First Metatarsophalangeal Joint Flexibility: A Comparison of Hallux Limitus, Functional Hallux Limitus, and Healthy

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Introduction

Hallux limitus is one of the most commonly encountered joint pathologies that a podiatric physician will diagnose in the clinical setting. It is second only to hallux valgus in terms of frequently encountered first metatarsophalangeal joint (MTPJ) deformities. The primary pathologic state which characterizes hallux limitus is a functional limitation of motion that should occur at the first metatarsophalangeal joint. A spectrum of negative sequelae has been hypothesized to result from loss of dorsiflexion including: hallux limitus, functional hallux limitus, osteoarthritis (hallux rigidus), hallux abductovalgus, and sub hallucial ulceration in individuals with diabetic neuropathy. Currently, clinical evaluation of the 1st MTPJ is limited to passive range of motion measurements, radiographic analysis, and subjective joint stiffness assessment. The purpose of this investigation is: (1) to develop a technique to objectively measure 1st MTPJ flexibility and (2) to apply this method to study individuals with hallux limitus, functional hallux limitus, and compare that to a healthy joint.

By examining the role of stiffness in the foot using a 1st MTPJ flexibility jig, the early flexibility (from 0 to 25% moment) and late flexibility (from 75% to 100% moment) of the first MTPJ can be measured. The angular excursion in degrees of the first MTPJ is also determined at the input moment of 3.41 in-lbs. This is the approximate region of slope change in the angle vs. torque bilinear curve of healthy subjects. The obtained value will be called the first MTPJ laxity.

The data collected from the 1st MTPJ flexibility jig can be useful in helping the medical community understand the biomechanics of the 1st MTPJ and more specifically joint flexibility in patients which suffer from hallux limitus and functional hallux limitus.

Methods

Selection of Subjects

A total of nineteen patients (n= 37 feet) were selected for this study. Subjects were recruited from the Foot and Ankle Institute at the Temple University School of Podiatric Medicine.

Several criteria for accepting a patient into the study were established:
1. Healthy patients must have greater than 65° of great toe dorsiflexion in the loaded and unloaded condition.
2. Hallux Limitus patients must have less than 45° of great toe dorsiflexion in the unloaded condition.
3. Functional hallux limitus patients must have greater than 65° of great toe dorsiflexion in the unloaded condition and less than 45° of dorsiflexion in the loaded condition.
4. No prior professional help and treatment was rendered for the previous six months of the presenting hallux limitus.
5. Onset of hallux limitus is not the result of an acute traumatic episode.
6. Hallux limitus is not of systemic origin.
7. There is no history of previous ulceration under the hallux or first metatarsal head.
8. There are no unresolved injuries to other joints of the lower extremity.
9. There are no neurological disorders of origin.
10. A woman’s shoe size cannot be smaller than six.
11. There is no evidence of osteoporosis or any pathology of bone.
9. There is no evidence, past or present of hallux abductovalgus.

**Instrumentation**

*First MTPJ Flexibility Jig.* This is a non-weightbearing passive range of motion device that quantifies the angular excursion via a potentiometer circuit and the moment from a 125 in-lb maximum torque transducer (Sensor Developments™). The transducer is aligned with the axis of the first MTPJ (see Figure 1). A Labview™ data acquisition system is used to collect and sample the data at 200 Hz. This will generate plots of the first MTPJ angular excursion (degrees) vs. the applied moment (in-lbs.).

![Figure 1- 1st MTPJ Flexibility Jig](image)

**Experimental Protocol**

After the subjects were selected according to the specific criteria listed above, the procedure was explained to each patient. Each patient required one testing visit, which consisted of a biomechanical exam, and an analysis in the flexibility jig.

With the patient supine, the biomechanical exam specifically quantified passive range of motion in the first MTPJ with the forefoot loaded and unloaded. This allowed for the patient to be placed into his/her proper clinical group.

Next, the patient underwent manipulation of the first MTPJ while the foot was positioned in the flexibility jig. The investigator added a torque to the MTPJ while completing the cycle of dorsiflexion-plantarflexion three times.

**Testing Parameters**

*Flexibility Jig*

A typical flexibility curve is a bilinear curve in which four parameters can be calculated: (1) the initial slope of the dorsiflexory portion of the angle vs. moment curve (early flexibility), (2) the late slope of the curve (late flexibility), (3) the slope of the entire...
dorsiflexory portion of the curve (total flexibility), and the angular excursion (laxity) for a specific applied input moment of 3.41 in-lbs (see Figure 2).

Clinically speaking, the early flexibility is representative of the smooth, gliding motion which takes place during the initial movement about a joint. Late flexibility represents the motion which occurs about a joint at its end range of motion when the capsular and ligamentous structures tighten to prevent subluxation. Total flexibility is representative of the total dorsiflexory motion which occurs about a joint, and laxity represents a numeric value in which two joints can be compared to describe structure and function.

Results and Discussion
Early flexibility (p=.006) and laxity (p=.010) demonstrated statistically significant differences across the groups studied by analysis of variance testing. Post-hoc t-tests revealed significant differences in these parameters between Hallux Limitus and Healthy as well as Hallux Limitus and Functional Hallux Limitus groups. However, there was no significant difference between Healthy and Functional Hallux Limitus cohorts. A technique was developed to measure 1st MTPJ flexibility that was sensitive to pathomechanical states.

References

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