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Effects of various techniques in muscle strength: A review article

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Abstract
Objective: This review examines four training techniques i.e. eccentric loading, blood flow restriction (BFRT), neuromuscular electrical stimulation (NMES), versus exercise variation and how each affects muscular strength and hypertrophy in healthy, athletic, and clinical populations.
Methodology: We synthesized data from systematic reviews, meta-analyses, and RCTs. Strength outcomes were measured using one-repetition maximum (1-RM) tests and isokinetic dynamometry.
Main findings: ECC training outperforms concentric training for strength and hypertrophy gains, especially in older adults and patients with conditions such as COPD. High-intensity resistance exercise (≥80% 1-RM) remains the most reliable approach for slowing age-related muscle loss. Rotating exercise selection drives greater strength gains than adjusting loads alone, due to broader motor unit recruitment. BFRT and NMES are useful adjuncts in clinical settings where heavy loading is not feasible.
Conclusion: Building muscular strength requires combining high-intensity loading, eccentric overload, and deliberate exercise variation. Newer techniques such as BFRT and NMES offer practical alternatives when traditional loading is not possible, but progressive overload remains the core principle underlying all long-term adaptation.

Keywords: Muscle strength, eccentric training, blood flow restriction, electromyostimulation, muscle hypertrophy, resistance training

Introduction

Muscular strength is the maximal force a muscle or muscle group can produce against resistance, measured under defined conditions of velocity and joint angle. It is a reliable marker of health and physical independence. Strength underpins nearly all human movement, from the low-intensity demands of daily tasks like rising from a chair or climbing stairs, to the high-velocity requirements of sprinting, jumping, and changing direction in sport. Research has shown that rate of force development (RFD) and joint power are just as important as absolute 1RM strength for fall prevention and movement efficiency.

High-Intensity Resistance Training (HI-RT) has long been the standard approach for building strength. Meta-analyses broadly support the idea that loads above 70% of 1RM are needed to drive meaningful myofibrillar hypertrophy and neural adaptation. The problem is that many people cannot tolerate these loads. In post-operative patients those recovering from total knee arthroplasty (TKA), distal radius fractures, or rotator cuff repairs heavy lifting risks damaging healing tissue, worsening inflammation, and causing pain that undermines compliance. The picture is similarly complicated in older adults: sarcopenia (the progressive loss of muscle mass and quality with age) demands high-intensity stimuli, yet many older people lack the joint integrity to train that way safely [1, 2, 3, 4, 5].

This gap has driven interest in training techniques that target the same physiological drivers of strength, mechanical tension, metabolic stress, and neural recruitment, without requiring heavy loads.

One approach is Eccentric-Only Training (ECC). During eccentric contractions, the muscle-tendon unit lengthens under tension, producing 30–50% more force than concentric or isometric efforts at lower metabolic cost and oxygen demand. ECC training also promotes longitudinal hypertrophy, the addition of sarcomeres in series which increases fascicle length and shifts muscle architecture toward greater strain resilience [6, 7].

A second technique, Blood Flow Restriction (BFR) training, applies a pneumatic cuff proximally to restrict venous return during low-load exercise (20–30% 1RM). The resulting local hypoxia increases growth hormone secretion and recruits high-threshold motor units, producing anabolic signals that roughly approximate those of heavy lifting [1, 8, 9].

A third approach, Electromyostimulation (EMS) takes a different route. By bypassing volitional control to elicit involuntary contractions, EMS can override the neural inhibition common after surgery or injury and activate fast-twitch fibers in patients who cannot voluntarily recruit them [10, 11].

Recent research has also questioned the rigidity of traditional periodization through the study of Exercise Variability. Rotating the exercises themselves rather than adjusting only load or volume appears to produce more uniform whole-muscle hypertrophy and greater maximal strength. The variety of the motor stimulus, it turns out, matters [12, 13].

This review draws on contemporary RCTs and meta-analyses to evaluate each of these techniques. We examine their physiological mechanisms from sarcomere addition in eccentric loading to metabolic signaling in BFR and compare them against traditional resistance training. The aim is to give clinicians, practitioners, and coaches a practical, evidence-based reference for designing strength programs that hold up across different ages, injury states, and performance goals.

