

# Effects of Eccentric Exercises on Foot Structure and Function

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# Disclosure

## **No Conflict of Interest**

Dr. Tom Michaud ([HumanLocomotion.org](http://HumanLocomotion.org)) provided ToePro Foot/Ankle Exercise Platforms for the study

# Learning Objectives

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- Benefits of Foot and Ankle Exercises
- Biomechanical Assessment of Foot Structure and Function
- Potential role of eccentric foot and ankle exercises

# Why Exercise Foot & Ankle Muscles?

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- Muscle atrophy occurs soon after immobilization.
  - MRI study (Grosset J 2008).
  - Stretching may be effective to combat muscle atrophy
- Doming or “short-foot” exercises
  - Increased Activation of intrinsic muscle, T2 MRI (Gooding 2016)
  - Decreased navicular drop (Namsawang 2019)
  - Improved dynamic balance (Lynn 2012)
  - More effective for Chronic Ankle Instability than the proprioceptive sensory exercise (Lee 2019)

# Why Exercise Foot & Ankle Muscles?

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- Flexor hallucis longus is the single best predictor of falls in the elderly (Mickle 2016)
  - Increased in hallucal strength equivalent to 1% of body weight reduced the risk of falls by 7%
- Eccentric foot strengthening (ToePro) exercises
  - Effects on toe strength, foot structure and function?



ToePro is a semi-rigid platform with a 10-degree tilt that stretches the toe flexor muscles and aid in eccentric strengthening exercises of toes



# Hypothesis

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Subjects who complete a 6 week eccentric foot and ankle exercises would demonstrate:

- Change in foot structure: Arch Height Index
- Dynamic Balance: Y-Balance Performance
- Foot Function: Plantar loading in barefoot walking

# Subject Criteria

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## Inclusion:

- Men or women between 18-40 years of age
- Able to perform exercises and walk independently without the use of assistive device

## Exclusion

- History of lower limb or lower back orthopedic surgeries
- Allergies to rubber
- Women who are pregnant or nursing

# Overview of Protocol & Procedures

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- N=25. Repeated Measures Design
  - Temple IRB approved the study protocol
- Visit 1 (Baseline Evaluation)
  - Screen & Enroll Participants
  - Assessment of foot structure and function
- Home Exercises
  - Perform specified exercises 3x/week for 6-weeks
- Visit 2 (Follow up Evaluation)
  - Repeat assessment of foot structure and function



# ToePro Eccentric Exercises

## A. Warm Up (Lower level)

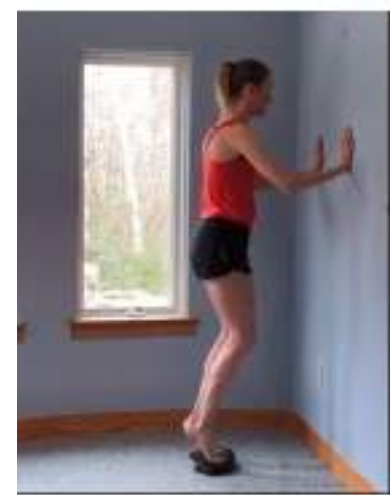
Forward leans, 3 sec x 25

## B. Heel Raises (Upper level)

1. Knees straight x 25
2. Knees Bents x 25

## C. Calf Stretch.

Keep heel 1" off the ground with Knee Flexed for 60 sec



# ToePro Eccentric Exercises

One-legged exercises with knee bent

Alternate D1 and D2 between days

## **D1. Peroneal.**

Lean left side, raise left heel. X 25;  
repeat on Right

## **D2. Posterior Tibialis**

Lean left side, raise right heel. X 25;  
repeat on left



# Subject Characteristics: preliminary

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- 16 (11 female) completed the protocol
- Age: 26.8 yo (23-32)
- BMI: 23.5 kg/m<sup>2</sup> (16.6 – 31.5)
  - Weight: 72.8 kg (47.3 – 106.1)
- Regular exercises:
  - Weight training: 9 participants. 49 min/week (30-90)
  - Aerobic exercises: 12 participants. 38 min/week (5-90)

