



## Comment on: “Stepwise Load Reduction Training: A New Training Concept for Skeletal Muscle and Energy Systems”

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Dear Editor,

Ozaki et al. [1] recently introduced ‘stepwise load reduction training’ (SLRT). In SLRT, an individual starts an exercise set with a heavy load, performs as many repetitions as possible at that load, then proceeds to do additional sets with lighter loads in a stepwise manner [1]. According to the authors, SLRT differs from traditional drop set training, because in traditional training, the initial load is not necessarily maximal or near maximal [1]. The authors argued that SLRT is a time-efficient training method that might result in “a broad range of adaptations” (i.e., concomitant increases in muscle strength, muscle endurance, maximal anaerobic power, anaerobic capacity, and  $VO_{2max}$ ) [1]. They acknowledge research is needed to test their hypothesis [1]. We think that SLRT is interesting, but it could be accomplished more effectively and efficiently with a connected adaptive resistance exercise (CARE) device. The aim of the current letter is to argue that, to the extent SLRT might be an effective training method, CARE devices work well for the SLRT concept.

Traditional resistance training equipment, such as free weights (e.g., dumbbells, barbells), weight stack machines, and elastic bands, can provide adequate stimuli for increasing muscle strength [2–7]. However, such equipment has limitations. First, the load cannot be altered after the set has commenced (i.e., no load alterations between repetitions).

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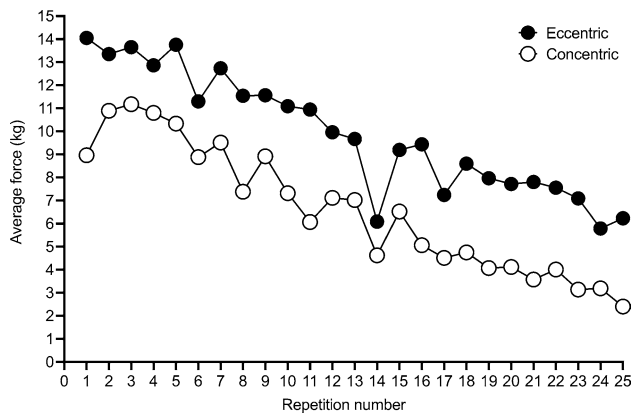
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When an individual fails to lift a load due to fatigue, they must stop and select a lighter load to complete more repetitions. Practical inconveniences exist for removing weight plates or selecting lighter dumbbells to achieve the stepwise load reductions associated with SLRT during an exercise session. Second, with traditional resistance training equipment, the same load is used for both the concentric and eccentric phases. However, eccentric strength is significantly greater than concentric strength [8–14]. Moreover, concentric fatigue occurs quicker than eccentric fatigue [8, 9, 12]. Thus, traditional equipment might not optimize the intensity for eccentric contractions. Eccentric exercise at a given load is also perceived as less effortful and demands less oxygen [15, 16]. Thus, eccentric exercise might be more appropriate for patients with heart and/or respiratory diseases or older adults with less tolerance to exercise [17, 18].

CARE devices are new resistance training equipment that have the potential to overcome limitations of existing equipment. CARE devices, which might also be called ‘connected strength trainers’, ‘smart trainers’, or ‘digital weights’, consist of a load-generating mechanism controlled by firmware that monitors user kinetics and kinematics and adjusts (‘adaptive’) the load-generating mechanism accordingly via wireless technologies (‘connected’).

CARE devices are well suited for SLRT (Figs. 1, 2, 3). CARE devices can adapt resistances within and between repetitions. Before the set begins, users can select a resistance that permits maximal or near maximal eccentric contractions, with the understanding the CARE device will reduce the resistance in the concentric phase to match the force-generating capacity of the muscle. Moreover, CARE devices can reduce resistances within a set as a user loses force-generating capacity due to fatigue. Thus, a user can perform a high number of repetitions without having to stop to reduce loads.

