Rate of Force Development for Injury Resistance, Fall Prevention, and Sports Performance

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Abstract

Injury- and fall prevention are important for improving quality of life and reducing healthcare costs. Rate of Force Development (RFD) is a reliable predictor of injury risk and falling incidents, as well as an important metric in sports performance. Improvements to RFD, specifically early RFD, have a substantial impact on these metrics, since injuries and postural adaptations often occur before Maximal Voluntary Contraction (MVC) has been reached.

It is therefore important to measure and improve RFD. The best method to improve RFD is proven to be Ballistic Strength Training (BST). BST is a form of training in which the movement pattern is carried out as fast and with as much force as possible. Traditional devices with physical weights have three major limitations for BST. Firstly, having to decelerate the weight at the end of the movement and control the coming down of the weight in order to not damage the equipment hinders the "all-out" nature of BST. Secondly, physical weights have a variable resistance profile due to inertial forces. And lastly, diagnosing deficiencies and tracking progress requires additional equipment.

The Reforter holds unique advantages over traditional devices in these respects. The electromotor allows for effective BST and accurate measurements, which makes it not only a tool for versatile training, but also for assessment and progress tracking.

Rate of Force Development as metric

Worldwide, 1.71 billion people have been reported to suffer musculoskeletal conditions, and each year approximately 37.3 million falls occur that are severe enough to require medical attention [1]. It is therefore important to diagnose and treat deficiencies in order to prevent injuries and incidents from occurring.

The Maximal Voluntary Contraction (MVC), is widely used as a proxy for health and performance [3–5]. However, studies suggest that MVC does not paint the full picture on topics such as injury resistance [6, 7], balance or proneness to falling [8–11], and sports performance [6, 12, 13]. The speed at which force is generated, also known as the Rate of Force Development (RFD), has also been shown to be a reliable metric regarding these three topics, if not more reliable than MVC, as discussed in the next three paragraphs.

First off, in injury prevention, RFD plays an important role in joint stabilization [6]. Most non-contact injuries occur before full MVC can be reached (which takes about 300ms). Anterior Cruciate Ligament (ACL) injuries, for example, happen in the first 50ms of ground contact. A high RFD could prevent injury by building up force rapidly to stabilize the joint in those first 50ms of contact with the ground, in which injuries tend to happen.

1.71B

PEOPLE AFFECTED BY MUSCULOSKELETAL CONDITIONS WORLDWIDE

Secondly, for mobility [10], balance issues [11], and falling proneness [9], RFD has proven to be an important screening parameter. Studies have for instance found that knee extensor RFD is a better predictor than MVC in the case of falling incidents among Multiple Sclerosis patients [9]. RFD progressively decreases with age (more than MVC does), and this decrease correlates with impaired balance and slower postural adjustments [11].

Finally, regarding sports performance, elite athletes showed up to 2.3 times the RFD (in the 0-50ms range), but only 28% more peak strength than the control group in a comparative study [13].

This suggests that the big physical difference between elite athletes and regular people is their explosiveness, more than their maximum force output.

2.3×

RFD OF ELITE ATHLETES VS. CONTROL GROUP, WHILE ONLY +28% PEAK STRENGTH

The Importance of Ballistic Training

Given the importance of RFD, the question is how to train and improve it. Even though RFD increases with multiple types of resistance training [8, 14–16], there are better ways to train for RFD specifically. RFD is mainly influenced by three factors: neural drive (the number of motor units and the speed at which they are recruited), MVC, and the fiber composition of the muscle [8, 17]. So the question is how these three factors can be improved.

Firstly, neural drive strongly correlates with early-stage RFD (up to 50-100ms). Neural drive, and thus early-stage RFD, is most effectively trained using Ballistic Strength Training (BST) [12, 15, 18–21]. BST is a type of strength training where movement patterns are performed as fast and with as much force as possible. Most progress in RFD is achieved within the first five weeks [8], with some other studies even reporting increases up to 54% in RFD and 56.2% in normalized RFD (rRFD) within a matter of weeks [12, 20]. People with lower rRFD have an increased response to training and quickly overcome their deficiency [8]. This means that BST has enormous potential to show rapid results for neural drive, and thus early-stage RFD, which greatly impacts balance issues and injury rehab.

