

# DES MOINES UNIVERSITY FOOT MODEL: RELIABILITY AND CASE REPORT

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## INTRODUCTION

Currently, foot and ankle surgeons assess deformity, plan surgical procedures and determine outcomes solely on radiographic images and clinical evaluations. While these procedures have been proven useful over the years they provide limited data in terms of functional/quantitative characteristics of the foot during dynamic tasks such as gait. Considering that pes cavus, planus, and hallux valgus and limitus are some of the more prevalent pathologies, considerable interest has been developed in a multi-segment foot model.<sup>1-5</sup> The objective of this study was to develop and test the reliability of a lower leg/foot model for mid/fore-foot functional assessment during clinical gait analysis. The efficacy of the model in foot deformity and surgery outcome evaluation was assessed.

## METHODS AND PROCEDURES

A six segment model of the leg below the knee (tibia, hindfoot, midfoot, lateral forefoot, medial forefoot, and hallux) was developed in MATLAB and was used to assess foot

function in bilateral stance and gait. 26 skin mounted markers were placed on each lower leg, of 5 healthy volunteers (10 feet) and a single hallux valgus patient (pre-operative on the right and 6 months post bunionectomy on the left). The 3D positions of the markers were captured by an 8-camera system motion capture system (EVaRT, Motion Analysis Ltd.) @ 120 Hz on 2 separate days, 2 sessions per day. A total of 10 trials (5R & 5L) were recorded at each session: 3 out of 5 trials per foot were analyzed for a total of 120 trials. The reliability between trials, sessions, days, and examiners in terms of consistency (RMSE, Root Mean Square Error) and waveform reproducibility error (VR, Variability Ratio) of the medial longitudinal (MLA) and the 1<sup>st</sup> metatarsophalangeal (MTP) projection angles on the foot midsagittal plane was assessed.

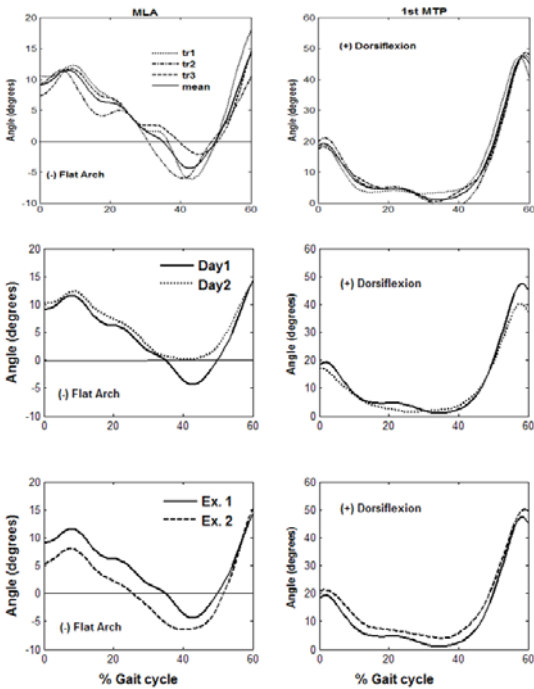
## RESULTS / DISCUSSION

Both of the clinical measures assessed here were consistent and reproducible across 10 feet (Figure 1). The average error for both

**Table 1:** The means and standard deviations of the RMSE (°) and the VR (%) for Medial Longitudinal Angle (MLA), and 1<sup>st</sup> MetaTarso-Phalangeal joint angle (1<sup>st</sup> MTP)

	Between Trials (B_Tr)	Between Sessions B_S	Between Days B_D	Between Examiners B_E
<b>RMSE values</b>				
MLA	<b>1.34</b> (± 0.23)	<b>1.36</b> (± 0.78)	<b>1.09</b> (± 0.32)	<b>1.47</b> (± 0.23)
1 <sup>st</sup> MTP	<b>1.45</b> (± 0.31)	<b>1.46</b> (± 0.70)	<b>1.12</b> (± 0.25)	<b>1.62</b> (± 0.36)
<b>VR values</b>				
MLA	<b>15.0 %</b> (± 6.2)	<b>16.4 %</b> (± 9.8)	<b>10.6 %</b> (± 4.4)	<b>21.9 %</b> (± 12.1)
1 <sup>st</sup> MTP	<b>5.7 %</b> (± 2.3)	<b>7.2 %</b> (± 8.9)	<b>2.2 %</b> (± 1.1)	<b>4.1 %</b> (± 2.0)

clinical measures was small ranging between  $1.09^{\circ}$  to  $1.47^{\circ}$  for the MLA and between  $1.12^{\circ}$  and  $1.62^{\circ}$  for the 1st MTP (Table 1). Considering the  $23.4^{\circ}$  average deformation angle range of the MLA (for all 10 feet) the MLA RMSE value of  $1.47^{\circ}$  reflects 6.3% error. The waveform reproducibility of the MLA ranged between 10.6% and 21.9%. The percent error for the 1st MTP joint angle was 3.5% based on the average dorsiflexion angle range of  $48.4^{\circ}$ . The 1st MTP waveform reproducibility was excellent ranging between 2.2% and 7.2%. The worst reproducibility values were found between examiners for the MLA which is potentially due to small variation in marker placement.<sup>4</sup>

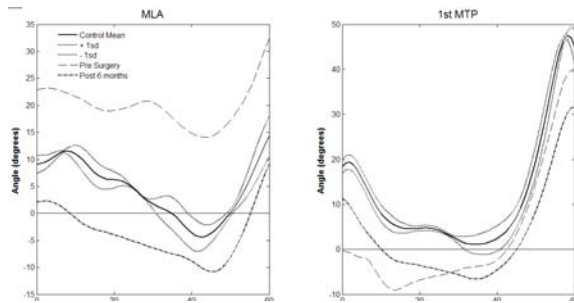


**Figure 1.** MLA change and 1st MTP angle during stance in gait. **Top** – Single session 3 trials and the mean. **Middle** – Between days comparison (3 trial) average waveforms. **Bottom** – Between examiners comparison.

### CASE STUDY

The pre surgical data for the MLA indicate limited mobility for the 0-50% of the gait cycle in the pes planus direction. The MLA remains in a relative pes cavus position during the entire stance phase of the gait cycle. The

post surgical MLA data indicate marked changes and while there is some residual rigidity (observed clinically); the MLA waveform presents remarkable similarity to control. The 1st MTP function during gait shows marked improvements as well especially over the initial 40% gait cycle. The surgery has restored much of the dorsiflexion range of motion at the 1st MTP and it improved its overall mobility for the entire stance phase of the gait cycle.



**Figure 2.** Time normalized waveforms of the MLA change and the 1st MTP angle. Normative data and hallux abducto-valgus (pre surgery – dash), and post-surgical bunion (post 6 months – dash/dot).

### SUMMARY

The results support the use of the Des Moines University Foot Model to assess foot function during gait. The medial longitudinal angle change (reflecting deformation of the arch) and the 1st metatarsal joint angle (reflecting dorsiflexion of the 1st MTP joint) are both robust and consistent. The shape of the entire waveform of these parameters is highly reproducible and maybe useful for diagnostic purposes of foot function during gait. The model shows potential in planning and assessment of surgery outcome as shown by the single hallux abducto-valgus case.

### REFERENCES

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