Literature Review

1. Eccentric vs. Concentric Muscle Contractions

Muscle contractions are fundamentally categorized based on the relationship between muscle tension and structural length changes. These mechanical modalities i.e. concentric (CON) and eccentric (ECC) exert highly distinct physiological, structural, and molecular influences on human skeletal muscle.

During a concentric contraction, the force generated by the muscle exceeds the external load, causing the muscle-tendon unit to shorten. Conversely, during an eccentric contraction, the external load exceeds the force produced by the muscle, forcing the muscle-tendon unit to lengthen while maintaining tension.

ECC actions are characterized by unique mechanical efficiencies: High Force Production ECC contractions can generate up to 20–30% more absolute force than CON contractions. Low Metabolic Cost despite higher force outputs, ECC actions consume significantly less adenosine triphosphate (ATP) and oxygen. The Role of Titin this metabolic efficiency is largely attributed to titin, a giant structural protein within the sarcomere. During an ECC action, titin acts as a "molecular spring." It binds to actin upon calcium influx and stiffens during muscle lengthening, contributing substantial passive elastic tension without additional ATP hydrolysis.

The distinct mechanical stress profiles of eccentric and concentric contractions dictate how muscle architecture remodels: Longitudinal Hypertrophy (Eccentric/ECC) adds sarcomeres in series (end-to-end), lengthening the muscle fascicles. This structural shift moves peak force-generating capacity to longer muscle lengths, offering robust protection against strain injuries like hamstring tears. Transverse Hypertrophy (Concentric/CON) adds sarcomeres in parallel (side-by-side), increasing the muscle's cross-sectional area (CSA) and overall belly thickness.

While both modes develop strength, ECC training yields superior gains in total muscle mass, fascicle elongation, and explosive power. This is primarily driven by a unique neural drive that preferentially recruits high-threshold, fast-twitch (Type II) motor units during lengthening tasks [6, 14].

2. Blood Flow Restriction (BFR) Training

BFR training involves applying a pneumatic cuff or elastic band to the proximal limb (upper arm or thigh) to compress the vasculature during low-load exercise (20–30% 1RM).

The cuff is inflated relative to the individual's Arterial Occlusion Pressure (AOP) to create a specific vascular environment: Complete Venous Occlusion prevents blood from escaping the working capillary beds; Partial Arterial Inflow allows oxygenated blood to continue entering the limb. This imbalance creates a localized, hypoxic environment that traps metabolites (e.g., lactate, H+, inorganic phosphate), triggering three key anabolic cascades: Hormonal Surge (spikes systemic growth hormone [GH] and localized insulin-like growth factor 1 [IGF-1]); Cell Swelling (induces osmotic fluid shifts that signal the cell membrane to initiate protein synthesis); and Accelerated Motor Unit Recruitment (rapidly exhausts slow-twitch [Type I] fibers, forcing the nervous system to prematurely recruit high-threshold, fast-twitch [Type II] motor units normally reserved for heavy lifting).

Clinically, Post-Operative Rehab benefits include minimizing joint stress following major surgeries (e.g., ACL reconstruction, total knee arthroplasty); BFR allows patients to achieve strength and hypertrophy using safe, ultra-low loads, effectively mitigating arthrogenic muscle atrophy. For Athletic Performance, BFR serves as a joint-sparing tool during high-volume training phases, allowing athletes to maintain or increase muscle mass without inducing the structural micro-damage, joint shear, or systemic fatigue of heavy lifting [1, 8, 9].

3. Electromyostimulation (EMS)

Electromyostimulation (EMS) involves the transcutaneous delivery of controlled electrical currents directly to a muscle belly or peripheral motor nerve, evoking involuntary skeletal muscle contractions.

Under normal, voluntary physiological conditions, the central nervous system recruits motor units in accordance with Henneman's Size Principle. This principle dictates an orderly, hierarchical recruitment: small, fatigue-resistant, slow-twitch (Type I) motor units are mobilized first, with larger, fatigable, fast-twitch (Type II) motor units engaged only when force demands escalate.

