

# New Technology for Objective Assessment of Chronic Ankle Instability



**By: Precious Hammond, MS, ATC**

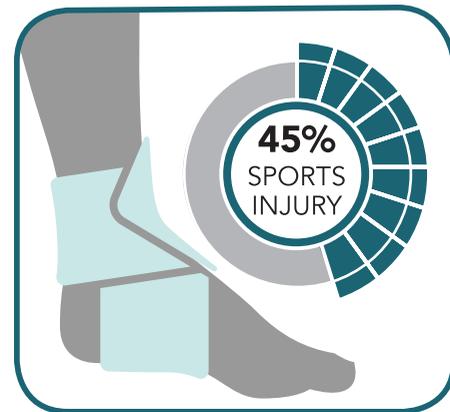
## About the Author

Precious Hammond is an Assistant Athletic trainer at a private boarding school in New Hampshire. She is a board certified Athletic Trainer and a licensed Athletic Trainer in the state of New Hampshire. She has presented research on balance and gait, at national conferences like the American College of Sports Medicine and the National Athletic Trainers Association. Her research has been published in the Complimentary Therapies in Clinical Practice Journal. Precious earned a Bachelor of Science in Athletic Training with a minor in Coaching and Health from Norwich University and a Master of Science in Athletic Training Higher Education from Plymouth State University.

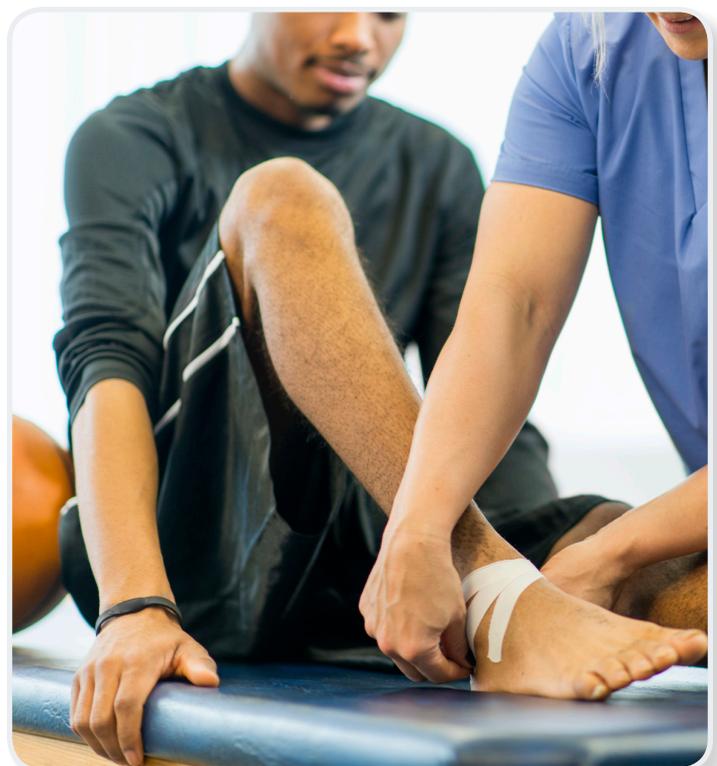


## Lateral Ankle Sprains are Among the Most Common Injuries in Athletic Programs

Chronic ankle instability (CAI) is a common musculoskeletal injury that is seen in today's population. CAI is a product of an acute lateral ankle sprain. A lateral ankle sprain causes structural damage and laxity to the anterior talofibular, calcaneofibular, and posterior talofibular ligaments, from an inverted and supinated foot (rolled ankle). In 2013, it was estimated that 28,000 ankle injuries occurred in the United States each day. In sports, an estimated 45% of injuries involve the ankle [5]. Of those with ankle sprains, about 1 out of 3 people report residual symptoms that classify as CAI, including loss of functions, repeated injury, and disability six weeks post injury [5]. This creates a significant financial burden on the population due to health care costs from hospital visits and physical therapy [1].



