Dynamic Splinting for Runner's Toe

A Case Report with Gait Analysis

Mathew M. John, DPM*
F. Buck Willis, PhD†
Alberto Portillo, MSE‡

We present a case report of runner's hallux limitus and the effect of dynamic splinting in reducing contracture as measured by gait analysis. After 4 months of treatment with dynamic splinting, the patient regained 45° in active range of motion, and the gait analysis showed significant and beneficial changes. (J Am Podiatr Med Assoc 99(4): 367-370, 2009)

Hallux limitus is a pathologic condition of limited range of motion that leads to degenerative arthritis in the first metatarsophalangeal joint of the great toe,[1-20] and this commonly affects runners as an overuse injury or an untreated injury.[1-5] Hallux limitus also presents in patients with an inherited foot structure and mechanics that predispose to hallux contracture. Athletes often develop hallux rigidus as the long-term sequelae of acute traumatic injuries of the metatarsophalangeal joint or chronic repeated microtrauma of the joint surface.[5, 7, 8, 20]

This condition affects the gait pattern as evidenced by decreased maximal ankle push-off power,[3] faster cadence (attributable to decreased support time of the involved foot), a longer elevation time of the asymptomatic foot, and external rotation.[3, 4] The action of the hallux requires the first metatarsal bone to plantarflex, which allows the proximal phalanx to dorsiflex. This bidirectional hinge action needs to take place with each step. A direct contusion injury or repeated microtrauma injuries in runners would impair this complex action, which would yield contracture, resulting in hallux limitus. The normal smooth motion of the proximal phalanx over the head of the metatarsal is disrupted, leading to compression of the phalanx against the head of the metatarsal as the joint is dorsiflexed.[6-14]

*Ankle & Foot Centers PC, Marietta, GA.

†Texas State University, San Marcos, TX. Dr. Willis is now with Dynasplint Systems Inc, Austin, TX.

‡University of Texas, San Antonio, Graduate College, San Antonio, TX; Engineering Department, University of Texas Health Science Center, San Antonio, TX.

Corresponding author: F. Buck Willis, PhD, PO Box 1735, San Marcos, TX 78667. (E-mail: BuckPhD@yahoo.com)

Brodsky et al[3] examined the gait pattern in hallux limitus by performing gait analysis of 23 symptomatic patients with hallux limitus. The investigators measured the temporospatial, kinematic, and kinetic parameters of gait. This gait analysis was performed with a five-camera motion analysis system and a force plate that was embedded in an 8-m walkway. They found that patients with hallux limitus had increased ankle-foot propulsive power and a wider step width. After surgical treatment of hallux limitus with a metatarsophalangeal joint arthrodesis, the patient's gait analysis was repeated. The "support time" during the gait pattern was significantly increased after treatment ($P = .0009$), which shows the unique effect that hallux limitus has on the gait pattern.

Reduction of pain, inflammation, edema, and irritation of the metatarsophalangeal joint is the goal of treating this pathologic condition, and dynamic splinting has shown effective results in a pilot study on restoring hallux flexion.[5] This cohort study examined the effectiveness of metatarsophalangeal joint dynamic splinting on three patient groups: runners with overuse injuries, patients with phalangeal fracture, and patients after bunionectomy. The study found a significant difference for all patient groups ($P < .001$).

The procedure of applying low-load, prolonged-duration stretch has been effective in treating similar conditions of reduced range of motion.[15, 16] Dynasplint systems use the protocol of low-load, prolonged-duration stretch to achieve greater time at each patient's end range of motion. As range of motion progresses, the tension of the dynamic splint is also increased to continue treatment at end range. This is the first investigation of dynamic splinting for hallux limitus with gait pattern analysis.

