CHAPTER **48**

RELIABILITY AND VALIDITY OF CLINICAL ASSESSMENT OF FIRST RAY DORSAL MOBILITY

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INTRODUCTION

The medial longitudinal arch plays an important role in how the foot functions during weight bearing. Not only is it a major source of frontal plane movement of the foot, but it is also a major load-bearing structure.[1] The first ray is composed of the first metatarsal and medial cuneiform bones of the foot. Together, these two bones act as a functional unit.[2] Because of its location within the longitudinal arch, the first ray plays an integral role in providing stability and maintaining structural integrity of the foot during weight-bearing activities.[3] Highlighting its functional importance is the fact that three different extrinsic muscles of the foot insert at the base of the first ray. The anterior tibialis, posterior tibialis, and peroneus longus muscles all act upon the first ray to help maintain stability of the arch during the crucial push-off phase of walking. Movement of the first ray is considered to occur primarily in the sagittal plane. Using cadaver feet, Hicks estimated that the axis of rotation for the first ray runs nearly horizontal from the posteromedial foot in an anterolateral direction.[2] This type of orientation results in triplanar movement. This means that the first ray simultaneously undergoes dorsiflexion and inversion or plantarflexion and eversion.[4] The magnitude of sagittal plane movement of the first ray in a non-weight bearing position has been measured using several different devices and has been shown to average approximately 6 mm, with a range of between 3 and 9 mm in young adults without pathology.[5-8]

During normal walking, the weight of the body passes through the foot starting from the heel and progresses forward along the lateral aspect of the foot. As the heel begins to rise from the supporting surface, body weight moves medial toward the first metatarsal in preparation of the foot leaving the ground. In response to this weight-bearing force, the first ray will dorsiflex. If there is a disruption in this normal movement, either hypomobility or hypermobility, the ability of the first ray to adequately stabilize the medial longitudinal arch can be compromised. Ultimately, this pathologic entity may cause trauma to the head of the first metatarsal as well as other areas of the forefoot.

The published literature indicates that the presence of hypomobility of the first ray results in high plantar pressures beneath the first metatarsal head.[5] This high pressure is particularly serious in individuals who have lost protective sensation because of the risk for development of neurotrophic ulcers at the site of high pressure. There is risk of amputation if the ulcer becomes infected with or without involvement of the underlying bony structures. In addition, hypomobility of the first ray compromises the ability of the medial longitudinal arch to attenuate the shock of impact during weight acceptance by the lower limb.[3] It is theorized that hypomobility can also limit the amount of overall motion of the foot during walking, thus leading to painful callus formation as well as a variety of mechanical overuse syndromes of the foot and lower extremity.[9] With the exception of excess plantar pressures in individuals with peripheral neuropathy, much of these proposed results of first ray hypomobility have not been documented using well-designed and adequately controlled research.

Conversely, hypermobility of the first ray leads to different biomechanical problems. It has been hypothesized in the literature that during gait because of excess dorsal motion of the first ray the medial longitudinal arch collapses. This collapse decreases the ability of the foot to effectively propel the body forward during walking.[10] The increased dorsal excursion of the first ray causes the foot to pronate and the lesser metatarsals must support an abnormal proportion of the person's body weight (lesser metatarsal overload). The resulting increased magnitude and duration of pronation significantly diminishes the ability of the peroneus longus muscle to stabilize the first metatarsal. As a result, ligamentous tissues that normally limit end-range dorsiflexion movement of the first metatarsal are overly stressed and joint laxity occurs.[3] Because of these mechanical consequences, hypermobility of

the first ray has been implicated in numerous conditions that are frequently accompanied by excessive or prolonged foot pronation. These conditions include, but are not limited to, acquired flatfoot, posterior tibialis tendonitis/posterior tibial tendon dysfunction, functional hallux limitus, lesser metatarsal overload leading to metatarsalgia (submetatarsal bursitis/plantar plate disruption) with eventual hammertoe formation, plantar fasciitis, and shin splints.[3] In addition, medial divergence and rotation of the first ray accompanies this excessive elevation (dorsiflexion). Theoretically, this malalignment position is compensated for by a valgus deformity of the hallux, termed hallux abductovalgus.[3,11-13] As such, hypermobility of the first ray is considered a causal factor in the development of bunions.

