Strength is Specific

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Extract from version 2.0
1. WHY ARE STRENGTH GAINS SPECIFIC?
Getting strong is really, really important.

In fact, strength is probably the single most important thing for many athletes.

But strength is very hard to measure with a single test.

Some people score very highly on one test of strength, but less highly on another similar test, even when it involves the same muscle groups.

Similarly, training for one particular strength test (such as a 1RM back squat) will make you stronger at the test exercise, but not necessarily increase your force production in another exercise, or during a sporting movement.

This is because strength is specific.
How is strength specific?

Strength gains are greater when tested under the same conditions as performed in training. There are 8 ways in which strength is specific:

1. Muscle action (eccentric or concentric)
2. Velocity (fast or slow)
3. Repetition range (maximum strength or muscular endurance)
4. Range of motion (full or partial)
5. Degree of stability (stable or unstable)
6. External load type (constant load or accommodating resistance)
7. Force vector (vertical or horizontal)
8. Muscle group

Maximizing the effectiveness of a strength training program means designing it to fit the specific goal you want to achieve.
How much difference does specificity make?

The impact of specificity on strength training is not a small detail.

It is huge.

Compare the effects of training with eccentric muscle actions, compared to training with concentric muscle actions. Using elbow flexion exercise, Vikne et al. (2006) showed that gains in eccentric 1RM after eccentric training are more than twice as large as those after concentric training.

Eccentric training preferentially increases *eccentric* strength?

**Study Objective**

To compare the effects of long-term strength training programs involving either eccentric (ECC) or concentric (CONC) muscle actions on changes in muscular strength and size, in strength-trained males.

**Training:** 2 – 3 workouts per week for 12 weeks, using 3 – 5 sets of 4 – 8 reps of a pulley-based biceps curl. The CONC group moved the weight with maximal speed, while the ECC group used a 3 – 4 second duration.

**How was this measured?**

- CONC biceps curl 1RM, in the pulley machine
- ECC biceps curl 1RM, in the same pulley machine (duration of ≥3.5 seconds)
- Ratio of ECC to CONC 1RM strength
- Maximum elbow flexion angular velocity at 30, 50, 70, and 90% of pre-training concentric 1RM
- Anatomical cross-sectional area of the elbow flexors with computed tomography, and changes in fiber type by muscle biopsy and subsequent ATPase histochemistry (data not shown)

**What happened?**

![Diagram showing the comparison between eccentric and concentric training](image)

**Eccentric training preferentially increases eccentric strength.**

Eccentric training increased eccentric strength by more than concentric training, and concentric training tended to increase concentric strength by more than eccentric training. This caused an increase in the ratio of ECC to CONC 1RM after eccentric training but a decrease after concentric training.

Compare the effects of training with fast or slow velocities.

Both high and low velocity training can produce gains in high-velocity and low-velocity strength, but the gains are velocity-specific (Coyle et al. 1981).

**Strength gains are velocity-specific; but fast transfers well to slow?**

**STUDY OBJECTIVE**

To compare the effects of long-term strength training programs with either slow or fast isokinetic velocities on changes in strength at slow, moderate, or fast velocities.

**MEASUREMENTS**

- Maximum isometric voluntary contraction (MVIC) knee extension torque (data not shown).
- Isokinetic knee extension torques at 60°/s, 180°/s and 300°/s (Nm/kg).
- Mid-thigh circumference and skinfolds; muscle fiber type, from biopsies and subsequent histochemistry (data not shown).

**How was this measured?**

**Training**: 3 workouts per week for 6 weeks. Each workout involved the 2-leg isokinetic knee extension exercise. The slow group performed 5 sets of 6 reps with maximal force at 60°/s. The fast group performed 5 sets of 12 reps with maximal force at 300°/s. The groups were matched for work done.

**What happened?**

**WHAT DOES THIS MEAN?**

Strength training at a **low velocity** tended to produce greater gains in strength at low velocities. In contrast, strength training at a **high velocity** tended to produce greater gains in strength at high velocities. However, the **gradient** was less marked, indicating greater transfer between velocities.