Case Report

The present report is of a 47-year-old man who had been a competitive runner for more than 30 years when he experienced a major runner's injury in 2004. After placing in a marathon in Melbourne, Australia, the patient noticed intense pain in his right hip and foot. He was diagnosed and was surgically treated for hip dysplasia and structural hallux limitus. The hip surgery corrected a labrum tear and debrided the acetabulum, with removal of osteophytes. A cheilectomy was performed on the right foot, removing dorsal and lateral exostoses from the first metatarsal head and the base of the proximal phalanx. Osteophytes were also resected from the first metatarsophalangeal joint.

The surgical procedures and postoperative physical therapy reduced the symptoms, but the patient had residual pain in his foot when running that he attributed to what he described as his "frozen, fat, elevated toe." Apparently, the metatarsophalangeal joint osteophyte removal benefited the patient, but contracture was not reduced because of excessive arthrofibrosis and continued microtrauma injuries to the great toe, and excessive fibrosis developed. Differential diagnosis eliminated bursitis, gout, metatarsal stress fractures, an elevated first metatarsal secondary to a hypermobile first ray, phalangeal fractures, hallux varus surgeries, osteophytes, osteoarthritis, rheumatoid arthritis, and osteochondral joint defect (common in runners' injuries).

Testing

Contemporary gait analysis was completed by using the VICON MX system (workstation, polygon, Butterworth filter, and force plate) (Vicon UK, Oxford, England)[8] before and after this treatment modality was worn. The computerized three-dimensional motion capture system used includes eight infrared, emitting, and filtering cameras to record changes from the 16 retroreflective markers placed on the patient's lower extremity in accordance with the VICON system instructions (metatarsophalangeal joint to iliac crest) (see reflector placement in Fig. 1). The subject was instructed to walk barefoot along the laboratory walkway approximately 28 feet long, which included four force plates (20 × 18.25 × 3.25 inches) that are aligned, tandem and flush along the walkway, to establish ipsilateral contact of heel strike to toe-off. The force plates were sampled at a frequency of 1,200 Hz, and the cameras were calibrated at a frequency of 120 Hz.

Kinetic and kinematic information gathered in symptomatic gait analysis can be compared to normal gait patterns for both quantified and qualified analysis.[3, 4, 6, 8] Kinematic measurements and temporospatial measurements were recorded and calculated to further analyze the patient's qualitative gait pattern, and the same procedures were used in the preintervention and postintervention test scenarios. The initial gait lab testing showed asymmetrical cadence (control versus symptomatic foot), asymmetrical foot aloft time, and asymmetrical ankle rotation (Table 1).

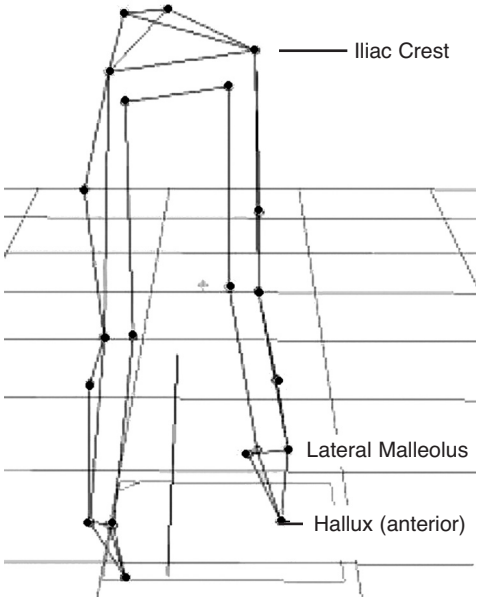

Figure 1. Gait analysis reflector placement.