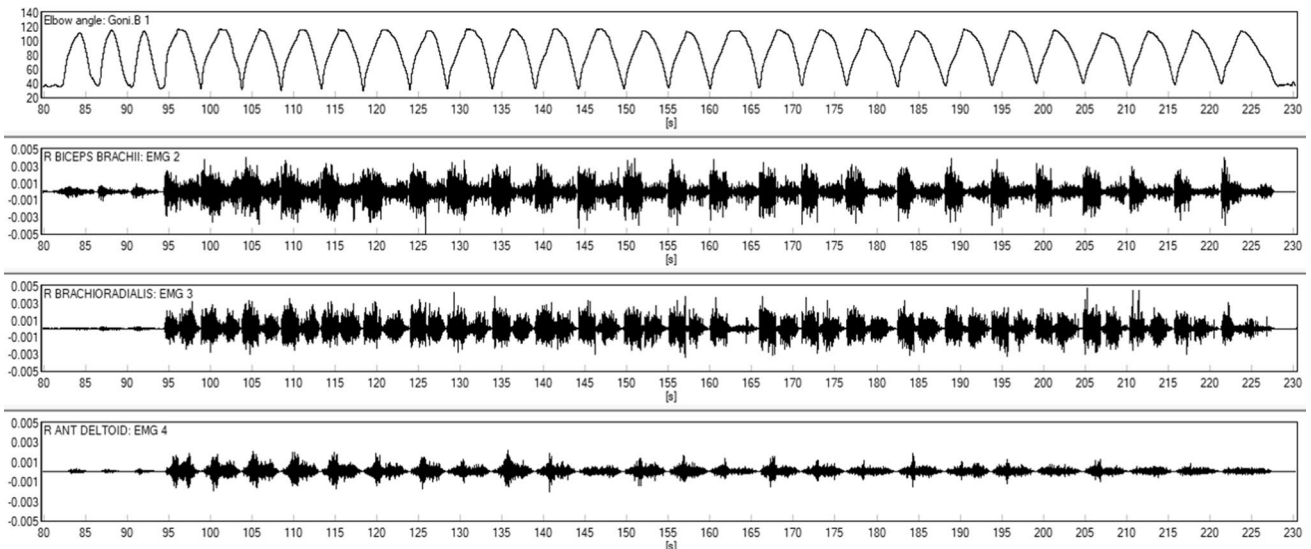
In Figs. 1, 2, we present data from use of a CARE device (V-Form Trainer, Vitruvian, Perth, Australia) to achieve 25 consecutive maximal concentric and eccentric contractions



**Fig. 1** Average force in concentric and eccentric phases during one set of 25 maximal concentric–eccentric contractions ( $CON_{max}$ – $ECC_{max}$ ) of unilateral elbow flexion exercise (i.e., biceps curl) on a connected adaptive resistance exercise (CARE) device (V-Form Trainer, Vitruvian, Perth, Australia). From repetition 2 to 25, average concentric and eccentric phase forces decreased by 77.9% (10.9 to 2.4 kg) and 55.3% (13.3 to 6.2 kg), respectively. Forces in the figure reflect the magnitude of resistance placed on the user by the device. The device reduced the resistance to match the user’s level of muscle fatigue. Reduced resistance in repetition 14 was due to the user’s temporary lapse in creating maximal force against the device, which caused the device to reduce the resistance. Once the user corrected his technique and re-established a maximal effort, the device adapted and delivered greater resistances

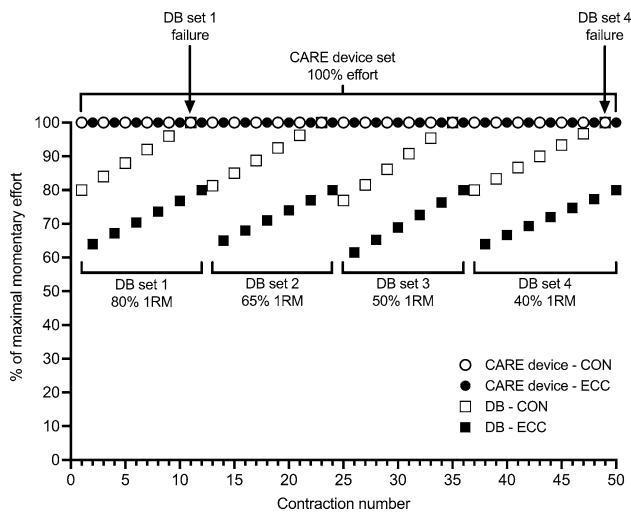
( $CON_{max}$ – $ECC_{max}$ ) for unilateral biceps curls. Prior to the set, the user, via the device’s mobile phone application, indicated he wanted to perform 25 repetitions with a resistance equal to his eccentric maximal strength on the device. In the set, the user never experienced this resistance in the concentric phase because the device adapted the resistance to the user’s force-generating capacity during the concentric phase. From repetition 2 to 25, average concentric and eccentric phase forces decreased by 77.9% and 55.3%, respectively. As the user fatigued, the CARE device reduced the resistance so the user could continue to exercise at 100% of maximal momentary effort. Reduced neural drive in later repetitions was observed for biceps brachii and anterior deltoid (Fig. 2)—a finding consistent with previous work on fatigue from repeated maximal contractions [8, 12]. The 25 repetitions were completed in 147 s without rest. This is longer than the ~120 s needed to complete the protocol described by Ozaki et al. [19], which involved ~35 repetitions over five dumbbell sets in SLRT. However, the five dumbbell loads were prepared in advance by test administrators and do not reflect time required to complete the protocol outside of a laboratory.

