Can minimal footwear improve knee osteoarthritis?

Isabel C. N. Sacco [associate professor]

MEDICINA

Physical Therapy, Speech and Occupational Therapy dept,
School of Medicine USP

www.usp.br/labimph/

LaBiMPH USP

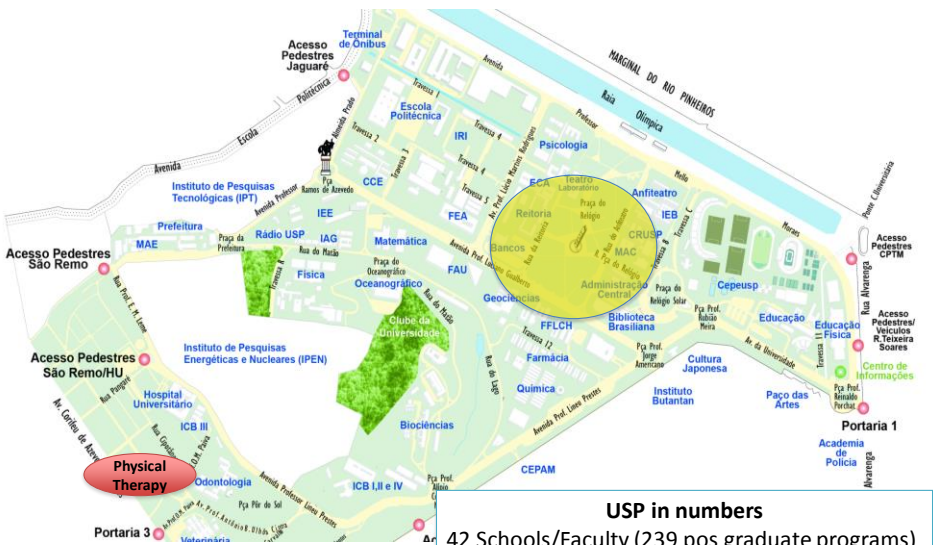
Disclosure

Nothing to disclose

There are no commercial relationships or of any other type that may lead to a conflict of interest

Session Learning Objectives

1. It will be presented and discussed evidences for the use of minimal footwear for orthopedic conditions, such as *knee osteoarthritis*.
2. It will be discussed the effect of minimal footwear on knee mechanics that lead to and exacerbate knee osteoarthritis.
3. It will also be discussed the effect of minimal footwear on functional outcomes in this population.

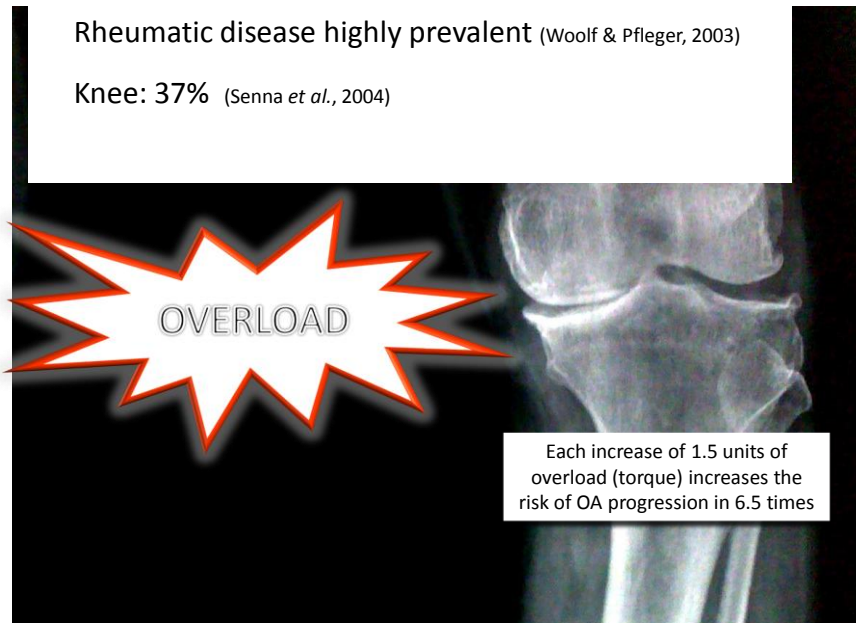


USP in numbers

42 Schools/Faculty (239 pos graduate programs)
~60.000 graduate students
~30.000 pos-graduate students
~6.000 professors
127th QS World University Ranking
147th ARWU Shangai
22% scientific production of the country

Rheumatic disease highly prevalent (Woolf & Pfleger, 2003)

Knee: 37% (Senna *et al.*, 2004)



Each increase of 1.5 units of overload (torque) increases the risk of OA progression in 6.5 times

OSTEOARTHRITIS (OA)

Internal forces direct measurement

Mechanical properties of modern footwear (with “high” heels) used for walking negatively affect the progression of OA (Kerrigan *et al.*, 1998; Kerrigan *et al.*, 2001; Kerrigan *et al.*, 2005)

ARTHRITIS & RHEUMATISM
Vol. 54, No. 9, September 2006, pp 2923–2927
DOI 10.1002/art.22123

Shakoor e Block, 2006

Walking Barefoot Decreases Loading on the Lower Extremity Joints in Knee Osteoarthritis

Najia Shakoor and Joel A. Block

Theory: barefoot locomotion

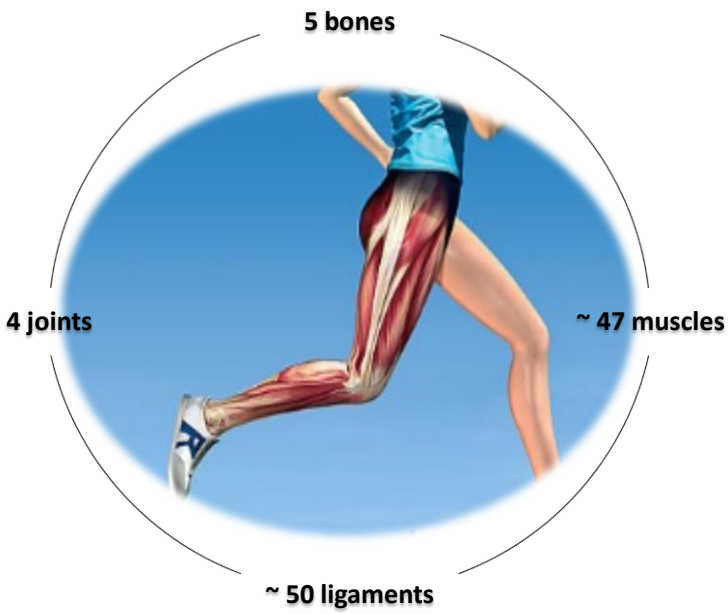
(Robbins & Hanna, 1987; Bergman *et al.*, 1995; Shakoor & Block, 2006)

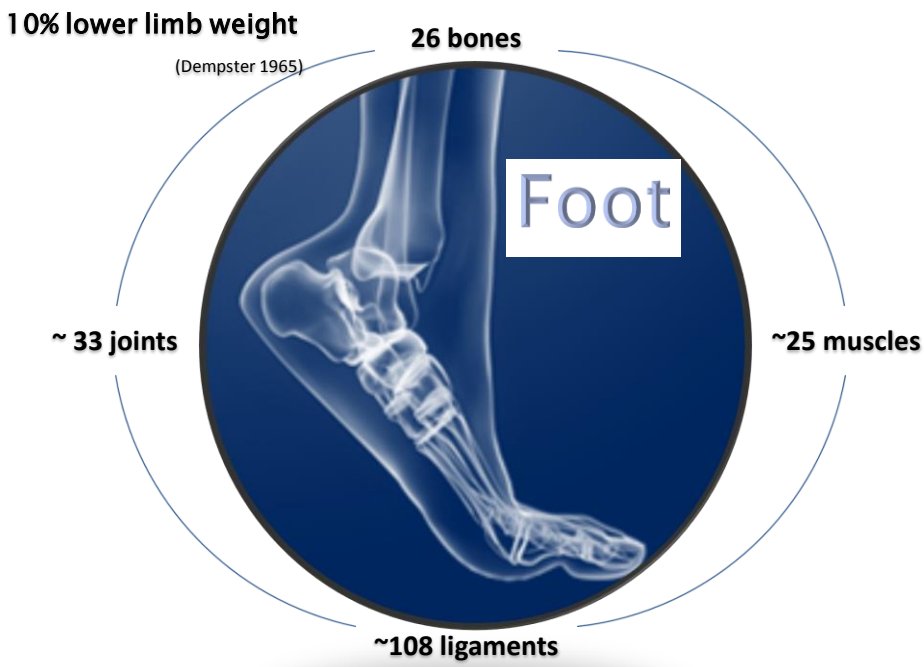
Better:

- Sensorial perception
- Foot & ankle ROM/ functionality
- intra-articular forces shifts
- forces attenuation before reaching the knee

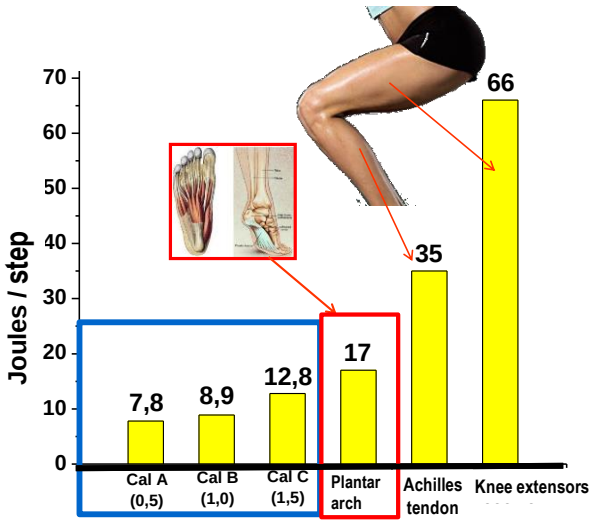
Proper mechanisms of foot rollover and consequentely, less damage joint loads

(Shakoor & Block, 2006, Doidge, 2007)





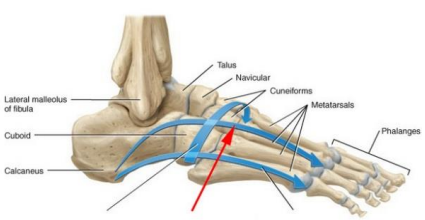
Impact attenuation

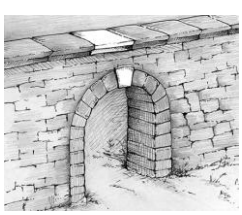


Shorten (1993), Ker et al. (1987), Shorten (1985)