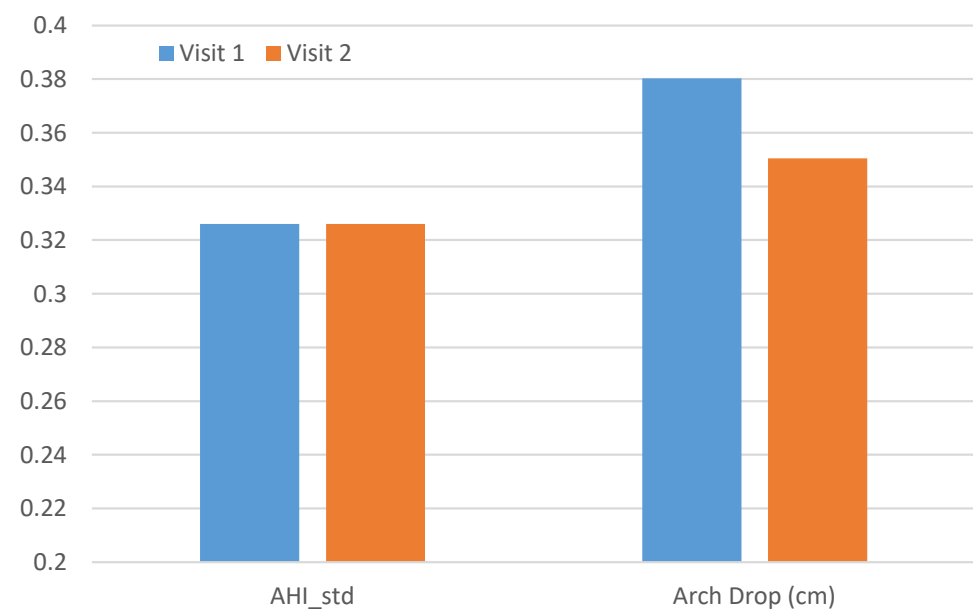
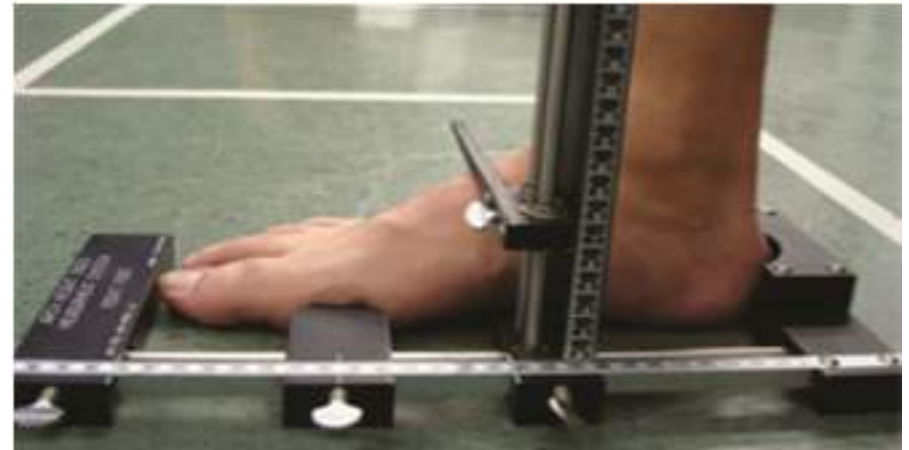
# Statistical Analysis

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- The SPSS, version 24 (IBM, Chicago) was used to perform descriptive statistics and normality testing.
- The **lower limb** was used as the unit of observation instead of the individual.
- A **Generalized Linear Model** with an identity link function was used to test the difference between 2 visits while accounting for potential dependence in bilateral data.
  - The Wald Chi-square was calculated for each dependent variable
  - Statistical significance,  $P < 0.05$ .