56.2%

PEAK REPORTED RRFD GAIN WITHIN WEEKS OF BALLISTIC TRAINING

Secondly, MVC is associated with late-stage RFD (from 150-250ms onwards) [17]. To improve MVC, Maximal Strength Training (MST) is more effective than conventional strength training [22]. MST is a form of BST in which high loads (85-95% of MVC) are lifted with maximal velocity for a low number of repetitions (3-5) [23]. MST performs 40% better in one-rep-maximum (1RM) strength tests and twice as good in RFD as conventional training (70% of MVC with 8-12 repetitions) [22]. Increases were reported of 50% in 1RM and 155% in RFD for MST, while conventional training only yielded 35% in 1RM and 83% in RFD. So MST is an effective strength training method to increase MVC and thus late-stage RFD.

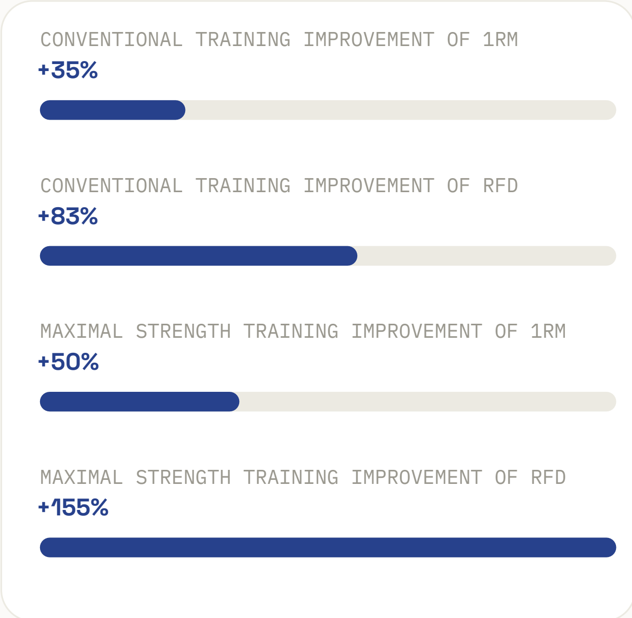

Figure 1: Maximal Strength Training (MST) is better in improving both 1RM and RFD

Lastly, the contraction speed of a muscle depends on the fiber composition (the ratio between fast and slow muscle fibers) [24]. Studies found that MST increased the percentage of type II muscle fibers (fast-twitch muscle fibers), and that MST promotes a more glycolytic muscle phenotype [25]. High-load, chronic eccentric training also produces more IIx fibers (fast glycolytic muscle fibers) instead of IIa (fast oxidative-glycolytic muscle fibers), which would make the muscle a faster, more explosive phenotype [26], but more research should be conducted to further explore the correlation. In general, high-load training such as MST promotes a faster muscle phenotype by changing the fiber composition of the muscle.

In summary, BST, which is fast, explosive resistance training, is very effective in stimulating early-phase RFD, which is important for robustness against injury and preventing falling incidents. Secondly, MST, which is BST that focuses on very heavy loads, increases MVC and RFD significantly more than conventional strength training. Lastly, MST also changes the fiber composition of muscles to promote a faster, more glycolytic phenotype by increasing the percentage of type II muscle fibers. Heavy eccentric training is suggested to also change the muscle to a faster phenotype, but more research is necessary.

Improving RFD in Practice

The nature of BST (as fast and with as much force as possible) makes it beneficial to train with motor-driven devices, rather than weight-based devices, because of three main reasons.

Firstly, in devices with physical weights, the weight has to be decelerated before the end of movement to prevent the weights from slamming into the end of the range of motion of the device and potentially causing damage. This required deceleration inherently hinders the 'all-out' nature of BST and does not allow people to train effectively. Also, the negative impulse of the weight coming down has to be controlled, which could be unexpected, uncomfortable, or injurious given the momentum of the weight.

Secondly, performing BST with physical weights provides a variable resistance profile due to the inertial forces, which makes it so that the majority of the stimulus is provided only in the starting portion of the lift.

The last reason why motor-driven devices are beneficial is that measuring the progression made to RFD is quite difficult to reliably track, if not impossible. In fact, additional measuring equipment would typically be necessary.

Therefore, to effectively perform BST, a device would have no physical weights to avoid the deceleration concern and variable resistance profile. Ideally, the device would also be able to measure relevant metrics such as RFD and MVC, without the need for separate equipment.

The Reforter is very well suited for this application because of its electromotor. The electromotor eliminates the need to decelerate and control the negative portions of the movements, as well as the variable resistance profile. Moreover, the Reforter accurately measures both RFD and MVC, making it possible to safely diagnose physical deficiencies and track progress.

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