Can minimal footwear improve knee osteoarthritis?

Isabel C. N. Sacco [associate professor]
Physical Therapy, Speech and Occupational Therapy dept,
School of Medicine

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.
Rheumatic disease highly prevalent (Woolf & Pfleger, 2003)

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

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).

Shakoor e Block, 2006

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

Naja 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 consequently, less damage joint loads

(Shakoor & Block, 2006, Doidge, 2007)
Can minimal footwear improve knee osteoarthritis?

- 25 bones
- ~47 muscles
- ~50 ligaments
- ~33 joints

10% lower limb weight
(Dempster 1965)

- 26 bones
- ~25 muscles
- ~108 ligaments

Foot
The Foot

A powerful tool with a structured arch, rigid and flexible within a single step to promote safe and efficient progression.
“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)
Walking Barefoot Decreases Loading on the Lower Extremity Joints in Knee Osteoarthritis

Naja Shakoor and Joel A. Block

**Acute usage**
**Positive results**

Shakoor et al., 2006

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

Shakoor et al., 2008

Inexpensive footwear decreases joint loading in elderly women with knee osteoarthritis


**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

Can minimal footwear improve knee osteoarthritis?

Shakoor et al., 2008

< 12%

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, Ricardo Fuller, Alessandra Matias, Mariane Yokota, Marco Butugan, Claudia Goldenstein-Schaimberg and Isabel C N Sacco

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

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.


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.

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

WOMAC Pain

-16%
-32%
-60%
-47%

Intervention Group
Control Group

Effect size: 1.32

Large ES: 1.32

(Score 0 - 20)

T0
T3
T6

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

Can minimal footwear improve knee osteoarthritis?

2/16/2017
Can minimal footwear improve knee osteoarthritis?

**WOMAC Function**

- **Intervention Group**
  - T0: -14%
  - T3: -25%
  - T6: -51%

- **Control Group**
  - T0: -45%

Large ES: 0.70

**WOMAC Total score**

- **Intervention Group**
  - T0: -24%
  - T3: -46%
  - T6: -52%

- **Control Group**
  - T0: -15%

Large ES: 0.75
Can minimal footwear improve knee osteoarthritis?

**Rescue medication**

- **Intervention Group**
- **Control Group**

<table>
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<tr>
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<td>5th</td>
<td>140</td>
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<td>6th</td>
<td>160</td>
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Significance levels:
- $p = .012$
- $p = .006$
- $p = .004$

**Joint moments**

- **Moleca use**
- **Control group**
- **Intervention group**

Adduction knee moment (%BW*height)

- Moment impulse
  - $14.9\%$
  - $12.0\%$

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

1. minimizing PAIN (67%)
2. improving FUNCTIONAL 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

[Diagram showing interactions between manufacturers, retailers, health professionals, and consumers]
Running shoes sales (USA)

Mass market vs. 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 maximalist 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 (<18 miles/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 lightweight efficient runners

Cushioning or/and support if injury prone

Current recommendations

Consumers

Retailers

Manufacturers

Health professionals

Runners World
Smart recommendations

X Based on RETAILERS’ beliefs

X Based on the current TREND

Based on the preferred COLOR

Based on COMFORT Only

✗

✗

?
Smart recommendations

NOT

• Weight of the person
• Foot type
• Weekly mileage

Smart recommendations

Habits
Fitting

Less shoes  More shoes

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

\[ MI : 52\% \]

Biomechanics in minimalist shoes are the same as in barefoot running

\[ MI : 96\% \]

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**Research**

A consensus definition and rating scale for minimalist shoes

Jean-François Esculier\(^1,2,3\), Blaise Dubois\(^1,3\), Clermont E. Dionne\(^4\), Jean Leblond\(^2\) and Jean-Sébastien Roy\(^1,2,4\)*

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 1 mm 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)

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

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

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Specific shoe characteristics, kinematics and kinetics

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

Small or no differences on kinematic and kinetic variables

Different SHOES = Different KINEMATICS

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

16 conditions

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

"Different SHOES = Different KINEMATICS"

The more maximalist the shoe (greater stack & greater drop), the greater the foot strike angle
• 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.)
Aims of the Minimalist Index

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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

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

- No more injuries
- Running related injury: 25%
- More injuries among regular runners than occasional runners?

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

* 36 experienced recreational runners, usually running with traditional shoes

- No stress fracture
- Increased bone marrow edema + 2 foot stress fractures

MRI

10 weeks

Progress up to 15 km / 30 km total
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

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. Fu, MD, Darren Theaker, PhD, Jonathan D. Buckley, PhD, Richard A. Burke, PhD, Jason Newsham-West, and Maggie E. Fagan, PhD

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

Running related injury: 37%
No more injuries
More injuries for heavy runners?
17-02-08

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

Tony Lin-Wei Chen*, Louis K.Y. See**, Irene S. Davis**, Rey T.H. Cheung***

* canoe@asics.com (exercise and foot biomechanics)
** Department of Rehabilitation Science, The Hong Kong Polytechnic University, Hong Kong
*** School of Physical Education and Rehabilitation, Arizona State University, Tempe, Arizona, USA

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**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.

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* 47 traditionally shod runners aged 20-45 years old (running >20km/wk for at least 12 months)
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
Role of intrinsic foot muscles (IFM)

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

IFM role in stabilization

- Weak IFM have been associated with impaired balance and increased risk of falls in the elderly\textsuperscript{5,6}
- Similar function to deep core stabilizers of the spine\textsuperscript{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. Does supportive footwear weaken the IFM?
- Runners with chronic plantar fasciitis have lower rearfoot IFM volume than healthy runners.
- Toe flexor strength of feet with plantar fasciitis (PF) is lower than healthy feet.
- MLA helps with shock absorption during loading. Do weak IFM → less control of MLA?
- Muscle weakness is a factor for stress fracture.
  - Runners who suffered from BME during transition to minimal footwear had smaller IFM during pre-transition testing.

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
IFM strengthening exercises –
Short Foot/Doming

IFM strengthening exercises –
Toe Flexion
IFM strengthening exercises – Heel Raises

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

Kamonseki, et al., 2015
### 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
### 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

Strength Changes After 8 Weeks

- Great Toe
- Lateral Toes
- Doming

- R+E
- R+MSW
- Control

*p<.05
Results – Muscle Size

Size Changes After 8 Weeks

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

References