

Understanding Foot Structure and Function: The Relationship Between Global Flexibility, Ankle Mobility, First Ray Mobility, Arch Height, and Plantar Pressures During Gait

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INTRODUCTION:

- Abnormal foot structure may influence activity performance under dynamic conditions predisposing individuals to increased injury risk.
- High arch individuals are prone to have ankle, bony, and lateral injuries while low arch individuals are prone to have knee, soft tissue, and medial injuries.¹
- Previous research has hypothesized associations between arch height, first ray mobility, ankle mobility, global flexibility, and plantar pressure.²
- Understanding relationships between structure and function may improve our ability to identify individuals that may be at risk for repetitive stress injuries.

PURPOSE:

The purpose of this study is to determine the following:

- Is arch height associated with ankle and first ray mobility?
- Are ankle mobility and first ray mobility associated with plantar pressures?
- Does global flexibility predict ankle dorsiflexion flexibility and first ray mobility?

These associations may be important in devising strategies that improve the ability to accurately identify problematic structural abnormalities.

METHODS:

Thirty-five healthy, active subjects (26 females and 9 males) ages 19-25. Each subjects' right ankle and foot were tested at the following stations:



Figure 1: Peak pressure, contact area, and pressure-time integral were determined using an EMED plantar pressure system. A 40/60 split of the foot was used for data collection to separate the hindfoot from the midfoot and forefoot.