EMS fundamentally bypasses and reverses this hierarchy through a non-selective, synchronous recruitment pattern: Spatial/Non-Selective Recruitment (EMS activates motor axons closest to the electrode pads first, which frequently includes large, superficial Type II fibers, even at lower overall force outputs) and Synchronous Firing (while voluntary actions utilize asynchronous firing to rotate motor unit recruitment and delay fatigue, EMS forces all targeted motor units to contract simultaneously).

This unique mechanism makes EMS highly effective at overriding Arthrogenic Muscle Inhibition (AMI), a neurological protective mechanism following joint trauma or surgery where the brain actively dampens voluntary neural drive to a muscle [10]

In elite performance tracking, EMS enhances neuromuscular efficiency by optimizing motor unit synchronization and rate coding (the frequency of motor neuron firing). These neural adaptations directly translate to improvements in absolute maximal strength and rate of force development (RFD).

The primary limitation of high-intensity EMS is localized discomfort and skin-electrode impedance pain. Emerging data suggests a hybrid intervention: combining EMS with low-load BFR. The local metabolic accumulation from BFR lowers the electrical excitation threshold of the underlying motor axons. This allows practitioners to utilize lower, more comfortable electrical currents while achieving compounded hypertrophic gains through simultaneous metabolic stress and direct, involuntary neural activation [10, 11, 15].

4. Exercise Variability and Loading Schemes

Traditional periodization models historically relied on linear or undulating alterations of load (intensity) and volume across a restricted selection of foundational movements (e.g., standard barbell back squat, bench press, deadlift). While highly effective for developing specific movement patterns, contemporary scientific evidence suggests this approach may limit holistic muscular development.

Skeletal muscles are not uniform blocks of tissue; they are structurally complex organs partitioned into distinct anatomical compartments or motor unit subpopulations. Research comparing homogenous (constant) exercise selection to varied exercise selection reveals that mechanical variation induces more uniform, global hypertrophy.

For example, when training the quadriceps femoris: Constant Selection (relying solely on the traditional back squat) tends to yield regionalized hypertrophy, primarily favoring the mid-to-distal portions of the vastus lateralis and vastus medialis. Varied Selection (rotating through biomechanically distinct movements such as front squats, leg presses, lunges, and sissy squats) ensures comprehensive hypertrophy across all four heads, including the bi-articular rectus femoris [12].

Altering joint angles, foot positions, and lines of action shifts the peak mechanical tension along different segments of a muscle belly. Varying Joint Angles performing a leg extension with hip flexion vs. hip extension changes the length-tension dynamics of the rectus femoris. Varying Planes of Motion transitioning from sagittal-plane movements (squats) to frontal-plane (lateral lunges) or transverse-plane movements alters the recruitment threshold of the stabilizing musculature (e.g., gluteus medius, adductor complex), ensuring balanced structural integrity and mitigating overuse patterns [12,13].

5. Strength in Aging and Sarcopenia

Sarcopenia is defined as the age-related, progressive decline in skeletal muscle mass, quality, and functional capacity. This condition is closely linked to dynapenia (the loss of muscle strength and power) which frequently declines at a rate two to three times faster than the loss of physical mass.

The hallmark physiological feature of sarcopenia is the preferential atrophy and denervation of Type II (fast-twitch) muscle fibers. Over time, alpha motor neurons die off, leading to the permanent loss of fast-twitch units or their partial, sub-optimal reinnervation by slow-twitch motor neurons. This cellular shift compromises structural power, leaving older adults highly vulnerable to balance loss, slower gait speeds, and an elevated risk of falls [16].

Progressive Resistance Training (PRT) is the most robust clinical intervention available to combat and reverse the trajectories of sarcopenia and dynapenia. The physiological adaptations driven by PRT occur across two distinct phases.

Neural Adaptations (Early Phase): Initial strength gains in older populations occur rapidly and are predominantly driven by improvements in neuromuscular efficiency rather than physical mass Increased Agonist Activation (elevated voluntary activation and firing frequency of the target muscles), Improved Motor Unit Synchrony (enhanced coordination and simultaneous firing of available motor units), and Reduced Antagonist Co-contraction (the nervous system learns to decrease the counter-productive, simultaneous braking activation of opposing muscles, streamlining the movement vector).

