What is the optimal design of a rocker shoe

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The SSHOES Project

Aims of Project: Develop new production capabilities for diabetic feet, specifically for personalisation of footwear.

Consortium: 11 EU partners, including 5 R&D institutions and 6 SMEs

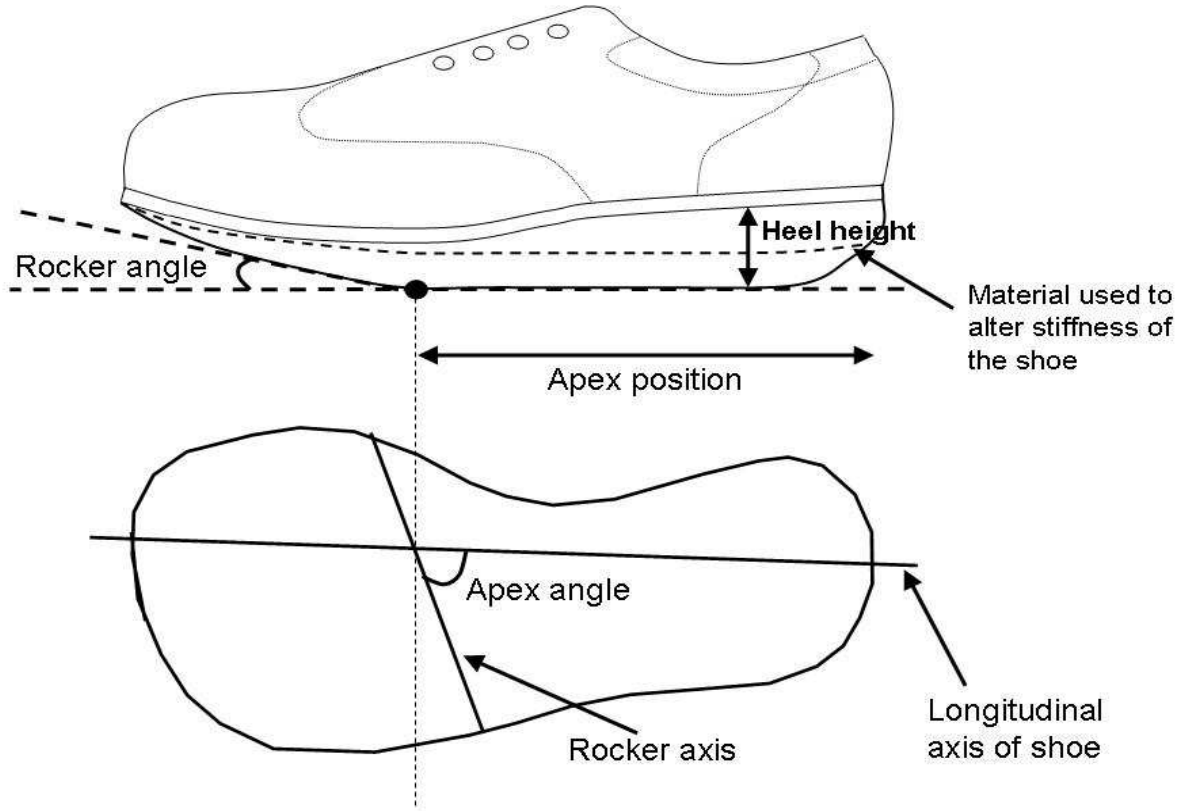
Funding: FP7, €3.5 million

Specific topics addressed include :

- Innovative 3D integrated design tools for footwear personalisation
- Musculoskeletal modelling of the lower limb and feet
- Adaptive production technologies for improved functionality & performance
- Development of innovative high-performing materials
- Development of production processes to achieve eco sustainability

The toe-only curved rocker shoe

- Most effective shoe for minimising pressure
- Has 3 principle design features
- Can be adjusted for optimal performance



1. Apex Position

2. Rocker Angle

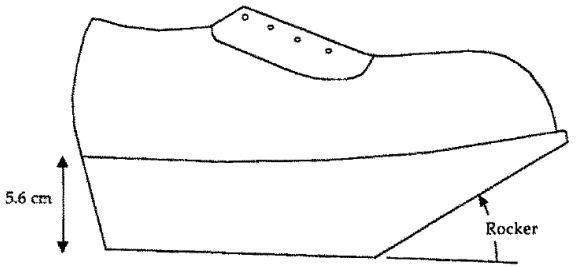
3. Apex Angle

Previous research

- Not one combination has been proven to work on everyone

  van Schie, C., J. S. Ulbrecht, et al. (2000). "Design criteria for rigid rocker shoes." Foot & Ankle International 21(10): 833-844.

