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ABSTRACT
The ability to decelerate is a key component of any successful rehabilitation program, yet it is often overlooked in favor of more traditional forms of rehabilitation and training. Deceleration, which is defined as the ability to reduce speed or momentum and stop or change direction, can be a key component of successful rehabilitation. The deceleration index is a new metric being used by some physical therapists and rehabilitation specialists to improve patient outcomes. The index is based on the principle that deceleration forces should match those created with acceleration. When patients can quickly and efficiently decelerate during physical activity, they are less likely to experience pain or injury. While the deceleration index is still in its early stages of development, there is promising evidence that it could be the missing link in effective rehabilitation. In this editorial commentary, we’ll explore what the deceleration index is and why it is important to the rehabilitation process.

Key Words: Rehabilitation, momentum, deceleration, deceleration index, acceleration.

Rehabilitation providers know that the ability to change direction quickly is essential for the success of any athlete. Performance relies heavily on athletes' ability to react quickly in sports-specific situations, especially with regards to agility, coordination, and change of direction (COD). Higher intensity accelerations and decelerations are fundamental components of COD movements and are integral to successful performance of COD. To date, change of direction speed (COD-S) tests are commonly used to identify an athlete's performance capability and potential risk of injury. To fully assess an athlete's ability to quickly change direction, a measurable evaluation tool should be used. Unfortunately, change of direction has been measured as a time-to-completion to perform the task. When using the total time for a change of direction test, one assumes that the COD is simply one measure of the athlete's ability. While this measure can grossly compare left and right COD ability and asymmetry, it gives very little insight into the component parts of COD. COD incorporates key qualities associated with athletic performance such as acceleration, deceleration, and directional changes. In addition to these key qualities, the demands of deceleration are increased in athletes that have a greater body mass. This is related to the fact that these athletes achieve a higher level of momentum (mass x velocity) before initiating a deceleration maneuver.

Nimphius et al proposed that the change of direction deficit (COD-D) may better distinguish an athlete's COD ability compared to a simple time-to-completion in a COD-S test. Specifically, the COD-D is calculated as the difference between COD-S test time and the time taken to cover the same total distance in a linear sprint. Some investigations have reported that athletes with faster sprint times displayed a larger COD-D, while others have found the contrary. It is possible that sprint momentum, which is a function of velocity and body mass, may be more closely linked to COD-D because momentum better represents the mechanical
demands associated with the COD than velocity alone.\textsuperscript{11}

While most research and training have been directed at increasing an athlete’s power or ability to accelerate, the ability to decelerate may be more important and the missing link in rehabilitation. Deceleration refers to the ability to slow down quickly and efficiently from one activity or movement to another, thereby allowing the individual to adjust their momentum and reduce the risk of injury. The ability to decelerate is a key component of any successful rehabilitation program, yet it is often overlooked in favor of more traditional forms of increasing power and speed. In this paper, we will examine the role deceleration plays in rehabilitation and how the change of direction deficit can impact patient outcomes.

**What is Deceleration and Why is it Important for Rehabilitation**

Deceleration can be defined as the ability to reduce speed or momentum with respect to time. Harper\textsuperscript{12} has defined deceleration as a player’s ability to proficiently reduce whole body momentum, within constraints, and in accordance with the specific objectives of the task (i.e., braking force control), while skillfully attenuating and distributing the forces associated with braking (i.e., braking force attenuation). Deceleration is vital in change of direction, and a deficit in this category can have a major impact on the patient’s performance. Therefore, deceleration is a fundamental skill that must be developed in order for an athlete’s to successfully complete their rehabilitation program. In addition to having an impact on the athlete’s performance, a decrease in the ability to quickly decelerate or quickly reduce momentum could lead to injury.\textsuperscript{11} Poor deceleration capability has been identified as a potential mechanism associated with non-contact ACL injury due to the high forces generated during the deceleration.\textsuperscript{13,14} Additionally, due to the high eccentric braking demands associated with deceleration, this may have the potential to induce muscle damage.\textsuperscript{14} High deceleration forces may be linked to eccentric induced muscle damage. Researchers have reported elevated levels of indirect muscle damage biomarkers such as creatine kinase (CK) during the 72 hour period following repeated sprints with intense decelerations.\textsuperscript{16,17}

Similar findings have been reported between the number of high-intensity deceleration actions and CK levels post-competitive match play in team sports, such as soccer.\textsuperscript{18,19} In these instances, the eccentric braking force requirements of deceleration can impart damage on soft-tissue structures through high muscular tensions that can disrupt the structural integrity of the muscle fibers and result in myofibrillar degeneration, which may leak CK into the blood plasma.\textsuperscript{15,20} If the muscular system has a decreased capacity to attenuate high eccentric loading forces, it may lead to loading beyond the tissues structural capability, causing muscle strain or tearing.

