Dynamic muscular contractions can be characterized by two primary actions, concentric and eccentric contractions. A concentric contraction results in muscle shortening and occurs when the torque produced during a contraction exceeds the force applied to the muscle. Alternatively, an eccentric contraction occurs when the muscle is forcibly lengthened or elongated. Put another way, an eccentric contraction results when the force produced inside the muscle is less than what is applied to the muscle externally and results in active lengthening of the muscle fibers under some level of load (3). Eccentric training is mainly incorporated in an indirect manner by strength and conditioning professionals, and as a result, it is often underused and undervalued. Many discuss the aspect of eccentrics for its application to strength training and conditioning, and while the field of strength and conditioning certainly benefits from eccentric training, its application extends heavily into the clinical field as well. The purpose of this article is to address both the implications and clinical applications of eccentric training, how eccentric training affects the outcomes within various clinical populations, general exercise guidelines, and future directions within eccentric training and clinical populations.

**CLINICAL BENEFITS OF ECCENTRIC TRAINING**

Incorporating eccentric training and proper programming into a resistance training program can facilitate numerous benefits that extend well beyond increases in strength and hypertrophy. This includes populations ranging from athletes desiring peak performance to clinical patients involved in physical rehabilitation as well as various other clinical populations. Eccentric exercise is generally considered a highly effective mode of conditioning for strength and hypertrophy, but also extends these benefits to various clinical populations.

For example, research from LaStayo and colleagues documented that eccentric exercise has successfully been explored for cancer survivors, adults with metabolic disorders such as type 2 diabetes, and in neurological conditions such as Parkinson’s disease and cerebral palsy in children (8). It has also been used in rehabilitation after knee surgery, in particular, replacement surgery for an injured anterior cruciate ligament (ACL) as well as knee arthroplasty (8). In addition, the energy cost of eccentric exercise is relatively low, despite the high muscle force being generated (8). The authors contend that the major defining properties of eccentric muscle contractions, the high force generating capacity of the muscle, and the low energy cost makes eccentrics an appealing strategy and represents a unique training environment and effective countermeasure for muscle wasting in many clinical populations where muscle atrophy is of concern (8). Further, the aging process results in a progressive and continual reduction in muscle strength. Research indicates that due to sarcopenia and other age-related muscle loss, muscle mass and strength decrease approximately 10% per decade after the age of 50 (5,14,16,18). For this reason alone, incorporation of eccentric training can be considered in an elderly population for its known ability to improve muscle strength and power while also reducing the risk for falls and potential bone fractures (9,10).

In addition, those within the clinical populations can benefit from incorporating eccentric training, particularly if the patient
CLINICAL APPLICATION OF ECCENTRIC TRAINING

LaStayo et al. found greater strength increases following eccentric training that resulted in improved balance, stair climbing, and straight-knee calf raises twice a day, seven days per week over a 12-week period. Subjects were told to work through pain, only ceasing exercise if pain became disabling. The load was increased in 5-kg increments with the use of a backpack that carried the weight once bodyweight was pain free. Researchers found that all 15 patients returned to pre-injury levels of activity (2). Additionally, the subjects had a significant decrease in pain with a significant increase in strength (2).

Similar results by Shalabi et al. found that eccentric training resulted in decreased tendon volume and decreased intratendinous signal, which correlated to improved clinical outcomes (17). Langberg et al. found similar results in a population of soccer players (7). Due to the incidence of injury and emphasis on recovery, it is advised that the load should not be determined by a one-repetition maximum (1RM). For a training application, in general, load and volume should be progressed gradually and should be dictated by the amount of pain the client or athlete experiences.

ECCENTRIC EXERCISE AND CLINICAL OUTCOMES

Strength and conditioning professionals often have to develop resistance training programs to accommodate clients and athletes who may possess certain clinical conditions that need attention through eccentric exercise. Eccentric loads can be appropriately dosed and increased over time, meaning that eccentric exercise training can be used safely and effectively in rehabilitation of serious medical conditions and clinical applications. Therefore, this section will highlight a variety of clinical and rehabilitation circumstances in which eccentric training has had a beneficial effect or has been used as an effective treatment strategy.

TENDIOPATHIES

Multiple studies have shown that eccentric exercise can be very promising as a potential non-operative training modality for tendinopathies. Although “tendonitis” is often used as a general term for tendon injuries, early work by Leadbetter previously defined tendonitis as a symptomatic degeneration of a tendon with vascular disruption and inflammatory repair (11). However, more recently, the term “tendinopathy” has been used as an all-encompassing term for tendon injuries. Over the past decade, eccentric training has been effectively used as a treatment for tendinopathies. An earlier study by Alfredson investigated eccentric exercise on diseased tendons, and the protocol used in that study has been used in many studies on eccentric training (2).

In his original report, 15 athletes with chronic Achilles tendinosis performed three sets of 15 repetitions of eccentric-only bent-knee and straight-knee calf raises twice a day, seven days per week over a 12-week period. Subjects were told to work through pain, only ceasing exercise if pain became disabling. The load was increased in 5-kg increments with the use of a backpack that carried the weight once bodyweight was pain free. Researchers found that all 15 patients returned to pre-injury levels of activity (2). Additionally, the subjects had a significant decrease in pain with a significant increase in strength (2).