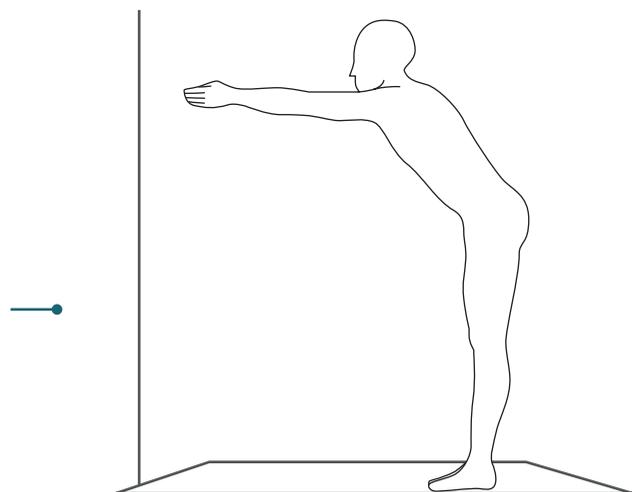
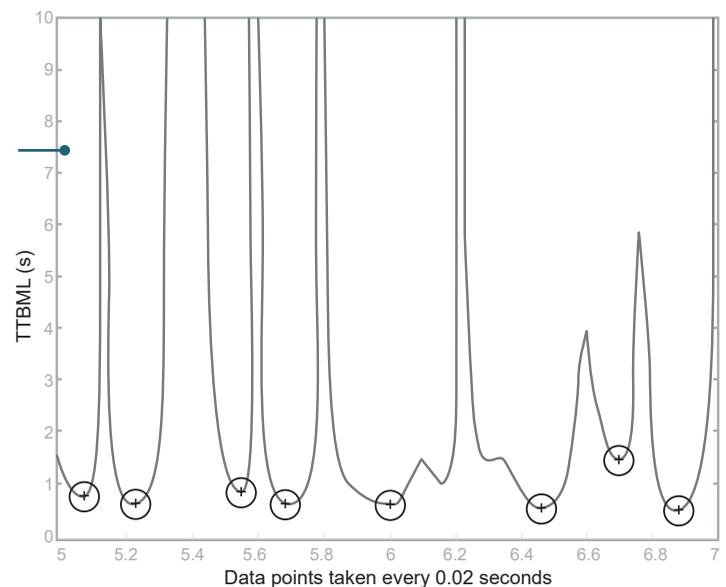
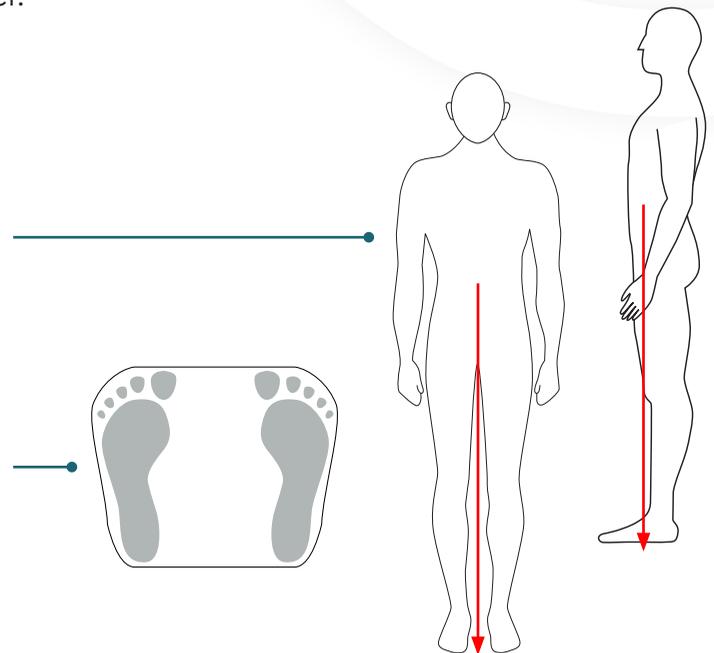
Over the past 40 years, there have been numerous investigations into the contributing factors for the development of CAI. Currently, the most studied contributing factors are deficits in single limb balance. Finding the appropriate instrument to measure balance from the options available based on functionality, cost, and the measurements to be analyzed has traditionally been problematic for the clinician or researcher. Typically, balance assessments are based on measurements of center of pressure displacement; but, more recently, time-to-boundary (TTB) has been utilized because of its ability to discriminate postural control deficits present in subjects with CAI [7]. The newest technology available using TTB is the MobileMat® with SportsAT™ software by Tekscan®, which will meet clinical expectations for CAI measurements.



## Key Definitions

Before we go into the heart of this white paper, let's first review some of the key definitions and concepts that will be discussed throughout this paper.