Compare the effects of training with heavy or light loads.

Both heavy and light loads can increase muscular strength, but the gains in maximum strength are almost always much greater when using heavy loads. Similarly, the gains in repetition strength (muscular endurance) are usually much greater when using lighter loads (Schoenfeld et al. 2015).

**Heavy better for strength; light better for muscular endurance?**

**Study Objective**

To compare the effects of light (25 - 35 reps per set; 30 - 50% of 1RM) and heavy (8 - 12 reps per set; 70 - 80% of 1RM) strength training in trained males on changes in muscle size, strength, and muscular endurance.

**Measurements**

- 1RM bench press and 1RM back squat
- Quadriceps and upper arm (elbow flexor and elbow extensor) muscle thickness with ultrasound (data not shown for elbow flexor)
- Muscular endurance (max number of reps with 50% of 1RM bench press)

**What happened?**

![Graph showing comparisons between heavy and light load training](image)

- **Heavy load training** produced greater gains in 1RM bench press and 1RM back squat, while both heavy and light load training produced **similar gains in muscle size**. In contrast, muscular endurance was only increased by **light load training**.

Compare the effects of training with partial or full ranges of motion.

When partials do improve full range of motion strength, it is almost never as much as full range of motion training. On the other hand, they usually produce larger gains in partial range of motion strength (Rhea et al. 2016).

**Squat strength gains are highly joint-angle specific?**

**STUDY OBJECTIVE**
To compare the effects of long-term strength training programs involving the quarter squat, half squat, and full squat, in male athletes

**MEASUREMENTS**
- Full squat 1RM (>110° knee angle)
- Half squat 1RM (85 - 95°)
- Quarter squat 1RM (55 - 65°)
- Jump height and sprint times (data not shown)

*Training: 2 upper-body workouts, and 2 lower-body workouts per week for 16 weeks, including 4 - 8 sets of squats (full, half or quarter)*

*What happened?*

*Quarter squat 1RM* was increased most by quarter squat training, *Full squat 1RM* was increased most by full squat training, *Half squat 1RM* was increased most by half squat training. Squat strength is highly joint-angle specific.

Compare the effects of training under different stability conditions.

An easy way to explore the effects of stability is to look at strength gains after training on machines that use fixed bar paths or on machines that use cables to allow freedom of movement (Cacchio et al. 2008). Strength gains are totally different between the two types of machine.

**Less stable training causes stability-specific strength gains?**

**STUDY OBJECTIVE**
To compare the effects of long-term chest press training in stable conditions with a fixed bar path machine (FIXED) and less stable conditions with a cable machine (CABLE) in untrained females.

**MEASUREMENTS**
- 1RM FIXED, 1RM CABLE, and the ratio of 1RM CABLE to 1RM FIXED
- Electromyography (EMG) amplitudes for agonists, antagonists and synergists in the 6RM of the exercise used in training
- Joint angle movements using motion analysis

**How was this measured?**
Changes in EMG amplitudes from pre- to post-training during the 6RM cable machine test.

**WHAT DOES THIS MEAN?**
- **CABLE training** increased CABLE 1RM relatively more than FIXED 1RM. **FIXED training** increased FIXED 1RM proportionally more than CABLE 1RM. Strength gains were therefore stability specific. Gains in CABLE 1RM after CABLE training occurred alongside larger increases in antagonist and increases in synergist activation, which suggests a neural mechanism for stability-specific strength gains under less stable conditions.

Compare the effects of training with different external load types.

Pneumatic resistance provides a constant external force, while free weights involve a force that is greatest at the start of the exercise and smallest at the end, because of inertia. Training with pneumatic resistance leads to greater gains in pneumatic resistance strength, than in free weight strength. Training with free weights leads to greater gains in free weight strength, than in pneumatic resistance strength (Frost et al. 2016).

**Pneumatic resistance: greater high-velocity strength gains?**

**STUDY OBJECTIVE**
To compare the effects of strength training with free weights vs. pneumatic resistance in strength-trained males.