A key difference between SLRT with free weights and the CARE device used in this example is the CARE device permitted maximal effort at every moment (Fig. 3). With free weight-based SLRT, the individual works submaximally



**Fig. 2** Raw traces of elbow joint angle ( $^{\circ}$ ), biceps brachii electromyographic activity (EMG), brachioradialis EMG, and anterior deltoid EMG during one set of 25 maximal concentric–eccentric contractions ( $CON_{max}$ – $ECC_{max}$ ) of unilateral elbow flexion exercise (i.e., biceps curl) on a connected adaptive resistance exercise (CARE) device (V-Form Trainer, Vitruvian, Perth, Australia). Elbow joint angle was acquired from an electrogoniometer (Biometrics, Ladysmith, USA) taped to the medial aspects of the right arm and forearm. EMG was acquired using Delsys surface electrodes (Trigno wireless

system, Delsys, Natick, USA) over the muscles of interest. Exercise began with three range-of-motion calibration repetitions that involved minimal external resistance, followed by 25  $CON_{max}$ – $ECC_{max}$  contractions. Peaks and troughs of the elbow joint angle trace represent the ends of concentric and eccentric phases of the movement, respectively. Large bursts of EMG were observed in the concentric phase followed by lower EMG during the eccentric phase. For biceps brachii and anterior deltoid, decreased amplitude of the EMG can be seen in the last 10 repetitions compared with the first 10 repetitions



**Fig. 3** Depiction of theoretical differences in effort required to complete a set of stepwise load reduction training (SLRT) with a connected adaptive resistance exercise (CARE) device versus a dumbbell (DB). With a CARE device, an individual can complete SLRT such that both the concentric and eccentric phases of each repetition are performed at momentary-maximum effort. With a DB, this is not possible. The DB protocol depicted is based roughly on the study by Ozaki et al. [19], where individuals completed a drop set protocol consisting of 5 sets, with loads based on the one repetition maximum (1RM). With DB SLRT, the individual must complete numerous repetitions at submaximal efforts before reaching momentary-maximum effort (i.e., the repetition in which failure occurs in the concentric phase). Also, with DB SLRT, maximal effort in the *eccentric* phase is never achieved because loads are based on the concentric 1RM and because fatigue occurs quicker in the concentric than eccentric phase [8, 9, 12]. Other assumptions built into the model for the DB SLRT are that eccentric phase effort is 20% less than concentric phase effort for each repetition and that changes in concentric and eccentric effort occur linearly. These assumptions should be considered with caution and require future examination

at a given load until the repetition that causes failure. Conversely, the CARE device in this example gives the user the opportunity to perform SLRT with resistances that are maximal or near maximal at every moment based on joint angle, lift phase, and fatigue. Submaximal resistances can also be used with CARE devices.

In sum, CARE devices utilize adaptable resistances. They have the potential to overcome limitations of traditional resistance training equipment. They can provide different resistances within a given repetition based on joint angle and movement phase (concentric, eccentric) and between repetitions as fatigue occurs. CARE devices also make it possible to perform a repetition composed of multiple exercises because the resistance adapts to user force-generating capacity at each moment. For example, a user could perform a deadlift-to-curl-to-overhead press using maximal or near maximal resistances for each part of the exercise. Such an exercise would be appropriate for time-efficient, minimal effective dose workouts [20]. Also, CARE devices

are ‘connected’ and record exercise data. Thus, they can be used in telehealth interventions, particularly as the COVID-19 pandemic has caused individuals to shift to home-based resistance exercise, but with less external loading than would be used at gyms [21]. Nevertheless, the impact of resistance training with CARE devices on health and function requires more investigation, including whether SLRT with CARE devices causes different neuromuscular adaptations than SLRT with free weights.

## Declarations

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**Conflict of interest** James L. Nuzzo is Head of Exercise Science Research at Vitruvian, a company that manufactures and sells connected adaptive resistance exercise devices. Kazunori Nosaka has no conflicts of interest with the content of this letter.

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