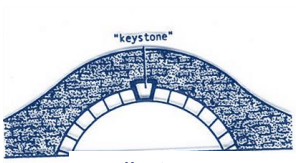
The Foot

A powerful tool with a structured **arch**, rigid and flexible within a single step to promote safe and efficient progression

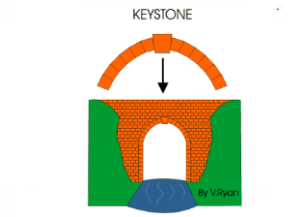




Sports Research, Nike Inc, 1990

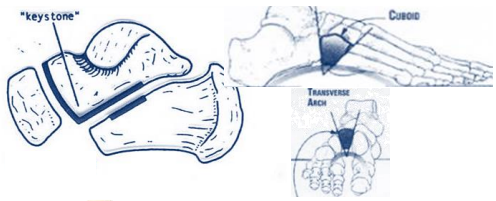


Keystone

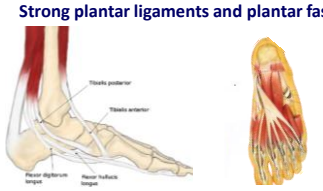


Tie beam

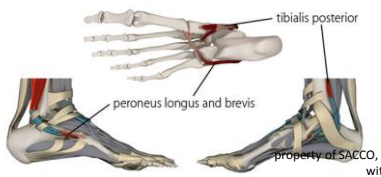
Suspentions



Strong plantar ligaments and plantar fascia



Massive intrinsic and extrinsic muscles



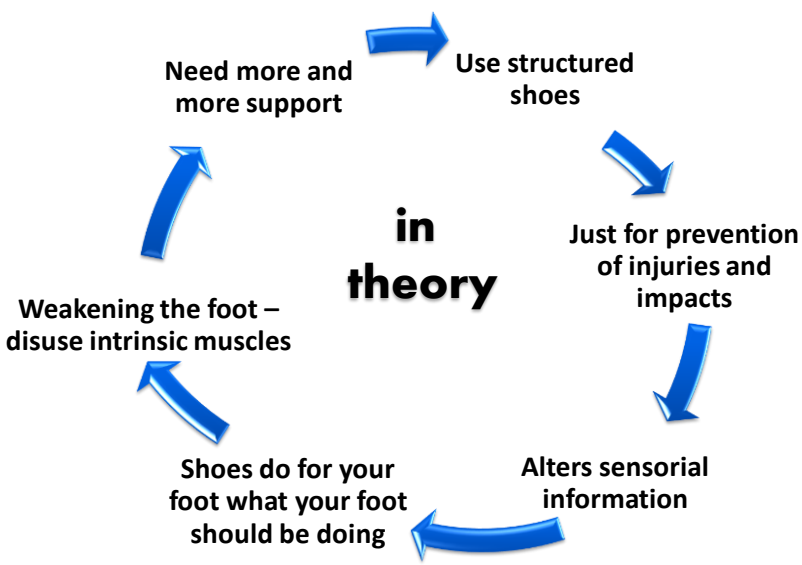
"The human foot is a masterpiece of engineering and a work of art"

Leonardo da Vinci

Maasai tribe (Kenya)

known for their agility, strength and habit of walking barefoot

Evidences that muscles may loss CSA in more structured shoes: Brüggemann et al.2005 (XX ISB Proceedings), Miller et al.2014 (J Sport Health Sci)



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Shakoor e Block, 2006

Walking Barefoot Decreases Loading on the Lower Extremity Joints in Knee Osteoarthritis

Najia Shakoor and Joel A. Block

Shakoor *et al.*, 2008

Acute usage
Positive results

Shakoor *et al.*, 2010

High cost for development or for purchase by elderly people of middle / lower middle social class

Gait & Posture 34 (2011) 126–130
Contents lists available at ScienceDirect
Gait & Posture
journal homepage: www.elsevier.com/locate/gaitpost

Inexpensive footwear decreases joint loading in elderly women with knee osteoarthritis

Francis Trombini-Souza [a,*], Aline Kimura [a], Ana Paula Ribeiro [a], Marco Butugan [a], Paula Akashi [a], Anice C. Pássaro [a], Antônio C. Arnone [b], Isabel C.N. Sacco [a]
[a] Department of Physical Therapy, Speech and Occupational Therapy, School of Medicine, University of São Paulo, Rua Cipotânea, 51 – Cidade Universitária, 05360-160 Sao Paulo, Brazil
[b] Orthopedics Clinics, University Hospital, University of São Paulo, São Paulo, Brazil

Arthritis Care & Research
Vol. 64, No. 3, March 2012, pp 368–374
DOI 10.1002/acr.20690
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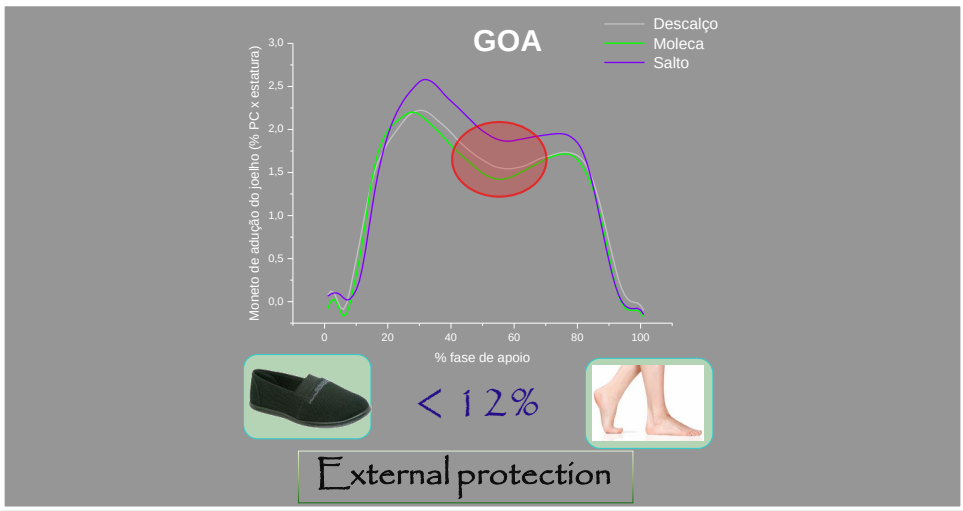
ORIGINAL ARTICLE

Joint Loading Decreased by Inexpensive and Minimalist Footwear in Elderly Women With Knee Osteoarthritis During Stair Descent

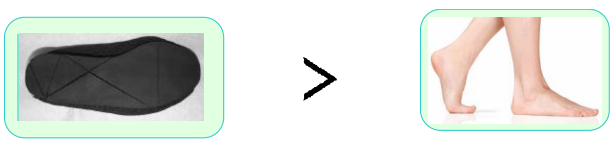
I. C. N. SACCO, F. TROMBINI-SOUZA, M. K. BUTUGAN, A. C. PÁSSARO, A. C. ARNONE, AND
R. FULLER

Expressive reduction in the knee loads acutely: walking and stair descent

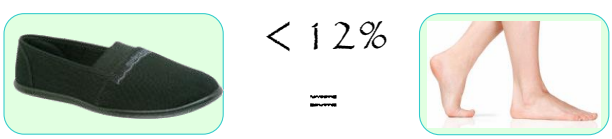


Expressive reduction in the knee loads acutely

Trombini-Souza, Sacco *et al.*, 2010, Sacco *et al.*, 2012



Shakoor *et al.*, 2008



Shakoor *et al.*, 2010

Effectiveness of a long-term use of a minimalist footwear versus habitual shoe on pain, function and mechanical loads in knee osteoarthritis: a randomized controlled trial

Francis Trombini-Souza[1], **Ricardo Fuller**[2], **Alessandra Matias**[1], **Mariane Yokota**[1], **Marco Butugan**[1], **Claudia Goldenstein-Schainberg**[2] and **Isabel C N Sacco**[1]*

* Corresponding author: Isabel C N Sacco icnsacco@usp.br ▾ Author Affiliations

[1] Department Physical Therapy, Speech, and Occupational Therapy, School of Medicine, University of São Paulo, Cidade Universitária, Rua Cipotânea 51, 05360-160, São Paulo, São Paulo, Brazil

[2] Rheumatology Division, School of Medicine, University of São Paulo, São Paulo, Brazil

For all author emails, please log on.

BMC Musculoskeletal Disorders 2012, **13**:121 doi:10.1186/1471-2474-13-121

The electronic version of this article is the complete one and can be found online at:
http://www.biomedcentral.com/1471-2474/13/121

No conflict of interest.
Independent of any industry partnership.

Clinical Biomechanics 30 (2015) 1194–1201

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Long-term use of minimal footwear on pain, self-reported function, analgesic intake, and joint loading in elderly women with knee osteoarthritis: A randomized controlled trial☆

Francis Trombini-Souza [a], Alessandra B. Matias [a], Mariane Yokota [a], Marco K. Butugan [a], Claudia Goldenstein-Schainberg [b], Ricardo Fuller [b], Isabel C.N. Sacco [a,*]

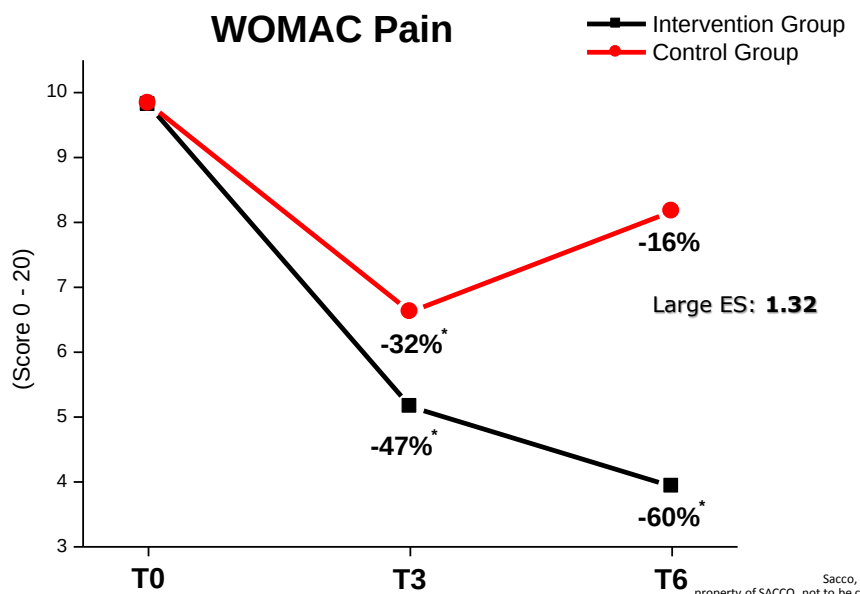
[a] Department of Physical Therapy, Speech, and Occupational Therapy, School of Medicine, University of São Paulo, Brazil
[b] Rheumatology Division, School of Medicine, University of São Paulo, Brazil

