Footstrike, Form and Footwear:

A Running Mechanics Review

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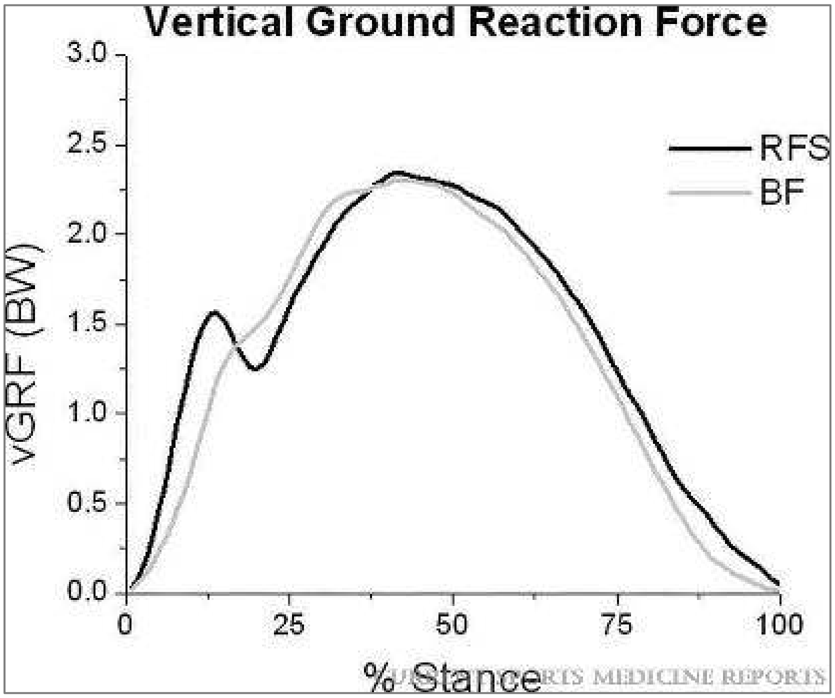
The Ideal Barefooter

Assumptions about running barefoot

- We are born and bred to run barefoot
- Its natural and therefore better
  - Better for injury
  - Better for performance
- Shoes inhibit our innate and superior running technique
- Shoes have not decreased injury rates since their intro duction in the 1970s

What are ideal barefoot running mechanics?

- Less impact loading (transient and rate)
- Less joint loads
- Different kinematics



Is the ideal supported?

Yes, when research compares the best of barefoot running with a rearfoot strike in cushioned running shoes differences in mechanics exist.

However, exceptions do occur and other factors beside simple running barefoot influence the mechanics of running.

This e-book will explore those differences

Differences between Barefoot and Shod

Warning: Difficulties comparing across studies

We should have some reservations when making blanket statements about absolute differences in running mechanics between running barefoot and running shod. Running barefoot is associated with certain running kinematics that can influence all other running mechanics. It is possible that it is these running kinematic differences that are responsible for changes in running mechanics and running barefoot is a catalyst to obtain those kinematics

An Overview of Barefoot Differences

Altman and Davis (2012) demonstrated a number of kinematic and kinetic differences between running barefoot and running shod.

Table 1. Means of the variables of interest, * indicates a moderate ES, and ** indicates a high ES.

	SH Mean (SD)	BF Mean (SD)	*ES*
SI	32.6 (22.9)	64.9 (10.8)	*1.3***
DF@FS	8.0 (7.9)	-1.2 (3.6)	*1.3***
KF@FS	-12.7 (3.0)	-21.3 (4.0)	*1.5***
VILR	90.3 (23.2)	70.9 (34.3)	*0.6**
VALR	81.9 (20.6)	55.4 (31.8)	*1.0***

In general we see the following trends:

- Footstrike shifts anteriorly to more of forefoot strike or midfoot strike (SI = Stride Index)
- Barefooter's ankles tend to be more plantarflexed at footstrike and that ankle joint goes through a greater range of motion
- Barefooter's tend to land with their foot in greater inversion, have greater calcaneal eversion range but less peak calcaneal eversion when compared to shod heel running. Morley et al (2010) showed a decrease of >5 degrees in calcaneal eversion range when running barefoot in those with increased pronation values
- Ankle stiffness is therefore reduced when running barefoot with a forefoot strike versus a shod gait using a more rearfoot strike (Lieberman 2010)
- BF have increased arch strain (Perl et al 2012)
- Joint torques at the ankle tend to be increased while running barefoot with greater plantar flexion impulse (Standifird 2012, Kerrigan 2009, Perl)
- BFs tend to land with their knee more flexed and go through a smaller range of knee flexion range
- This decreased knee flexion excursion leads to increased stiffness at the knee
- BF knee torques are reduced in flexion, internal rotation and varus (Kerrigan 2009, Standifird 2012)
- BF tends to have decreased stride length and increased stride rate (Squadronne 2010)
- BF with a forefoot strike is associated with a loss of the impact transient, decreased rate of impact loading with no change in peak loading during push off (Lieberman 2010)

The previous trends in barefoot running assume a forefoot foot strike. Certain kinematic variables must be obtained during barefoot running to obtain differences in kinematics and kinetics. Unfortunately little research has compared running in shoes in a kinematically identical manner to running barefoot. Thus, we can not fully tease out the influence of barefoot running alone on running mechanics.

Kinematic Changes with Barefooting

The Ankle

During the impact period, FFS runners (filled boxes) dorsiflex the ankle rather than plantarflexing it, and have more ankle and knee flexion than do RFS runners (open boxes).

Calcaneal eversion excursion range is increased by peak eversion is less (Morley 2010)

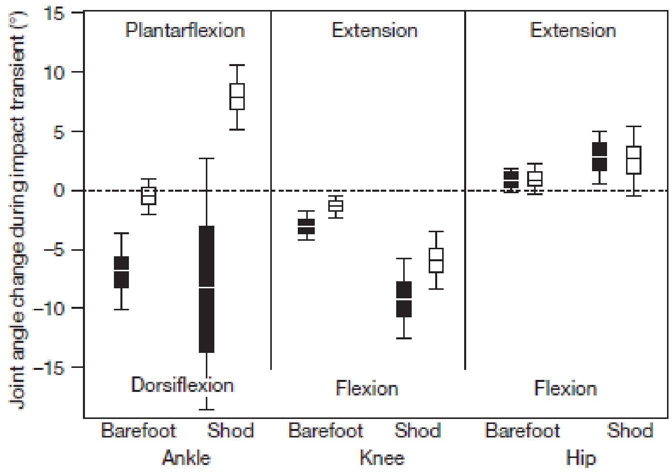


Table 1 Group means (*M*) and standard deviations (*SD*) for all measured parameters for each experimental condition (shod versus barefoot)