**Introducing the Deceleration Index - What is it and why is it important for athletes.**

Measuring an athlete’s ability to decelerate and accelerate quickly is essential for assessing their performance. Using motion capture devices, force plates, and wearable technology, a clinician can observe changes in speed throughout the movement. The deceleration index is a measure of the rate at which an object slows down relative to its ability to accelerate. This measure has typically been used to describe the braking performance of a vehicle. In the automotive industry, the deceleration index is usually expressed in terms of gravitational-force, where 1 g is the acceleration due to gravity. For example, if a car has a deceleration index of 0.5 g, it means that it can slow down at a rate of 0.5 times the acceleration due to gravity. The higher the deceleration index, the faster the vehicle can stop. The deceleration index can be used to compare the braking performance of different vehicles and to determine whether a vehicle’s brakes are operating properly.

In both performance and rehabilitation, it is important to focus on both acceleration and deceleration to ensure that the body is able to move efficiently and safely. Acceleration time is the time it takes for the same athlete to reach their maximum speed from a standing start or a slower pace. In this case, both acceleration and deceleration are determined using speed difference and time. The basic formula for calculating acceleration is the change in velocity (\(\Delta v\)) over the change in
time ($\Delta t$), represented by the equation $a = \frac{\Delta v}{\Delta t}$. This allows you to measure how fast velocity changes in meters per second squared (m/s²). Deceleration can be described as the opposite of acceleration and is the time it takes for an athlete to come to a complete stop after sprinting or performing another high-speed activity. Deceleration can be calculated by dividing the final velocity minus the initial velocity, by the amount of time taken for this drop in velocity. Much like acceleration, deceleration plays a key role in an athlete's change of direction speed. Athletes can increase their COD-S by improving deceleration techniques and learning how to properly use deceleration throughout their movement. Ideally, an individual should be able to create a deceleration force equal to or better than the acceleration force.

By dividing the deceleration time by the acceleration time, the deceleration index provides a measure of how quickly athletes can slow down relative to how quickly they can speed up. The deceleration index refers to the ratio of deceleration (or braking) force to acceleration force in the body's movement patterns. This measurement is important in rehabilitation because it can indicate how well an individual is able to control their movements and prevent injury. A high deceleration index suggests that an individual is able to effectively control their movements and reduce the risk of injury, while a low deceleration index suggests a lack of control and a potential for increased risk of injury. Therefore, tracking the Deceleration Index can help athletes maximize their performance and safety in competition.

The Deceleration Index (DI) offers a straightforward measure of how an athlete's deceleration compares to their acceleration. The deceleration index can be useful in a number of contexts. For example, in team sports, such as basketball or soccer, the ability to quickly decelerate and change direction is often critical for success. A high deceleration index indicates that an athlete is able to slow down quickly and efficiently, which may give them an advantage on the court or field. To improve an athletes' change of direction speed or deficit, employing the DI as a measurable metric ensures that their COD-S development is monitored through both acceleration and deceleration phases. This can lead to increased performance, improved safety, and higher quality training for athletes.

The DI can be used to monitor an athlete’s progress over time. By tracking changes in an athlete's deceleration index, rehabilitation providers can assess the effectiveness of rehabilitation and training programs, thereby identifying areas for improvement. For example, if an athlete's DI is consistently low, it may indicate that they need to focus more on eccentric training and deceleration drills in their training. Therefore, the DI can be used as a tool to track progress in rehabilitation and identify areas that need improvement.