Randomized controlled blinded trial

- 6 months of usage
- 5x/week – 6 daily active hours
- Daily Living Activities

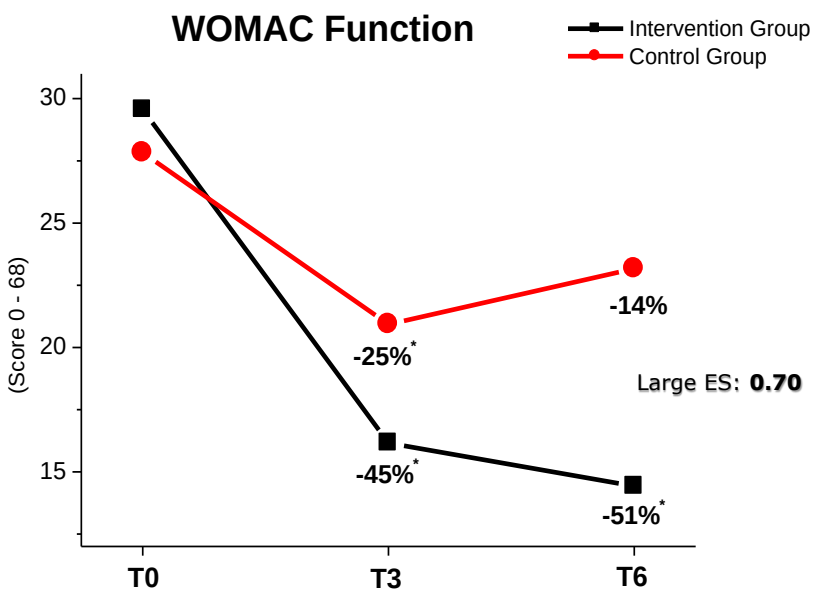
No conflict of interest.
Independent of any industry partnership.

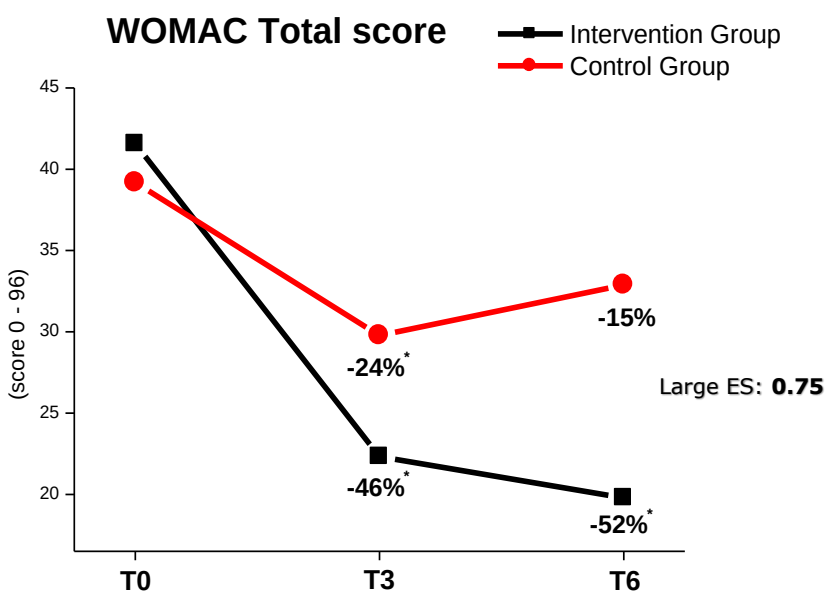
Primary outcome

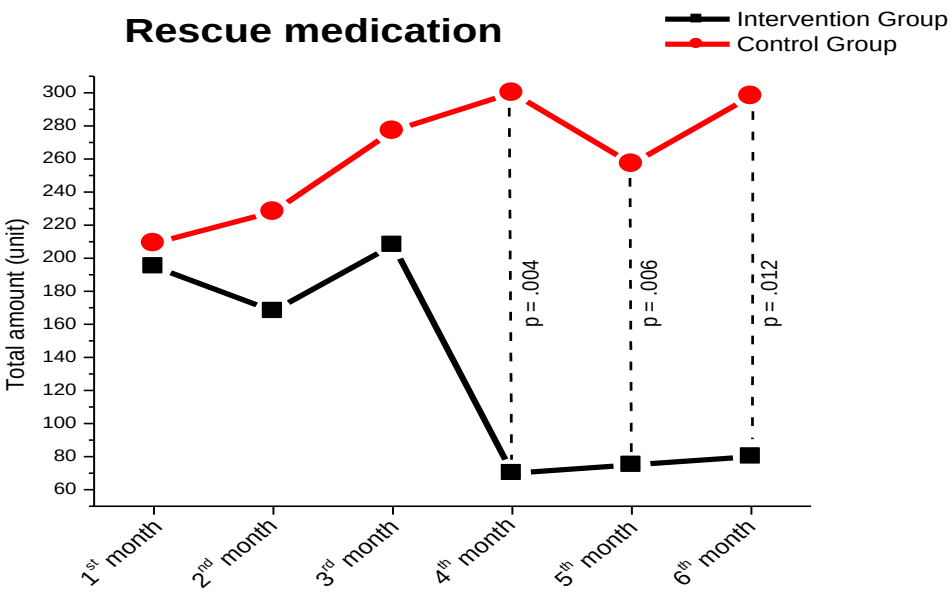


Effect size: **1.32**

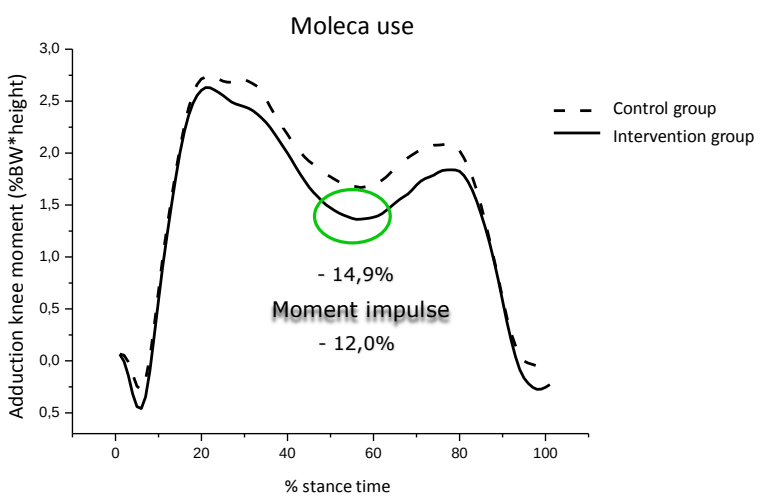
Effect size: 0.21
(Zhang *et al.*, 2004)







Joint moments



... a successful option of a conservative mechanical treatment for OA aiming at:

1. minimizing PAIN (67%)

2. improving FUNCIONAL aspects for ADLs (63%)

3. reducing RESCUE MEDICATION intake

4. attenuating KNEE LOADS (15%)

5. avoiding worsening of the clinical signs (joint edema and effusion)

"The task is not so much to see what no one has yet seen, but to think what **nobody** has yet thought, about *that which* everyone sees."

Arthur Schopenhauer

Update on Minimal Footwear: Is Less More?

Blaise Dubois, PT, SPC Diploma

Speakers:
Irene Davis, PhD
Sarah Ridge, PhD
Isabel Sacco, PhD

Session Learning Objectives

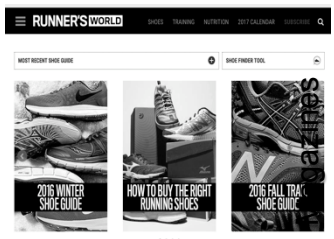
- Explore common recommendations on running shoes, and evaluate them based on scientific evidence.
- Learn about the Minimalist Index and its psychometric properties.
- Understand clinical and scientific applications of the Minimalist Index.

Disclosure

Blaise Dubois and The Running Clinic™ have NO conflict of interest relative to the shoe industry.

The Running Clinic is a worldwide continuing education organization for health professionals.

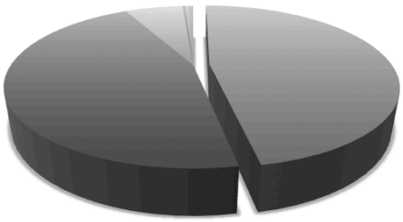
Commercial influences

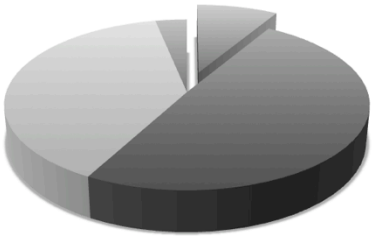


Running shoes sales (USA)