# Results: AHI & AHF

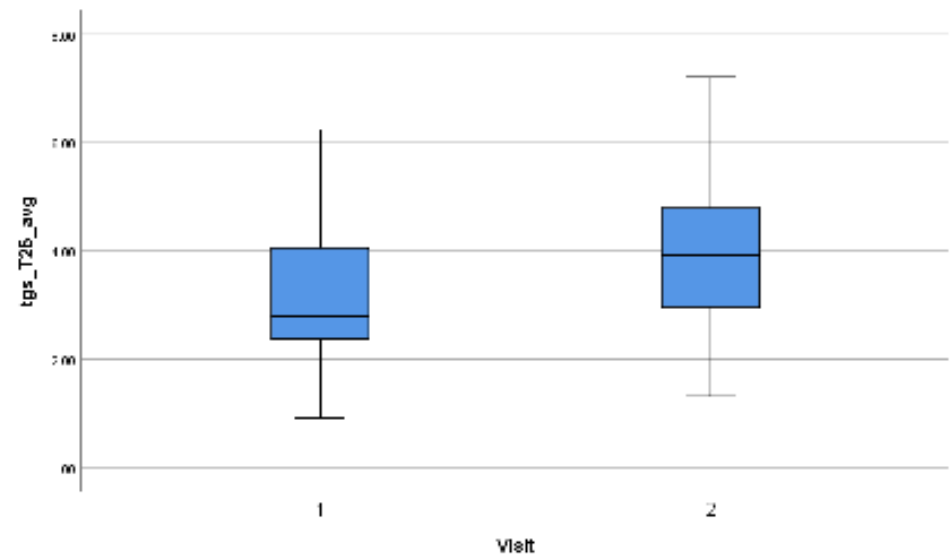
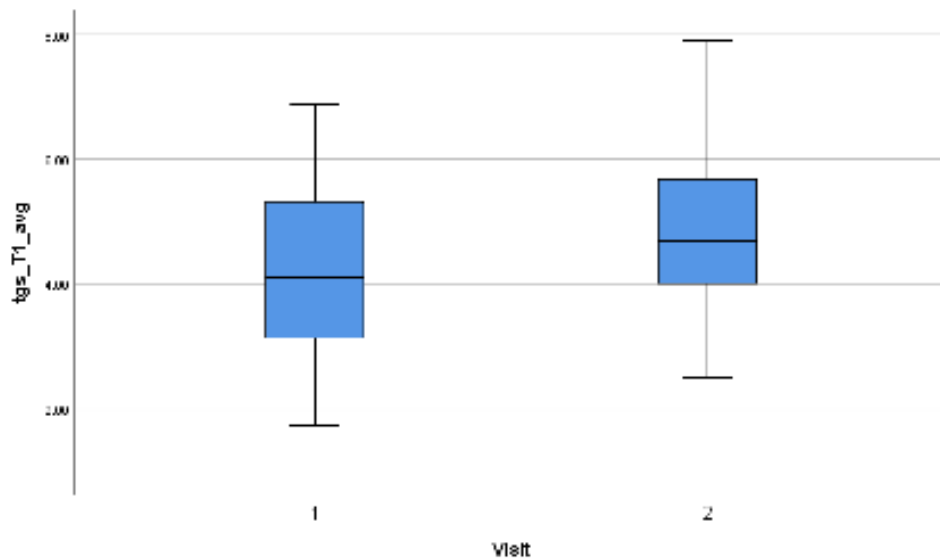
	Visit 1	Visit 2	p-value
AHI, standing	0.326	0.326	0.864
Arch Drop (cm)	0.38	0.35	0.520
AHF (mm/N)	13.9	12.4	0.398
Truncated FL, standing (cm)	25.5	25.6	0.205



# Results: Toe Grip Strength

TGS (kg) †	Visit 1	Visit 2	p-value
Hallux	4.21	4.98	0.002
Toes 2-5	3.18	3.95	0.000