Variable	Shod Condition Low	Shod Condition Middle	Shod Condition High	Barefoot Condition Low	Barefoot Condition Middle	Barefoot Condition High
ME	$6.7^{N,O}$ ± 2.1	$10.3^{O,*}$ ± 0.9	14.8* ± 1.5	6.3^{O} ± 2.6	6.7* ± 1.7	9.2* ± 3.2
TME	38.6* ± 7.1	40.6* ± 10.9	36.9* ± 8.3	25.0* ± 11.5	23.8* ± 10.2	27.2* ± 8.4
PM	0.10 ± 0.03	0.13 ± 0.05	0.10 ± 0.04	0.10 ± 0.03	0.14 ± 0.05	0.11 ± 0.03
TPM	32.9* ± 10.4	28.7 ± 11.2	23.9 ± 13.7	24.0* ± 13.1	22.4 ± 7.9	21.9 ± 10.8
PL	0.11 ± 0.06	0.09* ± 0.02	0.11 ± 0.05	0.12 ± 0.03	0.13* ± 0.04	0.12 ± 0.03
TPL	22.5* ± 20.3	17.7* ± 6.2	20.0* ± 14.9	12.9* ± 12.2	7.23* ± 3.4	9.72* ± 9.0
AD	0.20^{N} ± 0.05	$0.23^{O,*}$ ± 0.06	0.21 ± 0.05	0.22 ± 0.04	0.27* ± 0.08	0.24 ± 0.05
IPM	4.75* ± 3.5	5.61 ± 3.7	3.67 ± 3.2	3.36* ± 1.9	4.81 ± 3.3	3.47 ± 2.3
IPL	1.25 ± 0.8	1.11 ± 0.5	2.85* ± 3.8	1.35 ± 0.8	1.04 ± 0.7	1.43* ± 0.7
TMI	5.52 ± 3.5	6.65 ± 3.8	4.25 ± 3.4	4.29 ± 2.3	6.16 ± 3.6	4.37 ± 2.1
TLI	2.27 ± 1.7	1.86 ± 1.0	4.96 ± 3.8	2.54 ± 1.47	2.07 ± 1.0	3.71 ± 2.6

Note. Subjects were divided into three equal groups ($N = 10$) based upon their peak eversion values: the low pronation (3–8.9 deg), the middle pronation (9–12.9 deg), and the high pronation (13–18 deg) groups. The kinematic parameters are the maximum eversion (ME) and the time to maximum eversion (TME). The ML-GRF parameters are the peak medial ML-GRF (PM), the peak lateral ML-GRF (PL), their respective times of occurrence (TPM and TPL), the absolute difference between PM and PL (AD), the impulses associated with the PM and the PL (IPM and IPL) and the total medial and lateral impulses (TMI and TLI). Timing parameters are expressed in percentage of stance, ME in degrees, impulses in newton seconds, PM and PL in body weight.

*Significantly different between conditions for the same group ($p < 0.05$).

^{N,O,U}Significantly different between groups for the same condition ($p < 0.05$).

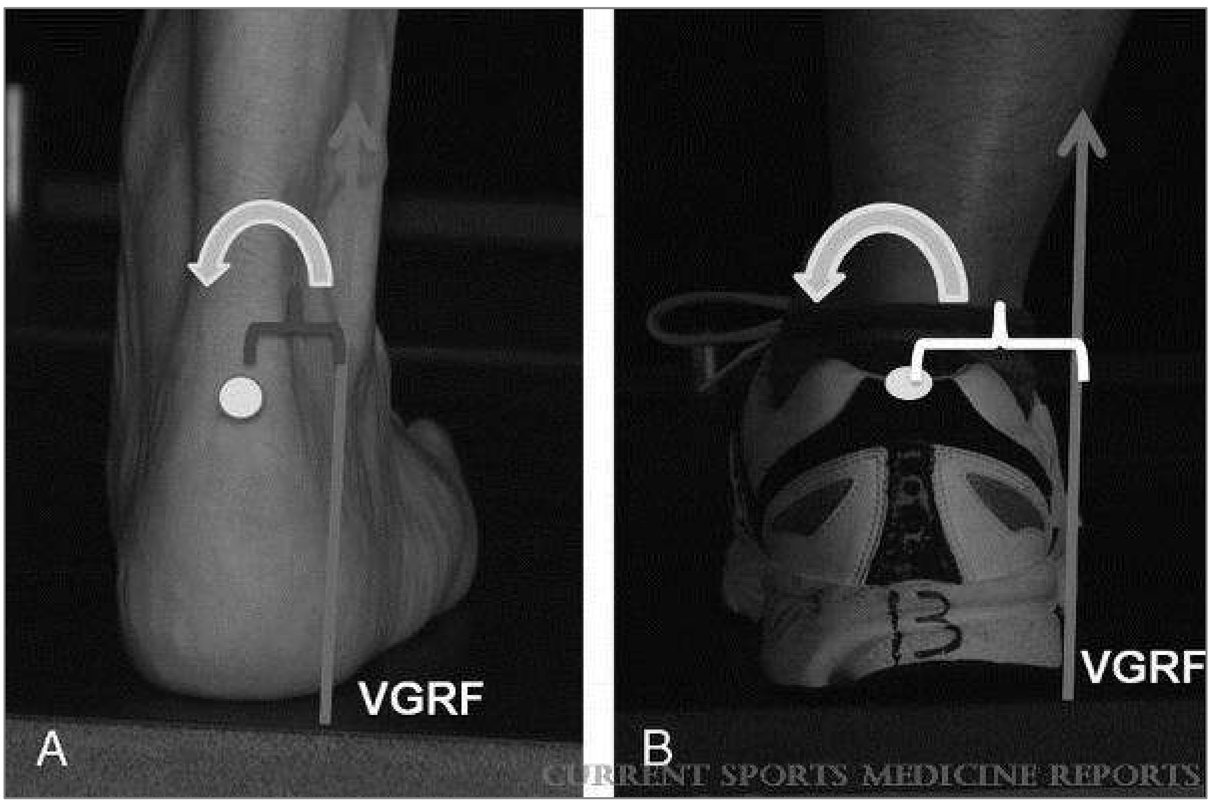
Kinematic Changes with Barefooting

The Ankle - Increases in calcaneal eversion with shoes

Shoes may increase the propensity to calcaneal eversion.

Eversion (pronation) moment (curved arrow) during barefoot (A) and shod (B) running, created from the vertical ground reaction force at landing. The eversion moment is higher in the shod condition (B) due to the larger moment arm resulting from the increased width of the shoe and heel flare.

From Altman and Davis 2012



Kinematic Changes with Barefooting

The Knee

In general the knee is bent to a greater degree at footstrike but flexes less (decreased excursion) during the loading period. This leads to increases in knee stiffness.

However, the response is highly variable across the shod condition and the type of foot strike.

Perl et al (2012 - Table on the right) documents these changes.

Table 1 below is from Lieberman et al (2010)

	Knee Excursion (degrees)			
	Barefoot		Standard Shoes	
Subject	FFS	RFS	FFS	RFS
1	18.30	20.10	21.50	17.50
2	26.00	27.00	26.80	29.70
3	24.30	25.80	28.20	28.00
4	19.90	16.20	20.10	15.00
5	21.90	22.20	25.70	29.60
6	29.70	25.00	29.70	27.10
7	20.60	22.30	26.40	19.90
8	20.60	23.90		
9	23.50	16.60		
10	16.10	20.00	17.60	23.30
11	20.60	22.00	20.90	25.10
12	22.70	22.10	22.60	28.40
13	24.50	29.30		
14	24.20	26.90	26.40	29.30
15	24.40	24.10	27.40	30.30
Mean ± SD	22.49 ± 3.33	22.90 ± 3.70	24.44 ± 3.76	25.27 ± 5.21

Table 1 | Foot strike type and joint angles of habitual barefoot and shod runners from Kenya and the USA

