Classification of strength qualities

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Strength can be classified into many different types, each defined by different capabilities of the neuromuscular system and different time frames. Some types can be defined further yet by type of muscular contraction. This paper classifies these capabilities and defines these contraction types.

Limit Strength: The peak force or torque that the neuromuscular system is capable of exerting in a single maximal contraction. Limit strength is typified by a survival (instinctual) response to a life-threatening situation that involves little or no prior thought or preparation. It is also known as maximal involuntary strength.

Maximal Strength: The peak force or torque that the neuromuscular system is capable of producing in a single maximal voluntary contraction, irrespective of the time element. There are three types of voluntary maximal strength, one for each type of muscular contraction: isometric, concentric, and eccentric.

Isometric (static) contraction: The muscle develops tension while its length remains unchanged, thus producing no external movement; muscle develops tension without a change in joint angle.

In fact, the muscle belly and accompanying fascia does shorten internally during the process of developing tension, but the shortening in the agonist is countered equally by a shortening in the antagonist. In certain sporting movements, such as moving out of starting blocks in sprinting, an isometric contraction in the set position precedes a concentric contraction, but there is no external movement.

Concentric Contraction: The muscle develops tension and shortens, causing movement to occur. During a chin-up, the joint angle at the elbow is decreased from 180 degrees to 15 degrees as the biceps work concentrically, resulting in an elevation of the body.

Eccentric Contraction: The muscle lengthens while producing tension, thus braking, slowing or controlling the speed of movement. This contraction is typified by the action of quadriceps during a change of direction. Eccentric contraction of the biceps occurs by lowering the body from the completed chin-up position, with the elbow joint angle increasing from 15 degrees to 180 degrees. During the positive phase in the bench, the triceps contract concentrically as the joint angle at the elbow increases, but contract eccentrically as the joint angle decreases during the return phase (the weight moves up and down, respectively). The highest forces that the human body is voluntarily capable of occur during an eccentric contraction—forces of 40 to 50 percent above values produced by concentric contractions. Maximal eccentric strength exercises provide maximal stimulus to the neuromuscular system, but at the cost of greater levels of muscle soreness for the athlete.

Isokinetic: Literally same speed, meaning that the muscle performs a maximal contraction in moving the joint at constant speed throughout the full range of motion.

Note that the contraction is maximal throughout the range of motion; thus, the resistance against which the muscle works varies depending on the length of lever arm offered by the changing joint angle. The accommodating resistance apparatus is allowing a constant and predetermined speed of movement. The force exerted by the contracting muscle must be maximal during an isokinetic contraction. Some isokinetic devices also allow the maximum speed of contraction to be preset and thus better enable the simulation of contraction speeds required by a specific sport. Isokinetic strength training is most

specific to the so-called isokenetic sports such as swimming, synchro-swimming, canoeing and kayaking, where acceleration occurs against the resistance provided by water (an isokinetic medium). It has low specificity in sports such as sprinting, jumping, and throwing, where acceleration against gravity plays a major role. However, it does provide the option to any sport of exposing the nervous system to a different stimulus for athletes, thus adhering to the principle of variety.

Maximal strength plays a major role in sports such as hammer throwing, shot putting and weightlifting, where a great external force must be overcome. Its importance as a determinant of athletic performance diminishes as the duration of the event increases. For example, swimming for 50 meters requires more maximal strength than swimming for 1500 meters. As **Table 1** indicates, strength requirements vary greatly from one sport to another. Sports of an intermittent nature (such as racquetball), which require intense periods of power interspersed with lower intensity recovery periods, are also dependent upon high levels of maximal strength.

Speed-Strength (power, fast strength or elastic strength): The ability of the neuromuscular system to produce the greatest possible force in the shortest possible time span; the capacity of the neuromuscular system to overcome resistance with the greatest contraction speed possible.

Speed-strength is a high priority in most acyclical sports such as field events; in the sprinting, kicking, jumping and throwing activities of team sports; and in the starts and acceleration phases of sprinting, cycling, rowing, cross-country skiing, ice skating and kayaking.

Speed-strength encompasses three other strength qualities: starting strength, explosive strength and reactive strength.

Starting Strength: The capacity to generate maximal force at the beginning of a muscular contraction; the capacity to overcome resistance and initiate movement.

Starting strength is important in movements that require great initial speed, such as boxing blows and racquetball strokes. Starting strength is a key determinant of performance in sports where the resistance to be overcome is relatively light. It is dependent upon the number of motor units accessed at the beginning of the contraction.