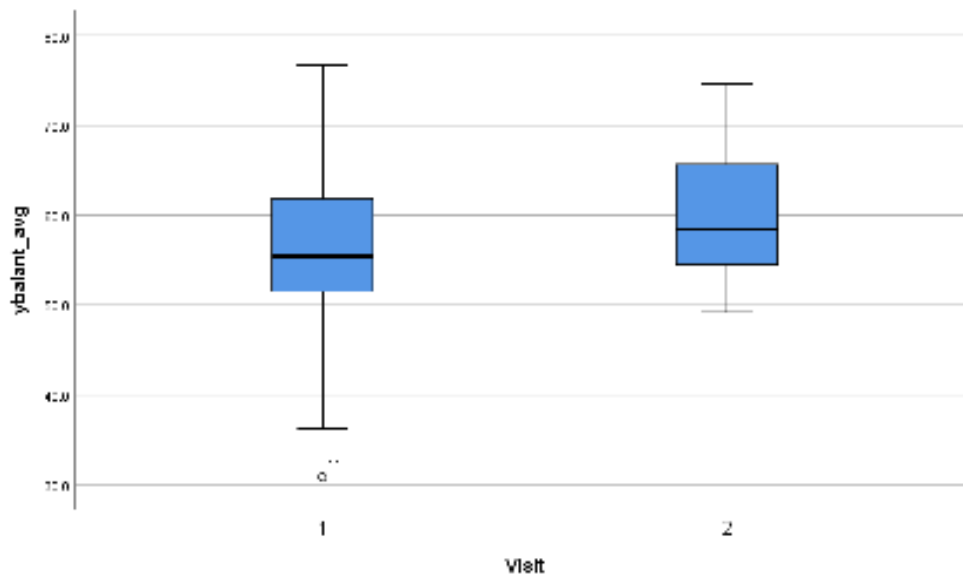
†Note, Average of 3 trials per foot



# Results: Y-Balance™ Test

Y-Balance (cm) †	Pre	Post	p-value
Anterior	56.51	59.38	0.007

†Note, Average of 3 trials per foot



## Y-Balance Test™ (YBT)

- A reliable and sensitive indicator of injury risk in athletes
- Collegiate football players with a composite score below 89% had an increased probability of injury from 37.7% to 68.1% (Butler RJ 2013)

# Results: Plantar Loading

	Visit 1	Visit 2	p-value
Contact time, total (ms)	701.7	705.9	0.490
Peak Pressure, total (N/cm <sup>2</sup> )	63.5	66.7	0.076
Maximum Force, total (N)	805.1	824.3	<b>0.006</b>
Contact Area, total (cm <sup>2</sup> )	124.8	124.3	0.589
CPEI (%)	19.32	19.16	0.793