Group	N (male/female)	Age (age shod) (yr)	Strike-type mode (%)*				Joint angle at foot strike			Speed (m s^{-1})
			Condition	RFS	MFS	FFS	Plantar foot†	Ankle†	Knee	
(1) Habitually shod adults, USA‡	8 (6/2)	19.1 ± 0.4 (<2)	Barefoot	83	17	0	−16.4 ± 4.4°	0.2 ± 3.0°	12.1 ± 7.9°	4.0 ± 0.3
			Shod	100	0	0	−28.3 ± 6.2°	−9.3 ± 6.5°	9.1 ± 6.4°	4.2 ± 0.3
(2) Recently shod adults, Kenya	14 (13/1)	23.1 ± 3.5 (12.4 ± 5.6)	Barefoot	9	0	91	3.7 ± 9.8°	18.6 ± 7.7°	21.2 ± 4.4°	5.9 ± 0.6
			Shod	29	18	54	−1.8 ± 7.4°	15.0 ± 6.7°	22.2 ± 4.3°	5.7 ± 0.6
(3) Habitually barefoot adults, USA§	8 (7/1)	38.3 ± 8.9 (<2)	Barefoot	25	0	75	8.4 ± 4.4°	17.6 ± 5.8°	17.3 ± 2.5°	3.9 ± 0.4
			Shod	50	13	37	−2.2 ± 14.0°	8.1 ± 15.9°	16.6 ± 2.4°	4.0 ± 0.3
(4) Barefoot adolescents, Kenya	16 (8/8)	13.5 ± 1.4 (never)	Barefoot	12	22	66	1.13 ± 6.8°	14.6 ± 8.3°	22.8 ± 5.4°	5.5 ± 0.5
			Shod‖	—	—	—	—	—	—	—
(5) Shod adolescents, Kenya	17 (10/7)	15.0 ± 0.8 (<5)	Barefoot	62	19	19	−10.1 ± 9.7°	4.1 ± 10.9°	18.9 ± 6.5°	5.1 ± 0.5
			Shod	97	3	0	−19.8 ± 10.3°	−2.7 ± 9.0°	18.4 ± 6.6°	4.9 ± 0.5

Data shown as mean ± s.d.
* RFS equivalent to heel-toe running; FFS equivalent to toe–heel–toe running.
† Angle of the sole of the foot or shoe (column 8), or of the ankle (column 9), relative to ground. Negative values indicate dorsiflexion relative to standing position; positive values indicate plantarflexion relative to standing position.
‡ Joint angles calculated from RFS only.
§ Joint angles calculated from FFS only.
‖ No shod condition reported because subjects had never worn shoes.

Kinematic Changes with Barefooting

The Hip

No substantial changes documented. However, changes in strides length and stride rate (Heiderscheit 2011) have been associated with:

- decreased hip adduction

	Step Rate Condition				
Measure	**−10%**	**−5%**	**Preferred**	**+5%**	**+10%**
Hip					
Peak Flexion Angle (°)	30.7 (5.7)*	27.9(5.8)	26.7(5.5)	25.3(5.5)	23.6(6.0)*
Peak Adduction Angle(°)	11.3 (3.6)*	10.8(3.3)	10.4(3.3)	9.5(3.1)*	8.7(3.1)*
Peak Internal Rotation Angle(°)	1.3 (4.9)*	0.8(4.6)	0.4(4.3)	0.3(4.3)	0.4(4.4)
IC Extension Moment (Nm/kg)	0.2 (0.5)	0.3(0.6)	0.3(0.5)	0.4(0.5)	0.4(0.5)
Peak Abduction Moment (Nm/kg)	1.9 (0.5)	1.8(0.4)	1.8(0.4)	1.8(0.4)	1.7(0.4)*
Peak Internal Rotation Moment(Nm/kg)	0.7 (0.2)*	0.6(0.2)	0.6(0.2)	0.6(0.2)	0.5(0.2)*
Knee					
IC Flexion Angle (°)	16.9 (4.2)	17.0(4.1)	17.8(4.0)	18.7(3.9)	19.6(4.2)*
Peak Flexion Angle(°)	50.6 (4.8)*	48.0(4.7)*	46.3(4.5)	44.1(4.7)*	42.8(4.4)*
Peak Extension Moment(Nm/kg)	2.7 (0.6)*	2.7(0.6)	2.5(0.6)	2.4(0.6)	2.2(0.4)*

*significantly different from preferred, $p<0.05$

Spatiotemporal changes with Barefoot

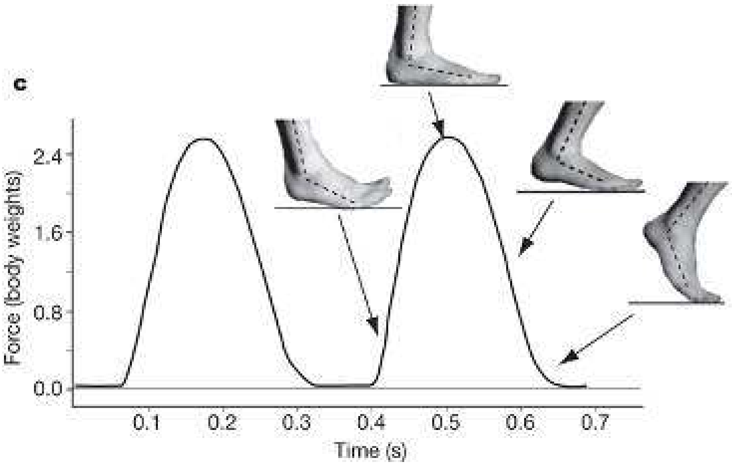
TABLE I.—*Spatio-temporal, kinetic, physiological and kinematic variables (means and standard deviations of 8 subjects).*

Variables	Barefoot (mean±SD)	Vibram fivefingers (mean±SD)	Running shoes (mean±SD)
Stride length (m)	2.19±0.2	2.29±0.16*	2.34±0.15*
Stride frequency (stride/min)	91.2±0.9	88.3±0.9*	86.0±1.1*
Step time (s)	0.327±0.002	0.343±0.002*	0.350±0.003*
Contact time (s)	0.245±0.002	0.242±0.002	0.255±0.002†
Flight time (s)	0.082±0.002	0.101±0.003*	0.096±0.003*
CP line length (mm)	133±6.4	150.3±3.8*	160.3±9*
Strike index (%)	58±6	56±5	40±6* †
Amplitude of the impact peak vertical force (BW)	1.62±0.4	1.59±0.5	1.72±0.4* †
Amplitude of the thrust peak vertical force (BW)	2.43±0.5	2.49±0.5	2.46±0.6
$\dot{V}O_2$ (mL kg^{-1} min^{-1})	45.7±2	45±2	46.3±2†
Heart rate (bps)	132±6	129±4	130±5
Knee angle -15 ms before touchdown (deg)	155±4	156±3	159±4
Ankle angle -15 ms before touchdown (deg)	94±5	93±4	87±5* †
Foot angle -15 ms before touchdown (deg)	3±4	4±4	12±4* †
Knee range of motion during the support phase (deg)	25±4	24±5	27±4
Ankle range of motion during the support phase (deg)	29±3	28±4	21±3* †

CP: center of pressure; BW: body weight. *Significantly different from barefoot condition; P<0.05. †Significantly different from vibram fivefingers; P<0.05.