**MEASUREMENTS**
- Free weight and pneumatic resistance bench press 1RM; peak force (with a force plate), peak velocity (with a linear potentiometer), and peak power in explosive free weight bench presses with 15, 30, 45, 60, 75, and 90% of 1RM.

**Training:** 3 workouts per week for 8 weeks, in 2 phases (strength and power) of 4 weeks each. In phase 1, subjects used 80 – 95% of 1RM for the bench press exercise. In phase 2, subjects used 30 – 45% of 1RM. Programs for the free weight and pneumatic groups were identical except for the external load type used for the bench press.

Strength gains were specific to the external load type, as shown by the ratios of 1RM strength gains.

**What happened?**

**Ratio = 1.1 times**

<table>
<thead>
<tr>
<th>1RM free weight</th>
<th>1RM pneumatic</th>
<th>Peak force</th>
<th>Peak velocity</th>
<th>Peak power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free weight training</td>
<td>Pneumatic training</td>
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**WHAT DOES THIS MEAN?**

Training with pneumatic resistance ↑ peak force at 15% of 1RM. Free weight training did not. No other ↑ in peak force with sub-maximal loads were seen.

Training with pneumatic resistance ↑ peak power (likely by ↑ bar speed) as well as force with a light load (15% of 1RM) by more than training with free weights. Free weight training ↑ peak force by more. 1RM strength gains were specific to the external load type used in training.

Why are strength gains specific (part 1)?

People get confused about the relationship between muscle size and strength, and this leads them to make extreme statements in one direction or another.

Some people think that muscle size and strength have little connection with each other. They believe that it is possible to increase strength substantially and over a long-term period of time without gains in muscle size. Other people think that strength is only a function of size, and that it is impossible to increase strength without hypertrophy.

**Muscle size predicts strength; but other factors also important?**

**STUDY OBJECTIVE**

To identify the determinants of maximal isometric knee extension torque and slow speed concentric knee extension torque in a varied group of young males.

**MEASUREMENTS**

- Muscle cross-sectional area (CSA), fascicle length (FL) and pennation angle (PA) with ultrasound; moment arm length of the patellar tendon with X-ray scans; activation of the rectus femoris, vastus lateralis, vastus medialis, and biceps femoris by EMG normalized to M wave; involuntary torquus and voluntary activation by superimposed involuntary contractions.

**WHAT DOES THIS MEAN?**

Measures of quadriceps CSA were most strongly associated with isometric and concentric torques. Many other aspects of muscle structure (moment arm length, pennation angle, and fascicle length) and neural drive (voluntary activation and EMG amplitudes) were also moderately associated.

In fact, the truth is halfway between these extremes. Although muscle size is the single most important predictor of strength, other factors also have an impact. This is apparent even in cross-sectional studies (Trezise et al. 2016).

The remainder of the difference is probably accounted for by many different peripheral and central factors (not just neural ones, like you might read in an old textbook), including:

1. muscle fascicle length
2. muscle pennation angle
3. moment arm length
4. single fiber contractile function
5. lateral force transmission
6. neural drive to the agonists
7. coactivation of antagonists
8. coordination

And these factors are also what makes strength gains specific.
Why are strength gains specific (part 2)?

The specific nature of strength gains is produced by lots of small peripheral and central adaptations that interact with each other.

Across the fitness industry, you will find that most people simply refer to vague “neural adaptations” whenever specificity or the Specific Adaptation to Imposed Demand (SAID) is raised.

The reality is much more complex.

Specific gains in strength can occur through many different mechanisms, some of which are neural and some of which are due to changes within the muscle itself.

Let’s take a look at the mechanisms underlying the 5 most important ways in which strength is specific.

#1. Muscle action

Strength gains are specific to the muscle action (contraction mode) you use.

Eccentric training produces greater gains in eccentric strength than in concentric strength.

Although many people will argue back and forth about the hypertrophic potential of eccentric training, the specificity effect is not caused by differences in the amount of hypertrophy produced.