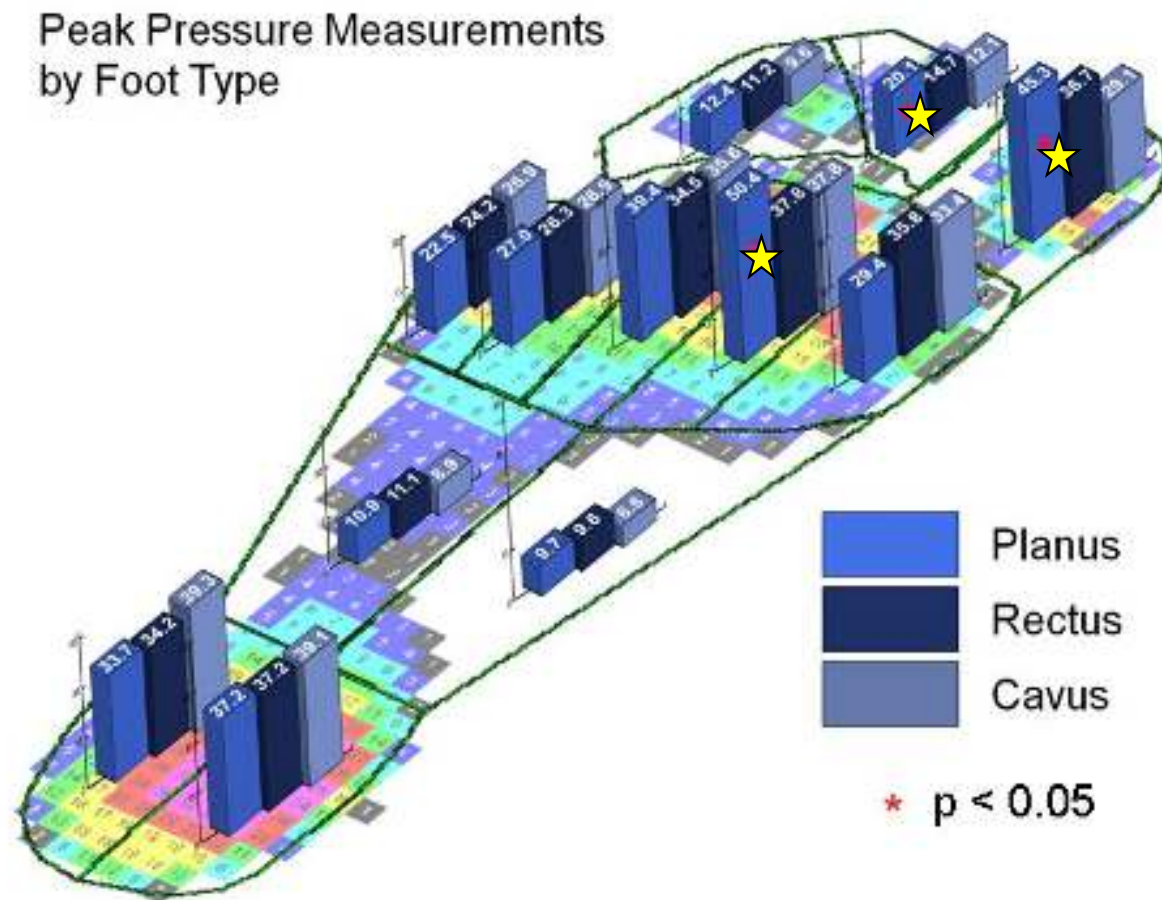


novel emed-X plate, sampling rate of 100 Hz  
Five trials per foot during self-selected  
comfortable pace of barefoot walking



# Results: Peak Pressure (N/cm<sup>2</sup>) at baseline

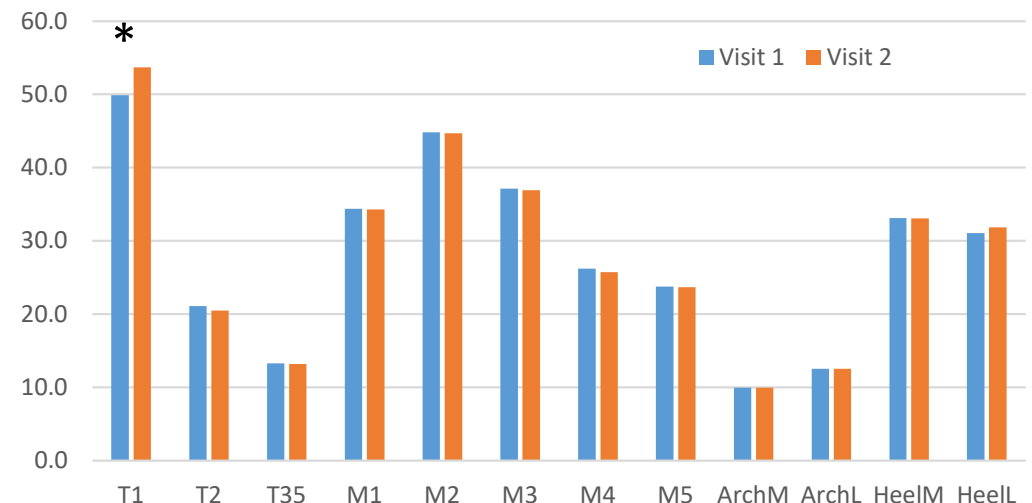
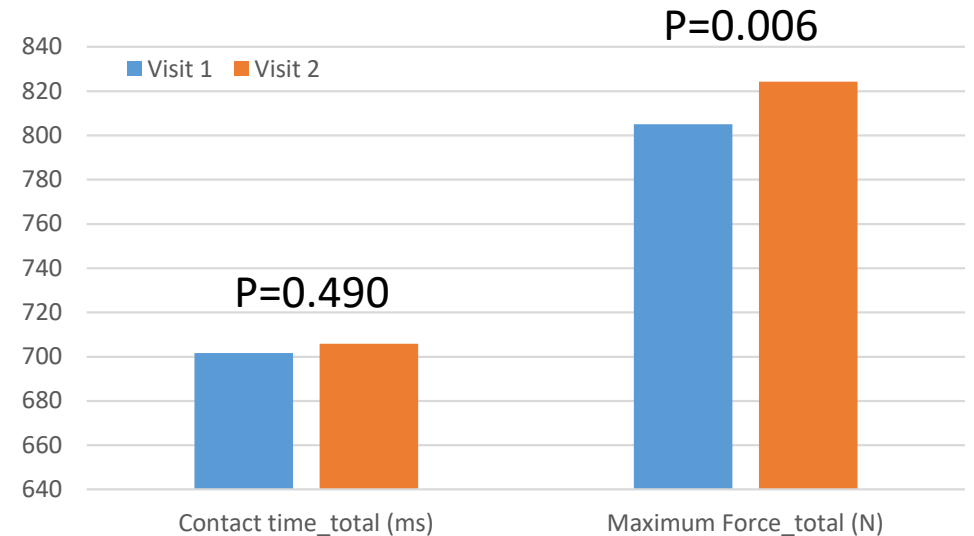
13.3	21.1	49.9		
23.8	26.2	37.1	44.8	34.4
12.6	10.0			
31.1	33.1			