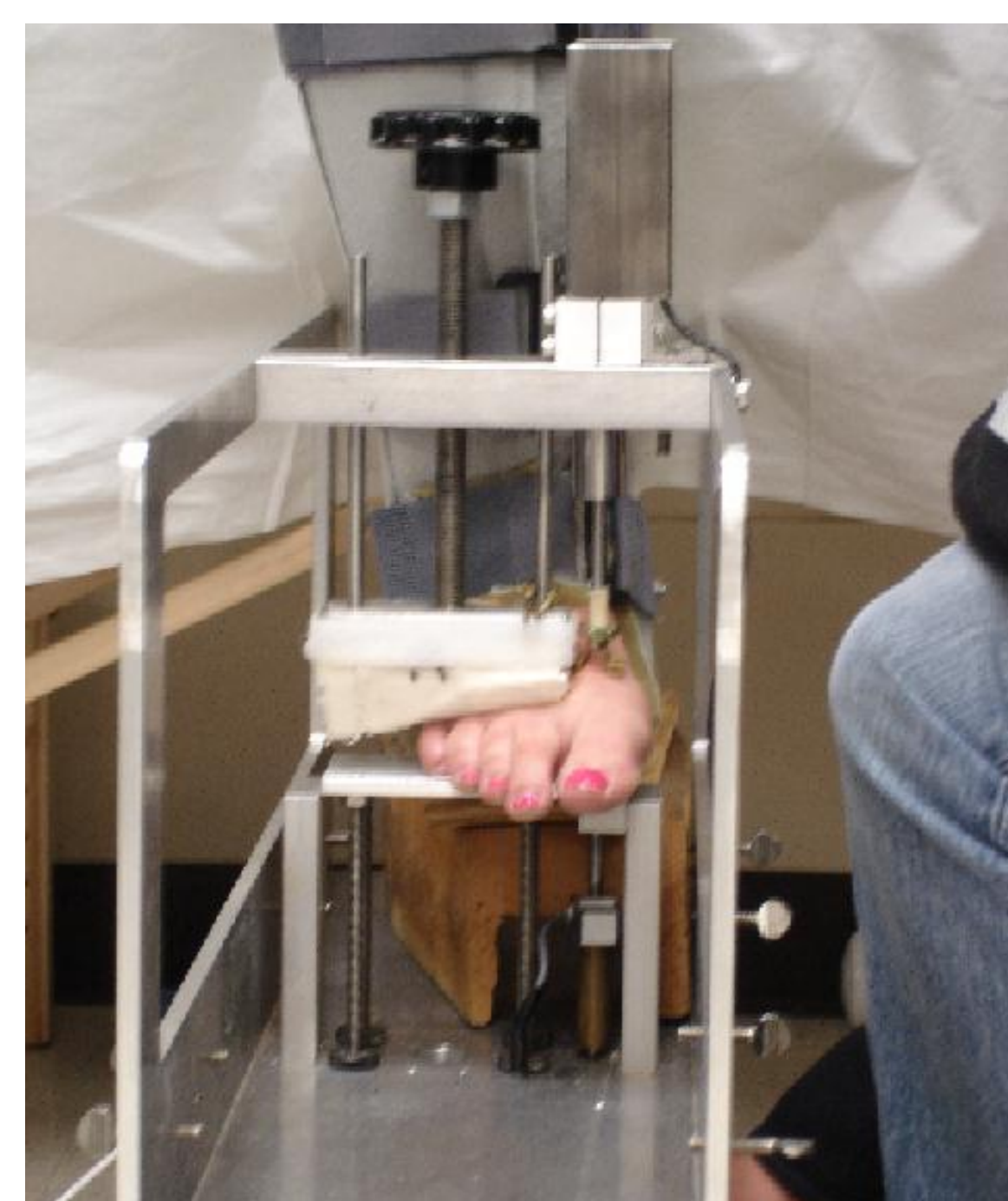


Figure 3: Glasoe measurement device was used to determine peak dorsiflexion of the first metatarsal with 55 N of force. Stiffness was determined using a force range from 10-55 N.



Figure 2: Arch height (N-ratio) was measured using digitized points. N-ratio was determined by dividing the height of the inferior border of the navicular by truncated foot length.



Figure 4: lowa Ankle Range of Motion device was used to measure peak dorsiflexion and ankle stiffness. Torques of 10, 15, 20, and 25 Newton-meters were applied about the ankle joint while a digital inclinometer was used to measure the angle of dorsiflexion.



Figure 5: The Beighton Scale was used to determine global flexibility. Flexibility was determined by assessing hyperextension of the wrists, opposition of the thumbs (shown above), hyperextension of the elbows, hyperextension of the knees, and trunk flexion in standing with knees straight and palms flat on the floor.

Statistical Analysis: Linear associations were assessed using Pearson's product moment correlation, Spearman's rho, and stepwise linear regression.

RESULTS/DISCUSSION:

Associations:	Pearson's r	p-value
Arch height & first ray mobility	-0.47	0.005
Arch height & first ray stiffness	0.54	0.001
Arch height & plantar pressure (total contact area)	-0.42	0.01
Arch height & plantar pressure (forefoot/midfoot contact area)	-0.38	0.02
First ray mobility and plantar pressure (total contact area)	0.42	0.01
First ray mobility and plantar pressure (forefoot/midfoot contact area)	0.45	0.007
First ray stiffness & plantar pressure (total contact area)	-0.37	0.03
First ray stiffness & plantar pressure (forefoot/midfoot contact area)	-0.40	0.02

Table 1: Relationships between foot structure and function ($p < .05$). Results indicate that static measures of arch height and first ray mobility are related. In addition, arch height and first mobility are associated with dynamic foot function measured by plantar contact area.

