Overload injuries in barefoot/minimal footwear running: evidence from crowd sourcing

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Abstract

Background: The incidence of injuries in minimal footwear or barefoot runners compared to runners using conventional running shoes is still being discussed.
Methods: We focus here on methods and results of a online survey in a community of minimal footwear/barefoot (MF/B) runners. The aim of the survey was to investigate the viability of the method and to record first insights on running behavior, distance performance and injuries.
Results: In total 226 runners answered the questionnaire, 15 subjects had to be removed due to invalid data. A total of 211 (94%) subjects (152 male, ages 15-71 years [mean=40]) were included in the analysis.
The risk to suffer a running related injury was significantly increased during the time period of changing from shod running to MF/B running (see Table 2). The injury rate per km was markedly lower – about one half - in MF/B than in shod running, but threefold higher during the transition period.
Disucssion/Conclusion: Future research into the right “dosage” of barefoot/minimal footwear running in the transition period is warranted. We speculate that special adaptations - which may take years and thousands of kilometers to become effective - of the neuromuscular control play a major role, very similar to the thousands of hours a person needs to play and practice playing the piano before becoming a musician.

Introduction

Barefoot running has a high impact on the gait pattern [Lieberman1]. Kinematic and kinetic analyses have shown that even on hard surfaces, barefoot runners who forefoot

strike, generate smaller collision forces than shod rear-foot strikers. This differences result primarily from a more plantar flexed foot at landing and more ankle compliance during impact, decreasing the effective mass of the body that collides with the ground. A major problem is that with increasing fatigue, runners may not continue using a forefoot strike pattern but shift to a rear-foot strike. Using barefoot running shoes makes it even easier to use a rear-foot strike without the protection of a shoe [Hatala].

Especially well trained runners with a short transition period to barefoot running or minimalist shoe concepts are at risk to develop overload/ overuse injuries. These include harmless blisters (figure 1), stress fractures of the calcaneus and the metatarsals (figure 2) as well as bone edema and tendon problems [Arndt].

Although a study with self reported injury incidence found the incidence to be lower in the barefoot and minimalist shod population, [Goss], there is an increasing number of reports on injuries related to barefoot running [Altman], [Goble], [Olin].

A recently published paper focused on tissue vibration properties and running strike pattern [Enders]. This study showed that the use of a preferred movement pattern resulted in lower damping coefficients of running related soft tissue vibrations. While rearfoot striking showed lower vibration frequencies in shod and barefoot running, it did not consistently result in lower damping coefficients. This study also showed that the use of a preferred movement resulted in lower damping coefficients of running related soft tissue vibrations. Also the average Achilles tendon loading is about 15% higher in a forefoot strike pattern compared to a rearfoot strike [Almonroeder].

The barefoot and minimalist shod running has demonstrated to have a significant effect on tissue loading and there is a strong influence on the strike pattern. Especially bradytrophic tissues like tendons and bones are at a major risk for overload injuries, due to not having enough time to adapt to the new loading situation. However, there is increasing evidence that more factors have to be considered. It seems that the strike pattern (and the load related to it) is influenced by much more than just the type of shoe worn. Soft tissue vibrations as well as running speed are factors which may be still underestimated in the discussion about the benefits and risks of different running styles [Hatala], [Enders], [Goss].

The incidence of injuries in minimal footwear or barefoot runners compared to runners using conventional running shoes is still being discussed [Lieberman1], [Lieberman2], [Bonacci], [Daoud], [Hatala]. We focus here on methods and results of a online survey in a community of minimal footwear/barefoot (MF/B) runners. The aim of the survey was to

investigate the viability of the method and to record first insights on running behavior, distance performance and injuries.

Figure 1: Example of an injury related to barefoot running: Hemorrhagic blister of a female barefoot runner (not part of the study)