Intervention

A Dynasplint system for metatarsophalangeal flexion (Dynasplint Systems Inc, Severna Park, Maryland) was prescribed to give the patient the low-load, prolonged-duration stretch to reduce this anterior contracture. When the patient was fit with the Dynasplint system (Fig. 2), the fitting was customized to the patient's foot size and hallux edema. The patient was then instructed on donning, wear and care, and in the protocol for use of this splint. The patient was instructed to begin wearing the Dynasplint system for a total of 30 min in the first few days while seated or on the bed before sleeping. Tension was initially at the No. 2 setting (0.24 foot-pounds of torque), and the patient was instructed to keep a log of the dates, times, and tensions used. After the first few days of accommodation, the patient was instructed to increase the

Table 1. Gait Analysis Data

Test	Initial Analysis		Final Analysis	
	Left	Right	Left	Right
Cadence (steps/min)	109	107	104	104
Foot aloft (sec)	10.1	11.6	11.2	11.4
External ankle rotation (°)	+12	–4	+6	–3
MPJ flexion (active ROM) (°)	55	0	55	50

Abbreviations: MPJ, metatarsophalangeal joint; ROM, range of motion.
Note: Data are given as means.

wear time by 5 min per bout per day until he could comfortably wear the system for 30 min in each bout.

The patient was instructed to increase the tension one increment each week until he reached setting No. 4. If excess fatigue from each wear was experienced, the patient was instructed to decrease the tension by one-half increment and to wear it at the new setting for the next few days. (This never occurred.) The goal was to wear the system for 30 min three times per day. Patient compliance was tracked by using a weekly journal submitted to the attending clinicians, and it showed reduced compliance because the patient was consistent in wearing the system only 90 min a day (30 min each bout) but at a higher tension level than prescribed (tension setting No. 6; 1.0 foot-pound of torque). This behavior is commonly seen when treating competitive athletes with this modality.

Discussion

After 4 months of treatment with the Dynasplint system, the patient regained 45° in active range of motion, and the post-treatment gait laboratory test displayed significant changes in cadence (steps per minute) and foot aloft time (seconds and left versus right) and reduced ankle rotation of the symptomatic foot (Table 1 and Fig. 3).

Gait analysis showed that the patient's symptoms of hallux limitus were resolved, consistent with other research: decreased maximal ankle push-off power,[3, 6] reduced cadence,[3, 6] and symmetrical foot aloft time.[4] Post-gait analysis showed that after the hallux had regained 45° of flexion in active range of motion, the asymptomatic foot's compensation of excessive external rotation was reduced by 50%. This Dynasplint system modality was effective in regaining hallux flexion for this patient, preventing the need for secondary arthrodesis,[6] and the patient has returned to competitive running and has regained the speed of running a 5-km race in under 20 min.



Figure 2. Metatarsophalangeal Dynasplint system.

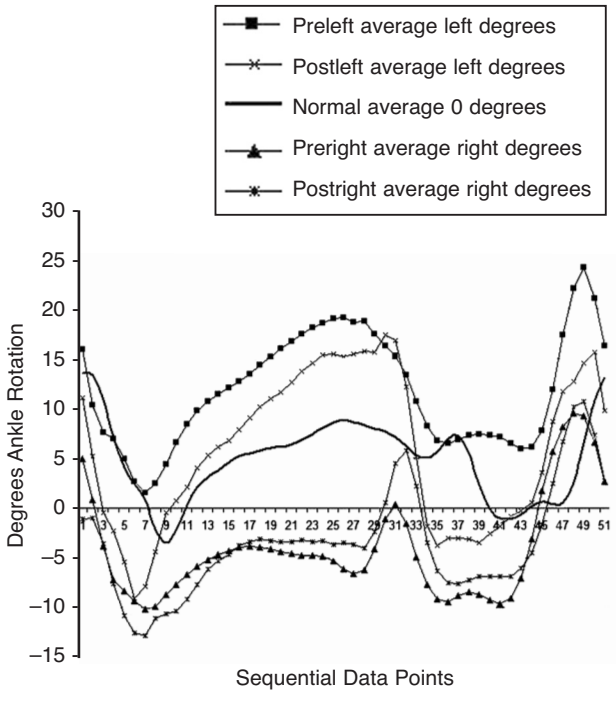

Figure 3. Ankle rotation gait analysis.