N Ratio vs Mean 1st Ray Dorsal Mobility

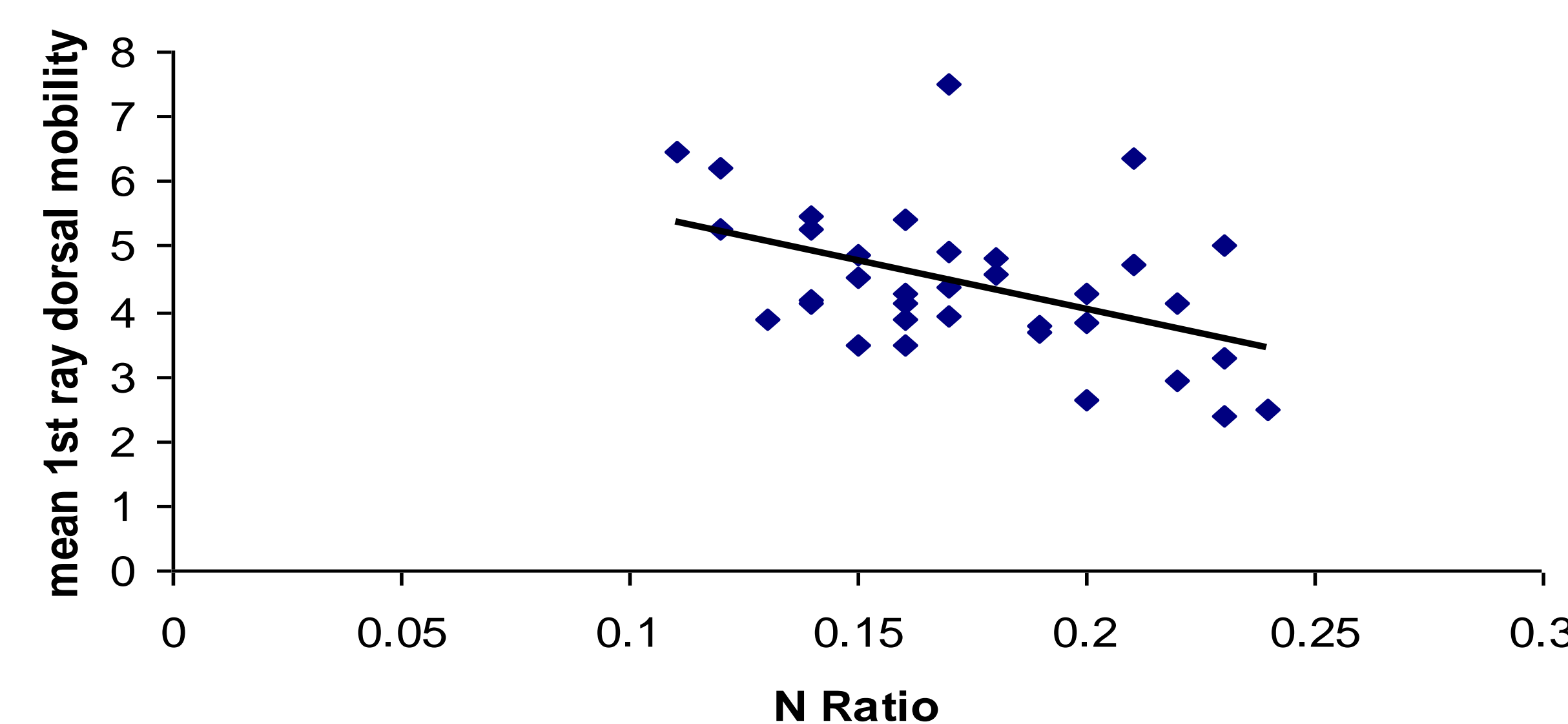


Figure 6: Results demonstrated an inverse relationship between N-ratio (arch height) and first ray dorsal mobility indicating that as arch height increases first ray dorsal mobility decreases.

CASE STUDIES:

The following subjects demonstrated extreme arch heights in addition to foot mobility and loading characteristics commonly thought to represent a typical patient presentation. Our results revealed that this presentation is the exception and not the norm causing us to question the validity of using commonly discussed "typical patient presentations" to understand dynamic foot function.

Subject ID	Arch Height	Rank (out of 35)	1st Ray Mobility	Rank (out of 35)	1st Ray Stiffness	Rank (out of 35)	Midfoot /forefoot Contact Area	Rank (out of 35)
13	0.23	2	2.4 mm	1	16.8 N/mm	1	70.1 cm ² /kg	5
32	0.11	35	6.5 mm	34	6.2 N/mm	34	102.9 cm ² /kg	33