- Varied
  - Apex Position
  - Rocker Angle via heel height
- Key finding
  - Need individual apex position for best off loading
  - Increase in rocker angle reduced pressure
  - Suggests need for bespoke footwear
- Limitations
  - Used a traditional rocker shoe
  - Collected data on healthy subjects not diabetic
  - Only evaluated 2 of 3 principle design features



Aims and Methods

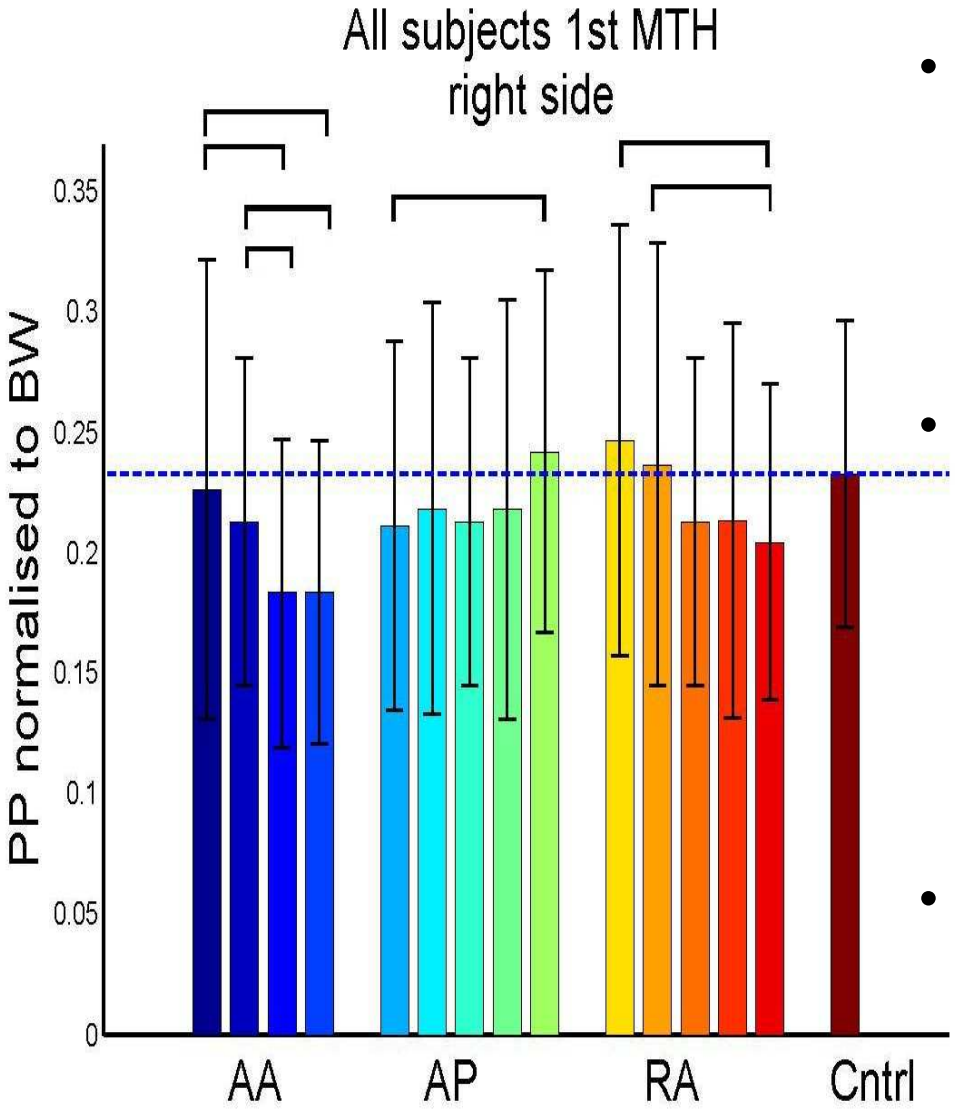
- Aims
  1. Evaluate the mean effect of the 3 principle design features on in-shoe pressure in (30) diabetic and (30) healthy subjects.
  2. Quantify inter subject variability
  3. Establish whether there is any difference in the response of the diabetic and the healthy cohort

- Methods
  - Subjects to walk in the 12 rocker and 1 control shoe over ground at controlled speed 1 ms^{-1} whilst in shoe pressure was recorded.
  - In shoe pressure was recorded using Novel Pedar
  - Footscan used to express design features in an anatomical coordinate system
  - Mean peak pressure under 1st MTH calculated for each shoe using custom software in Matlab

Specifications of footwear

Shoe	Rocker angle (RA)	Apex position (AP)	Apex angle (AA)
1 (control)	(Heel height)	-	-
2 (reference*)	20º (3 cm)	60%	+80º
3 (RA1)	10º (1 cm)	60%	+80º
4 (RA2)	15º (2 cm)	60%	+80º
5 (RA4)	25º (4 cm)	60%	+80º
6 (RA5)	30º (5 cm)	60%	+80º
7(AP1)	20º (3 cm)	50%	+80º
8 (AP2)	20º (3 cm)	55%	+80º
9 (AP4)	20º (3 cm)	65%	+80º
10 (AP5)	20º (3 cm)	70%	+80º
11 (AA1)	20º (3 cm)	60%	70º
12 (AA2)	20º (3 cm)	60%	90º
13 (AA4)	20º (3 cm)	60%	100º

