The benefits and applications of eccentric overloading

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Abstract

Billions of people suffer from musculoskeletal conditions globally, affecting their daily lives and reducing their ability to participate in society. Resistance training is a useful therapeutic modality for performance, injury prevention, rehabilitation, and fall prevention. However, the load used in traditional resistance training is constrained by the maximal concentric capacity. The eccentric phase is therefore chronically understimulated.

Loading the eccentric phase of movement patterns heavier than the concentric phase is called Eccentric Overload (EOL). Studies show that EOL outperforms traditional resistance training in strength gains, injury prevention, rehabilitation, and improving balance. EOL also primarily targets type II muscle fibers, which can shift them toward a faster, more glycolytic phenotype. Special mechanisms improved by EOL, such as the Repeated Bout Effect and cross-education, make it a very effective tool for injury prevention and rehabilitation.

To achieve EOL in practice, specialized equipment, techniques, or third-party assistance is required. The Reforter allows for easy EOL using its electromotor by increasing the load during the eccentric phase, also known as biphasic loading, or using its isokinetic mode.

Traditional training is limited by concentric capacity

Musculoskeletal conditions are the leading contributor to disability worldwide [1]. They significantly limit mobility, lead to early retirement from work, lower levels of well-being, and reduce the ability to participate in society [1]. It is therefore important to focus on prevention and rehabilitation of musculoskeletal conditions. Resistance training is often used successfully as a therapeutic modality in musculoskeletal conditions [2, 3]. The question is: what is the most effective way to perform resistance training?

In traditional weightlifting, the eccentric phase is chronically under-stimulated [4–6]. This results from the load in traditional weightlifting being limited by the maximal force exerted during the concentric phase. Muscles can generally produce 20-60% more force during the eccentric than during the concentric phase [7–9]. The eccentric phase can be (additionally) stimulated by a physiological principle called Eccentric Overloading (EOL). EOL occurs when the eccentric phase is loaded heavier than the concentric phase, often heavier than the maximal capacity of the concentric phase (supramaximal loading). In this paper, we also define EOL to include all trainings in which only the eccentric phase is loaded. EOL has a positive impact on performance and shows good results in various clinical applications, which will be elaborated on in the following sections.

The effect of EOL on muscle structure and performance

EOL positively impacts three key metrics: muscle strength, muscle hypertrophy (increasing muscle size and mass), and the change to a faster muscle phenotype [6, 10–14].

Firstly, muscle strength shows larger increases with EOL than with traditional weight training [4, 6, 15–18]. EOL increases maximal isometric torque by 18%, with the traditional group only seeing an increase of 11% in a 10-week comparative study with traditional weight training [15]. In addition to that, only EOL led to significant strength gains of 60% within 11 weeks in a comparison study between EOL and traditional weight training [18]. Lastly, EOL led to double the strength gains of standard training in a study done over the course of 7 days [17]. This means EOL has a substantial effect on both acute and chronic strength gains.

18%

ISOMETRIC TORQUE GAIN WITH ECCENTRIC OVERLOAD IN 10 WEEKS, VS. 11% FOR THE TRADITIONAL GROUP

Secondly, a meta-analysis showed significant differences in muscle hypertrophy between EOL and conventional resistance training [6]. A comparative study also shows that EOL increases muscle fiber cross-sectional area (CSA) by 60% compared to 41% with traditional resistance training [18]. However, the results of this study do not differ significantly, likely due to the relatively small number of participants. EOL shows higher rates of muscle activation during the eccentric phase than traditional weight training, which likely correlates with muscle hypertrophy [13]. Finally, EOL also causes a more rapid rise in Myofibrillar Protein Synthesis, which could translate into greater protein accretion and muscle hypertrophy [12]. These findings suggest EOL stimulates muscle growth more effectively than traditional training. Some studies did not find a significant difference in muscle hypertrophy between traditional training and EOL [15, 16]. However, these studies had few participants and did not all follow a hypertrophy-specific training regimen.

The last metric positively affected by EOL is the conversion to faster muscle phenotypes [4, 14, 19, 20]. How fast a muscle contracts is largely determined by the composition of fast (type II) and slow (type I) muscle fibers [21]. EOL predominantly affects type II muscle fibers [20]. Multiple studies also show that the CSA of type II muscle fibers increases significantly as a result of EOL [4, 14, 19]. In addition to that, it has also been shown that EOL stimulates fiber type transitions [4]. The changes EOL induces structurally convert muscles into a faster, more glycolytic phenotype and allow muscles to contract faster and more explosively.