Mass market

Running specialty

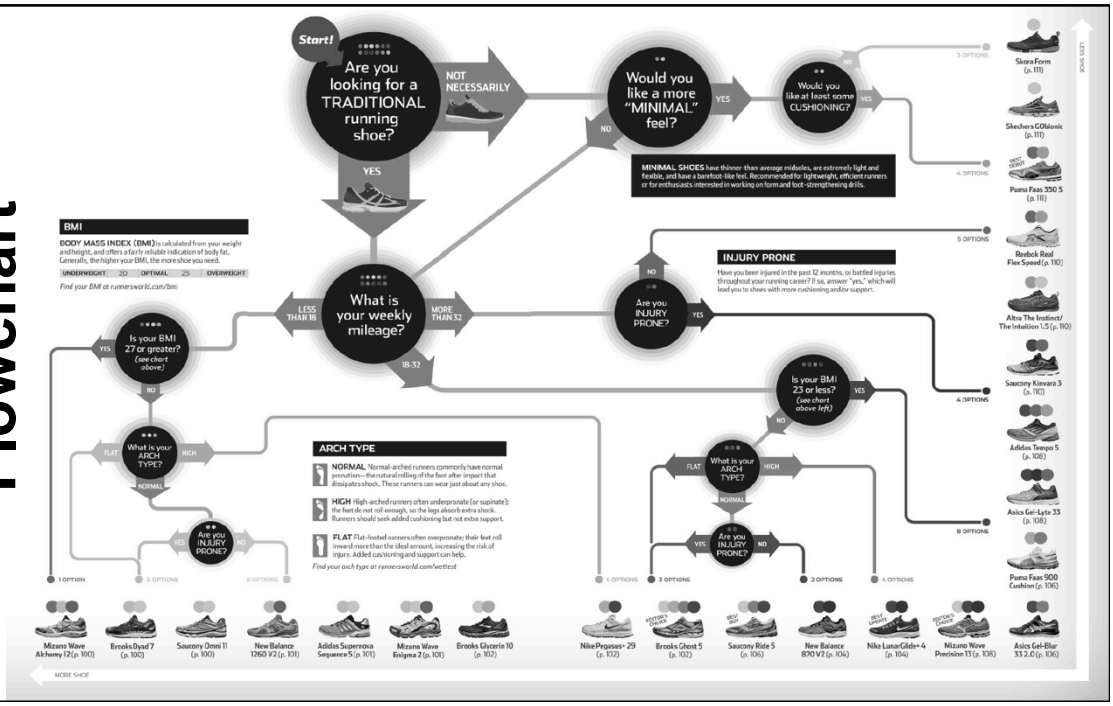




- Light weight performance
- Neutral Cushion
- Stability
- Motion Control
- Barefoot
- Not specified

Source: The NPD Group Retail Tracking service

Runner's World Flowchart



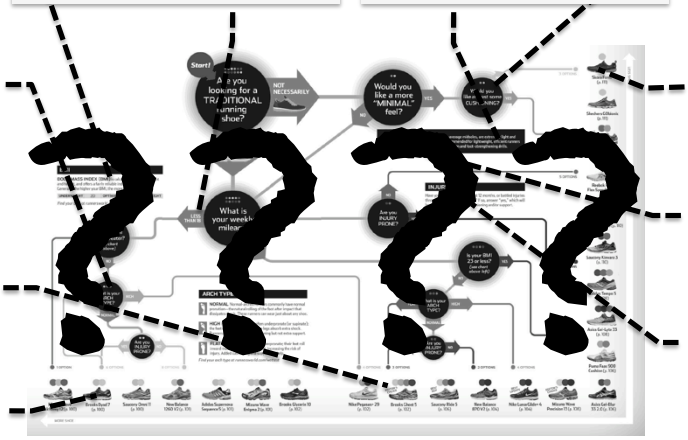
Maximalist shoes for maxi-malist people

Prescription based on arch type and foot dynamics

Editor's choice … if you paid enough?

Greater injury risk if flat feet

Beginners and recreational runners (<18miles/wk) must wear maxi-traditional shoes



Minimalist shoes just for enthusiasts working on form and foot strengthening

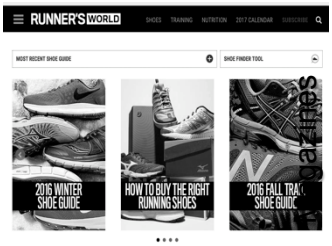
Selection of minimal shoes is exceptional

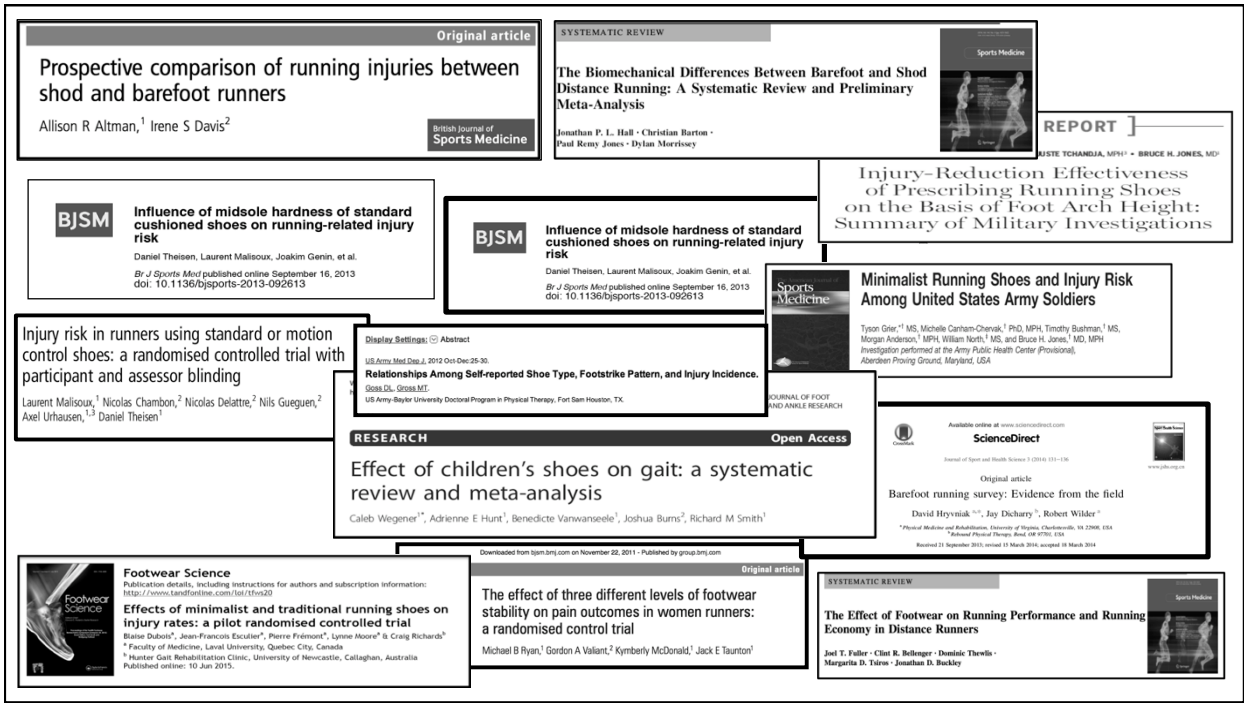
The most minimalist shoes score 60% on MI (minimalist index)

Minimalist shoes just for light-weight efficient runners

Cushioning or/ and support if injury prone

Current recommendations





Smart recommendations

Based on RETAILERS' beliefs

Based on the current TREND

Based on COMFORT Only

Based on the preferred COLOR

Smart recommendations

NOT

- **Weight of the person**
- **Foot type**
- **Weekly mileage**

Less shoes **More shoes**

Smart recommendations

Less shoes **More shoes**

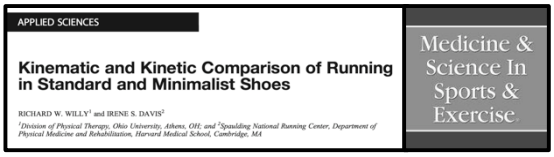
Smart recommendations

How much LESS shoes
How much MORE shoes

Aims of the Minimalist Index

- Design a validated rating scale that allows to quantify the level of minimalism of running shoes.
- Compare the effects of footwear characterized by different levels of minimalism on running kinetics, kinematics and tissue stress.
- Provide guidelines on safe transition times between shoes characterized by different levels of minimalism.
- Facilitate the prescription of running shoes by grouping relevant characteristics within one combined score.

Minimalist shoes, kinematics and kinetics



Biomechanics in minimalist shoes are the same as in traditional running shoes

MI : 52%

MI : 96%

Biomechanics in minimalist shoes are the same as in barefoot running

Esculier *et al. Journal of Foot and Ankle Research* (2015) 8:42
DOI 10.1186/s13047-015-0094-5

JOURNAL OF FOOT AND ANKLE RESEARCH

RESEARCH **Open Access**

A consensus definition and rating scale for minimalist shoes

Jean-Francois Esculier[1,2,3], Blaise Dubois[1,3], Clermont E. Dionne[1,4], Jean Leblond[2] and Jean-Sébastien Roy[1,2*]

Modified Delphi study, 42 experts from 11 countries

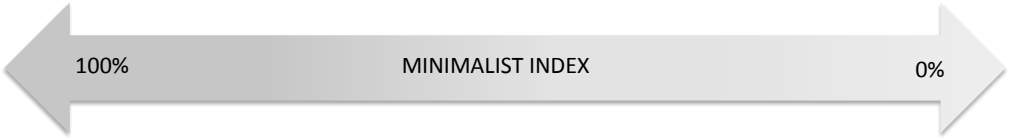
(Four electronic questionnaires on an optimal definition of minimalist shoes and on elements to include within the Minimalist Index)

Definition

Footwear providing minimal interference with the natural movement of the foot with its high flexibility, low weight, stack height and heel to toe drop, and the absence of motion control and stability technologies.

(The following definition of minimalist shoes was agreed upon by 95 % of participants)