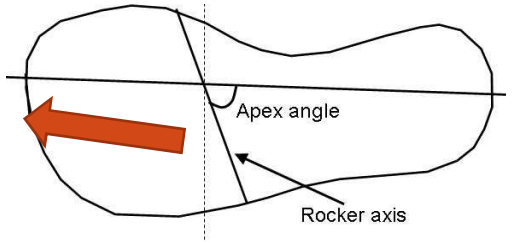
Results – Mean effect of design features



$\alpha = 0.001$ (Bonferroni adjustment)

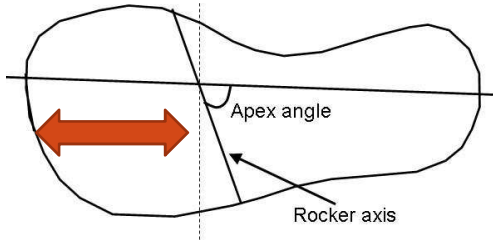
- Observed a decrease in pressure as apex angle increased:

AA



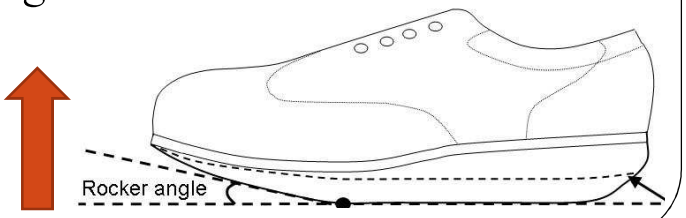
- No consistent change in pressure with change in apex position:

AP



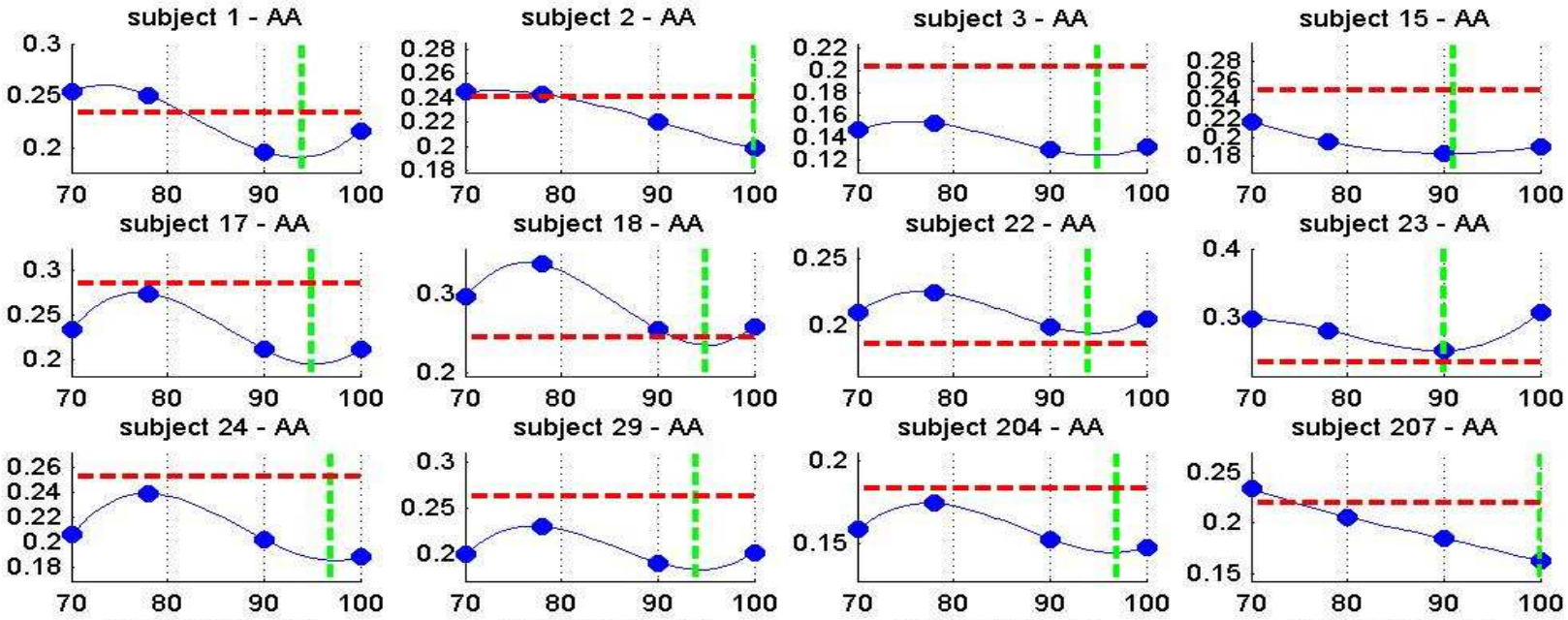
- Observed a decrease in pressure as rocker angle increased :