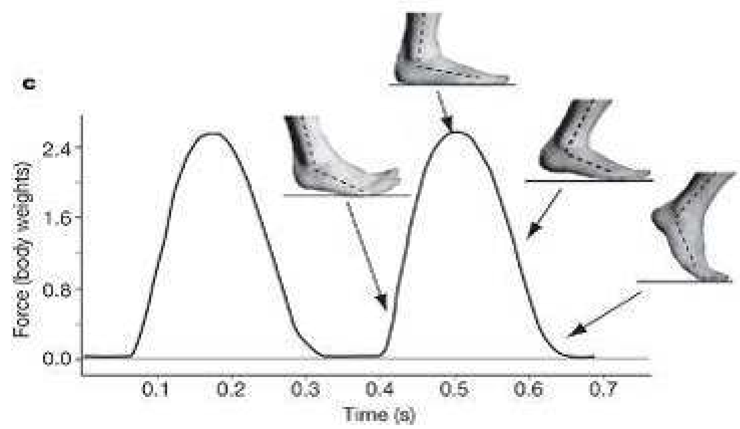
From Squadrone 2010

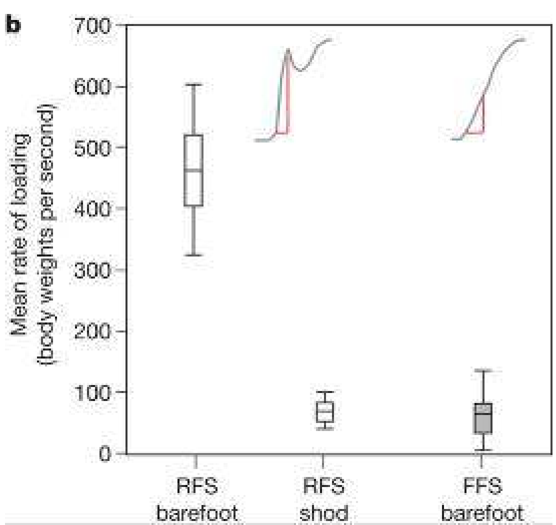
Ground Reaction during Barefooting

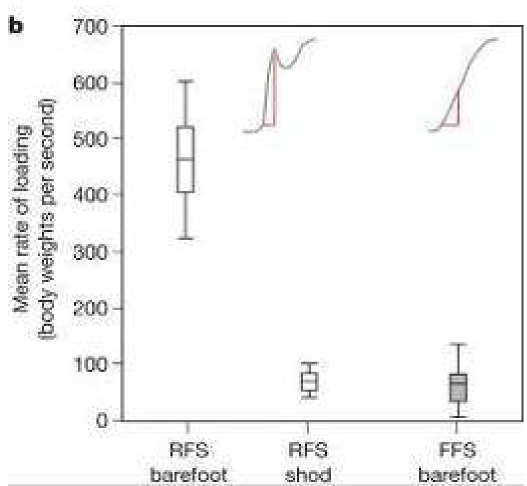


Lieberman et al (2010) documented that barefoot runners who used a forefoot striking pattern obtained a loss of the initial impact transient as well as a reduction in the rate of impact loading. The impact transient can be seen in the picture on the right. It is the first initial bump in the vertical ground reaction force. The rate of impact (i.e. the slope or how quickly force is developed) is also lessened when using a barefoot forefoot striking pattern versus a rearfoot, shod pattern. Altman and Davis (2012) have documented similar changes in the VGRF

Lieberman et al (2010) showed the greatest changes in impact loading when comparing barefoot forefoot striking versus barefoot rearfoot striking. If running barefoot with a heelstrike we can expect large increases in the rate of loading and an occurrence of a transient. Wearing shoes appears to offer some protection for a heel strike. See the charts below from Lieberman et al (2010).







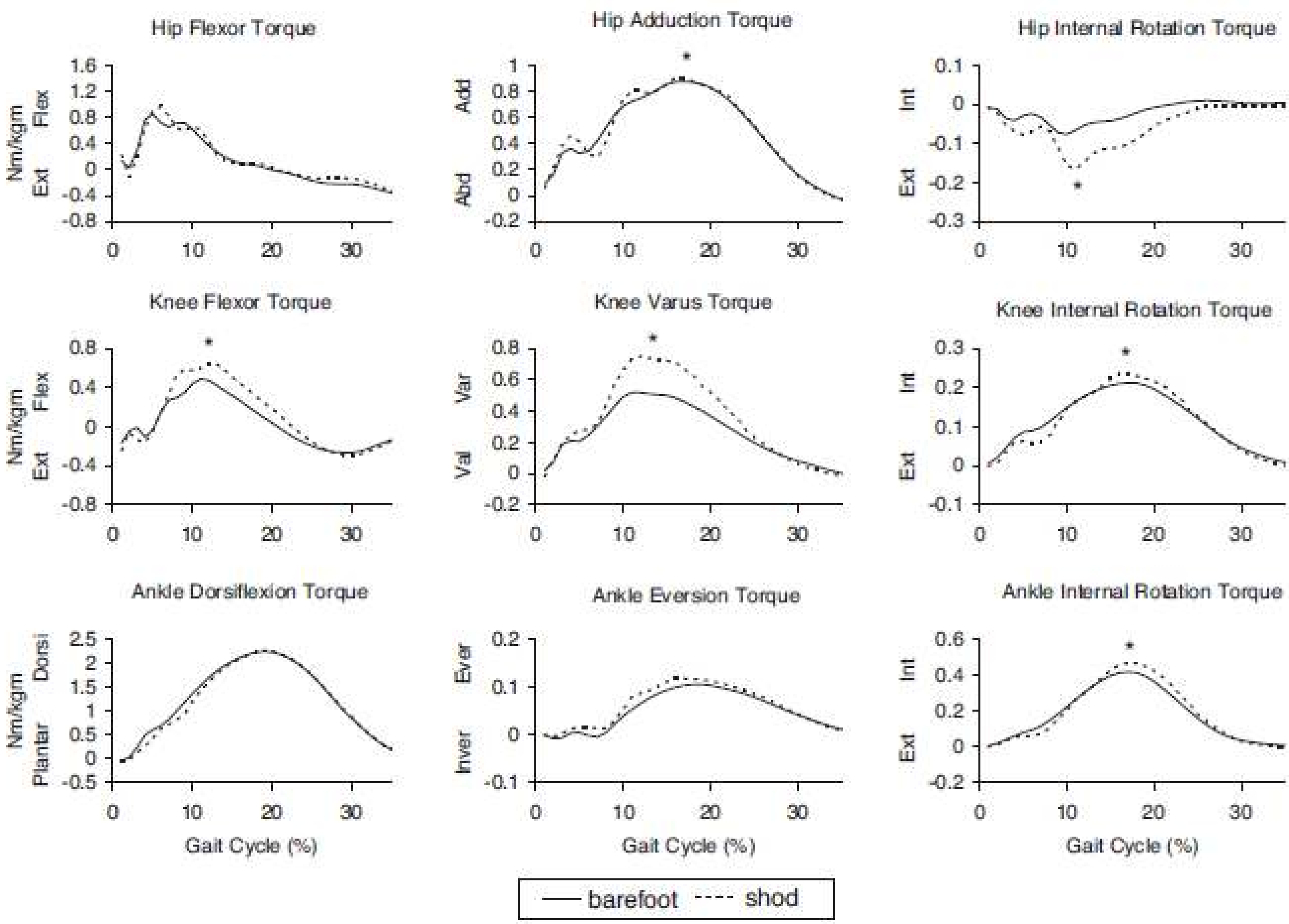
Joint Loading during Barefoot Running

Standifird et al (2012)

Table 1: Joint moments at the active peak vertical ground reaction force
B=Significant difference from barefoot
V=Significant difference from Vibram®

Joint	**Barefoot**	**Vibram**	**Shoe**
Ankle Plantarflexion Moment (Nm/kgm)	1.49	1.43	1.21[BV]
Knee Extension Moment (Nm/kgm)	1.86	1.96	2.26[BV]
Hip Extension (Nm/kgm)	1.49	1.43	1.35[B]

Kerrigan et al (2009) documented increases in joint torques when running shod verus barefoot. No information on footstrike style was provided by increases in stride rate and decreases in stride length were noted.