Morphological Adaptations (Late Phase): With sustained, long-term PRT, structural transformations manifest within the remaining muscle architecture Type II Fiber Hypertrophy (high-intensity resistance training, and targeted high-velocity power training, selectively overloads high-threshold motor units, stimulating protein synthesis and restoring the cross-sectional area of remaining Type II fibers) and Myofibrillar Protein Synthesis (overcoming age-related anabolic resistance by providing sufficient mechanical tension to stimulate the mechanistic target of rapamycin [mTOR] pathway, resulting in improved overall muscle quality and density) [5, 16].

Methodology

This review followed PRISMA 2020 guidelines. Sixteen papers published from 2000 onwards were included. Eligibility criteria required English-language publication in peer-reviewed journals, a focus on training techniques affecting muscular strength, and quantitative outcome data. Animal studies, case reports, editorials, and studies without primary data were excluded. Searches were conducted across three databases, PubMed, Google Scholar, and Semantic Scholar, covering medicine and physiotherapy. Search terms included "Muscle strength," "Eccentric training," "Blood Flow Restriction," "Electromyostimulation," "Muscle hypertrophy," and "Resistance training."

The initial search returned 40 studies. After screening titles and abstracts, full texts were reviewed to confirm eligibility; disagreements between reviewers were resolved by discussion or, where needed, a third reviewer. Data were extracted using a standardized form recording publication year, study design, participant characteristics, intervention duration, outcome measures, and key findings. Two reviewers independently verified all extracted data for accuracy and consistency.

Results and Discussion

1. Efficacy of Eccentric Loading

Across the literature, including the meta-analysis by Maia *et al*. [14], ECC training produces greater absolute strength gains than CON training when both are performed at maximal effort. This is not simply because eccentric loads are heavier, the structural adaptations differ. Franchi *et al*. [6] showed that while both modes produce hypertrophy, they do so through different mechanisms. ECC training predominantly increases fascicle length, reflecting sarcomere addition in series, whereas CON training tends to increase pennation angle, consistent with sarcomere addition in parallel.

For athletes, longer fascicles translate directly to high-velocity force production: they extend the effective range of motion and shift the length-tension curve in a way that reduces strain injury risk. This explains the consistent success of the Nordic Hamstring Exercise (NHE). Systematic reviews show the NHE reduces hamstring strain incidence by up to 51% in elite soccer and rugby populations.

The molecular response to ECC loading is also more pronounced. ECC contractions produce greater satellite cell activation and a larger rise in muscle protein synthesis markers, including IGF-1 and mTOR signaling, compared to CON contractions which is pointing to a stronger stimulus for long-term myogenic adaptation in athletes prioritizing explosive power and injury resilience [6].

2. The BFR Advantage: Hypertrophy without High Mechanical Stress

Meta-analyses evaluating knee arthroplasty and upper-limb fractures consistently support the practical value of Blood

Flow Restriction (BFR) in rehabilitation. Standard protocols require 60–80% 1RM for meaningful hypertrophy. BFR can match those outcomes at loads as low as 20–30% 1RM [1, 9].

In post-operative Unicompartmental Knee Arthroplasty (UKA) patients, BFR attenuated the quadriceps weakness common in the first month following surgery. Standard rehabilitation typically involves a 60% drop in quadriceps strength; the BFR group substantially reduced this loss through elevated metabolic stress. By accumulating lactate and hydrogen ions locally, BFR generates a hypoxic stimulus that recruits high-threshold Type II fast-twitch fibers, which would otherwise remain inactive at low loads [9].

The review by Johnson *et al*. [1] also documented BFR benefits for upper-extremity rehabilitation. In distal radius fractures and lateral epicondylitis, BFR preserved forearm and grip strength during immobilization or restricted loading. Emerging data from Sénéchal *et al*. [8] indicates possible sex differences in BFR response: women appear to show greater relative lean mass gains than men at low volumes, though both sexes benefit meaningfully from the protocol [1, 8].