RA

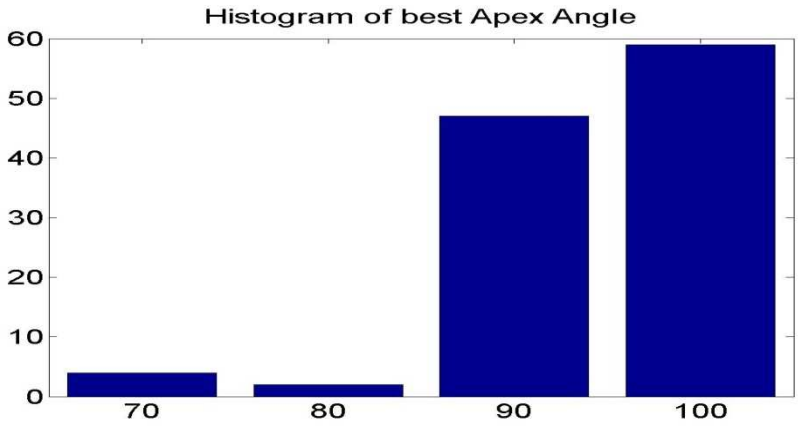


Results - Quantifying inter subject variability

- Individual responses Apex angle in relation to shoe

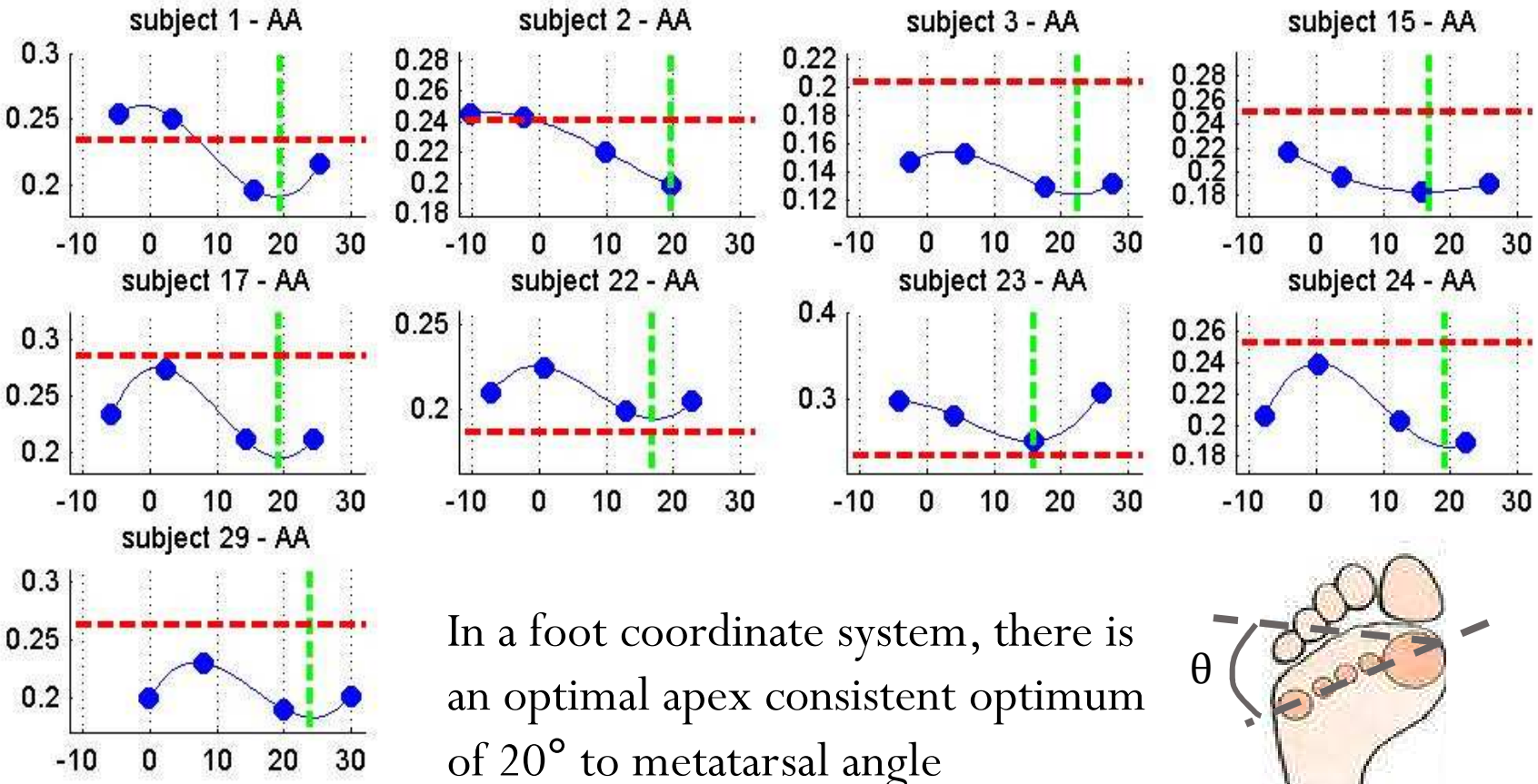


Mean/std	95.00 ±4.8



Results - Quantifying inter subject variability