When is barefooting problematic?

Increases in the rate of impact loading and the impact transient have been documented when running barefoot. This primarily occurred in studies where the participants were asked to run with heel strike or in a study where they chose to run with a heelstrike. Without the protective influence of ankle dorsiflexion and decreased stride length barefoot heelstriking is associated with increased loading rates.

From De Wit et al (2010)

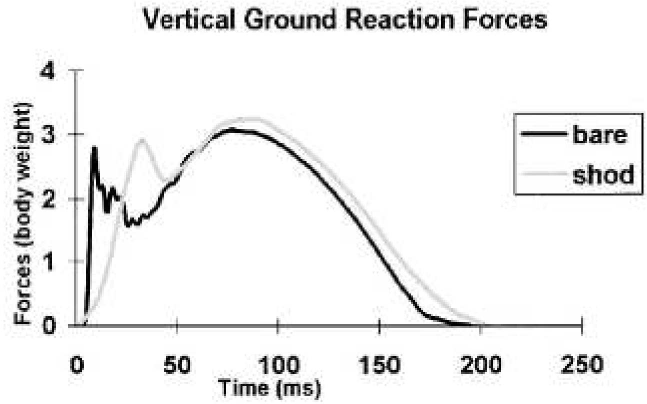


Fig. 3. Vertical ground reaction curves of 1 representative person (1 trial barefoot and 1 trial shod) at a velocity of 4.5 m s^{-1}.

Barefoot running is also associated with **increases in arch strain and plantar flexion impulse**. Perl et al (2012) documented increases in these variables in runners running barefoot with a forefoot strike pattern versus running barefoot with a heelstrike pattern.

	Triceps Surae Impulse (bw*s)			
	Barefoot		Standard Shoes	
Subject	FFS	RFS	FFS	RFS
Mean ± SD	49.99 ± 7.64	39.44 ± 7.32	45.12 ± 6.27	35.01 ± 4.82

	Arch Strain - NH (max-min/standing)			Arch Strain - Curvature (max-min/standing)		
	Barefoot			Barefoot		
Subject	FFS	RFS	**Percent Difference: FFS vs RFS**	FFS	RFS	**Percent Difference: FFS vs. RFS**
Mean ± SD	23.13% ± 85.1%	15.51% ± 7.61%	**44.11% ± 22.17% (<0.0001)***	23.28% ± 8.58%	11.58% ± 7.86%	**78.62% ± 33.84% (<0.0001)***

NH, navicular height; FFS; forefoot strike; RFS, rearfoot strike

Footstriking Loading Issues

Merely changing your shoes is not sufficient to achieve changes in loading variables and footstrike kinematics. Becker et al (2012) showed that running barefoot does not consistently lead to changes in footstrike style and when it does lead to a transition to a Midfoot or Forefoot strike this does not necessarily lead to lower impact characteristics

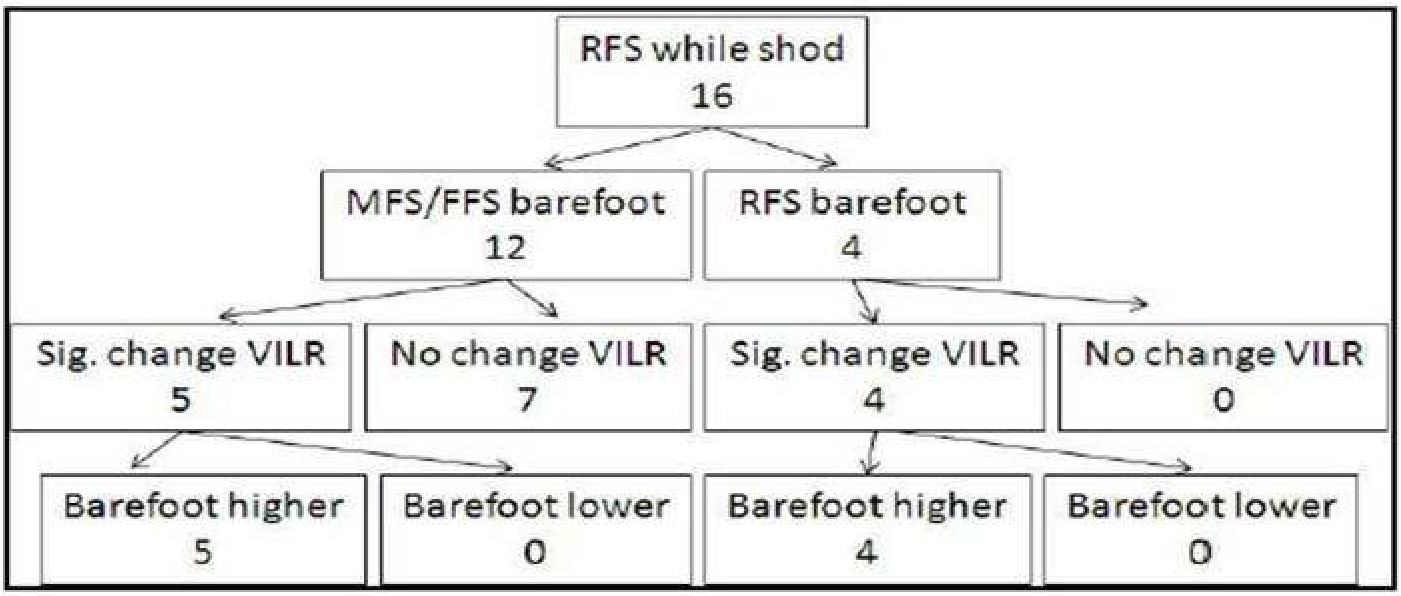


Figure 2. Changes in VILR in subjects with a RFS while running shod.

Becker et al (2012)

Mimicking Barefooting

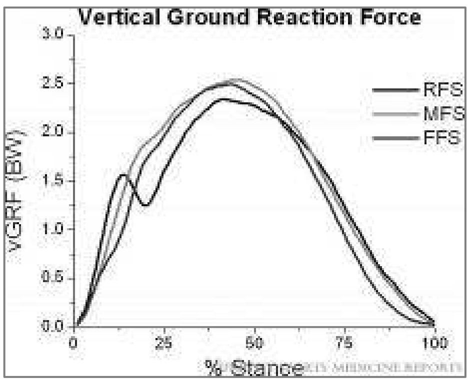
Can we change gait variables to achieve the assumed benefits of barefoot running?

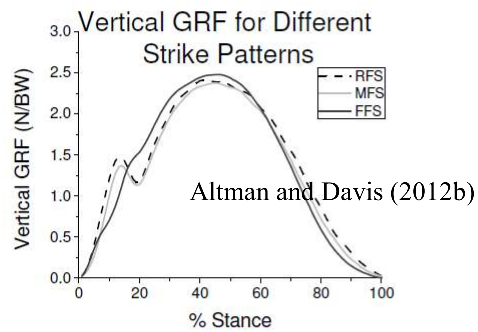
Assumed Ideal Barefoot Characteristics

- Midfoot to forefoot strike
- Increased stride rate and decreased stride length
- Minimal interference between the foot and the ground

Differences in Footstrike

Altman and Davis (2012a) have shown that running with a midfoot or forefoot strike while wearing shoes can be associated with decreases in loading rates and a loss of the impact transient..