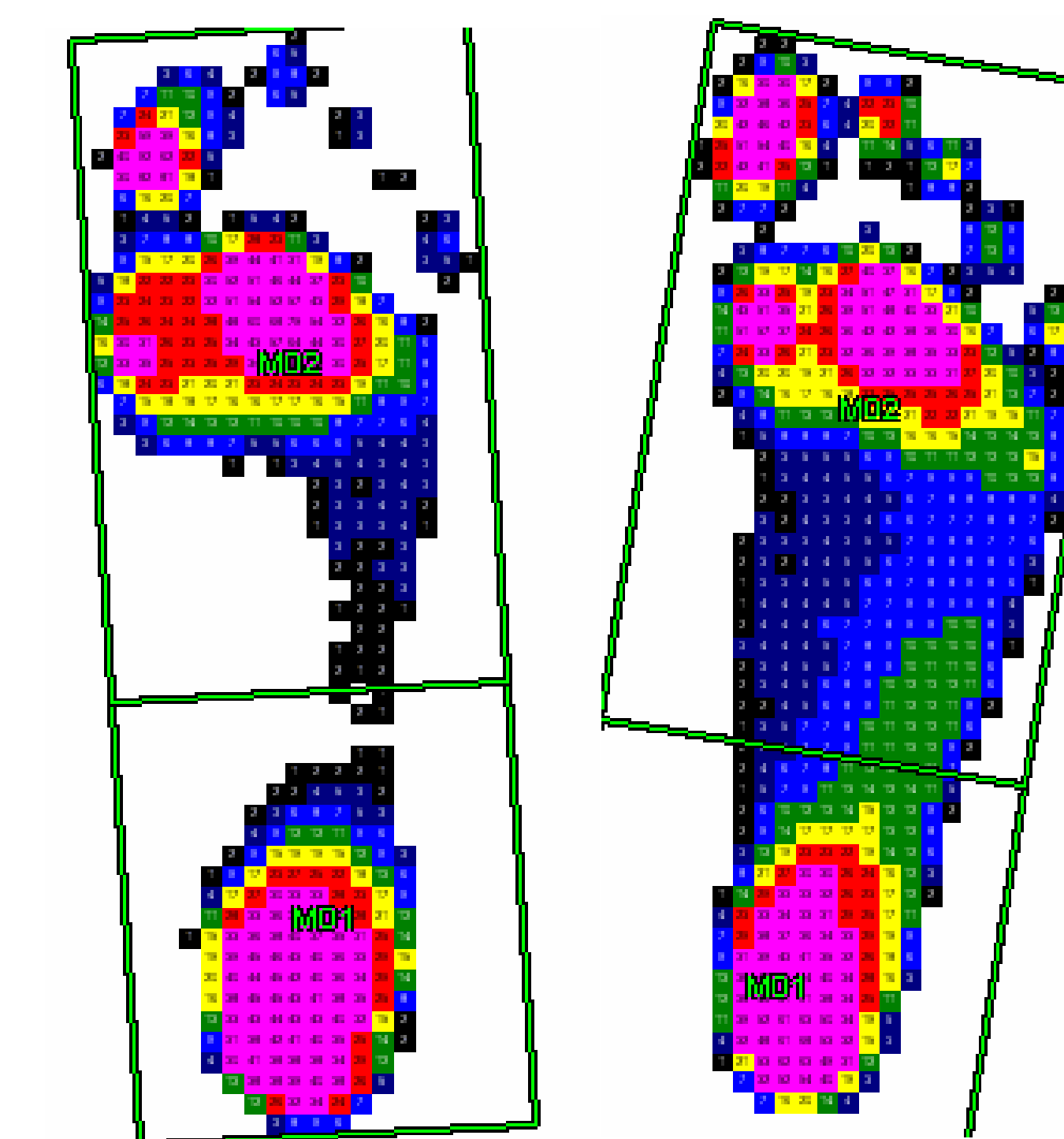


Table 2: Mean values and ranks for arch height, first ray mobility and stiffness, and plantar contact area for two subjects. These subjects demonstrate characteristics commonly discussed within a typical patient presentation. Subject 13 has a high arch, decreased first ray mobility, and low contact areas while the opposite is true for subject 32.

Figure 7: Contact areas for subject 13 (left) and subject 32 (right). Subjects 13 and 32 demonstrate plantar pressure patterns commonly seen in individuals with high and low arches respectively.

CONCLUSIONS:

- Commonly discussed relationships between foot structure and mobility/function thought to represent a typical patient presentation may not be the norm, but rather an exception that occurs in a small percentage of the population.
- Only fair associations were observed within and between the structural and functional variables assessed in this study.
- Arch height and first ray mobility are associated and appear to be variables that can be used to predict plantar contact area.
- Assessment of foot structure to predict foot function may have implications for clinical use, however further research is needed for confident clinical application.

REFERENCES:

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- Morag E; Cavanagh PR. Structural and functional predictors of regional peak pressures under the foot during walking. *Journal of Biomechanics*. 1999;32(4):359-370.