fibers within a muscle is the primary source of sarcopenia, although a small reduction in fiber size may occur (6). The muscles of older people (65–83 years of age) contain less contractile tissue and more non-contractile tissue when compared with the skeletal muscle of younger people (26–44 years of age) (7). Noncontractile tissue is composed of fat and connective tissue. A greater percentage of noncontractile tissue results in a decreased force production capacity.

The size of type I (slow) fibers does not change substantially with age but type II (fast) fibers undergo selective atrophy (4, 1210). The number of types I and type II fibers appears to decline similarly with age (4).

There is some evidence that blood supply to tendons decreases with aging. Studies of vascularity of tendons show a significant decrease in blood flow in the intra tendinous region in elderly subjects compared with younger subjects. (13, 14).

The dynamic sensitivity of the muscle spindle decreases with aging (48), which leads to a lower discharge frequency in response to muscle stretch.

Aging is accompanied by a loss of motor units (15, 16) and changes in the morphology and properties of existing motor units (17). There is an indication that MU firing rates decrease with age (18) or may become more variable (19). Increased variability in MU firing rates may lead to deficiencies in motor control and force production.

4.3.2 Benefits of strength training for elderly people

Appropriate exercise can alter, slow, or even partially reverse some of the age-related physiological changes that occur in skeletal muscle, including sarcopenia, reduced lean muscle mass, decreased force production (4, 20, 21, 22, 23–25).

4.3.3 Injury prevention

Older people or athletes are more prone to getting injuries like rotator cuff tear and bicipital tendonitis, patellofemoral arthrosis, trochanteric bursitis, quadriceps tendonitis, and rupture, gastrocnemius tear, bone fractures, and discogenic low back pain. Variating the exercises, not going to failure in each set, and listening to the body will lower the risk of getting injured. An adequate progression in load and training volume will have a positive influence as well.

4.3.4 Strength training methods for elderly people

Progressive resistance training (PRT) programs or high-intensity training programs are both examples of strength training. High-intensity resistance programs usually consist of 2 to 6 sets of 8 repetitions at approximately 80% of a person's one-repetition maximum (1-RM) (25, 26, 27) A common misconception is that older people need to "take it easy" when performing exercise. Researchers suggest that older people who are healthy respond to strength and endurance training in a similar fashion to younger people (4, 26, 28). Thus, to get optimal results, health professionals need to train their older patients at intensities that are optimally suited to induce the desired training effects.

As we can conclude from a theoretical point of you 8 RM is not considered high intensity. There are several levels above that, which will enable us to get access to the most powerful and fastest muscle fibers in the human body. But the question is, do we need to go there and what are the potential outcome?

The number of muscle fibers decreases and especially type II (a and x) – the fastest muscle fibers. As stated earlier, the number of MU's decreases as well. On top of that, we should pay attention to the high risk of getting injured with high-intensity training with reps down to 1-3.

Putting everything into perspective, it is not worth the risk of operating in the highest intensity zone. And being extremely strong and powerful in our later days does not in my belief appeal to many people.

Besides that, an elderly person should train for both strength and power. It will help them in their daily life as well and raise or keep their general health in a good state. In theory and for some people the toolbox with plyometric training, power training, and reverse muscle action can and should be applied for the elderly population. Remember the importance for elderly people to produce force rapidly to avoid falls and change of direction. Power training can slow down the loss of ability to produce force rapidly. Of course, the task should reflect the individual's age, experience, and general health. As we have seen, changing some of the parameters for a given exercise can change the outcome of an exercise. Decreasing the load and increasing the speed, will to a greater extent affect intramuscular control (firing rate) and add greater power to the individual's physiological capacity. Loading with 30-40 % of 1RM is recommended for maximal mechanical power. Plyometric exercises like vertical jump and medicine balls exercises are known to develop power in the lower and upper body.

Another important aspect of strength training for elderly people is rest. The need for recovery time increases during aging. It is difficult to argue for a specific rest time between training sessions, but high intensity or high volume training sessions might require more than 3 days for the elderly population. Listening to the body is vital to avoid overuse injuries and to maintain training motivation.

In some countries, it is recommended to get consent from a physician prior to participating in a strength training program.

Below is a framework for a training program for elderly individuals. To accommodate all the principles and requirements listed above this could be an example. The goal is to train for hypertrophy, strength, and power. It is designed as a split program, strength for the upper and lower body on different days, with two sessions of each per week. The sessions are combined with power drills for the reverse body part. This will ensure time efficiency; the power exercises can be done in between strength exercises without interrupting the rest time between sets.

Goal	**Power – ability to react fast**	**Hypertrophy and strength**
Method	Dynamic effort method (DE)	Submaximal effort method (SE)
Intensity	6 rep of 30-45 % of 1 RM	10-12 RM - 1-2 rep less than failure
Exercise type	Vertical - bilateral or unilateral, lateral jumping unilateral, medicine ball throwing in different ways	A combination of free weights and machines for the whole body. A big variety of exercises for the same muscle, which ensures a more complete and bigger muscle mass
Rest intervals between sets	4-5 minutes	1-2 minutes
Rest intervals between workouts Emphasizing same muscle groups	24-48 hours	48-72 hours – maybe longer
Training volume	Low: Relative small load and relative few sets	Medium: Moderate load, many reps not to failure, and a moderate number of sets.

Table 4.1.4 Considerations planning a strength training program for elderly people.

5 Conclusion

The review of the theory has given us answers according to the synopsis. I have described the physiological adaptation of body tissues exposed to various forms of strength training. Hopefully, it gives a good understanding and illustration of how a targeted training effort can provide a specific training response in human tissues. The inclusion of considerations for specific training groups in section 4 is only an overall review of essential points in the planning. Preparation of the actual training program is the next step. There is a myriad of different exercises which can create the desired results. The choice depends, among other things, on the goal of the training effort, coach preferences and experience, as well as the athlete's or exerciser's level, anatomy, and injury history.

For myself, as a physical trainer and a manual osteopath, it has been a motivating and exciting journey through the theoretical foundation on which my work rests. I make extensive use of the science available, but I also recognize that there are many considerations in the practical implementation of training interventions and programs, that conflicts with the pure theory. The optimal training course is a balance between theory and individualization in respect to the challenges mentioned above.

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