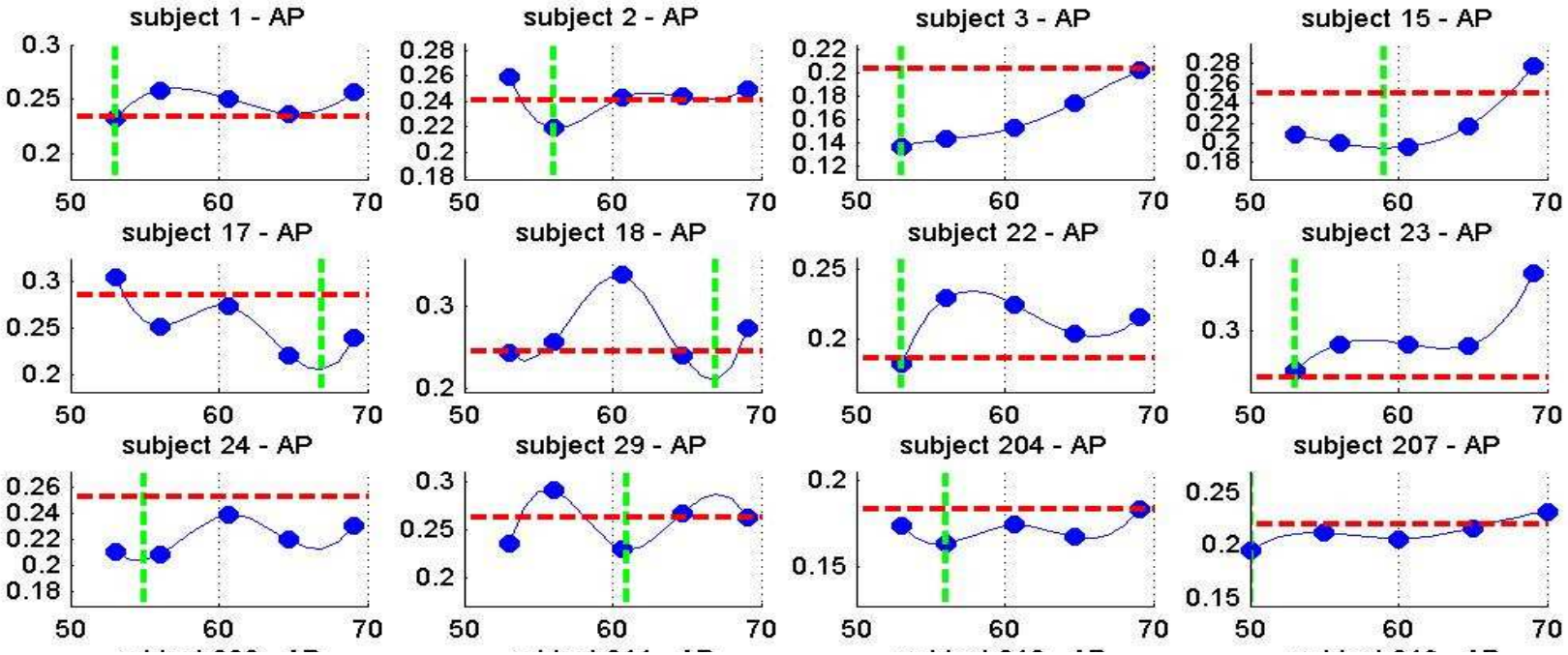
- Individual responses Apex angle



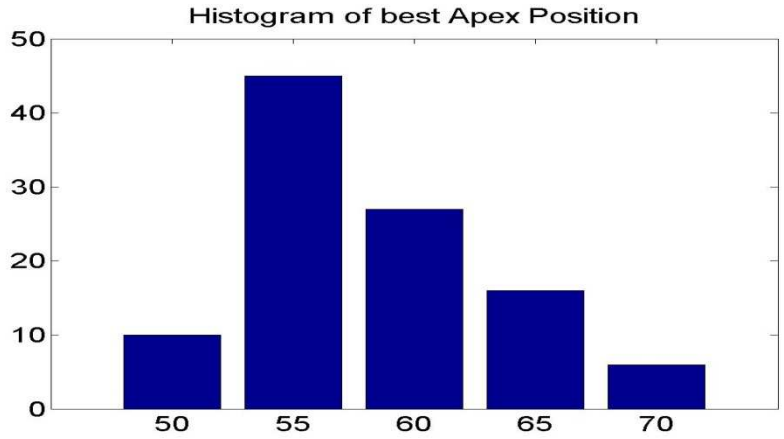
In a foot coordinate system, there is an optimal apex consistent optimum of 20° to metatarsal angle