The evaluation and treatment of individuals with a variety of foot problems is frequently a challenge to clinicians. This challenge is made even more difficult because of clinical assessment tools with questionable or even unknown reliability and validity. Clinical assessment of first ray dorsal motion is performed subjectively by using one hand to stabilize the lateral four metatarsal heads while the examiner's other hand applies a dorsal displacement force to the head of the first metatarsal.[14-16] The patient's degree of mobility is then classified as being normal, hypomobile, or hypermobile. Although this method of assessment is common, its reliability and validity has not yet been established. The purpose of this study was to determine the between-rater reliability as well as the validity of clinical assessment of first ray dorsal mobility.

METHODS

Subjects

Thirty-eight individuals (16 male, 22 female) between the ages of 22 and 54 years (mean ±SD, 29.1 ± 8.4 years) served as subjects for this study. The subjects had a mean ±SD weight of 68.9 ±13.5 kg and a mean ±SD height of 168.9 ± 8.4 cm. None of the subjects had a history of congenital deformity, pain, or traumatic injury to either of their lower extremities at least 6 months before the start of the study. Two clinicians (RATER1 and RATER2) were selected to evaluate each subject's dorsal first ray mobility. Each had extensive experience in the evaluation and treatment of foot and ankle disorders.

Instrumentation and Procedure

A first ray mobility device was used to quantify the amount of dorsal mobility of the first ray in each subject similar to that reported in the literature by Glasoe et al.[6,14] The device stabilized the lateral toes on a platform while the first metatarsal was displaced dorsally by means of an inferior force (Figure 1). The magnitude of dorsal linear displacement was recorded using a linear voltage displacement transducer (LVDT) mounted above the first metatarsal to eliminate error caused by distortion of the plantar fat pad and had a resolution of 0.025 mm.[6] Previous research has shown that a device similar to that used in this study is both reliable and valid.[7]

The height and weight of each subject was obtained and the amount of dorsal first ray mobility was assessed by each clinician using standard evaluation procedures described in the literature.[14,15] This

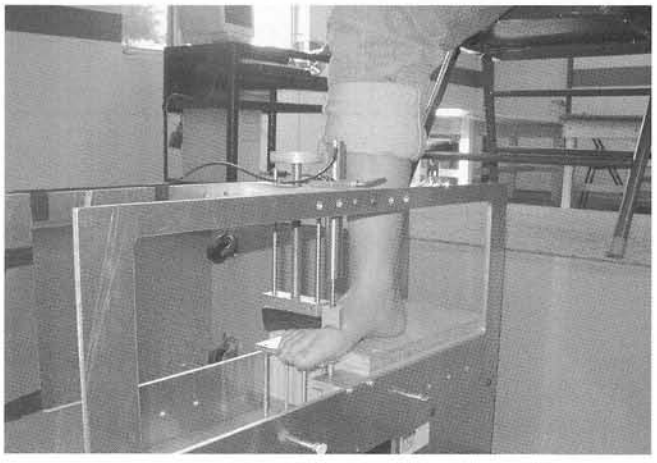

Figure 1. First ray dorsal mobility assessment device used in this study.

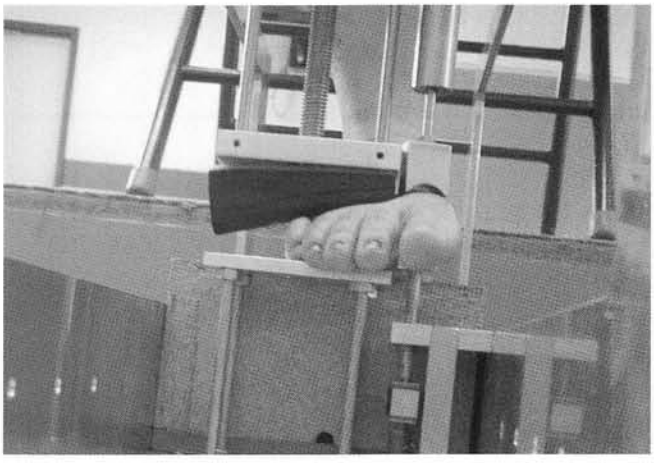

Figure 2. The clinical assessment method used in this study.

procedure involved stabilizing the second metatarsal head and lateral toes with one hand of the examiner and grasping the first metatarsal head between the thumb and first finger of the other hand. A dorsal force through the first metatarsal was then applied and the amount of displacement of the first metatatarsal relative to the second metatarsal head was assessed (Figure 2). After applying the dorsal force, each clinician then classified the magnitude of first ray dorsal mobility as "normal," "hypomobile," or "hypermobile". The operational definition used for this classification was as follows. "Normal" mobility existed when a dorsiflexion force applied to the first metatarsal head brought the inferior aspect of the first metatarsal level with the plane of the lesser metatarsals. If the inferior aspect of the first metatarsal did not reach the plane of the lesser metatarsals, the first ray was judged "hypomobile." On the other hand, if the inferior aspect of the first metatarsal head rose above the plane of the lesser metatarsals, the first ray was judged "hypermobile."[14,15] Alternatively, if the first metatarsal head moved greater than one full thumb breadth (dorsal to plantar) the first ray was classified as being "hypermobile."[15]