3. Neural Contributions of Electromyostimulation (EMS)

Seyri and Maffiuletti found that EMS substantially enhanced neural drive-in elite athletes, increasing isometric strength by 15–20% and improving vertical jump height through better motor unit synchronization. The non-selective recruitment pattern of EMS is especially useful here: because it activates motor units without following the voluntary hierarchy, fast-twitch fibers are targeted early in the session rather than only at very high effort levels [11].

EMS has real limitations. It lacks the proprioceptive and kinaesthetic feedback that voluntary training provides, which are essential for motor learning and movement coordination. EMS can build force capacity but does not train the coordination required for complex skills. Current sports science positions EMS as a supplement during maximal strength phases of a periodized program, or as a recovery tool that maintains muscle tone without taxing the central nervous system.

4. Strategic Exercise Variation vs. Constant Loading

Among the more thought-provoking findings in recent strength research is the work of Fonseca *et al*. Their study challenged the assumption that strength in a movement is best built by repeating that movement. Two groups were compared: Constant Intensity, Constant Exercise (CICE) and Constant Intensity, Varied Exercise (CIVE) [13].

The CIVE group, which used leg press, lunge, and deadlift alongside the squat showed larger 1RM squat gains than the CICE group. Different exercises recruit distinct motor unit subpopulations within the same muscle group; the quadriceps, for instance, are not uniformly activated by any single movement. Rotation across exercises ensures that synergistic muscles are fully developed and weak links in the kinetic chain are addressed. For whole-muscle hypertrophy and maximal strength, rotating exercise selection appears more effective than simply adjusting sets and reps of a single movement [12, 13].

5. Combating Sarcopenia: Power and Function in Older Adults

The Peterson *et al*. meta-analysis (47 studies, 1,079 participants) is straightforward: resistance training is the most reliable intervention for sarcopenia. Average strength gains were: 29% (±2%) for the Leg Press, 24% (±2%) for the Chest Press, and 33% (±3%) for Knee Extension [5].

An important distinction here is between strength (maximal force) and power (force × velocity). Power declines faster than strength in older adults and is more directly tied to the ability to perform daily activities and avoid falls. Power training protocols where the concentric phase is performed as rapidly as possible have outperformed traditional slow-speed resistance training for functional longevity [4, 16].

There is a clear dose-response relationship: older adults gain strength with a single weekly session, but 2–3 sessions per week appears optimal for improving muscle quality (force per unit of mass). Gains at this frequency reflect both neural adaptation (reduced antagonist co-activation) and morphological changes, particularly hypertrophy of Type II fibers, which are the most vulnerable to age-related loss. [5, 16]

Summary of Results (Discussion Table)

Technique	Primary Mechanism	Key Benefit	Ideal Population
Eccentric (ECC)	Sarcomere genesis in series	Increased fascicle length & Power	Athletes, Injury Prevention
BFR Training	Metabolic stress & Hypoxia	Hypertrophy with low loads	Post-op Rehab, Seniors
EMS	Non-selective neural recruitment	Activation of "silent" motor units	Athletes, Neural inhibition
CIVE (Variability)	Heterogeneous motor unit recruitment	Whole-muscle hypertrophy	Bodybuilders, General Fitness
Power Training	High-velocity neural drive	Fall prevention & Functional speed	Geriatrics, Sarcopenia

Conclusion

There is no single approach that works for every person or context. Traditional high-intensity training remains the most reliable route to maximal strength, but several specialized techniques offer effective alternatives depending on the clinical or performance situation:

Eccentric Training is the preferred choice for athletes who need both power and structural resilience, given its distinct effects on fascicle length and sarcomere architecture.

BFR Training is well suited to post-operative rehabilitation and deload phases, delivering hypertrophic stimulus without placing significant mechanical stress on joints.

EMS is most useful for overcoming neural inhibition after injury or surgery and for activating fast-twitch fibers that voluntary effort cannot reliably recruit.

Exercise Variation is essential for uniform muscle development and for breaking through strength plateaus by recruiting motor unit populations that fixed exercise selections miss.

Future work should examine the long-term effects of combining these methods like ECC with BFR and move toward standardized protocols for different age groups and clinical populations. Combining these techniques thoughtfully gives clinicians and coaches more tools for building strength safely and effectively across a wide range of individuals.

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