Results - Quantifying inter-subject variability

- Individual responses Apex position in relation

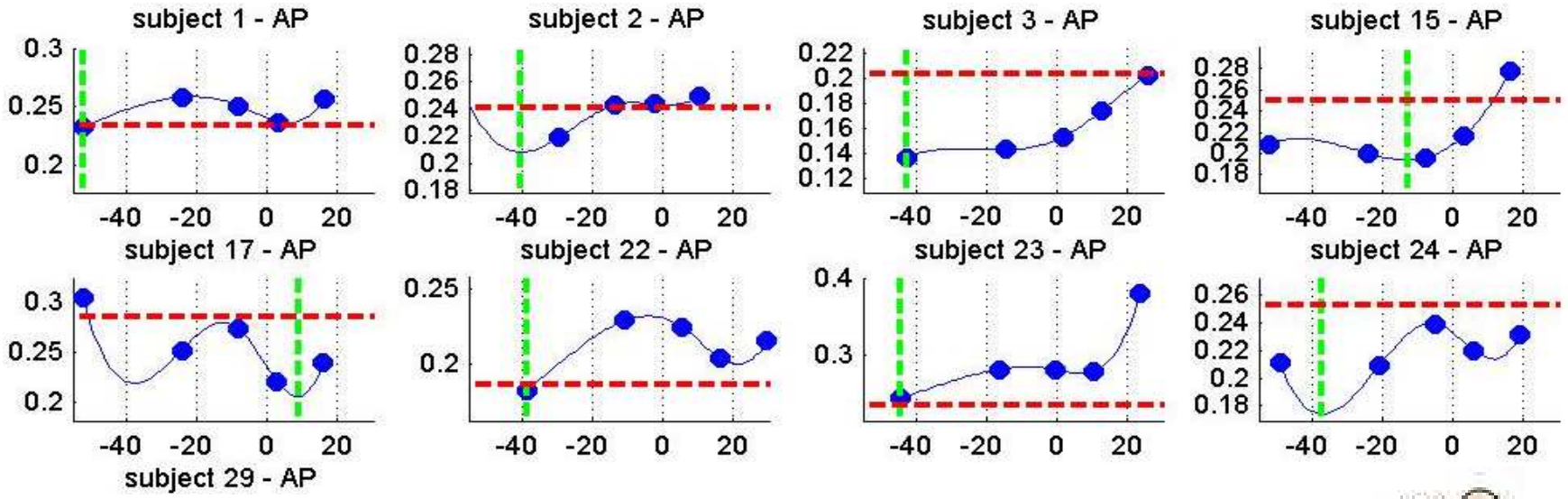


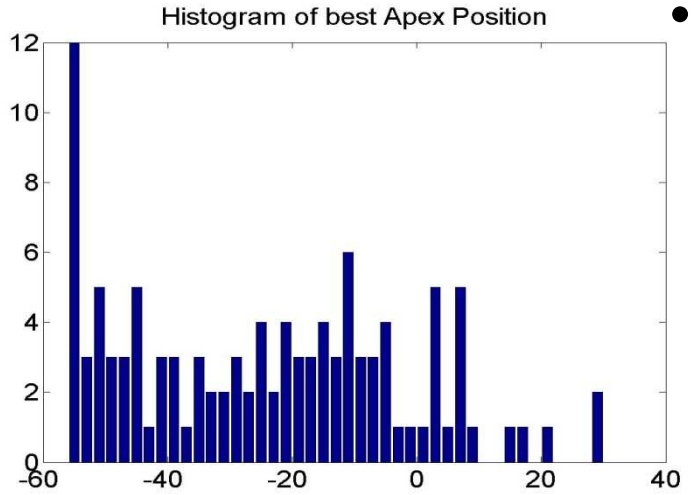
Mean/std	57.8 ±5.2



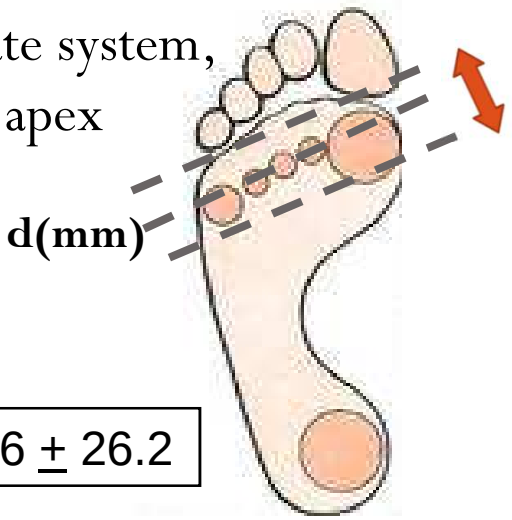
Results - Quantifying inter-subject variability