However, a midfoot stride is not a sufficient condition to achieve decreases in impact loading. Altman and Davis (2012b) showed inconsistent changes in the rate of impact loading. Altman and Davis (2012b) suggested that some runners had their toes dorsiflexed during landing which may have been a factor in not seeing decreases in impact loading.

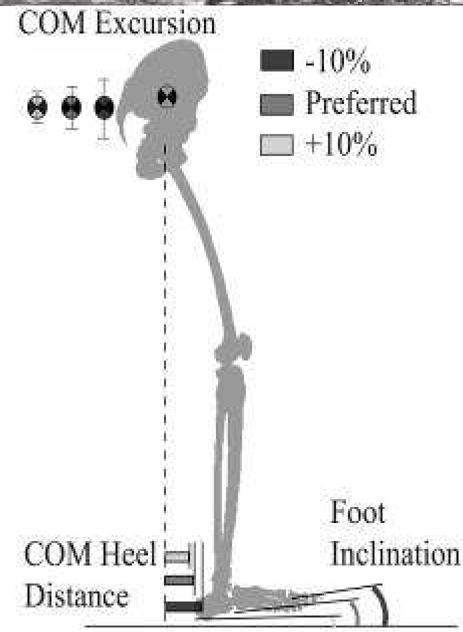
Giandolinni (2012) documented similar changes following a long term, well trained, transition to a midfoot strike. They found:

•loss of the impact transient when switching (also found in the COMBI)
•greater than 50% decrease in the rate of loading (also found in COMBI)
•interestingly no change in step rate (this is of interest because we often assume that this happens with a midfoot strike. We typically assume that running midfoot versus the heel naturally shortens the stride – suggesting that we can get changes in loading rates without decreasing stride length)

Laughton, Davis and Hamill (2003) investigated fifteen habitually rearfoot strike runners and then converted them to a forefoot strike pattern in a single session. The authors found:

•increased average peak vertical ground reaction force
•increased Anterior to Posterior GRF
•Increased Anterior to Posterior loading rates
•no difference in average or instantaneous GRF loading rates
•The difference was that the heel was not allowed to come down to the ground - thus all forefoot striking is not created equal

Changing Stride Length and Rate



Heiderscheit (2011)

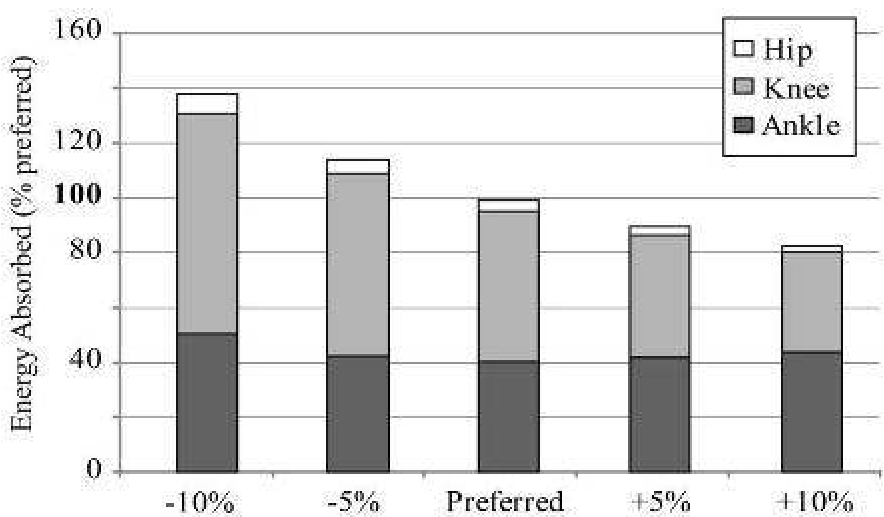
Increasing rate by 5% and 10%

- decreased step length
- decreased Center of Mass vertical excursion (less bouncing up and down)
- decreased horizontal distance from the center of mass to the foot (i.e. less overstriding in front of you)
- less knee flexion (excursion) during the foot contact (i.e. increases stiffness)
- decreased energy absorption and energy production at the knee
- decrease in the impact transient occurrence (there were times when runners did not have that sharp spike in ground reaction force plot)
- decreased braking impulse

Increasing step rate by 10%

- decrease in foot inclination angle at contact (toes point down more)
- decreased stance time duration
- increased rating of perceived exertion
- less hip flexion and adduction
- increased knee flexion at initial contact
- decreased peak vertical ground reaction force
- decreased energy absorption at the hip

Energy Absorbed with changes in Step Rate



Stride Length Changes Kinematics

Heiderscheit (2011)

	Step Rate Condition				
Measure	**−10%**	**−5%**	**Preferred**	**+5%**	**+10%**
Hip					
Peak Flexion Angle (°)	30.7 (5.7)*	27.9(5.8)	26.7(5.5)	25.3(5.5)	23.6(6.0)*
Peak Adduction Angle(°)	11.3 (3.6)*	10.8(3.3)	10.4(3.3)	9.5(3.1)*	8.7(3.1)*
Peak Internal Rotation Angle(°)	1.3 (4.9)*	0.8(4.6)	0.4(4.3)	0.3(4.3)	0.4(4.4)
IC Extension Moment (Nm/kg)	0.2 (0.5)	0.3(0.6)	0.3(0.5)	0.4(0.5)	0.4(0.5)
Peak Abduction Moment (Nm/kg)	1.9 (0.5)	1.8(0.4)	1.8(0.4)	1.8(0.4)	1.7(0.4)*
Peak Internal Rotation Moment(Nm/kg)	0.7 (0.2)*	0.6(0.2)	0.6(0.2)	0.6(0.2)	0.5(0.2)*
Knee					
IC Flexion Angle (°)	16.9 (4.2)	17.0(4.1)	17.8(4.0)	18.7(3.9)	19.6(4.2)*
Peak Flexion Angle(°)	50.6 (4.8)*	48.0(4.7)*	46.3(4.5)	44.1(4.7)*	42.8(4.4)*
Peak Extension Moment(Nm/kg)	2.7 (0.6)*	2.7(0.6)	2.5(0.6)	2.4(0.6)	2.2(0.4)*

*significantly different from preferred, $p<0.05$

WARNING

Again, changes are not automatic. Giandolini (2012) found no change in impact variables with changes in stride rate alone

- no change in the rate of impact loading
- no change in the impact transient
- no change in the time that your foot is on the ground
- a decrease in the aerial time (time you are in flight)
- increase in stiffness (vertical)

Concerns about changing footstrike

Derrick et al 2012

A change in footstrike pattern is not sufficient to change loading variables.

Further a transition to a forefoot strike increases arch strain and strain on the plantar flexors (Perl et al 2012). Increases in Gastrocnemius and Tibialis Anterior muscle activation was found just prior to footstrike (Giandolini et al 2012). Increases in calf muscle strain have been associated with increases in tibial strain with a musculoskeletal modelling (Altman and Davis 2012 and Derrick et al 2012). This research is currently only published as abstracts the American Society of Biomechanics conferences so the research may not have been sufficiently vetted.

Table 1. Means (sd) for group (RF and FF) and running style (rf and ff) compressive stresses (MPa) in each quadrant of a cross section 75% from the proximal end of the tibia.