Minimalist Index



Weight

5 = less than 125g

4 = from 125g to less than 175g

3 = from 175g to less than 225g

2 = from 225g to less than 275g

1 = from 275g to less than 325g

0 = 325g and more

Stack height

5 = less than 1 mm

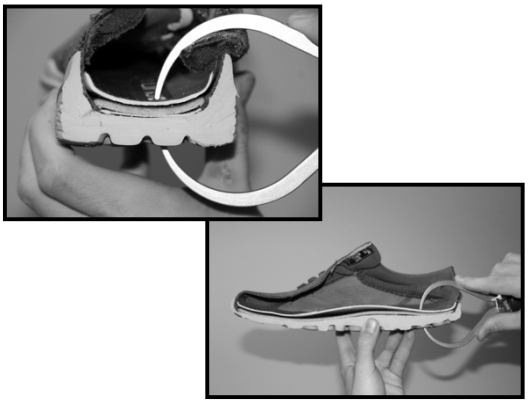
4 = from 1mm to less than 4 mm

3 = from 4 mm to less than 7 mm

2 = from 7 mm to less than 10 mm

1 = from 10 mm to less than 13 mm

0 = 13 mm and more



Heel to toe drop

5 = less than 8 mm

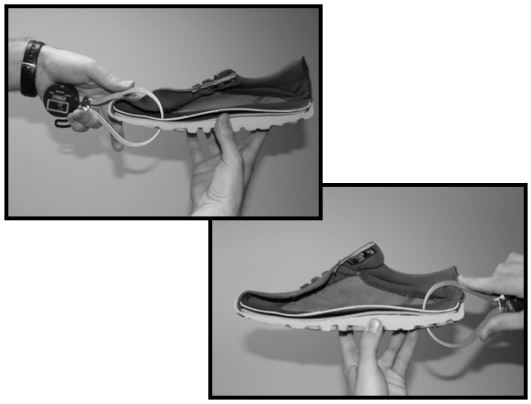
4 = from 8 mm to less than 14 mm

3 = from 14 mm to less than 20 mm

2 = from 20 mm to less than 26 mm

1 = from 26 mm to less than 32 mm

0 = 32 mm and more



Stability and motion control technologies

5 = None

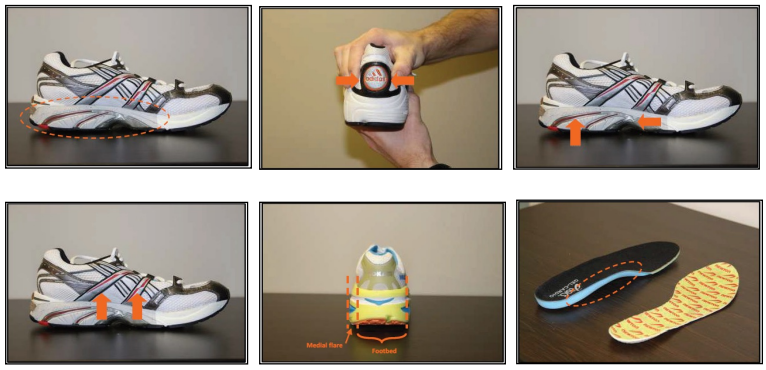
4 = 1 device

3 = 2 devices

2 = 3 devices

1 = 4 devices

0 = 5 or 6 devices



Flexibility (longitudinal)

2.5 = Minimal resistance to longitudinal bending (the shoe can be rolled on itself more than 360 degrees)

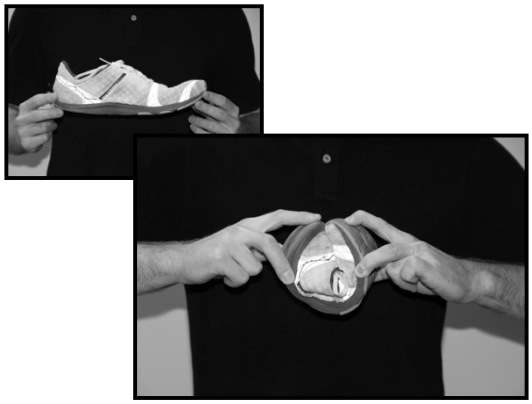
2.0 = Slight resistance to longitudinal bending (anterior tip of shoe sole reaches posterior tip of shoe sole in a maximal bending of 360 degrees)

1.5 = Moderate resistance to longitudinal bending (anterior tip of shoe sole doesn't reach posterior tip of shoe sole, but anterior and posterior parts of the shoe can form an angle of at least 90 degrees)

1.0 = High resistance to longitudinal bending (anterior and posterior parts of the shoe can form an angle between 45 and 90 degrees)

0.5 = Very high resistance to longitudinal bending (longitudinal deformation is possible, but anterior and posterior parts of the shoe form a maximum angle of 45 degrees)

0 = Extreme resistance to longitudinal bending (longitudinal forces don't significantly change the orientation of the anterior part of the shoe relative to the posterior part)



Flexibility (Torsional)

2.5 = Minimal resistance to torsion (anterior part of the shoe is turned 360 degrees; anterior outsole faces inferiorly after a complete twist while posterior outsole faces inferiorly)

2.0 = Slight resistance to torsion (anterior part of the shoe is turned at least 180 degrees but less than 360 degrees; anterior outsole faces at least superiorly while posterior outsole faces inferiorly)

1.5 = Moderate resistance to torsion (anterior part of the shoe is turned more than 90 degrees but less than 180 degrees; anterior outsole faces at least laterally while posterior outsole faces inferiorly)

1.0 = High resistance to torsion (anterior part of the shoe is turned more than 45 degrees but less than 90 degrees; anterior outsole can't face laterally while posterior outsole faces inferiorly)

0.5 = Very high resistance to torsion (torsional deformation is possible, but anterior part of the shoe reaches less than 45 degrees)

0 = Extreme resistance to torsion (torsional forces don't significantly change the orientation of the anterior part of the shoe relative to the posterior part)

Minimalist Index

Total MI score highly correlated with VAS
(r = 0.91)

100% MINIMALIST INDEX 0%

Minimalist Index

A significant rank effect ($p < 0.001$)
confirmed the MI's discriminative validity

100% MINIMALIST INDEX 0%

Minimalist Index

Excellent intra- and inter-rater reliability (ICC = 0.84-0.99)

100% MINIMALIST INDEX 0%

Aims of the Minimalist Index

- Design a validated rating scale that allows to quantify the level of minimalism of running shoes.
- Compare the effects of footwear characterized by different levels of minimalism on running kinetics, kinematics and tissue stress.
- Provide guidelines on safe transition times between shoes characterized by different levels of minimalism.
- Facilitate the prescription of running shoes by grouping relevant characteristics within one combined score.

Specific shoe characteristics, kinematics and kinetics

Computer Methods in Biomechanics and Biomedical Engineering, 2013
Vol. 16, No. S1, 97–98, http://dx.doi.org/10.1080/10255842.2013.815919

The effect of shoe drop on running pattern

N. Chambon[a,b,*], N. Delattre[b], E. Berton[a], N. Guéguen[b] and G. Rao[a]
[a]*Institute of Movement Sciences, Aix-Marseille University, Marseille, France;* [b]*Oxylane Research, Villeneuve d'Ascq, France*

Stack-2
- Drop-0
- Drop-4
- Drop-8

Small or no differences on kinematic and kinetic variables

Contents lists available at ScienceDirect
Gait & Posture
journal homepage: www.elsevier.com/locate/gaitpost

Is midsole thickness a key parameter for the running pattern?

Nicolas Chambon [a,b,*], Nicolas Delattre [b], Nils Guéguen [b], Eric Berton [a], Guillaume Rao [a]
[a] *Aix-Marseille University, CNRS, ISM UMR 7287, 163 Avenue de Luminy, 13288 Marseille Cedex 09, France*
[b] *Oxylane Research, Decathlon Campus, 4 Boulevard de Mons, 59665 Villeneuve d'Ascq, France*

Drop-0
- Stack-0
- Stack-2
- Stack-4
- Stack-8
- Stack-16

Small or no differences on kinematic and kinetic variables

Effect of midsole geometry on foot-strike pattern and running kinematics

N. Horvais [a] & P. Samozino [a b]
[a] Salomon SAS , Amer Sports Footwear Laboratory of Biomechanics and Exercise Physiology , France
[b] Laboratory of Exercise Physiology (EA4338) , University of Savoy , France
Published online: 22 May 2013.

Different SHOES = Different KINEMATICS

The more maximalist the shoe (greater stack & greater drop), the greater the foot strike angle

16 conditions

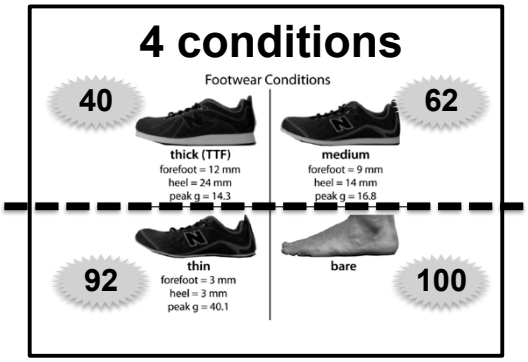
Footwear Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tfws20

Effects of unknown footwear midsole thickness on running kinematics within the initial six minutes of running

Trampas M. TenBroek [a] , Pedro Rodrigues [a] , Edward C. Frederick [c] & Joseph Hamill [b]

- The amount of underfoot material had significant effects on many kinematic variables.

(Barefoot and minimalist footwear acute responses included more plantar flexion, less knee excursion, reduced stance times, etc.)



Midsole Thickness Affects Running Patterns in Habitual Rearfoot Strikers During a Sustained Run

Trampas M. TenBroek,[1,2] Pedro A. Rodrigues,[1,2] Edward C. Frederick,[3] and Joseph Hamill[2]
[1]New Balance Sports Research Laboratory; [2]University of Massachusetts-Amherst; [3]Exeter Research, Inc.

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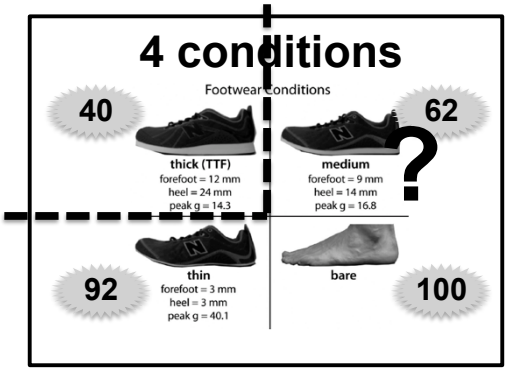

JOURNAL of SPORTS SCIENCES

Acute effect of different minimalist shoes on foot strike pattern and kinematics in rearfoot strikers during running

ROBERTO SQUADRONE[1], RENATO RODANO[1], JOSEPH HAMILL[2] & EZIO PREATONI[3]