Quantification of first ray dorsal mobility was measured by placing the foot in a specially designed frame, which stabilized the lateral toes while applying a vertical force to the plantar aspect of the first metatarsal head. This device has been shown in the literature to be safe, reliable, and valid.[7] The procedure used to measure first ray dorsal mobility in each subject was similar to that utilized by Glasoe et al.[16] This procedure involved recording the amount of linear displacement after first applying a dorsal force of 15N followed by recording the amount of displacement with a force of 55N.[6,7] The difference in the two linear displacements was then calculated and normalized to the subject's foot length (heel to first metatarsal head). The displacement from each of three trials were recorded and then averaged. The calculated mean value was used in later analysis. In order to compare the subjective classification of first ray mobility by the two clinicians to the information obtained by the quantification method, values greater or less than 1.5 standard deviations from the mean of all feet were classified as "hypermobile" or "hypomobile" respectively.

In addition to descriptive statistics, between-rater reliability and the validity of clinical measurement of each rater compared to the quantitative first ray mobility device (DEVICE) was determined using the κ coefficient.[17] Before comparing each clinician's mobility classification to that of the quantitative device, between-trial reliability of the device was determined using the type (2, k) intraclass correlation coefficient (ICC).[18,19] An α level of 0.05 was used for all tests of statistical significance.

RESULTS

Between-Rater Reliability

Table 1 shows the frequency of feet classified as having a hypomobile, normal, or hypermobile first ray by each of the two clinical raters. The result of the κ analysis showed that there was only a 48.7% agreement between the two raters (κ = 0.103). Chance agreement was calculated to be 42.8%. Table 2 contains a 3 x 3 contingency table showing the differences in classification between the two clinicians. As can be seen, RATER1 and RATER2 agreed only twice on whether a particular first ray was hypomobile. Conversely, the two raters agreed eight times on the presence of hypermobility. The greatest discrepancy was whether a first ray should be classified as "normal." RATER1 thought 26 of the feet to be "normal," while RATER2 considered them

Table 1

Frequency distribution of first ray dorsal mobility classification by RATER1, RATER2 and DEVICE.

	RATER1	RATER2	DEVICE
Hypomobile	**8**	**6**	**6**
Normal	**56**	**36**	**67**
Hypermobile	**12**	**34**	**3**

Table 2

A 3 X 3 contingency table showing the differences in classification between RATER1 and RATER2.

	RATER1		
	Hypomobile	Normal	Hypermobile
RATER2			
Hypomobile	**2**	**3**	**1**
Normal	**6**	**27**	**3**
Hypermobile	**0**	**26**	**8**

to be hypermobile.

Validity of Clinical Assessment

The mean ± SD first ray dorsal mobility normalized to the subject's foot length was found to be 3.58 ± 0.94 percent. This corresponds to a mean (±SD) linear displacement of 6.51 ± 1.66 mm. Using a criteria of ±1.5 standard deviations from the mean, a "hypomobile" first ray was assigned to all feet with displacement values less than or equal to 2.17% (4.02 mm). A designation of "hypermobility" was assigned to those feet with dorsal displacement greater than or equal to 4.99% (9.00 mm).

Before the classification ratings of each clinician were compared to that of the first ray mobility device, the between-trial reliability of the device was determined, ICC = 0.996. Average between-trial coefficient of variation for the 74 feet was found to be 2.79%. The comparison between each of the clinical raters (RATER1 and RATER2) and the mobility classification based on the quantitative assessment (DEVICE) can also be seen in Table 1. Although the number of feet assigned to each category is close for RATER1 and the first ray device, statistical analysis on the magnitude of agreement between the two methods was poor. There was only a 67.1% agreement between the RATER1 and the DEVICE (κ = 0.021). Chance agreement was estimated to be 66.4%. A more detailed analysis of the two rating methods is found in the Table 3. As can be seen in Table 3, compared to the classification based on quantitative assessment, RATER1 was only able to correctly identify a hypomobile first ray once and was unable to correctly classify any of the hypermobile feet. Furthermore, RATER1 classified two feet as having a hypermobile first ray when in reality they were hypomobile.