Stress	RF		FF	
Quadrant	rf	ff	rf	ff
AM	-128 (34.1)	-136 (35.7)	-135 (34.6)	-141 (39.6)
AL	-109 (28.9)	-134 (31.6)	-108 (25.4)	-130 (44.9)
PM	-128 (41.5)	-121 (33.1)	-139 (43.2)	-132 (32.9)
PL	-30 (7.9)	-31 (7.7)	-66 (15.9)	-65 (12.3)

Altman and Davis 2012: Comparison of tibial strains and strain rates in barefoot and shod running

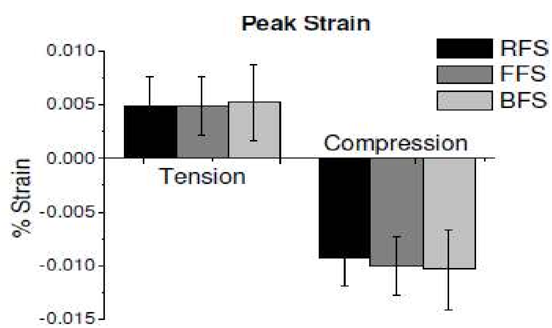


Figure 1: Peak strain shown for the rearfoot (RFS), forefoot (FFS) and barefoot (BFS) conditions in both tension and compression.

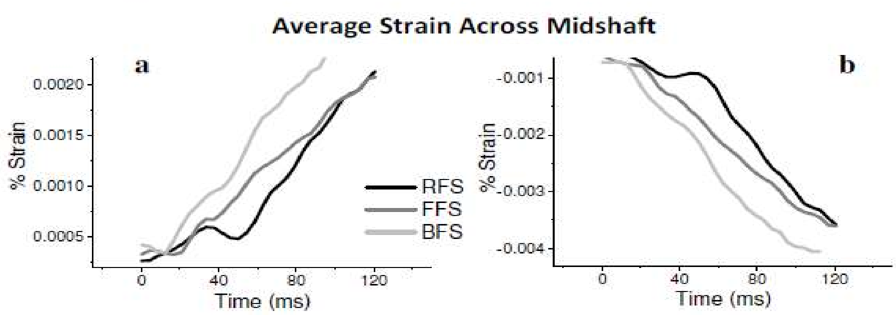


Figure 2: Average tensile (a) or compressive (b) strain from the all elements in the midshaft for a representative subject.

Quote

"While peak strains were similar between conditions, strain rates were highest in the forefoot condition due to muscular contributions. It may be that barefoot running requires less muscle force than the shod forefoot condition due to the lower inclination angle of the foot at footstrike"

Altman and Davis 2012

Changing shoes for form changes

ACCURACY OF SELF-REPORTED FOOTSTRIKE PATERNS AND LOADING RATES ASSOCIATED WITH TRADITIONAL AND MINIMALIST RUNNING SHOES

1Donald L. Goss, 1Michael D. Lewek, 1Bing Yu, and 1Michael T. Gross

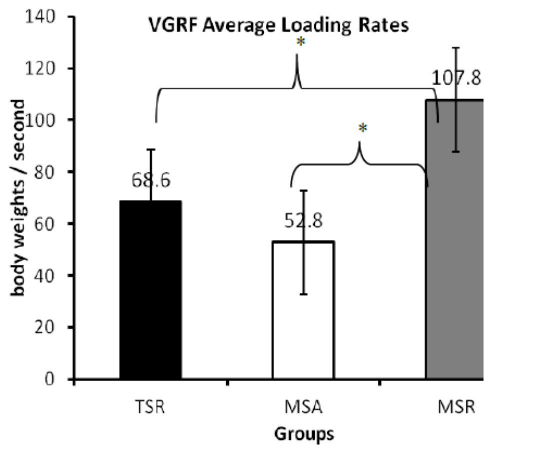


Figure 1: Average vertical loading rates for rearfoot striking runners in traditional shoes (TSR), anterior footstriking runners in minimalist shoes (MSA), and rearfoot striking runners in minimalist shoes (MSR).

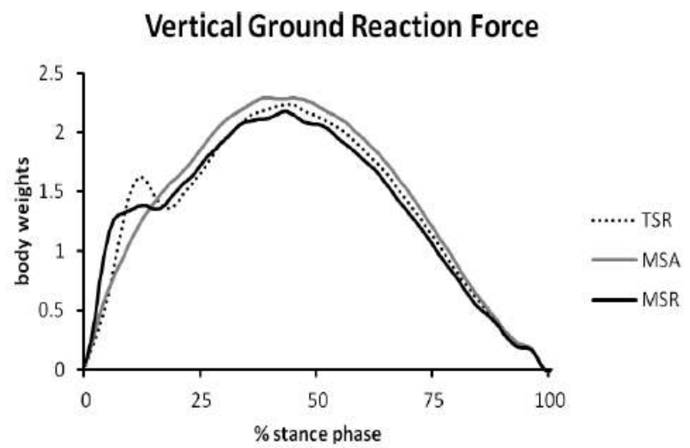


Figure 2: Vertical ground reaction force curves for rearfoot striking runners in traditional shoes (TSR), anterior footstriking runners in minimalist shoes (MSA), and rearfoot striking runners in minimalist shoes (MSR).

Take Home Message:

1. Don't heelstrike if you are running in minimalist shoes
2. Don't trust your own perception of how you footstrike

Table: Self-reported vs. actual footstrike pattern.

Footstrike pattern	Reported	Actual
Rear footstrike	20	34
Anterior footstrike	37	23

$X^2 = 6.90$, 1df, $p = .01$, $n = 57$

Midfoot Concerns Again

PLANTAR PRESSURE DIFFERENCES BETWEEN REARFOOT AND MIDFOOT STRIKING RUNNERS DURING SHOD RUNNING

1James Becker, 1R.J. Howey, 1Louis Osternig, 2Stan James, and 1Li-Shan Chou

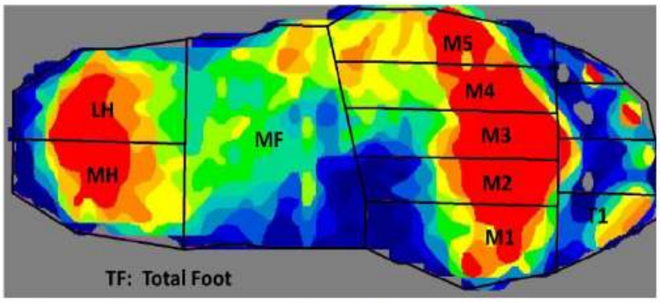


Figure 1. Regions selected for analysis. MH: medial heel, LH: lateral heel, MF: midfoot, M1-5: metatarsals 1-5, T1: hallux.

CONCLUSIONS

"The results of this study suggest overall loading of the metatarsals is greater in individuals who naturally use a MFS compared to those who naturally use a RFS. It is unknown whether these differences would still be present in individuals who convert from a RFS to a MFS. However, the authors hypothesize these differences likely will still exist, as it has previously been reported that individuals using a converted foot strike pattern closely replicate kinematics and kinetics of individuals who naturally use that foot strike pattern [5]. Thus, while individuals who convert their foot strike pattern may obtain lower impact forces and loading rates in the vertical ground reaction force, these reductions may come at the trade off of higher loading of the metatarsals. How this may influence injury rates requires further investigation."