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ECCENTRIC EXERCISE GUIDELINES

While the clinical benefits of eccentric training extend beyond what has been discussed in the previous sections, it is important for the strength and conditioning professional to apply eccentric training guidelines to potential clients that experience any number of the clinical conditions outlined, as long as it is within the professional’s scope of practice. Suggested progressions and guidelines are provided depending on the training background and abilities of clients. LaStayo and colleagues suggest the following (8):

- An eccentric exposure-adaptation phase must be employed initially to avoid unnecessary muscle damage; therefore, this phase can help to prepare the muscle to experience the higher forces that often accompany the progressive eccentric negative work phase (Table 1).
- In general, the expectation is that the loading goal during the progressive eccentric work phase should exceed an isometric maximum load, and the eccentric exercise duration should be performed for up to 20 – 30 min per session, 2 – 3 times per week for 6 – 12 weeks. Repetition and set ranges will need to be determined according to each individual’s ability and goals.
- During the progression and incorporation of eccentric work, the goal should be to progressively resist higher loads for prolonged periods. Specifically, the exercise load being resisted should surpass the participant’s isometric strength in eccentric training groups in the elderly population seem to be linked to an increase in fiber cross-sectional area (9).

The use of heavier eccentric loading is an appealing strategy to help combat the age-related muscle and type II fiber loss that is often accompanied by old age. However, the value of eccentric exercise has often been questioned considering those individuals unaccustomed to this type of exercise can likely experience muscle soreness and muscle damage. This is of particular concern in the elderly or in patients with neuromuscular disease; although, many believe the response to damage may be overstated. Nonetheless, recently, Lovering and Brooks concluded that exercise (including eccentric components) is generally recommended in elderly populations; however, there are currently no common recommendations for all individuals, and guidelines for eccentric exercise are still lacking (12).

OSTEOPENIA

It has been suggested that eccentric training, due to its high force production, also yields increases in bone adaptation (1,6,15). Hawkins et al. found that following 18 weeks of maximal effort eccentric exercise on one leg and concentric exercise on the other leg (using a leg dynamometer), 12 women between the ages of 20 – 23 significantly increased mid-femur bone mineral density by 3.9% in the eccentrically trained leg, while a non-significant increase of 1.1% was noted in the concentrically trained leg (6). This finding suggests that eccentric training elicits a greater osteogenic stimulus than concentric resistance training. While these results show a positive response on bone from eccentric training, additional investigation into the osteogenic effects and potential outcomes of eccentric training is needed.

ECCENTRIC TRAINING GUIDELINES

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maximum load (i.e., the load should exceed that which can be moved concentrically).

- Eccentric exercise can be implemented with traditional resistance exercise equipment or with the use of bodyweight alone. In addition, functional weight-bearing activities, such as moving from standing to sitting, can be used as an eccentric activity.

CONCLUSION
A number of eccentric training strategies exist that can allow for a wide variety of applications across nearly all populations, particularly in the case of clinical patients. From a clinical perspective, in terms of eccentric exercise and its acute and chronic effects on healthy and diseased tendons, evidence does suggest eccentrics as a first line of treatment for some conditions. The strength and conditioning professional should assess each client individually in order to potentially incorporate eccentric training into a client's training program.

REFERENCES
ABOUT THE AUTHOR
Jonathan Mike completed his PhD in Exercise Physiology from the University of New Mexico in Albuquerque, NM. He received his Bachelor's and Master's degrees in Exercise Science from Western Kentucky University in Bowling Green, KY while also serving as a Strength and Conditioning Assistant. He also worked at the University of Louisville as a Strength and Conditioning Assistant and has been a frequent contributor and guest host of several websites and radio shows. He is a member of the National Strength and Conditioning Association (NSCA) Exam Development Committee for the NSCA-Certified Personal Trainer® (NSCA-CPT®), Job Analysis Committee, and a member of the Personal Trainers Special Interest Group (SIG). Mike has authored or coauthored various works related to sports nutrition and strength and conditioning. Further, he has been published in the Strength and Conditioning Journal and has both authored and coauthored multiple book chapters in areas of sports nutrition and strength training and conditioning. His research interests include strength and power development, functional movement, exercise and energy metabolism, and areas of sports nutrition. In addition, he writes for numerous fitness and bodybuilding consumer magazines and outlets.

TABLE 1. SAMPLE PROGRESSION OF TOTAL VOLUME OF ECCENTRIC WORK ON ECCENTRIC ERGOMETER OVER 12 WEEKS (8)

<table>
<thead>
<tr>
<th></th>
<th>EXPOSURE-ADAPTATION PHASE (WEEKS 1 – 2)</th>
<th>PROGRESSIVE ECCENTRIC WORK PHASE (WEEKS 3 – 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2 – 3 times per week</td>
<td>2 – 3 times per week</td>
</tr>
<tr>
<td>Duration</td>
<td>5 – 8 min per session</td>
<td>10 – 12 min per session (weeks 3 – 4)</td>
</tr>
<tr>
<td>*Duration may be substituted with sets and repetitions of different eccentric movements</td>
<td></td>
<td>14 – 16 min per session (weeks 5 – 6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 – 20 min per session (weeks 7 – 12)</td>
</tr>
<tr>
<td>Intensity</td>
<td>Very light</td>
<td>Fairly light (weeks 3 – 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderately hard (weeks 6 – 12)</td>
</tr>
</tbody>
</table>