MI : 100 | 96 | 88 | 88 | 72 | 48 | 52 | 10

	Barefoot	Vibram FiveFingers Seeya	Inov8 Bare-X 200	New Balance MR00GB	Newton Running MV2	Saucony Kinvara 2	Nike Free 3.0V4	Cushioned shoe
Foot strike variables								
Strike index (%)	27.0 ± 4.6	25.5 ± 4.4 # *b*	24.5 ± 5.2# *b*	25.4 ± 5.0# *b*	21.0 ± 4.9* *a*	19.6 ± 5.2* *a*	19.9 ± 5.4* *a*	18.6 ± 6.2*
Foot angle at contact (°)	7.3 ± 3.4	6.9 ± 3.2 # *a*	7.6 ± 3.2 # *a*	8.0 ± 3.1 # *a*	10.7 ± 3.2* *b*	11.8 ± 3.1 * *b*	12.3 ± 2.7 * *b*	12.1 ± 2.9 *
Spatio-temporal stride variables								
Stride frequency (step/min)	86.8 ± 2.3	85.4 ± 2.0* # *b*	83.6 ± 2.2 * *a*	84.1 ± 2.1* *a*	84.9 ± 1.8*# *b*	84.0 ± 1.9* *a*	83.7 ± 2.2 * *a*	83.4 ± 2.4 *
Stride length (m)	2.30 ± 0.04	2.34 ± 0.04*# *a*	2.38 ± 0.05* *b*	2.37 ± 0.04* *b*	2.35 ± 0.05* *a*	2.37 ± 0.04* *b*	2.38 ± 0.05* *b*	2.38 ± 0.05*
Step time (ms)	346 ± 5	352 ± 5*# *a*	358 ± 6* *b*	357 ± 5* *b*	354 ± 6*# *a*	357 ± 5* *b*	358 ± 6* *b*	358 ± 6*
Contact time (ms)	234 ± 4	238 ± 4*# *a*	246 ± 4*# *c*	242 ± 4*# *b*	247 ± 4* #*c*	250 ± 4* *d*	252 ± 4* *d*	251 ± 4*
Kinematic variables								
Stride angle (°)	73.2 ± 4.6	72.6 ± 4.7	73.4 ± 4.6	74.3 ± 4.5	74.2 ± 4.4	73.3 ± 4.2	72.5 ± 4.7	74.5 ± 4.8
Overstride angle (°)	7.2 ± 3.4	8.1 ± 3.5	7.7 ± 3.6	7.5 ± 3.4	8.8 ± 3.6	8.6 ± 3.5	8.5 ± 3.6	8.6 ± 3.4
Knee contact angle (°)	163.8 ± 3.4	165.1 ± 3.2 a,b	164.5 ± 3 # a	165.2 ± 3.3 a,b	165.4 ± 3.3 a,b	165.6 ± 3.2 a,b	166.3 ± 3.1*b	166.6 ± 3.2*
Peak stance knee flex angle (°)	138.8 ± 4.6	138.5 ± 4.3	137.9 ± 4.5	138.2 ± 4.7	138.0 ± 4.6	137.6 ± 4.4	137.4 ± 4.2	137.5 ± 4.2
Knee ROM stance phase (°)	25.1 ± 4.2	26.7 ± 4.2 #*a*	26.6 ± 4.1 #*a*	26.9 ± 3.8 #*a*	27.4 ± 4.0**a*	28.0 ± 4.1**a,b*	28.9 ± 4**b*	29.0 ± 4.0*
Hip vertical displacement (mm)	8.0 ± 3.2	8.2 ± 3.4 #*a*	7.8 ± 3.6 #*a*	7.3 ± 3.4 #*a*	9 ± 3.6 *a*	11.5 ± 3.2**b*	10.8 ± 3.3**b*	10.8 ± 3.4*
Number of variables significantly similar to barefoot (*n*)	–	8	8	8	5	4	3	–
Number of variables significantly different from cushioned model (*n*)	–	8	6	5	3	0	0	–

Notes: *Significantly different from Barefoot. #Significantly different from the Cushioned shoe. Letters are linked to the trend in the values (from lower to higher) and separate minimalist shoes into statistically homogenous subgroups within row: means with the same letters were not significantly different ($P > 0.05$).

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Influence of the Heel-to-Toe Drop of Standard Cushioned Running Shoes on Injury Risk in Leisure-Time Runners

A Randomized Controlled Trial With 6-Month Follow-up

Laurent Malisoux,*† PhD, Nicolas Chambon,‡ PhD, Axel Urhausen, Prof.,†§ MD, and Daniel Theisen,‡ PhD

+/- 20

* 553 leisure-time runners, 18 to 65 years, no prior use of minimalist running shoes with drop less than 4 mm

176

190

187

40

Stack-24 **Drop-10**

48

Stack-21 **Drop-6**

52

Stack-21 **Drop-0**

0 weeks (no transition time)
1-2 x 50min/week, 26w follow-up

Running related injury : 25%

No more injuries

No more injuries

More injuries among regular runners than occasional runners?

Foot Bone Marrow Edema after a 10-wk Transition to Minimalist Running Shoes

SARAH T. RIDGE[1], A. WAYNE JOHNSON[1], ULRIKE H. MITCHELL[1], IAIN HUNTER[1], ERIC ROBINSON[2], BRENT S. E. RICH[3], and STEPHEN DOUGLAS BROWN[4]

+/- 20

* 36 experienced recreational runners, usually running with traditional shoes

MRI

17

19

20

96

10 weeks
Progress up to 15km / 30km total

MRI

No stress fracture

Increased bone marrow edema + 2 foot stress fractures

BJSM

Examining injury risk and pain perception in runners using minimalist footwear

Michael Ryan, Maha Elashi, Richard Newsham-West, et al.

Br J Sports Med published online December 19, 2013

* 103 recreational runners, usually running with traditional shoes, preparing for a 10k

32

32

35

12 weeks
Progress up to 115min/215min

Low injuries rate

More injuries?

No more injuries?

Body Mass and Weekly Training Distance Influence the Pain and Injuries Experienced by Runners Using Minimalist Shoes

A Randomized Controlled Trial

Joel T. Fuller,*† BSc, Dominic Thewlis,† PhD, Jonathan D. Buckley,† PhD, Nicholas A.T. Brown,† PhD, Joseph Hamill,§ PhD, and Margarita D. Tsiros,† PhD

* 61 male endurance-trained traditionally shod runners runners, 18 to 40y, no minimalist shoes experience, < 23 min on 5K.

30

31

26 weeks
Transition to new shoes gradually : +5%/w up to 21-24k/w

Running related injury : 37%

No more injuries

More injuries for heavy runners?

CLINICAL BIOMECHANICS

Effects of training in minimalist shoes on the intrinsic and extrinsic foot muscle volume

Tony Lin-Wei Chen [a], Louis K.Y. Sze [b], Irene S. Davis [c], Roy T.H. Cheung [a,*]

[a] Gait & Motion Analysis Laboratory, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong
[b] Industrial Centre, The Hong Kong Polytechnic University, Hong Kong
[c] Spaulding National Running Center, Department of Physical Medicine and Rehabilitation, Harvard Medical School, The Harvard University, MA, Cambridge, USA

* 47 traditionally shod runners aged 20-45 years old (running >20km/wk for at least 12 months)

MRI

23

20

24

92

26 weeks
Progress up to 30km average (total)

MRI

No injury

No injury

+ Increase foot muscles volume

Transition between shoes

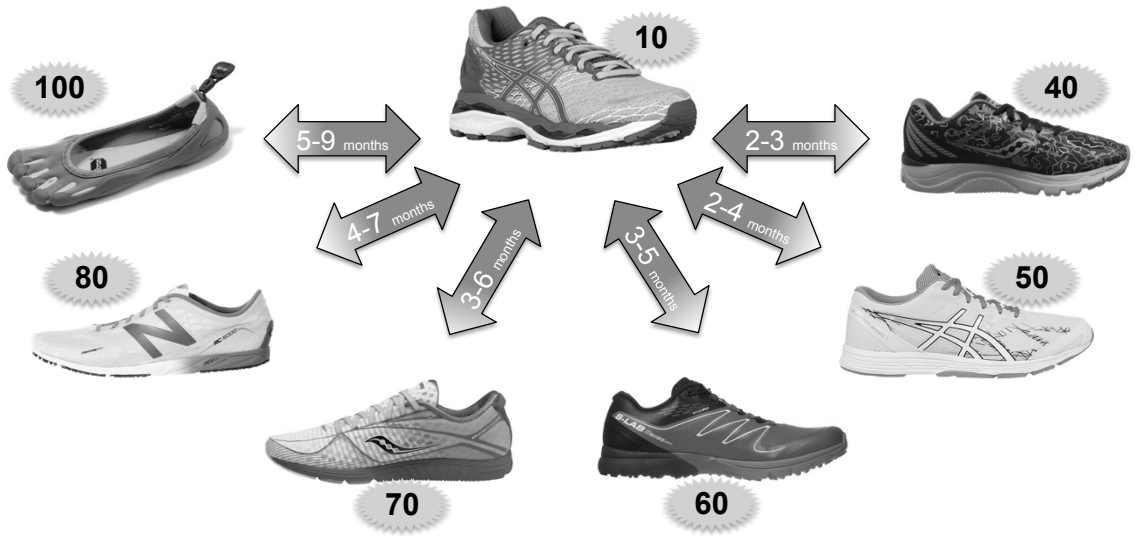
- No strong evidence on the topic
- Based on clinical experience (thousands of runners)
- Acute changes in kinematics (causing changes in tissue stress) increase the risk of injury if implemented too quickly
- Transitioning between different MI scores (to higher or lower scores) is potentially injurious.

Transition between shoes

- Safe transition for recreational runners is:

  1 month for each 10 to 20% of MI

- Experienced runners may expect to double that time.
- Increase by **1 more minute per training** and implement plateaus if foot or calf soreness = best recommendation when no follow-up is made by a clinician.
- Many other factors influence transition time (age, general health, previous history of footwear & sports, etc.).



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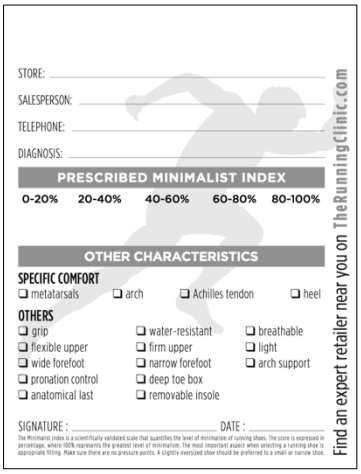
TRC tools



Update on Minimal Footwear: Is Less More?