- **Postural stability** is the upright stance of vertical projection of the center of gravity that is located within an equilibrium region of stability boundary for a postural task [10].
- **Center of pressure (COP)** is the location of the resultant ground reaction forces on the surface of support and is an emergent property of the forces exerted, so that the vertical projection of the center of gravity and the sway of the body can be accommodated [10].
- **Base of support (BOS)** is determined by the area contained within the spatial boundaries of the position of the feet on a support surface [9].
- **Virtual time-to-contact (VTC)** is the temporal proximity of the potential time to collision of the COP trajectory with two-dimensional stability boundary [9]. In other words, VTC is the time the body's sensory and motor control systems have to respond to a perturbation before a potential loss of balance.
- **Time-to-boundary (TTB)**, adapted from the virtual time-to-contact concept, is a spatiotemporal (range and velocity) measurement tool that estimates the time an individual has to make postural corrections in order to maintain balance. The main idea is that a person would lose their balance and fall if the COP reached the boundary of support [2]. A higher TTB value would indicate better stability and lower value would indicate less stability. The measurement algorithm uses the distance and velocity of the COP with respect to the BOS in a patient's double leg, upright stance [11]. Traditional calculation models the foot as a rectangle, to allow for separations of anterior-posterior (front and back) and medial-lateral sections (side to side) [3]. Time-to-boundary is reported in units of time (generally seconds).
- **Limits of stability (LOS)** is the maximum angle range in which center of mass can be moved safely without changing the BOS. The idea is that the body acts like an inverted pendulum and has limits before falling or stepping to correct balance and maintain an upright stance [4]. Limit of stability is reported in units of degrees.
- **Chronic ankle instability (CAI)** is defined as frequent and repetitive bouts of the ankle giving way during functional activities, after initial ankle sprain due to ligament weakness [2].



## TTB Data Collection and Calculations

TTB measurements are taken during the course of double or single leg, upright standing trials on a force-plate or force-plate-like instrument, such as the MobileMat platform. The TTB calculations are based on the COP in the Medial-Lateral direction (ML) and Anterior-Posterior (AP) directions during reactive postural control. If the COP ML moves medially, the distance between COP ML and the medial border of the foot is calculated. The distance is then divided by the corresponding velocity of the COP ML to calculate the time it will take COP ML to reach the medial border of the foot if it were to continue moving in the same direction with no acceleration or deceleration. Similar equations are performed if COP moves laterally or in AP directions. Another measurement examined in TTB is the TTB minima. TTB minima are defined as the lowest points that are identified within a search window of approximately five data points in a time series. TTB minima represent the most precarious times when the sensorimotor system is at risk of losing balance.

## The Value of TTB

TTB is beneficial to use with the MobileMat because the TTB measurement uses both area and velocity within its calculation. This is a quick and easy way for clinicians to quantify and understand the appropriate relationship between the COP excursions within the BOS, to maintain double or single limb quiet standing. The mean TTB and standard deviation (SD) of TTB provide the subject with a sense of how much sensorimotor control they have while standing.

## Clinical Application of TTB

For clinicians using TTB to assess patients with CAI, baseline TTB measurements would be recorded using the MobileMat, prior to prescribing ankle rehabilitation exercises. Then following completion of the ankle rehabilitation program, TTB measurements would be re-recorded to quantify the progress. The goal would be to see an increase in TTB value, indicating that the patient has improved their stability. Ideally, by modifying the patient's BOS and sensorimotor control through rehab, the patient will gain more time to make balance corrections. Again, higher TTB values mean the patient is more stable; lower TTB values mean the patient is less stable. Frequent measurements produced by the MobileMat will allow clinicians to identify whether intervention strategies are effective in improving balance control and help the patient regain as much function as possible, while managing their CAI.

## Time-to-boundary (TTB) and Limits of Stability (LOS) are not the Same Parameters

TTB and LOS are often confused in everyday conversation; however, the terms are very different. TTB measures reactive postural control of the COP while maintaining quiet double or single limb balance. This method is identified as a feedback driven strategy that controls balance within the sensorimotor system. LOS measures volitional (subconscious movements) control during double limb balance when the COP is moving towards a target. LOS measures how far one can lean in a given direction before they have to make a compensatory step to correct their balance, using the feedforward strategy of the sensorimotor system. Overall, the two variables are based on two different methods: feedback and feedforward strategies of testing the sensorimotor system control of balance.

In TTB measurements, the COP is recorded over the course of a trial time and is automatically calculated with or without total loss of balance. LOS evaluates the maximum angle of movement allowed without changing the BOS. The range of the calculation is computed based on movements in all directions: side to side and forward and backward.