- Individual responses Apex position





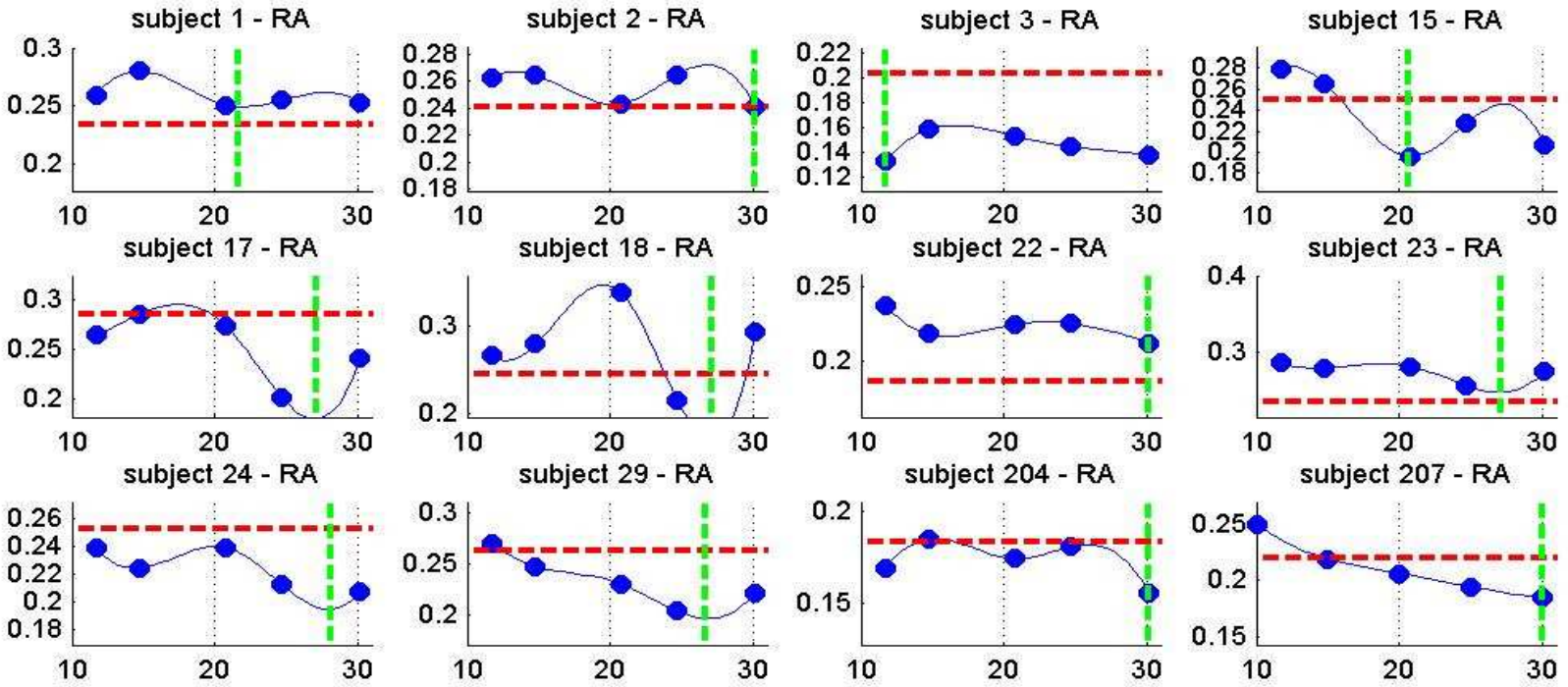
- In a foot/shoe coordinate system, there is still no optimal apex position.