Irene Davis, PT, PhD
Blaise Dubois, PT
Sarah Ridge, PhD
Isabel Sacco, PhD

Disclosure

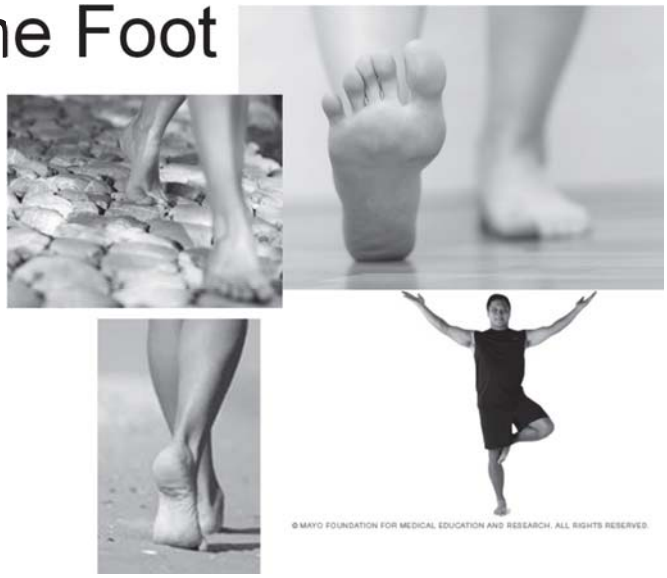
- No relevant financial relationship exists

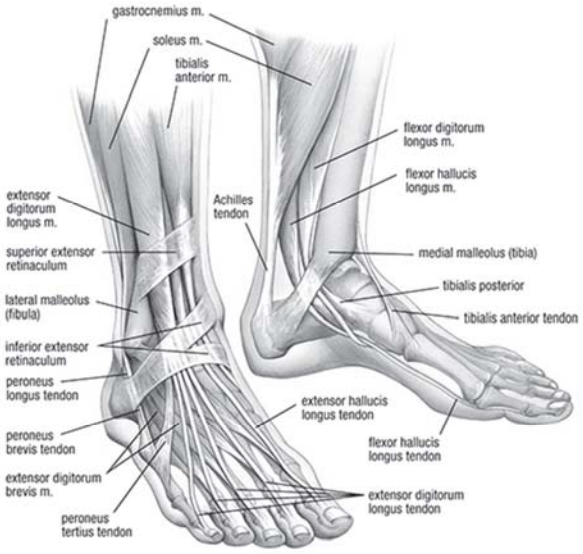
Session Learning Objectives

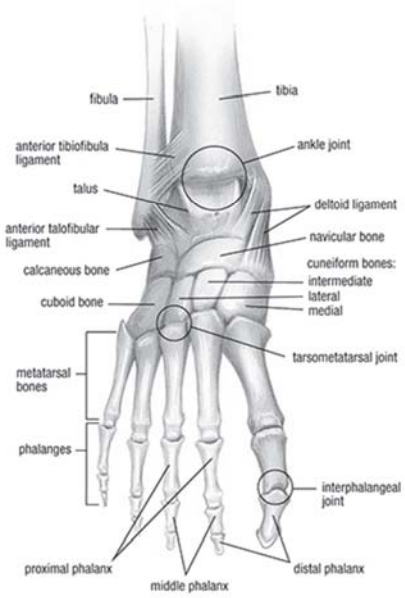
- Describe the role of the intrinsic foot muscles
- Describe the effect of minimal footwear on foot muscle strength

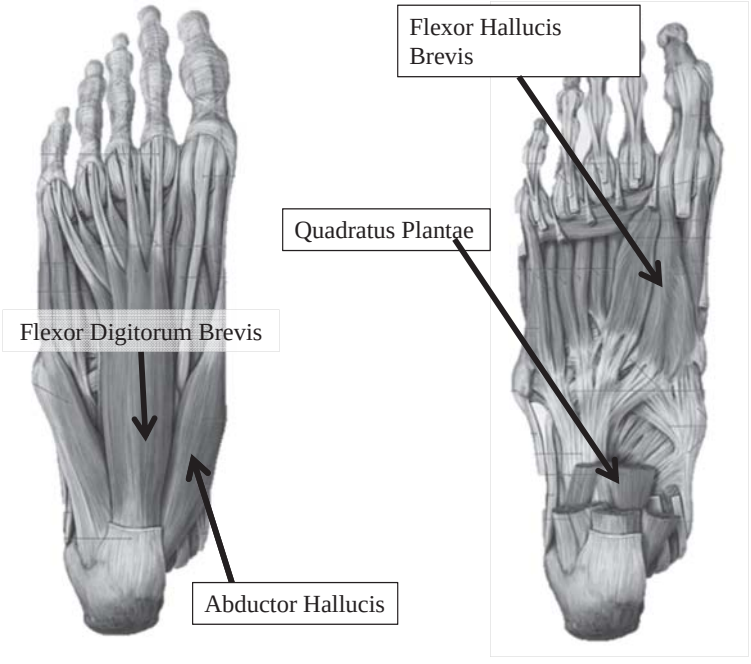
The Foot

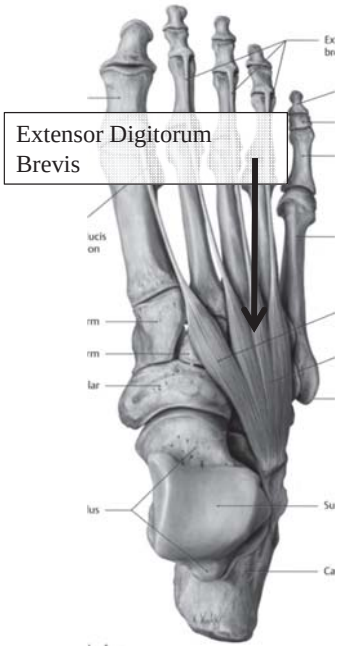
- Multi-functional
  - Support
  - Shock absorption
  - Stabilization
  - Power production




gastrocnemius m.
soleus m.
tibialis anterior m.
flexor digitorum longus m.
flexor hallucis longus m.
extensor digitorum longus m.
Achilles tendon
superior extensor retinaculum
medial malleolus (tibia)
lateral malleolus (fibula)
tibialis posterior
tibialis anterior tendon
inferior extensor retinaculum
peroneus longus tendon
extensor hallucis longus tendon
peroneus brevis tendon
flexor hallucis longus tendon
extensor digitorum brevis m.
extensor digitorum longus tendon
peroneus tertius tendon


fibula
tibia
anterior tibiofibula ligament
ankle joint
talus
deltoid ligament
anterior talofibular ligament
navicular bone
calcaneous bone
cuneiform bones:
intermediate
cuboid bone
lateral
medial
tarsometatarsal joint
metatarsal bones
phalanges
interphalangeal joint
proximal phalanx
middle phalanx
distal phalanx

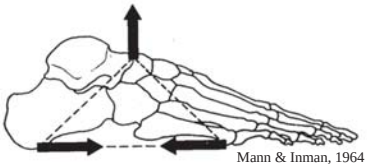

Flexor Hallucis Brevis
Quadratus Plantae
Flexor Digitorum Brevis
Abductor Hallucis


Extensor Digitorum Brevis

Role of intrinsic foot muscles (IFM)

- Support medial longitudinal arch (MLA) during loading[1,2]
- Control pronation during standing and walking[2,3,4]
- Stabilize foot during propulsion of walking[1]
- Shock attenuation/energy dissipation?

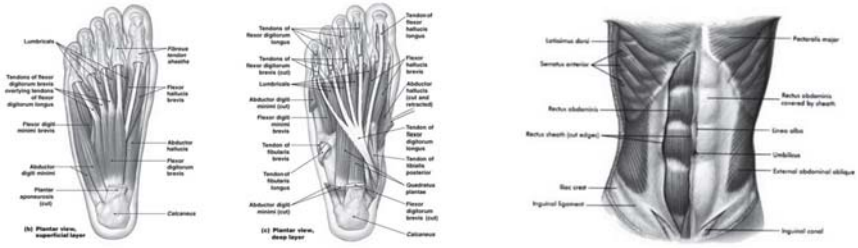
Basmajian & Stecko, 1963



Mann & Inman, 1964

IFM role in stabilization

- Weak IFM have been associated with impaired balance and increased risk of falls in the elderly[5,6]
- Similar function to deep core stabilizers of the spine[7,8]
  - Local and global stabilizers



Evidence of the importance of IFM

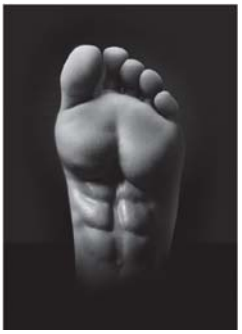
- Children and adults who spend less time in footwear have a lower incidence of flatfoot.[9,10]
  - Does supportive footwear weaken the IFM?
- Runners with chronic plantar fasciitis have lower rearfoot IFM volume than healthy runners.[11]
- Toe flexor strength of feet with plantar fasciitis (PF) is lower than healthy feet.[12]
- MLA helps with shock absorption during loading.[13]
  - Do weak IFM → less control of MLA?
- Muscle weakness is a factor for stress fracture.[14]
  - Runners who suffered from BME during transition to minimal footwear had smaller IFM during pre-transition testing.[15]

Does exercise increase IFM strength?

YES!

Unger & Wooden, 2000
Jung, et al., 2011
Mulligan & Cook, 2013
Hashimoto & Sakuraba, 2014
Brueggeman, et al., 2005
Miller, et al., 2014
Johnson, et al., 2016

Jung, et al., 2011



www.AFXonline.com

IFM strengthening exercises – Short Foot/Doming

IFM strengthening exercises – Toe Flexion

Figure 3. Set-up for toe flexor strength training using the archxerciser. Unger & Wooden, 2000

Fig. 1. Custom-fabricated pulley system positioned for fatiguing exercises.
Headlee, et al., 2008

IFM strengthening exercises – Heel Raises

IFM strengthening exercises – Resistance

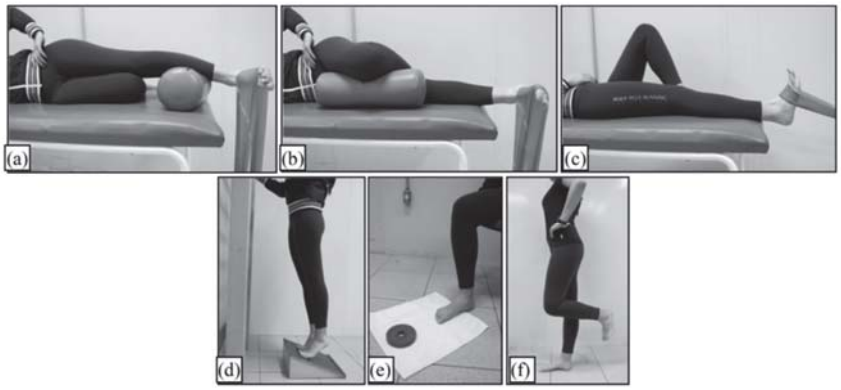


Fig. 2. Foot Exercise Group. (a) Evertors muscles strengthening. (b) Invertors muscles strengthening. (c) Dorsiflexors muscles strengthening. (d) Plantar flexors muscles strengthening. (e) Toe curl exercise. (f) Short foot exercise.