## Recent Research Findings with TTB

Recently, TTB has been used to measure CAI among athletic populations. Multiple authors, cited within this paper, performed similar testing methods. Due to the authors' continuous collaboration on projects, prior research is used as building blocks to further develop the understanding of a topic. The studies being reviewed, which have used different types of force platforms to measure the TTB and traditional COP measurements, explore the relationship between CAI and TTB

CAI postural stability protocols are fairly consistent, with subjects performing three 10-second trials of quiet barefoot standing. CAI studies have used single leg upright stances, comparing both "involved or injured" limbs and "non-involved or uninjured" limbs. Testing protocols use both eyes open and both eyes closed conditions, testing ankle functionality, as well as postural stability, without vestibular feedback. With both eyes open, subjects were asked to stare at a target placed in front of them on the wall during the trials. If a "touchdown" were to occur during the trial, the trial was discarded and then repeated. The tested foot was placed in the same position for each trial, based on the force plate surface grid position. The grid allowed for the foot to be bisected by AP and ML midlines. Recording frequencies have been at 50 Hz. A time series of 500 data points was calculated and then filtered with a fourth order zero lag, low pass filter with a cutoff frequency of 5 Hz [2, 3, 6, 7, 8].

Measurements produced by the TTB were TTB Medial-Lateral (ML), TTB Anterior-Posterior (AP), absolute minima, mean of minimum samples, and SD of minimum samples in the ML and AP direction. The absolute minimum and mean of minimum samples represent the temporal margin to the BOS; SD of the minimal samples in the AP and ML directions represent the variability [3]. With computer software, graphs are produced from the data, representing the movements. In the TTB graph, a wave pattern is formed from the data points, displaying both peaks and valleys. The TTB peaks (high values) are viewed as points of postural stability, while the valleys (lowest values) are points of postural instability. The valleys are thought to be where the COP is closest to the boundary of the BOS, before it changes directions to correct the postural instability. These measurements have frequently been compared with COP measurements of mean velocity, SD of COP excursions, range of COP excursions, and percent of available ranges in the ML and AP directions [2].



Athlete shown on MobileMat performing TTB test protocol of a single-leg stance with eyes closed.

## Research Findings with TTB

The following are findings from the TTB investigated studies:

CITATION	STUDY OBJECTIVES	POPULATION	FINDINGS
2	Examine postural control in single leg stance in subjects with and without unilateral CAI using traditional COP based and TTB measures.	15 physically active females with self-reported unilateral CAI 9 healthy females	Determined: – Good reliability of TTB for single leg stance. – Validity of TTB for patients with CAI. 
3	Examine the intrasession reliability of TTB and traditional COP-based measures of postural control, and the correlations between these measures.	Convenience sample: 24 young females, without pathologies affecting balance	TTB provides unique insights into periods of postural stability and instability. 
6	Identify the effect of diminished plantar cutaneous sensation on TTB measures of postural control during double and single limb quiet standing.	32 healthy young adults	Elimination of foot sensation resulted in increased TTB values for single leg stances in subjects with CAI.  Traditional COP measurements did not detect the same changes. 
7	Compare TTB measures between a mixed-gender group with CAI and a gender-matched control group.	32 subjects with self-reported CAI Matched with 32 healthy controls (18 healthy & 18 CAI males) (14 healthy & 14 CAI females)	Elimination of vision resulted in decreased TTB values for single leg stances in subjects with CAI.  Traditional COP measurements did not detect the same changes. 
8	Determine the effect of a 4 week balance training program on static and dynamic postural control and self-reported functional outcomes in those with CAI.	31 physically active subjects with self reported CAI (12 males) (19 females)	TTB measures were more sensitive at detecting improvements in static postural control compared with COP-based measures. 

## MobileMat for CAI Assessments

Using the MobileMat® has many advantages for the clinician or researcher because the MobileMat is a low-cost, portable, and light-weight device, which allows for versatile testing locations. The SportsAT software enables the MobileMat to measure TTB, which is an important variable for understanding sensorimotor function in those with CAI, as well as patients that might be at risk for developing it. While TTB is one of many sensitive variables in elucidating the effects of CAI, it could be a very powerful measurement for guiding clinical decisions when working with CAI patients.

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## What is SportsAT Software?

SportsAT Software provides essential information for objective balance and concussion assessments. Together with the MobileMat, a portable pressure measurement platform, clinicians and researchers can feel more confident in their assessments with quantitative data to evaluate chronic ankle instability, assess fall and injury risk, monitor improvements in balance, strength and weight bearing and more.

Learn more here, [www.tekscan.com/sportsat](http://www.tekscan.com/sportsat)

## About Tekscan

Tekscan is a world leader in manufacturing pressure and force measurement solutions. For over twenty-five years, Tekscan medical systems have been used by leading clinicians, hospitals and universities around the world to gather accurate, reliable data and improve patient care.

Ultra thin sensors work with application specific software and innovative scanning electronics to provide objective and actionable biomechanical data. Information from these systems help you identify pathologies, make better decisions, assess interventions and improve patient outcomes and results. Learn more at [www.tekscan.com](http://www.tekscan.com).