Acknowledgment: The technicians at the Gait Lab at the Audie Murphy VA Hospital associated with the University of Texas Health Science Center in San Antonio for their expertise in testing and participation in this study; Bob Pankey, EdD, of Texas State University, Health Physical Education and Recreation Department, for participation in this gait testing at the VA hospital.

Financial Disclosure: None reported.

Conflict of Interest: Dr. Willis is employed by Dynasplint Systems Inc.

References

1. Nagel A, Fernholz F, Kibele C, et al: Long distance running increases plantar pressures beneath the metatarsal heads: a barefoot walking investigation of 200 marathon runners. Gait Posture **27:** 152, 2008.
2. Dierks TA, Davis I: Discrete and continuous joint coupling relationships in uninjured recreational runners. Clin Biomech (Bristol, Avon) **22:** 581, 2007.
3. Brodsky JW, Baum BS, Pollo FE, et al: Prospective gait analysis in patients with first metatarsophalangeal joint arthrodesis for hallux rigidus. Foot Ankle Int **28:** 162, 2007.
4. Scherer PR, Sanders J, Eldredge DE, et al: Effect of functional foot orthoses on first metatarsophalangeal joint dorsiflexion in stance and gait. JAPMA **96:** 474, 2006.
5. Willis B, John M: Dynamic splinting increases flexion for hallux rigidus (pilot study). BioMechanics **14:** 49, 2007.
6. DeFrino PF, Brodsky JW, Pollo FE, et al: First metatarsophalangeal arthrodesis: a clinical, pedobarographic and gait analysis study. Foot Ankle Int **23:** 496, 2002.
7. Goucher NR, Coughlin MJ: Hallux metatarsophalangeal joint arthrodesis using dome-shaped reamers and dorsal plate fixation: a prospective study. Foot Ankle Int **27:** 869, 2006.
8. Hockenbury RT: Forefoot problems in athletes. Med Sci Sports Exerc **31:** S448, 1999.
9. Hurst JM, Nunley JA II: Distraction osteogenesis for the shortened metatarsal after hallux valgus surgery. Foot Ankle Int **28:** 194, 2007.
10. Bal A, Aydog E, Aydog ST, et al: Foot deformities in rheumatoid arthritis and relevance of foot function index. Clin Rheumatol **25:** 671, 2006.
11. Talarico LM, Vito GR, Goldstein L, et al: Management of hallux limitus with distraction of the first metatarsophalangeal joint. JAPMA **95:** 121, 2005.
12. Payne C, Chuter V, Miller K: Sensitivity and specificity of the functional hallux limitus test to predict foot function. JAPMA **92:** 269, 2002.
13. Kennedy JG, Chow FY, Dines J, et al: Outcomes after interposition arthroplasty for treatment of hallux rigidus. Clin Orthop Relat Res **445:** 210, 2006.
14. Stuck RM, Moore JW, Patwardhan AG, et al: Forces under the hallux rigidus foot with surgical and orthotic intervention. JAPMA **78:** 465, 1988.
15. Willis B: Dancers restore knee flexion through dynamic splinting. BioMechanics **15:** 49, 2008.
16. Hepburn G: Contracture and stiff joint management with Dynasplint. J Orthop Sports Phys Ther **8:** 498, 1987.
17. Ahn TK, Kitaoka HB, Luo ZP, et al: Kinematics and contact characteristics of the first metatarsophalangeal joint. Foot Ankle Int **18:** 170, 1997.
18. Canseco K, Long J, Marks R, et al: Quantitative characterization of gait kinematics in patients with hallux rigidus using the Milwaukee foot model. J Orthop Res **26:** 419, 2008.
19. Shereff MJ, Bejjani FJ, Kummer FJ: Kinematics of the first metatarsophalangeal joint. J Bone Joint Surg Am **68:** 392, 1986.
20. Becher C, Kilger R, Thermann H: Results of cheilectomy and additional microfracture techniques for the treatment of hallux rigidus. Foot Ankle Surg **11:** 155, 2005.