Electromechanical Measurement of First Ray Mobility: Reliability and Utility

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INTRODUCTION:

Excessive or insufficient First Ray Mobility (FRM) within the foot has been associated with painful and disabling pathologies including: tarsometatarsal OA[1,7], Hallux Valgus (HV),[1–3,8,] Hallux Rigidus (HR)[1,4,5,6,7], hallux limitus, metatarsalgia[9], lesser metatarsal head stress fractures, diabetic foot ulceration[10,11], pes cavus[1], plantar fasciitis, Morton's 2nd toe, and pes planus[1]. FRM, superior translation of the first metatarsal in response to a 50N dorsal load, is an important factor for medial forefoot loading, pathomechanics, and treatment planning. FRM has informed surgical and non-surgical treatments. To this end, reliable measures of FRM are important for clinical outcome.[12-18] However, there are no commercially available tools to measure FRM with high inter-rater reliability. Version 1 of the First Ray Mobility and Position device (MAP1stV1), the predecessor to MAP1stV2, was heavier, based upon mechanical graticules, and exhibited only moderate inter-rater reliability (ICC=0.58).[17] We developed Version 2 (MAP1st V2) to better solve this unmet need. As an individual with 1st ray hypermobility walks the first metatarsal phalangeal (MTP) joint elevates superiorly unloading the 1st metatarsal head while overloading the 2nd metatarsal head. The hallux may increase plantar loading by tightening the medial band of the plantar fascia as per the Windlass mechanism during 1st MTP joint dorsiflexion and FRM. It appears that foot pathomechanics is at least associated, if not related, to an individual's FRM and foot type. Two hypotheses have been formulated: (H1) MAP1stV2 will demonstrate intra-rater and inter-rater reliability (ICC(2,1)>0.75 and (H2) the ratio of 1st to 2nd metatarsal head loading will be negatively related to FRM ($p<0.05$).

METHODS:

The current study includes 32 asymptomatic subjects (64 feet). The cohort is comprised of 10 bilateral rectus, 15 bilateral planus, and several mixed foot type subjects. Foot type was determined for each individual by the arch height index (AHI).[19] MAP1stV2 encompasses two units (right and left) for measuring FRM sitting or standing. Two raters with 30+ years-experience measuring foot and ankle alignment, arch height, and range of motion were included in this protocol to determine intra and inter-rater reliability. The reliability analysis (H1) was performed for each foot separately using an ICC(2,1) two way random analysis with absolute agreement. A linear regression (H2) examined the relationship between FRM and the ratio of 1st and 2nd metatarsal head (MH1/MH2) loading as measured by a Novel emed-X plantar pressure measuring device while ambulating at comfortable walking speed. All statistical analyses were performed with SPSS (IBM, Ver 28.01).

RESULTS:

The mean intra-rater (ICC=0.86) and inter-rater (ICC=0.85) reliability values supported MAP1stV2 being a reliable device for measuring FRM. As shown in Figure 1, the ratio of 1st to 2nd metatarsal head loading was negatively related to FRM. MAP1stV1 achieved an inter-rater ICC of 0.58. A ruler-based device demonstrated an inter-rater ICC of 0.06.[17] We may conclude that the design improvements to MAP1stV2 provide good to excellent reliability for measuring FRM which is a substantial improvement on the previous version (MAP1stV1). The ratio of 1st to 2nd metatarsal head loading was negatively related to FRM suggesting that the larger the FRM, the smaller the MH1/MH2 pressure or force ratio. An increase in FRM results in a decrease in 1st MH loading and an increase in 2nd MH loading.

DISCUSSION AND CONCLUSION:

MAP1stV2 has demonstrated reliability for replicated measurements of FRM within and between raters. Increasing levels of FRM drives decreasing MH1 and increasing MH2 plantar loading. FRM has demonstrated utility in distinguishing how the medial forefoot is loaded. This technology will be used in subsequent studies to examine pedal disease and treatment mechanisms in the context of first ray mobility. The MAP1stV2 system is fully automated, easy to use, efficient, light weight and portable based upon clinician feedback.

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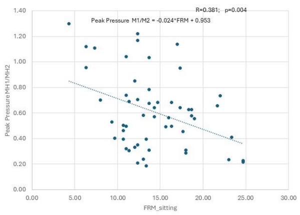

Figure 1: Peak Pressure MH1/MH2 vs. FRM
where MH1 = Metatarsal Head 1 and MH2 = Metatarsal Head 2

Table I: First Ray Mobility Reliability ICC (95%CI)

Sitting Left				
Rater 1 - Intra-rater Reliability		Rater 2 - Intra-rater Reliability		Inter-rater Reliability
Test-Retest	Remove-replace	Test-Retest	Remove-replace	Rater 1 - Rater 2
0.95 (0.91-0.98)	0.85 (0.71-0.93)	0.68 (0.47-0.83)	0.93 (0.85-0.96)	0.85 (0.71-0.92)
Sitting Right				
Rater 1 - Intra-rater Reliability		Rater 2 - Intra-rater Reliability		Inter-rater Reliability
Test-Retest	Remove-replace	Test-Retest	Remove-replace	Rater 1 - Rater 2
0.90 (0.81-0.95)	0.89 (0.78-0.95)	0.80 (0.63-0.90)	0.89 (0.79-0.95)	0.85 (0.71-0.92)
Mean Intra-rater Reliability ICC(2,1) = 0.86				
Mean Inter-rater Reliability ICC(2,1) = 0.85				