Explosive Strength: The capacity to develop a vertical rise in force once movement has been initiated, measured in terms of the increase in force per unit of time; the ability of the neuromuscular system to continue developing the already initiated force as quickly as possible; the rate at which one can develop maximal or peak force.

Explosive strength is a key determinant of performance in sports where the resistance to be overcome is relatively great such as wrestling, hammer throwing and shot-putting.

Reactive Strength: The ability to quickly switch from an eccentric contraction to a concentric contraction. This is also known as the stretch-shortening cycle.

Reactive strength regulates performance in sports where the stretch-shortening activity of the musculature is great, such as volleyball, basketball, and weightlifting.

Plyometrics: A form of training that utilizes fast eccentric contractions followed by concentric contractions through such activities as bounding and depth jumping and certain forms of medicine ball work. The term *plyometric* refers to the enhancement of

Table 1. Maximal strength performances of male athletes of different sports and different levels of qualification (modified from Letzelter and Letzelter, 1986; Poliquin 1988).

Discipline	Qualification	Full Squat	Bench Press
Weightlifting (100 kg)	220 kg jerk	285 kg	170 kg
Shot-put	20 m	235 kg	200 kg
Hammer throw	72 m	225 kg	190 kg
Sprint	9.78 s	200 kg	190 kg
Cycling	Sprint	205 kg	97.5 kg
Bobsled	Olympic team	200 kg	140 kg
Hammer throw	60 m	180 kg	150 kg
Judo (86 kg)	Olympic team	180 kg	140 kg
Alpine ski	National team	170 kg	80 kg
Speed skating	40.5 s	150 kg	
Shot-put	14 m	140 kg	115kg
Decathlon	8000 points	145 kg	110 kg
Decathlon	7500 points	130 kg	95 kg
Rowing	Nat. class	140 kg	90 kg
Badminton	Nat. league	95 kg	65 kg

force development of a concentric contraction that occurs when it is immediately preceded by a rapid eccentric contraction. As a training method, plyometrics bridges the gap between pure strength training and speed-strength training. This training method aims at producing the explosive-reactive movements inherent in takedowns in wrestling and in jumping, throwing and sprinting.

Strength endurance (muscular endurance): The athlete's tolerance level against fatigue in strength performances of longer duration; the capacity of a muscle to maintain consistent force output with repeated contractions over time at a percentage of maximal strength superior to 30 percent; the capacity of muscles to resist fatigue while generating force over a period of time.

Strength endurance is characterized by high strength levels coupled with high levels of endurance. It is of particular importance in cyclical endurance events such as rowing, cross-country skiing, swimming and canoeing/kayaking, where the ability to overcome exceptional resistance must be maintained over long periods of time. It also plays a key role in sports or events of acyclical nature such as gymnastics, wrestling, boxing, judo, downhill skiing and most team sports.

Absolute Strength: The maximum force an athlete can generate, irrespective of body weight and time of force development. Body weight and performance are closely correlated in athletes where absolute strength is an important physical quality such as throwers and American football linemen. Maximal strength gains through hypertrophy methods can be used by these athletes.

Relative Strength: The maximum force an athlete can generate per unit of body weight and time of force development. High relative strength is of critical importance to performance in sports where athletes have to move their entire body weight such as jumps and gymnastics and in sports which involve weight classes such as judo, wrestling and boxing. Strength training for these athletes should aim at improving the neural drive (maximal weights—nervous system methods).

Optimal Strength: The optimal level of maximal strength needed for a particular sport; any further increase in maximal strength would not improve performance.

In sports such as powerlifting, where strength is expressed at slow speeds, the level of optimal strength is open-ended; that is, the more strength the athlete has, the higher the sports performance. In sports where motor skills predominate, like table tennis, the levels of optimal strength are quite low, since maximal strength and performance are not highly correlated in these sports. **Table 1** illustrates the different levels of strength commonly found in elite athletes.

Accumulation Phase: A training phase where the main stressor is volume. Increased muscle cross-section or increased strength endurance levels are sought in this phase.

Intensification Phase: A training phase where the main stressor is intensity. Increases in relative strength or speed strength are sought in this phase.

In strength training the total volume of work varies considerably from one sport to another. What represents intensification for one sport is accumulation for another. For example, when synchro-swimmers are working in the 6 to 8 RM range, they are doing intensification work; for weightlifters this range represents accumulation. ●