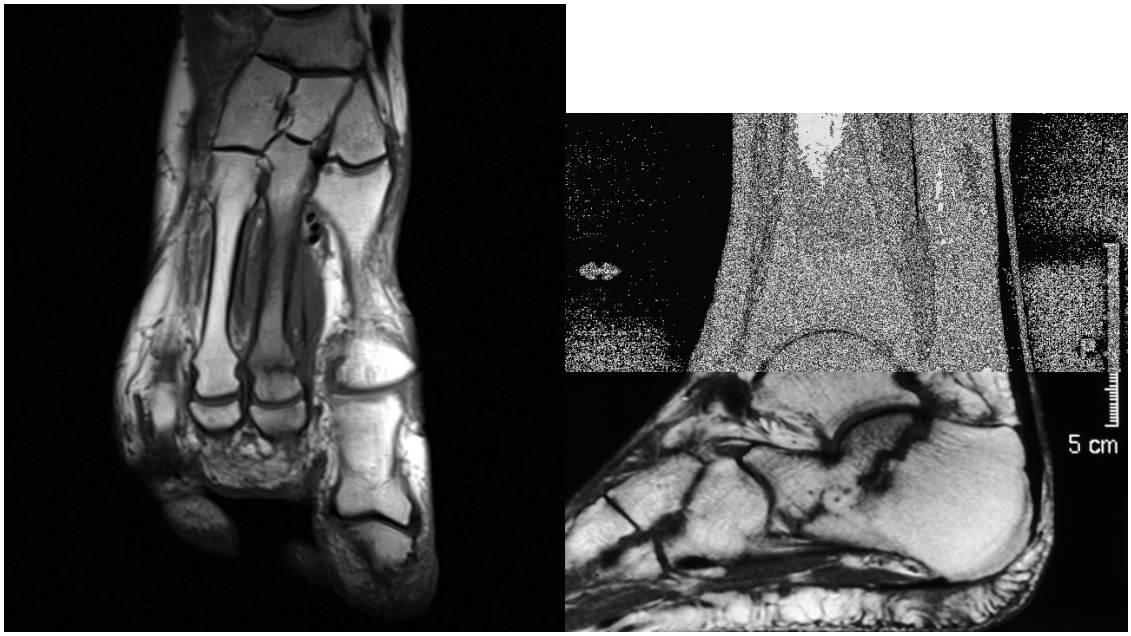

Figure 2: Examples of fractures related to barefoot running.

Methods - A survey with the social network of the "barefoot runners society"

An online questionnaire was set up using Google forms (figure 3) and advertised by the “barefoot runners society” website (http://thebarefootrunners.org/threads/update-new-study-being-conducted-running-injuries-in-shod-vs-minimal-footwear-barefoot-runners.12871/, with an automatic post on facebook and twitter) and by the online-newsletter and Facebook of the “free heel running pad” (https://www.facebook.com/RunningPad).
Runners were eligible to fill out the questionnaire, if they used to run with regular running shoes, but, after a certain transition phase, have been running mostly either in minimal footwear or barefoot.
The subjects were asked about their sex, age and running habits. These included running related injuries (e.g. Plantar Fasciitis, Achilles Tendinitis, IT Band Syndrome, Runner's Knee, and Shin Splints), the weekly distance and duration of months or years for each period of shod running, transition phase and MF/B running. Furthermore the subjects were asked for their personal opinion on benefits and risks of MF/B running and their reason why they changed their running style.

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Running injuries in shod vs minimal footwear/barefoot runners

There is an ongoing debate about the benefits and risks of running in minimal footwear/barefoot instead of running in normal running shoes (see, e.g.
"DOI: 10.1177/1941738112448055 2012 4: 480 originally published online 19 June 2012 Sports Health: A Multidisciplinary Approach Daniel S. Lorenz and Marisa Pontillo
Is There Evidence to Support a Forefoot Strike Pattern in Barefoot Runners? A Review" - concluding that "Prospective studies on running injuries in those who run
barefoot or with minimalist shoes would be of great benefi to the sports medicine community and should be of primary importance. "

We - a team of students from the TUM Munich from the lecture "clinical applications of computational medicine" headed by the inventor of the "free heel running pads www.runningpad.de" Dr. Martin Daumer (http://www.rcs.ei.tum.de/fileadmin/tueircs/www/clinical-applications-daumer/Flyer_CA12.pdf) together with Prof. Markus Walther, Schön Klinik Munich (https://www.schoen-kliniken.de/ptp/kkh/okm/faz/sprunggelenk/team/personal/00303/), - plan to collect information about the association between running injuries and footwear.

If this phase can be successfully completed we may expand the study to also include other groups as controls/reference. Even prospective studies that focus on the biomechanical
aspects of the effects of different running techniques in the runners normal environment may be doable (using, e.g., mobile accelerometry such as www.actibelt.com).

You are eligible to go through the questionnaire if you were used to run with normal running shoes some time ago but now, after a certain transition phase, you are running mostly either in minimal footwear or barefoot.

We will not collect any personal information about you. Results of the survey and comments will be published. By submitting the questionnaire you thereby agree with these terms and conditions.
* Erforderlich

How many years have you been running in normal running shoes? *
Please give the number of years

How many kilometers per week did you run on average? *
Please use 1 mile = 1.6 km

How many running injuries did you have in total in this phase? *
Examples are: Plantar Fasciitis, Achilles Tendinitis, IT Band Syndrome, Runner's Knee, Shin Splints

How many months of "transition phase" did it take you to become a minimal footwear/barefoot runner? *
Please give the number of months, not years

How many kilometers per week did you run on average in this "transition phase"? *
Please use 1 mile = 1.6 km

How many running injuries did you have in total in this "transition phase"? *
Examples are: Plantar Fasciitis, Achilles Tendinitis, IT Band Syndrome, Runner's Knee, Shin Splints

How many years have you now been running as a minimal footwear/barefoot runner? *
Please give the number of years

How many kilometers per week are you now running on average? *
Please use 1 mile = 1.6 km

How many running injuries did you have in total in your phase of minimal footwear/barefoot running? *
Examples are: Plantar Fasciitis, Achilles Tendinitis, IT Band Syndrome, Runner's Knee, Shin Splints

What is your personal view about the risks & benefits of minimal footwear/barefoot running?