With rising numbers of sports injuries, there is growing interest in finding solutions through training and rehabilitation. Going beyond just focusing on power and acceleration in training, deceleration training can be a useful tool in the rehabilitation program. COD-S is an integral aspect of an athlete's performance and having an effective measure of deceleration is key to injury prevention and efficient rehab. The Deceleration Index provides a comprehensive understanding of an individual's ability to decelerate versus their acceleration speed. Using this metric, clinicians are able to observe and measure an individual's ability to slow down as well as speed up, thus providing insight into the risk for injury. While research into its efficacy is still ongoing, initial findings suggest that the Deceleration Index has the ability to improve rehabilitation and may reduce the risk for further injury. The use of this metric could have significant implications for those working in the fields of sports medicine and physical therapy. As such, the Deceleration Index is poised to be the missing link in rehabilitation, allowing practitioners to make informed decisions with regards to an individual's training. With further research, athletes may soon reap the benefits of a reliable way to measure progress during rehabilitation exercises and reduce injury risk.
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**Introduction**

Static stretching was a mainstay for decades for warm-ups before activities, training to increase range of motion (ROM), and rehabilitation from injuries.\(^1\) The popularity of static stretching came into question starting in the late 1990s with research reporting acute static stretching-induced performance (i.e., strength, power, balance, sprint speed) decrements.\(^1,2\) Recent research has elucidated the weakness of these prior studies, including a lack of ecological validity in terms of static stretching durations, testing times, lack of inclusion of dynamic activities within a warm-up, and nocebo effects among others.\(^1,2\) Static stretching produces trivial effects on subsequent performance when less than 60 seconds of stretching per muscle group is incorporated into warm-ups that included dynamic activities.\(^1,2\)

Static stretching has recently taken another hit, with commentaries suggesting that stretching need not be incorporated as a fitness component like training for muscle strength and endurance, cardiorespiratory endurance, or body composition since activities such as resistance training, foam rolling, and local vibration can similarly increase flexibility.\(^3,4\) Though static stretching has fallen out of favour as a warmup activity, it still has merit as a means to increase ROM.

While the popularity of static stretching has diminished, the implementation of dynamic stretching during warm-ups has increased.\(^1,2\) Our recent meta-analysis reported no significant differences between static stretching, dynamic stretching, and proprioceptive neuromuscular facilitation (PNF) for increasing ROM.\(^5\) There were also no significant differences between stretching at higher or lower intensities. Therefore, though dynamic stretching may be an important warm-up component, it does not offer improvements over static stretching for increasing ROM.

Furthermore, the advent of new techniques to increase ROM does not necessarily mean that these alternative methods are better. Therefore, this perspective aims to expound on these alternatives.

**Resistance Training Effects on Range of Motion**

Although it has been known for centuries that resistance training can improve muscle strength, power, and endurance, our recent meta-analysis documented that resistance training (free weights, machines, Pilates, but not calisthenics) can provide similar ROM increases as static stretching.\(^6\) Subgroup analyses found that “untrained and sedentary” individuals had significantly higher, large magnitude ROM improvements than the small increases with “trained or active people”. Since resistance training can provide moderate magnitude improvements in ROM, stretching before or after resistance training may not be necessary.

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Foam Rolling Effects on Range of Motion
Foam rolling is a popular modality that acutely and chronically increases ROM without performance deficits. Our recent meta-analysis concluded that foam rolling had a moderate magnitude effect on ROM with >4 weeks of foam rolling training. There were differences between muscles, as foam rolling increased joint ROM when used on the hamstrings and quadriceps, but not ankle dorsiflexion when foam rolling was employed on the triceps surae. We suggested that certain joints with more limited ROM, such as the ankle, or with a prior history of injuries (e.g., sprains) may not be as receptive to foam rolling. Another meta-analysis from our lab revealed no significant ROM differences between single bouts of stretching and foam rolling suggesting they are equally effective. As such, the underlying mechanisms of increased stretch tolerance or soft-tissue compliance would likely be similar for static stretching and foam rolling.

Vibration
Local muscle vibration alone and combined with static stretching have been used to increase ROM. The research findings are diverse, with vibration (35 Hz with 2 mm amplitude) and static stretching augmenting hamstring flexibility more than static stretching alone, while in other studies, local vibration (i.e., 30 Hz at 4 mm displacement, 44 Hz with 0.1 mm displacement) alone induced similar ROM improvements as static stretching, and was more effective than dynamic stretching. The reported mechanisms underlying vibration-induced increases in ROM are increased stretch threshold, augmented blood flow, diminishing muscle viscosity, and decreases in the phasic and static stretch reflexes.

Don't count out static stretching (yet)!
For individuals with injuries that do not permit resistance training, another static stretching benefit is increased muscle strength and hypertrophy with daily static stretching of 10-60 minutes. Prior reviews have reported that static stretching did not have positive effects to prevent all cause injuries. However, our current reviews reported reduced musculotendinous injury incidence, improved balance, and reduced pain with static stretching as part of the warm-up before an activity or as part of a separate training program (≥30 seconds per muscle group with a total duration of ≥5 minutes). Unilateral static stretching can also have global body effects with large magnitude ROM increases in non-stretched limbs.