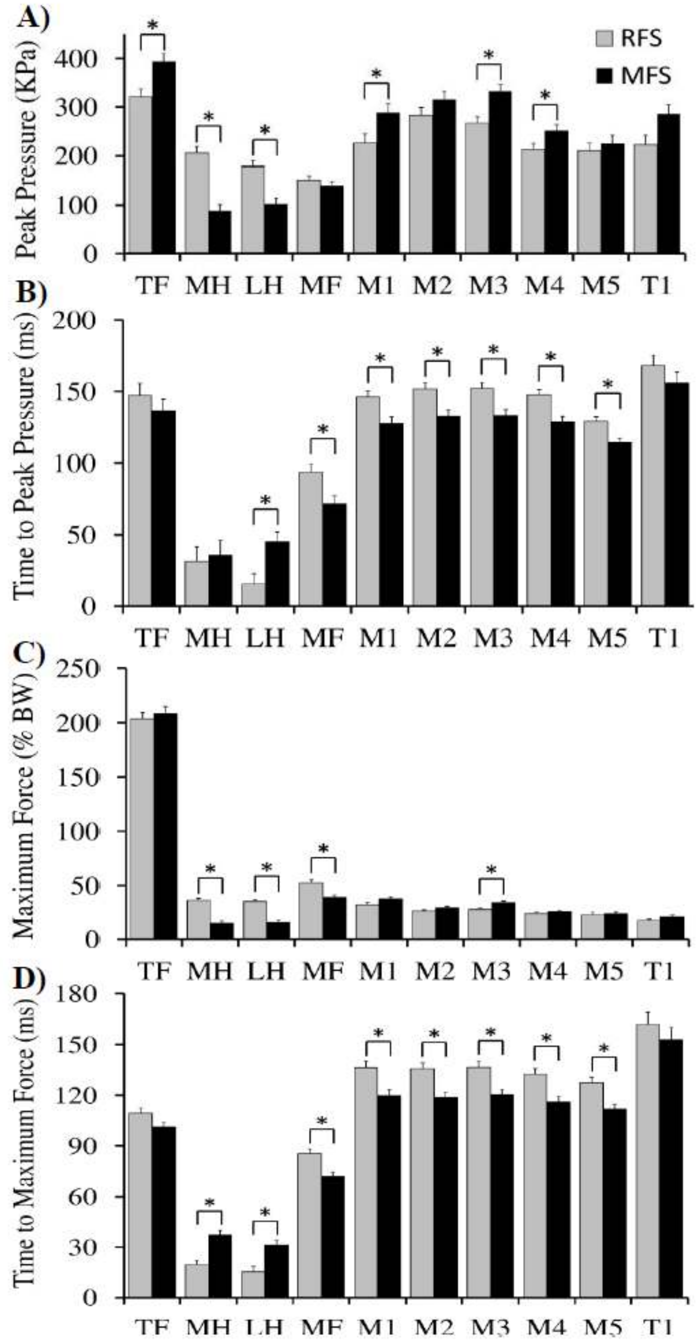


Figure 2. Peak pressure (A), time to peak pressure (B), maximum force (C), and time to maximum force (D) for the twelve regions analyzed.

How about just going minimal

GROUND REACTION FORCES BETWEEN RUNNING SHOES, RACING FLATS AND DISTANCE SPIKES IN RUNNERS
Suzanna Logan, Iain Hunter, Brent Feland, Ty Hopkins, Allen Parcell

Table 1: Results where significant differences were observed (mean± SD). Superscripts (A,B,C) denote differences between groups $p< 0.05$ for impact peak and vertical stiffness. Superscripts (A,B,C) denote differences approaching significance between groups $p< 0.10$ for loading rate and stance time.

Condition	Impact Peak (BW)	Loading Rate (BW/s)	Stance Time (s)	Vertical Stiffness (BW/m)
Trainers (A)	2.3 ± 0.44^{BC}	151 ± 56.9^{BC}	0.162 ± 0.013^{BC}	63 ± 26.4^{C}
Racing Flats (B)	2.7 ± 0.71^{A}	206 ± 113.3^{A}	0.156 ± 0.008^{A}	101 ± 77.3^{A}
Spikes (C)	2.9 ± 0.51^{A}	214 ± 131.8^{A}	0.156 ± 0.01^{A}	138 ± 106.7^{A}

"Impact peak and vertical stiffness significantly increased between running shoes and spikes. Differences between stance time and loading rate approached significance with trainers being lower (Table 1). Loading rate and impact peak in the flats and spikes were expected to be higher, given similar results from previous studies comparing barefoot and shod running (DeWit, 2000), and could be explained by the decreased cushioning in flats and spikes, which would affect the negative acceleration of the foot at impact. The increased vertical stiffness is attributed to the decreased cushioning in the spikes causing a greater negative vertical acceleration at ground contact.
Higher vertical stiffness is usually correlated to increased peak forces coupled with smaller lower extremity excursions, which leads to increased loading rates (Butler,2003). Increases in these variables have been associated with potential increased risk of bony injuries (Ferber, 2002; Williams, 2004)."

Giandolini (2012) compared runners running in traditional shoes with a racing flat. However, the racing flat was not zero drop shoe so many would not consider this a minimal shoe. The authors found no change in loading variables.

Relevance to Injury

Currently there is no high quality research that investigates whether changing any gait variables can prevent future injury. One correlational study did find a decrease in injury prevalence in college runners who ran with mid/forefoot strike versus those that ran with a heel strike.

Should runners change their shoes and form?

Sorry, we can't answer this question with certainty based on the existing research. If a runner is injured and is plagued with a series of injuries than a form change can be justified. All of the variables discussed previously would be worthwhile. The rationale for why this might relate to reduction in symptoms can extend far beyond biomechanics as we know that the link between biomechanics and pain is quite poor.

Changing form to prevent injuries. Is there an ideal way to run?

Suggesting that the majority of runners should change their form requires a leap in judgment and would be based on a number of assumptions. Three common recommendations are given; 1. transition to a minimal shoe 2. transition to a forefoot or midfoot footstrike and 3. decrease step length. Number one is suggested as it is assumed to allow for an easier transition to #2 and #3 yet no research exists to support this and some suggests the opposite.

From the previous review we can see that changing footstrike and stride cadence can change kinematics and can change ground reaction force variables. The research also suggests that these form changes do not always result in changes in impact loading. Further, the recommendation to change both footstrike and cadence is predicated on the belief that decreases in impact loading variables is important for a reduction in injury risk This assumes that other factors that might change with these form changes are not the greater drivers for injury risk. For example, changes in metatarsal loading, arch strain and plantar flexor strain will all increase with a transition to forefoot strike. We also do not know what we don't know. The research from Altman and Davis (2012) and Derrick (2012) suggest that changes in footstrike to forefoot strike while decreasing impact loading can also increase tibial strain. The concern is that we trade one problem for another.

Last, we can't see impact forces with the naked eye. Runners can run with a heelstrike and have smaller vertical impact forces than others with a forefoot strike. Making changes to runners in this case may increase the risk of injury.

Taking a cautious Leap: Increase cadence in overstriders to prevent injury

There is little research suggesting that changes in stride cadence are associated with negative consequences. Yet, small increases in stride rate (5-10%) appear to be associated with positive gait changes. Thus runners who appear to overstride (e.g. land with the knee very close to being straight) may benefit from increasing their cadence. This is a simple change that can be seen with the naked eye and may be one simple change that can be made as a preventative measure.