In conclusion, EOL is a very effective method to increase overall strength and speed. The question is what role EOL plays in real applications, of which we will discuss injury prevention, rehabilitation, and fall prevention, in the following sections.

Application 1: Injury prevention

Injury prevention is a well-documented application for EOL [22, 23]. Heavy eccentric loads are associated with muscle damage [22]. Afterwards, however, there is a protective muscle adaptation and a stimulus for beneficial muscle and tendon responses. The muscle hypertrophies, and the spring characteristics change to enhance power [22]. The tendon also increases stiffness and adapts to tolerate higher tensions [22, 24]. This protective adaptation is termed the Repeated Bout Effect [23]. Eccentric activity that would otherwise cause debilitating damage no longer has any harmful effects if previously exposed to heavy EOL [22].

Several studies analyzed the effect of heavy EOL on acute hamstring injuries among soccer players [25, 26]. In the control group, 11% of participants developed injuries, but in the training intervention group only 3% [25]. Therefore, EOL reduced the acute injury occurrence more than 3.3 times. Finally, tendon stiffness increased 136% following EOL, while only 54% after traditional weight lifting [24]. This is an important adaptation since muscle-tendon imbalances can increase tendon injury risk [27]. In summary, EOL triggers the Repeated Bout Effect, which is a protective muscle and tendon adaptation mechanism that greatly reduces muscle damage and injury occurrence. Although EOL can increase injury robustness, people are not impervious to injuries.

3.3×

FEWER ACUTE HAMSTRING INJURIES IN SOCCER PLAYERS AFTER HEAVY ECCENTRIC TRAINING

Application 2: Rehabilitation

The second application for EOL is Rehabilitation, both orthopedic and neurological [28–30]. Eccentric contractions have three main mechanisms that help with rehabilitation: low metabolic cost, cross-education, and tendon tissue adaptations.

First off, eccentric contractions have lower metabolic cost than concentric contractions [22]. This, in addition to the higher force capacity, makes it ideal for energetically impaired patients.

Secondly, eccentric contractions have shown high rates of cross-education [29, 31]. Cross-education is a neurophysiological process where training one side of the body increases strength and skill in the contralateral (opposite), untrained side. This is very useful for people with unilateral weakness, such as stroke patients. Eccentric-only training shows 1.8 times the contralateral strength increase of concentric-only training (39% vs. 22%), and up to 2.6 times more contralateral surface EMG activity [29]. In a different study, peak power increased in both the trained leg (34% concentric and 44% eccentric) and untrained leg (25% concentric and 34% eccentric) of stroke patients after EOL [31]. Scores improved significantly on the Berg Balance Scale (BBS), Timed Up-and-Go (TUG) and 30-Second Chair Stand test (30CST) following the unilateral EOL [31]. A different

study showed a paretic leg volume increase of 9.4% and power increase of 48.2%, with the untrained leg increasing 28.1% in power [32]. This study also noted an enhanced balance of 8.9% and gait performance of 10.6% after EOL. So EOL increases contralateral muscular strength and activation and is an effective rehabilitation method for strength, balance, and mobility among patients with unilateral weakness.

The third mechanism that helps with rehabilitation is tendon tissue adaptation. Tendon tissues undergo qualitative and quantitative changes with EOL [4]. A decrease in pain and regained strength were reported following a 12-week heavy load EOL program in patients with chronic Achilles tendinosis [30]. All patients in the training group were back at pre-injury levels of strength, and no significant difference between injured and uninjured side was reported [30]. Conventional rehabilitation methods, like ordinary training programs, anti-inflammatory drugs, and physiotherapy, were ineffective and eventually required surgical intervention [30]. Therefore, rehabilitation using EOL has shown good results in treating tendinosis and outperforms traditional treatments.

Application 3: Fall prevention

EOL is effective in preventing non-sports injuries, especially those that afflict the elderly, like falls [22]. For instance, fall risk for descending stairs is decreased by EOL [22]. In support of that, balance (7%) and stair descent abilities (21%) have improved significantly following a comparison study between heavy eccentric-only and traditional weight training [18]. The eccentric group also went from a high to a low fall risk after the training program [18]. EOL also resulted in significantly improved balance compared to traditional weight training, due to increased knee extensor power and ankle plantarflexor strength [24]. Finally, in rehabilitating stroke patients, unilateral EOL had a significant impact on balance and mobility [31, 32]. Therefore, EOL is an effective intervention for fall prevention, improving balance and mobility.

Overloading the eccentric phase in practice

Now that the applications and benefits of EOL are clear, the question remains how EOL is achieved in practice. Four main methods can be used to induce EOL: Manual, momentum, isokinetic, and biphasic-based solutions [6].