Summary
Hence, while there are other activities, such as dynamic stretching, PNF, resistance training, foam rolling, and vibration, that can increase ROM, the reported demise of static stretching may be premature, as it provides an array of fitness, performance, and health benefits and can be used in conjunction with other modalities where increased ROM is a priority of the goal activity. While resistance training and foam rolling can contribute to moderate magnitude increases in ROM, individuals who seek greater improvements may wish to augment these activities with stretch training.

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THE USE OF MSK ULTRASOUND IN THE EVALUATION OF ELBOW ULNAR COLLATERAL LIGAMENT INJURIES

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ABSTRACT

As physical therapists, understanding the anatomy and biomechanics of the musculoskeletal system is essential for accurate diagnosis and effective treatment outcomes. Musculoskeletal ultrasound (MSK-US) is one tool that has revolutionized the way physical therapists evaluate musculoskeletal pathology. Specifically to the elbow, assessing the ulnar collateral ligament (UCL) proves especially beneficial for providing both diagnosis and treatment planning. By directly visualizing static and dynamic loads to the ligament, physical therapists can gain valuable information about underlying pathology and guide the therapeutic decision-making process. In this sound byte, we will look at how incorporating MSK-US imaging into your patient assessments can provide you with more comprehensive data to make informed clinical decisions when treating UCL injuries in the elbow.

Overview of elbow anatomy and the role of the ulnar collateral ligament (UCL)

The ulnar collateral ligament (UCL) is a key component of the elbow joint and is the primary restraint to valgus instability. Anatomically, the UCL complex of the elbow is composed of three distinct bands: the anterior band, which assists in flexion and extension; the posterior band, which helps to secure lateral stability; and the posterior oblique band, which runs along a different plane than its counterparts and helps to direct ulnar forces during pronation and supination as well as resisting valgus stress. The anterior bundle is the strongest component of the ligamentous complex and from a functional standpoint, its primary purpose is to restrict valgus stress on the medial aspect of the elbow. The anterior bundle is also composed of two separate bands (anterior and posterior) that provide a

PATIENT POSITION

Figure 1a: Patient Position.
Supine with the involved arm abducted to 90 degrees, elbow flexed to 60-90 degrees and maintained in full external rotation. A bolster or towel under the arm applies a passive valgus stress to the elbow placing strain to the UCL ligament. The Green Box outlines the oblique longitudinal/LAX position of transducer.

TRANSUCER PLACEMENT

Figure 1b. Transducer Placement.
The transducer is placed in an oblique longitudinal/LAX position. The probe needs to be anterior to the medial epicondyle to visualize the targeted UCL. This LAX position will be used to view either the anterior or posterior bands.

Figure 1c: Transducer Placement with Valgus Stress Applied.
With the probe in place, the arm can be rotated back into external rotation with a bolster or towel under the elbow where the valgus stress is reapplied. This exam becomes a dynamic assessment showing the UCL laxity in real time.
NORMAL ANTERIOR BAND IN LONG AXIS (LAX)

Transducer Placement: Long Axis (LAX). The probe is placed in an oblique longitudinal/LAX position.

Figures 2a and 2b:
The normal anterior band of the ulnar collateral ligament is located by finding the hyperechoic bone contour of the medial epicondyle. The ligament is deep to the adjacent flexor tendon. The ulnar collateral ligament will appear hyperechoic and fibrillar. The humero-ulnar joint space must be visible for dynamic testing of the ulnar collateral ligament integrity.

reciprocal function with the anterior band being tight in extension, while the posterior band is tight in flexion. Attenuation or rupture of the UCL can result in valgus instability.

Exploring the diagnostic criteria for various UCL injuries
There are three main types of UCL injury: partial tear, complete tear, and avulsion fracture. Partial tears are further classified into either grade 1 or grade 2, depending on the severity of the injury. Grade 1 tears are small tears or fraying of the ligament, while grade 2 tears are more significant tears with some loss of function. Complete tears are when the ligament is completely torn, and avulsion fractures occur when a small piece of bone is pulled away from the bony attachment along with the ligament.