The amount of agreement between RATER2 and the DEVICE was found also to be poor. The amount of agreement between the two methods was only 46.1% (κ = 0.034) with chance agreement estimated at 44.1%. Table 4 contains the 3 x 3 contingency table that shows the differences in classification between RATER2 and DEVICE. From Table 4 it can be seen that RATER2 was unable to correctly classify any of the feet later found to be hypomobile with the DEVICE. RATER2 was able to correctly identify each of the three hypermobile first rays, but classified 29 feet as being hypermobile, when in reality they had normal mobility. Finally, Table 5 shows the normalized and absolute magnitude of displacement for each classification category based on the ratings by the two clinicians and the first ray mobility device.

DISCUSSION

The values obtained for the absolute amount of dorsal displacement of the first ray are comparable to that reported in the literature by Birke et al and Glasoe et al,[5,6] but slightly higher than those reported by Klaue et al and another study by Glasoe et al.[7,8] The results of this study indicate that clinicians, even those with significant experience in the evaluation and treatment of foot related problems have extreme difficulty agreeing whether an individual has problems with dorsal mobility of the first ray. Because between-rater reliability of first ray dorsal mobility assessment has not previously been reported in the literature, comparisons of these results cannot be made. These results however are consistent with findings found for other subjective clinical assessments of lower extremity function and posture.[20,21]

In addition to the poor between-rater reliability

Table 3

A 3 X 3 contingency table showing the differences in classification between RATER1 and DEVICE

	RATER1		
	Hypomobile	Normal	Hypermobile
DEVICE			
Hypomobile	**1**	**3**	**2**
Normal	**7**	**50**	**10**
Hypermobile	**0**	**3**	**0**

Table 4

A 3 X 3 contingency table showing the differences in classification between RATER2 and DEVICE

	RATER2		
	Hypomobile	Normal	Hypermobile
DEVICE			
Hypomobile	**0**	**4**	**2**
Normal	**6**	**32**	**29**
Hypermobile	**0**	**0**	**3**

of clinical assessment methods for first ray dorsal mobility, it is clear from the validity portion of this study that clinicians are unable to accurately classify an individual's first ray as being either "hypomobile," "normal," or "hypermobile". The reason for this error in classification is somewhat unclear, especially in the case of RATER2 who classified 46% of the feet as being hypermobile, yet the quantitative data indicated that dorsal mobility of the first ray is normally distributed and therefore highly unlikely that such a large proportion of feet would therefore be considered abnormal (Table 1). It is clear from the results of this study that current clinical methods of assessing first ray dorsal mobility needs to be re-examined as well as the clinical decisions that are often made as a result of such tests.

CONCLUSION

Despite the widespread use of clinical assessment of first ray dorsal mobility and the implications of clinical decisions based on a finding of abnormal motion, no studies have been conducted that have investigated the reliability or validity of such measurements. The purpose of this study was to investigate whether the commonly used method of clinical assessment and classification of first ray dorsal mobility can be reliably determined between two different clinicians with significant experience in the evaluation and treatment of foot-related disorders. The results of this study clearly indicate that there are serious problems with the current clinical measurement of first ray dorsal mobility and that there is no association between the clinically derived classification and classification based on extreme values from quantitative assessment. The use as well as the credence and importance placed on these clinical measurements for the determination of and basis for treating foot-related pathology needs to be reconsidered. Fortunately, clinical experience and anecdotal results allow the podiatrist to effectively treat a myriad of pedal disorders through their own "feel" of first ray mobility.

Table 5

Normalized and absolute dorsal displacement of the first ray based on 3 different methods of subject classification. Values in parentheses are standard deviations

	Hypomobile	Normal	Hypermobile
Normalized Values (% Foot Length)			
RATER1	3.49 (0.75) n=8	3.66 (0.96) n=56	3.31 (0.96) n=12
RATER2	3.76 (0.37) n=6	3.53 (0.85) n=36	3.61 (1.10) n=34
DEVICE	1.85 (0.47) n=6	3.64 (0.67) n=67	5.84 (0.98) n=3
Absolute Values (mm)			
RATER1	5.99 (1.38) n=8	6.69 (1.67) n=56	6.03 (1.72) n=12
RATER2	7.08 (0.66) n=6	6.46 (1.60) n=36	6.46 (1.84) n=34
DEVICE	3.38 (0.82) n=6	6.62 (1.21) n=67	10.20 (1.57) n=3

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