

## Guest Editorial

# The Positives of Negatives: Clinical Implications of Eccentric Resistance Exercise in Old Adults

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OCCASIONALLY, it takes time for a great scientific discovery to penetrate clinical practice. Bernhard Katz and Archibald Vivian Hill reported over 60 years ago that force steeply rises when skeletal muscle is lengthened at increasing velocities (eccentric contractions), whereas force sharply declines when skeletal muscle is shortened at increasing velocities (concentric contractions) (1,2), resulting in up to 5-fold greater force production in eccentric compared with concentric contractions. Mechanical loading is a critical stimulus for increasing the strength and the size of skeletal muscle. For years, clinicians and researchers have accepted the obvious hypothesis that the higher mechanical loading afforded by a training program consisting of maximal voluntary eccentric compared with concentric contractions should produce greater hypertrophy and strength gains in frail adults' skeletal muscle. The interest for developing a novel exercise modality was further heightened by another set of classic observations that the metabolic, neural, and cardiovascular demands are lower during eccentric compared with concentric contractions at the same absolute load and velocity (3,4). Thanks to the evolution of isokinetic dynamometers, only very recently has it become also evident that, somewhat surprisingly, age affects less the capacity of skeletal muscle to produce eccentric compared with concentric force (5,6). One interpretation of this observation was that aged skeletal muscle is well suited for eccentric training. Nevertheless, researchers first had to overcome many unexpected difficulties before the recent burst of studies, including the one by LaStayo and colleagues (7) in the current issue, had made it evident that the "high-load-low-cost" approach to exercise can be clinically exploited to combat the epidemic levels of sarcopenia in our aging society (8–14).

Muscle contracts eccentrically when the external load exceeds the torque the muscle generates. However, clinically and logistically, it is no easy feat to have individuals exercise with voluntary eccentric contractions. One popular, inexpensive, but scientifically unproved, form of eccentric exercise is to perform the eccentric phase of a movement slower than the concentric phase. Presumably, the longer exposure of muscle to eccentric contraction accelerates strength gains and muscle growth. Other approaches are far more involved and require an overloading of the muscle by manually (15) or mechanically (16) adding extra weight in the eccentric phase then removing the extra weight in the

concentric phase of the movement. To accurately control and quantify the load, one needs to attach the limb to the lever arm of a motor and, as the external torque produced by the motor overcomes the subject's resistance, the involved muscles lengthen or eccentrically contract.

LaStayo and colleagues (7) have overcome these logistical difficulties of administering eccentric training by having 80-year-old males and females bicycle backward on a custom-built ergometer. Under these conditions, the subject resists the reverse rotation of the pedals, imposing an eccentric contraction on most of the lower extremity muscles. The authors' selection of this type of motor activity for strength training is notable for several reasons. Backward bicycling is not the standard way of strength training as (forward) bicycling historically has been used for cardiovascular training. However, by resisting the backward rotating pedals, the patients, who were participants of a cardiopulmonary rehabilitation program, dramatically increased the isometric strength of the quadriceps muscle and also their capacity to do (negative) work. These isometric strength gains significantly exceeded the gains produced by the control patients assigned to conventional resistance exercise training. The choice of exercise is also notable because the movement pattern resembles the cyclic pattern of human gait. Indeed, LaStayo's data suggest that significant improvements occurred in activities of daily living and balance as a result of the training. Thirdly, the selection of bicycling as an exercise modality is important because not only does such exercise apparently increase muscle strength but, as the authors will report their data in a separate paper, it also produces meaningful cardiovascular adaptations, documented for the first time in patients undergoing cardiopulmonary rehabilitation. These observations represent a logical extension of prior data, demonstrating that greater increases in muscle strength can occur at lower cardiovascular demands using eccentric compared with concentric contractions or when old adults exercise with an eccentric overload compared with conventional resistance training (11,15).

There has been some uncertainty about the suitability of eccentric exercise training for old adults. High intensity eccentric contractions have been anecdotally linked to injuries and accidents. Eccentric exercise in extreme forms causes muscle damage in human as well as animal models of muscle damage (17–19). In these models, eccentric exercise also caused transient muscle soreness, joint stiffness, and

a reduction in joint range of motion. However, the study by LaStayo and colleagues in this issue (7) and previous studies suggest that eccentric training is safe for old adults. As in previous studies (16,20), LaStayo and coauthors also used submaximal exercise intensity, far lower than the intensity used in the studies that were designed to intentionally induce muscle damage. Indeed, the present study by LaStayo and colleagues (7) also confirms that old human muscle responds to eccentric loading with low levels of soreness and little, if any, myofibrillar disruption, especially in the quadriceps muscle (15,21). In a larger conceptual framework, this latter set of data seems to agree with the hypothesis that myofibrillar disruption is not a precursor or a necessity for muscle hypertrophy (22).

Even though the results of the study by LaStayo and colleagues should encourage geriatric practices and geriatric fitness program directors to consider adding eccentric training as an exercise modality to their programs, we all must continue to seek solutions to many unresolved practical and conceptual issues. Equipment for eccentric training is not yet widely distributed, and it may have to be individually engineered. Thus, the cost and availability of equipment seriously hinders a broad-based access to eccentric training. Large clinical trials are necessary to determine the efficacy of eccentric training in improving muscle strength, muscle size, and function in activities of daily living. The dose-response relationship for muscle strength, hypertrophy, and blood pressure, and the differences in the responses between men and women to eccentric training, are unknown. There is a paucity of data on how such contractions affect the involved joints, tendons, and ligaments. Also, at the cellular level, it is unknown if there is correlation between the unique strategy to recruit motor units (23) and gene expression and protein levels of the muscle fibers in these motor units during eccentric contractions (24). As always, the answers to these latter, fundamental questions will allow us to dissolve any lingering uncertainty associated with eccentric exercise. The present work by LaStayo and colleagues raises hope that it will not take another 60 years to address these issues.

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