1.8×

CONTRALATERAL STRENGTH GAIN OF ECCENTRIC-ONLY VS. CONCENTRIC-ONLY TRAINING (39% VS. 22%)

Method 1: Manual overload

The first method is using manual solutions. Manual solutions require specialized equipment, techniques, or external help. Weight releasers, for example, allow for heavier loading on the eccentric, although only for one repetition, after which the extra weight falls off. Another person could also help achieve EOL by assisting during a supramaximally loaded concentric or providing extra resistance on the eccentric. Techniques like the 2-up-1-down method also exist, where you lift the concentric with two hands and resist the eccentric with one. Techniques like these introduce skill, however. All of the manual solutions are quite constraining and impractical in consistent, long-term training programs.

Method 2: Flywheels

The second method is using flywheels [6]. Flywheels are specialized isoinertial devices that allow for EOL to occur. During the concentric phase, the exerted force unwinds a strap, which spins the flywheel and builds up momentum. At the end of the movement, the strap rewinds, and the flywheel's momentum provides the resistance for the eccentric phase. Flywheels have three main issues, however. Firstly, the concentric and eccentric energy total out to the same amount, but more force is available during the eccentric phase. This means the range of motion is cut short, or a delayed braking strategy has to be employed to effectively achieve EOL. These strategies and techniques introduce a skill curve to flywheel usage [33]. Secondly, the eccentric resistance completely depends on the concentric effort [33]. Very high concentric effort for every repetition is required to adequately stimulate the eccentric phase. Lastly, the turn-around point from concentric to eccentric is often not clear when using a flywheel. This could lead to a sudden harsh impulse and very high overload. So even though flywheels are able to induce EOL, the skill curve, concentric dependency, and unpredictable nature make it an inconvenient solution for EOL.

Method 3: Isokinetic training

The third method is using isokinetics (IK), which is a way to circumvent some of the shortcomings of manual and flywheel methods. Free weights and flywheels pose a risk during rehabilitation because their fixed mass and momentum can dangerously overload a healing joint if the patient experiences sudden pain or weakness [34]. IK training

serves as a highly controlled, safe method for early-stage rehabilitation because the patient can instantly decrease tension in response to pain or discomfort [34–36]. IK training is a training method in which the speed of a movement pattern is fixed, and the resistance is dictated by the amount of force provided by the user.

IK training allows the user to exert the maximal force throughout the entire movement pattern and is not limited by a sticking point that bottlenecks the load of the movement pattern [34]. This also allows EOL to occur using IK training, since there is more eccentric force the user can exert to increase the resistance [7–9]. IK has significantly greater improvements than isotonic eccentric training for all muscle mass outcomes, as well as for isometric and eccentric peak torques for people after Anterior Cruciate Ligament (ACL) reconstruction [34].

IK muscle strengthening also significantly improves muscle strength, gait speed, and mobility in post-stroke adults compared to conventional physical therapy [36]. Another study reported more peak torque and better scores on the 36-Item Short Form Health Survey in the IK training group compared to the isotonic group [37], though only the peak torque result was statistically significant. Ankle joint rehabilitation using IK training also shows better results than resistance band training, with more force and balance of ankle inversion and eversion [38]. Since IK provides resistance based on the exerted force, the entire movement pattern can safely be maximally loaded. It has shown substantial improvements during early rehabilitation in muscle mass, strength, balance, and mobility.

IK training is only possible using a motorized isokinetic dynamometer. IK dynamometers are currently mostly used for measurements and early rehabilitation. There are three main considerations for conventional IK dynamometers. First off, dynamometers are often very specialized, uniarticular machines. This means that various movement patterns would require multiple types of dynamometers. One exception to this is the Reforter. Secondly, high effort is required to induce EOL, since the resistance profile is completely dictated by the user. Because the self-induced training intensity determines the load, inconsistencies can occur. Lastly, conventional IK dynamometers (excluding the Reforter) are currently mostly used for early rehabilitation and measurements, and are quite expensive [35, 36]. This makes them rare and not typically found in commercial gyms.

Method 4: Biphasic training

The final method is a biphasic solution. Biphasic loading is a form of force- or weight-based loading that changes depending on the phase of the movement pattern. No additional skill curve is introduced, because the loading is predetermined and does not require additional strategies to induce EOL. The biphasic method of inducing EOL therefore holds a significant advantage over the manual and isoinertial methods.

The Reforter

The Reforter is a motorized pulley that allows for both IK and biphasic loading. The adjustable pulley system also allows it to be more versatile than the specialized, uniarticular IK dynamometers. This allows patients and athletes to safely and effectively perform EOL and enjoy the benefits of EOL.

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