The diagnosis of UCL injury relies on an accurate history and physical examination. Clinicians must consider several factors when diagnosing UCL injuries, such as activity level, history of any prior injuries, and the individual's presenting symptoms. Typically, patients with UCL injury will present with either acute or chronic onset of medial elbow pain. Symptoms of UCL injuries include pain and tenderness on the medial side of the elbow, swelling, loss of range of motion, and weakness in grip strength. Physical examination can often reveal crepitus (grating or grinding sensation) and joint line tenderness with palpation. Provocation testing can further localize the symptoms to the medial elbow. Particular attention should be given to ensuring that no other underlying condition is present when diagnosing a UCL injury. Imaging studies such as static radiographs, stress radiographs, and magnetic resonance imaging (MRI) can be helpful in making the diagnosis.

Incorporating musculoskeletal ultrasound in the diagnosis of UCL injuries
The diagnosis of UCL injuries can be complex; however, musculoskeletal ultrasound (MSK-US) is a useful and effective, noninvasive imaging modality for evaluating the UCL of the elbow due to its simplicity and convenience. Since MSK-US is not a radiation-based technology, its use is generally safe and painless for patients. Coupled with fast results and a smaller risk of complications, MSK-US is quickly becoming the go-to imaging method for diagnosing soft tissue issues such as ligament or tendon tears in the elbow region.

MSK-US offers several benefits compared to other imaging modalities in the diagnosis of elbow injuries making it increasingly easier to identify and diagnose UCL tears and other similar pathologies. MSK-US can provide instant real-time images during an examination, allowing examiners to accurately identify and grade any tear that may have occurred due to overuse, trauma or congenital anomalies. The common imaging findings associated with these conditions can be grouped into three distinct categories of MSK-US findings: tendinopathy, discontinuity of the ligament/tendon substance, and foreign bodies such as small particles of debris.

When evaluating a UCL tear with MSK-US, one may observe a widened UCL or redundant folds, irregular hyperechoic structures, clefts or gaps in the ligament coaptation line, discontinuity of continuous fibers within the UCL fibers, or pseudo fluid collections at some locations with laxity. Discontinuity appears as an apparent tear or
gap between the proximal and distal ends of the tendon/ligament with intra-tendinous hyperechoic areas. A high-resolution MSK-US image can also reveal other pathologies such as tendinopathies, swelling, joint effusions, and cartilage lesions. Tendinopathy consists of irregular fibers within affected muscles or tendons and occasionally thickening around the tendon which may present with hypoechoic regions. Debris in a joint space indicates foreign bodies such as bacteria or nutrient crystals which can cause inflammation and damage to the surrounding tissue. MSK-US can help differentiate these pathologies from chronic disruptions such as UCL tears or instability events. By accurately isolating these imaging findings together with the history and physical examination, MSK-US can safely diagnose and monitor musculoskeletal disorders providing accurate guidance for treatment options.

Technical considerations for musculoskeletal ultrasound examination of the elbow

An MSK-US examination of the elbow requires several technical considerations to achieve an optimal diagnostic result. The transducer must be carefully prepared with a coupling gel and placed perpendicular to the skin surface for a clear picture of the anatomy. Higher frequency transducers do not penetrate tissue as well but provide resolution of a more superficial structure. Scanning during dynamic movement should also be incorporated when imaging the elbow, as it can provide more detailed images essential for diagnosis in a clinical setting. Additionally, optimize the patient’s position so they feel comfortable during imaging and the angle of view is maximized. Following these technical considerations will ensure an optimal MSK-US examination of the elbow.

MSK-US has become a popular modality for evaluating UCL injuries due to its advantages of being cost-effective and avoiding the need for x-rays. Not only does MSK-US offer advantages over traditional diagnostics methods like radiology, but its recent advancements have made it even more efficient and successful in evaluating UCL tears. An advantage of MSK-US is that it can be used in the outpatient setting without prior preparation, such as an injection of contrast materials. In this setting, MSK-US provides excellent imaging of the elbow anatomy which aids in the accurate diagnosis and treatment of UCL injuries. Because of its reliability, MSK-US should be considered when diagnosing possible UCL tears or other elbow pathologies.

Figure 3a: Instability can be seen as a larger joint space (Green Arrows) between the ulna and medial epicondyle indicating a tear of the UCL ligament. Figure 3b: Under valgus stress, the elbow joint shows widening some echogenic fat (yellow arrows) herniated into the joint with widening of the joint space.