Song et al, 1996; Hillstrom et al 2013

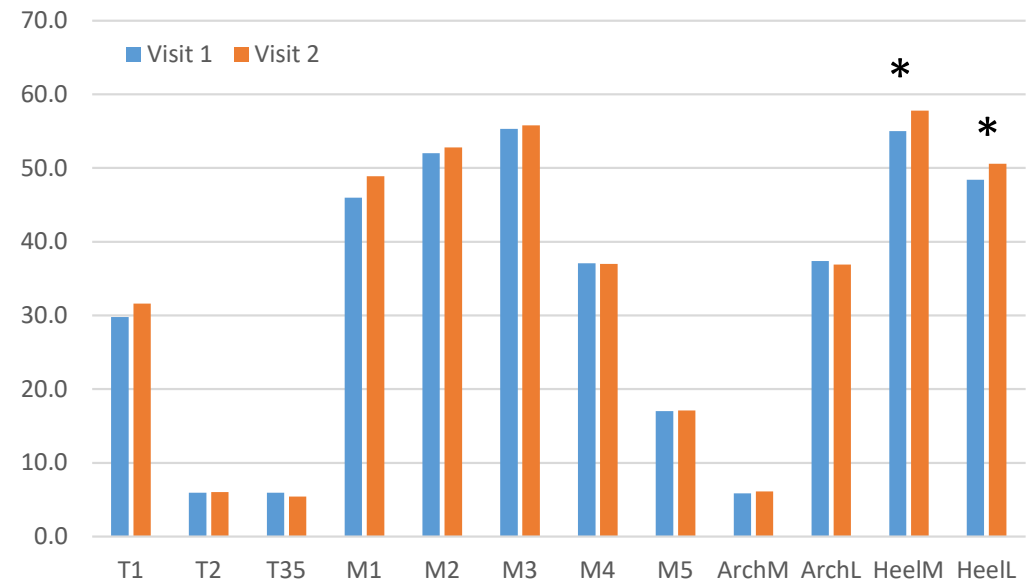
# Results: Plantar Loading ( $\Delta$ PP)

PP (N/cm <sup>2</sup> )	Visit 1	Visit 2	P-value
Hallux	49.9	53.7	0.039
Toe 2	21.1	20.5	0.571
Toes 3-5	13.3	13.2	0.892
Metatarsal 1	34.4	34.3	0.892
Metatarsal 2	44.8	44.7	0.958
Metatarsal 3	37.1	36.9	0.783
Metatarsal 4	26.2	25.7	0.432
Metatarsal 5	23.8	23.7	0.951
Arch, medial	10.0	10.0	0.939
Arch, lateral	12.6	12.6	0.953
Heel, medial	33.1	33.1	0.978
Heel, lateral	31.1	31.8	0.187



# Results: Plantar Loading ( $\Delta$ FTI)

FTI (Ns)	Visit 1	Visit 2	P-value
Hallux	29.8	31.6	0.227
Toe 2	5.9	6.0	0.957
Toes 3-5	5.9	5.4	0.203
Metatarsal 1	46.0	48.9	0.079
Metatarsal 2	52.0	52.8	0.530
Metatarsal 3	55.3	55.8	0.662
Metatarsal 4	37.1	37.0	0.971
Metatarsal 5	17.0	17.1	0.904
Arch, medial	5.8	6.1	0.554
Arch, lateral	37.4	36.9	0.684
Heel, medial	55.0	57.8	<b>0.020</b>
Heel, lateral	48.4	50.6	<b>0.036</b>



Melani T et al. J F and Ankle Research 2013.  
Lower leg muscle strengthening does not  
redistribute plantar load in diabetic  
neuropathy: a RCT

# Strength and Limitations

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- Non-supervised exercises
- No intrinsic strengthening and no gait retraining
- Simple exercises with no adverse effects
- Limited to 6 week intervention.
  - Longer (12 week) intervention?
- Involved healthy asymptomatic participants
- Not examine the effects on falls or sports performance

# Summary

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- Eccentric foot and ankle exercises yielded a significant change in toe grip strength, Y-balance:
  - May be a viable treatment option; need additional studies
  - Reconditioning following off-loading
  - Adjunctive treatment with foot orthoses
  - Chronic Ankle Instability
- No significant change in AHI, AHF, and dynamic barefoot plantar loading