In fact, it probably happens partly because of increased extracellular matrix and titin content, which increase passive force production, and partly because of neural adaptations that are specific to lengthening muscle actions.
#2. Velocity

Strength gains are specific to the velocity that you use.

High-velocity (light load) training produces greater gains in strength at high speeds than at low speeds.

Velocity-specificity is confusing, because some very influential research suggested that “intent” was the main factor driving velocity-specific strength gains, and not actual bar speed. However, this is probably not true, and both “intent” and actual speed likely contribute to velocity-specificity.

Velocity-specificity probably happens for many reasons, including greater increases in muscle fascicle length, larger increases in single fiber velocity, greater increases in early phase neural drive, more suppressed co-activation, and bigger improvements in coordination, compared to low-velocity (heavy load) training.

#3. Range of motion

Strength gains are specific to the range of motion you use.

Partial range of motion exercises produce greater gains in strength at partial ranges of motion than at full ranges of motion.

Partial range of motion exercises probably improve strength at short muscle lengths because of joint-angle specific increases in neural drive. In contrast, full range of motion exercises likely improve strength at long muscle lengths because of specific gains in regional hypertrophy.
#4. Load

Strength gains are specific to the load that you use.

Heavy loads lead to greater gains in maximum strength, while lighter loads (performed to failure) lead to greater gains in repetition strength (muscular endurance).

Greater gains in maximum strength with heavy loads likely occur because of more relevant increases in inter-muscular coordination in multi-joint exercises, greater changes in single fiber contractile properties, greater increases in lateral force transmission, and larger increases in neural drive.

Greater gains in repetition strength likely occur with lighter loads because of larger improvements in capillarization, and changes buffering capacity, and in the rate of ion (Na⁺, K⁺, Ca²⁺) transport.

#5. Stability

Strength gains are specific to the amount of stability you use.

Free weight strength training leads to greater strength gains on free weight exercises than on machine exercises.

Stability exists on a continuum with machines at one end, and lifting free weights while balancing on a stability ball at the other end. Lifting free weights while standing on the ground or lying on a bench sits somewhere in the middle.

Strength gains are specific to the type of stability used in training. This is because the need to balance in any less-than-perfectly stable environment affects the co-ordination patterns of muscles in multi-joint exercises, increasing both synergist and antagonist activation.

Training in an unstable environment leads to reduced antagonist activation and increased synergist activation, as the more complex nature of the movement is learned. These changes leads to a more efficient pattern of muscular contractions for those exact conditions of stability.

And this increases strength in a stability-specific way.
What about the other ways in which strength is specific?

Strength is specific in at least 8 ways.

However, the other 3 ways are specific mostly because of the way in which they produce changes in the big 5 ways.

- External load type (constant load or accommodating resistance) produces specific strength gains because of changes in joint angle-specific (range of motion-specific) strength and velocity-specific strength.

- Force vector (vertical or horizontal) also produces specific strength gains because of changes in joint angle-specific (range of motion-specific) strength, and because it tends to develop certain muscle groups more than others.

- Muscle group specific strength gains arise where an exercise trains a muscle group in a non-specific way, which then transfer to completely different joint actions involving the same muscles. A good example of this might be training the hamstrings in knee flexor exercises (such as Nordic hamstring curls or lying leg curls), which then transfers to hip extension strength.
What does this mean in practice?

Getting strong for sport means analyzing the requirements of a sporting movement, and figuring out how force is produced in terms of muscle action (eccentric or concentric), speed (high or low velocity), range of motion (point of peak contraction), load (maximum or repetition strength), and stability (stable or less stable).

Matching the features of sporting movement with the goals of your strength training program will lead to optimal sport-specific strength gains.

Many coaches have already figured this out.

The importance of eccentric strength for sprinting and change of direction is why eccentric training with flywheels is suddenly so popular. The success of velocity-based training points to the superior transfer of high-velocity strength gains to sporting movement. And partial squats are having a comeback for developing sprinting and jumping abilities.

It is only a matter of time before the rest of the industry catches up.
References