Kamonseki, et al., 2015

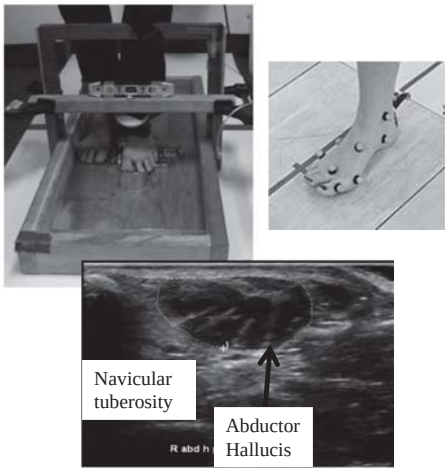
Researchers	Year	Intervention	Population	Measurements	Results
Unger & Wooden	2000	6 week toe flexor strengthening program	15 healthy subjects	Toe strength, vertical jump height, horizontal jump distance	Significant improvement in all categories
Jung, et al	2011	8 weeks of orthotics or SFE+orthotics	28 subjects with pes planus	CSA of ABDH, strength of FH	Increased CSA of ABDH and strength of FH in both groups, but more in the SFE+O group
Mulligan & Cook	2013	4 weeks of short foot/doming	21 asymptomatic subjects	Navicular drop, AHI, balance and reach task	Decrease in ND, increase in AHI, improvement in balance and reach task
Hashimoto, et al	2014	8 weeks of light resistance toe flexion	12 healthy males	Flexion strength, arch length, vertical jump, 1 legged long jump, 50m dash time	Increased flexion strength, decreased arch length, increased 1 legged long jump distance, increased vertical jump height, decreased 50m dash time
Lynn, et al	2012	4 week of SFE or TC, 100 reps/day	24 healthy	Navicular height, ROM of COP in ML direction for static and dynamic balance tests	No difference in navicular height or static balance test. Decrease ML COP movement in dynamic balance test - SFE group more than TCE group in non-dominant limb
Brueggemann, et al	2005	5 months of warm-up in minimalist shoes	25 healthy	Strength: MPJ flexor, subtalar inversion, plantarflexion, dorsiflexion Size: TA, peronei, TP, triceps surae, FH, FD	Increase in all strength measures, increase in ACSA of FH (4%), ABDH (5%), and QP (5%)
Chen, et al	2016	6 month transition to running in minimalist shoes	20 habitual shod runners	Forefoot and rearfoot muscle volume via MRI	Increase in forefoot muscle in experimental group
Miller, et al	2014	12 week transition to minimal footwear	17 runners	Muscle size (CSA, ACSA, MV), AHI, arch deformation	Increase in FDB muscle volume and ADM ACSA, no change in AHI, decrease in RAD
Johnson, et al	2016	10 week transition to minimalist footwear	18 runners	Muscle size	Increase in ABDH (10.6%)

The Effects of Foot Strengthening Programs for Runners

- Which muscles are influenced by strengthening?
  - Size?
  - Strength?
- What qualifies as a strengthening program?
- Are structural and functional changes induced?

The Effects of Foot Strengthening Programs for Runners

- 60 runners – 3 groups
  - Foot strengthening exercise (R+E)
  - Minimalist shoe walking (R+MSW)
  - Control (C)
- 8 weeks
  - Testing at 0, 4, and 8 weeks
- Measurements:
  - Foot strength
  - IFM muscle size
  - Arch deformation during running



Foot Strengthening Study Intervention

- Foot strengthening exercise (R+E)
  - Typical running
  - Progressive program of exercises 5-7 days/week
- Minimalist shoe walking (R+MSW)
  - Typical running
  - Progressively increasing # steps in minimalist shoes 5-7 days/week
    - Weeks 1 & 2: 2,500 steps/day
    - Weeks 3 & 4: 5,000 steps/day
    - Weeks 5-8: ≥ 7,000 steps/day
- Control (C)
  - Typical running

3 sets of all listed	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Double leg heel raises on flat surface	10 – 20 reps	20 – 30 reps						
Double leg heel raises off edge of step			10 – 20 reps	20 – 30 reps				
Single leg heel raises on flat surface					10 – 20 reps	20 – 30 reps		
Single leg heel raises off edge of step							10 – 20 reps	20 – 30 reps
Towel curls	10 – 20 reps	20 reps	20 – 30 reps	30 reps	30 reps	30 reps	30 reps	30 reps
Toe Spread	10 – 20 reps	20 reps	20 – 30 reps	30 reps	30 reps	30 reps	30 reps	30 reps
Toe Squeeze	10 – 20 reps	20 reps	20 – 30 reps	30 reps	30 reps	30 reps	30 reps	30 reps
Doming	10 – 20 reps	20 reps	20 – 30 reps	30 reps	30 reps	30 reps	30 reps	30 reps
Doming Hopping in place		10 reps	20 reps					
Doming Hopping Square			10 forward & back	20 forward & back	10 side to side	20 side to side	10 diagonal & back	20 diagonal & back

Measurements of IFM strength

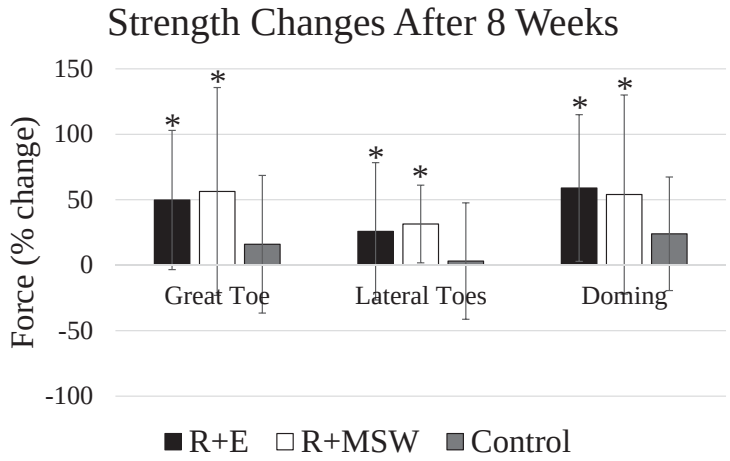
- Muscle size
  - Abductor Hallucis
  - Flexor Hallucis Brevis
  - Quadratus Plantae
  - Flexor Digitorum Brevis
- Functional strength measurements
  - Doming
  - Great toe flexion
  - Lateral toes flexion

Measurements of IFM strength

- Muscle size
  - Abductor Hallucis
  - Flexor Hallucis Brevis
  - Quadratus Plantae
  - Flexor Digitorum Brevis
- Functional strength measurements
  - Doming
  - Great toe flexion
  - Lateral toes flexion

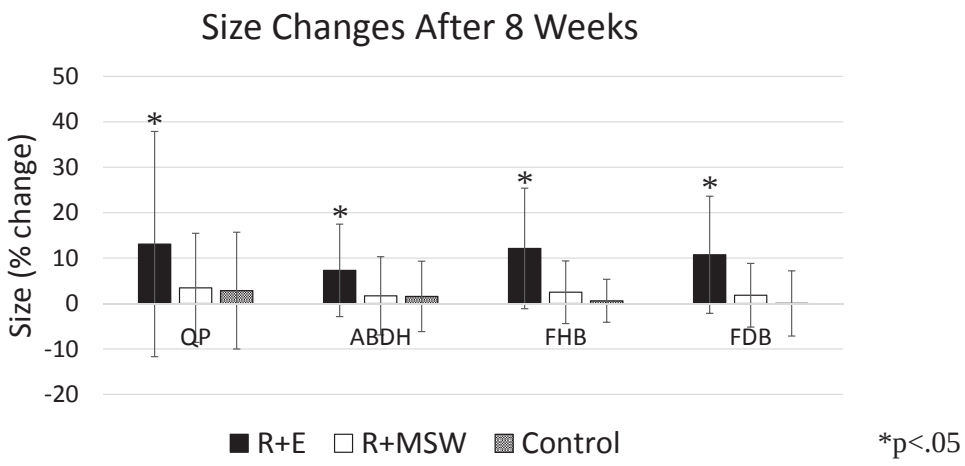



Results – Functional Strength



*p<.05

Results – Muscle Size



*p<.05

	Week 0 Averages (mm)			Week 8 Averages (mm)			Dynamic Arch Drop Change (mm)	Static Arch Height Change (mm)
	Static Arch Height	Dynamic Arch Height	Dynamic Arch Drop	Static Arch Height	Dynamic Arch Height	Dynamic Arch Drop		
Controls	14.38 ± 3.03	10.32 ± 4.84	4.06 ± 3.44	13.07 ± 3.47	9.05 ± 4.52	4.02 ± 3.20	-0.04 ± 1.61	-1.31 ± 3.75
Exercise (all)	14.99 ± 4.84	11.82 ± 5.25	3.17 ± 1.87	15.31 ± 3.36	12.71 ± 3.23	2.60 ± 1.76	-0.57 ± 2.33	0.33* ± 3.65
Exercise (≥3.8 mm initial drop)	15.04 ± 4.51	9.89 ± 4.44	5.15 ± 0.92	14.10 ± 2.68	11.36 ± 3.05	2.74 ± 2.06	-2.41† ± 2.28	-0.94 ± 2.72

*Significant difference in change in Static Arch Height between groups (p=0.013)
†Significant group by initial Dynamic Arch Drop interaction (p=0.005)

Preliminary Conclusions

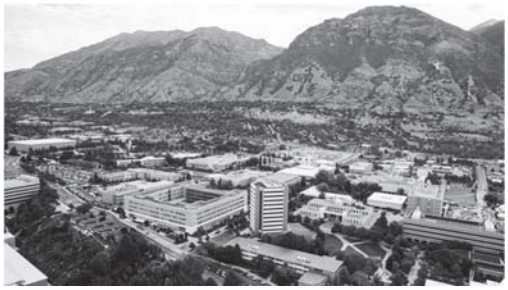
- Exercises increase IFM strength and size, may change dynamic arch stiffness during running
- Walking in MS increases IFM strength, but has not shown an increase in muscle size.
  - Neuromuscular adaptation prior to muscular adaptation
  - Length of “training” time?
  - Amount of stimulus?

Future Applications

- Effect of IFM strengthening on pain and foot pathologies
  - Plantar Fasciitis
  - Foot deformities
  - Neuropathies?
- Footwear/orthotics application?
- Injury prevention?
- Athletic performance?

Collaborators

- Wayne Johnson, PT, PhD
- Irene Davis, PT, PhD
- Bill Myrer, PhD
- Mark Olsen
- Tiffany deVries
- David Griffin
- Kevin Jurgensmeier
- Spencer Felton
- Kara Seabrook



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