Mean/std	-27.56 ± 26.2

Results cont

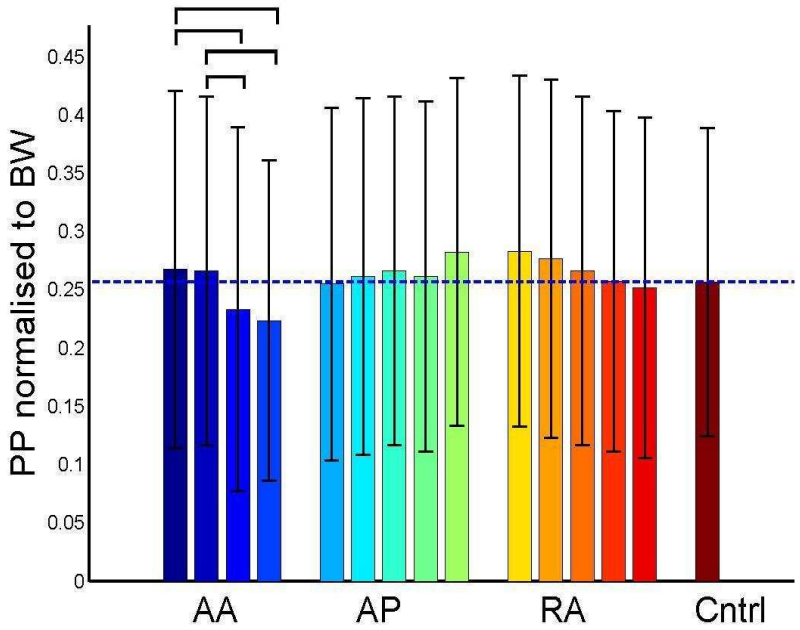
- Individual responses Rocker angle



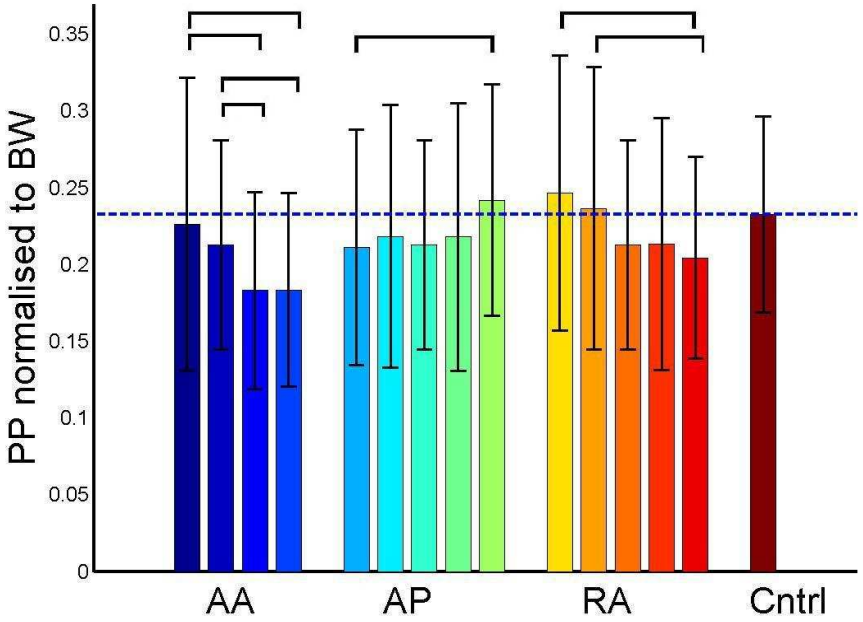
Mean/std	24.4 ±5.3

- In general the lower rocker angles do not perform as well as the higher angles.
- No clear optimal rocker angle

Results - Diabetic/Healthy comparison



Diabetic



Healthy

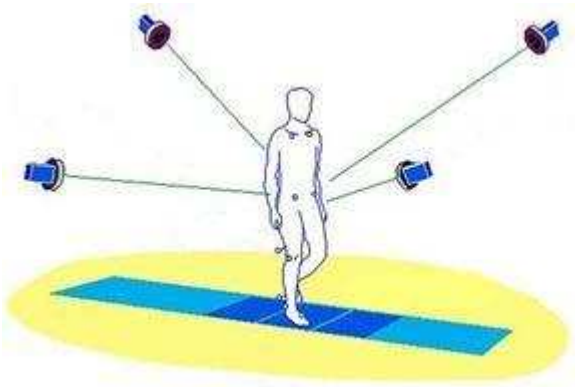
- Same mean trend between populations
- Both diabetic and healthy population showed same AA finding
- No significant differences for AP and AR for the diabetic population due to increased inter-subject variability (larger error bars).

Conclusions and design recommendation for rocker shoes

- For optimal pressure relief under 1st MTH
  - Apex Angle should be orientated 20° to the metatarsal angle
  - Apex Position needs to be individually adjusted but 70% of shoe length tends to lead to high pressures.
  - Rocker Angle needs to be individually adjusted but improved pressure offloading is obtained at higher angles

Salford's role in the SSHOES Project

- Research design characteristics of rockers shoes & develop system for producing bespoke designs
- Two Phase experiment: Phase 1
  - Collect data on foot shape
  - Establish the effect of 3 design characteristics on plantar pressure
- Phase 2:
  - Collect data on barefoot walking characteristics
  - Collect data on plantar pressure in different shoes
  - Develop algorithm to link best shoe with walking pattern



Assessment of walking biomechanics & clinical status

(Using a mini gait lab)

→

Input gait data into algorithm

Select footwear features to minimise pressure

→

Shoe Prescription

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Other regions of the foot