Gender? *
- male
- female

Age? *
Please enter your age in years

Why did you change from normal running shoes to minimal footwear/barefoot running?

Senden

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Figure 3: Online questionnaire using Google forms

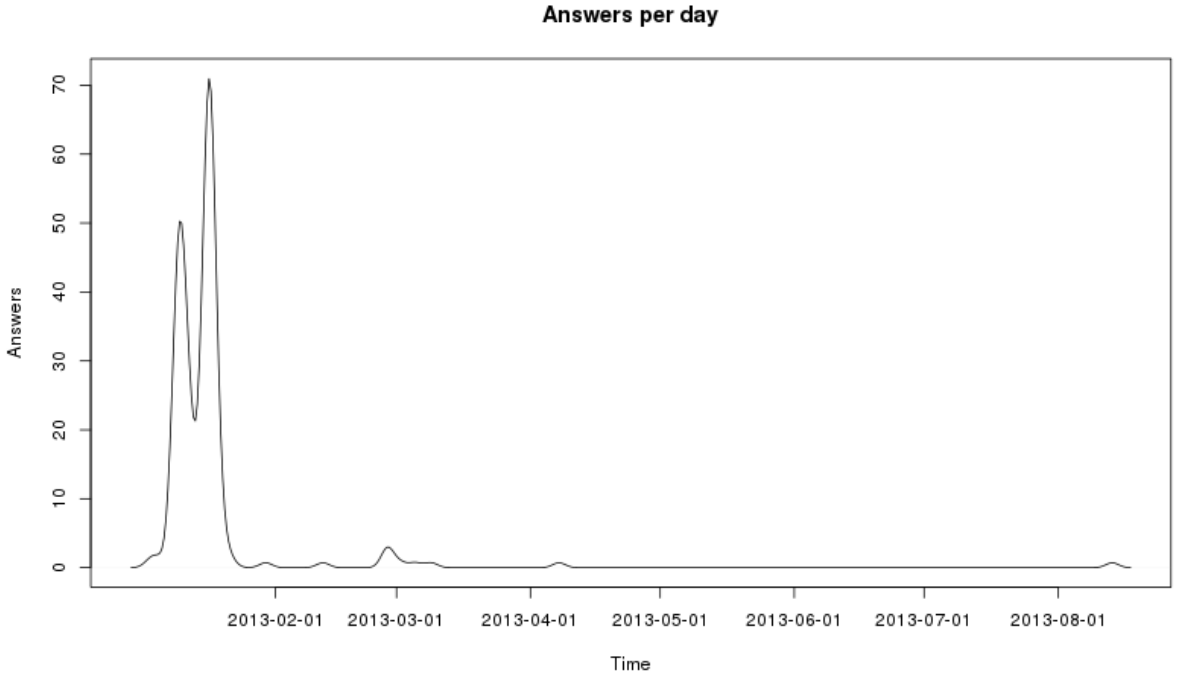

Figure 4: Number of filled in questionnaires per day. The scond peak corresponds to a second announcement of the questionnaire.

Results

In total 226 runners answered the questionnaire, 15 subjects had to be removed due to invalid data. A total of 211 (94%) subjects (152 male, ages 15-71 years [mean=40]) were included in the analysis.

Table 1: Mean values and SD of km per week of total dataset (male/ female) for each period, as well as mean duration and SD for each period.

	Mean km/week (male/female)	SD km/week (male/female)	Mean years (male/female)	SD years (male/female)
Shod	27.2 (28.7/21.9)	23.0 (24.2/17.8)	11.0 (11.6/9.3)	10.4 (10.9/8.7)
Transition phase	19.5 (20.5/15.9)	18.0 (18.6/15.3)	0.5 (0.5/0.4)	0.4 (0.5/0.3)
MF/B	35.3 (37.7/26.9)	26.63 (28.4/17.3)	2.6 (2.8/2.1)	2.7 (3.0/1.2)

In order to transform the free text data into a homogeneous, analyzable format, the following rules were applied:
1) Comments like „too many" or „many" were counted as three injuries
2) Plural forms of explicitly named injuries were counted as two injuries
3) Mean distance was used if weekly distance entries had the format "from...to".

The risk to suffer a running related injury was significantly increased during the time period of changing from shod running to MF/B running (see Table 2). The injury rate per km was markedly lower – about one half - in MF/B than in shod running, but threefold higher during the transition period (see also [4]).

Table 2: Calculated mean of injuries per 10.000 km for shod running, transition phase and minimal footwear/barefoot running (MF/B) and their standard deviations.

Injuries / 10.000 km	Mean	Standard deviation
Shod	12.1	55.7
Transition phase	35.8	101.5
MF/B	5.4	22.0

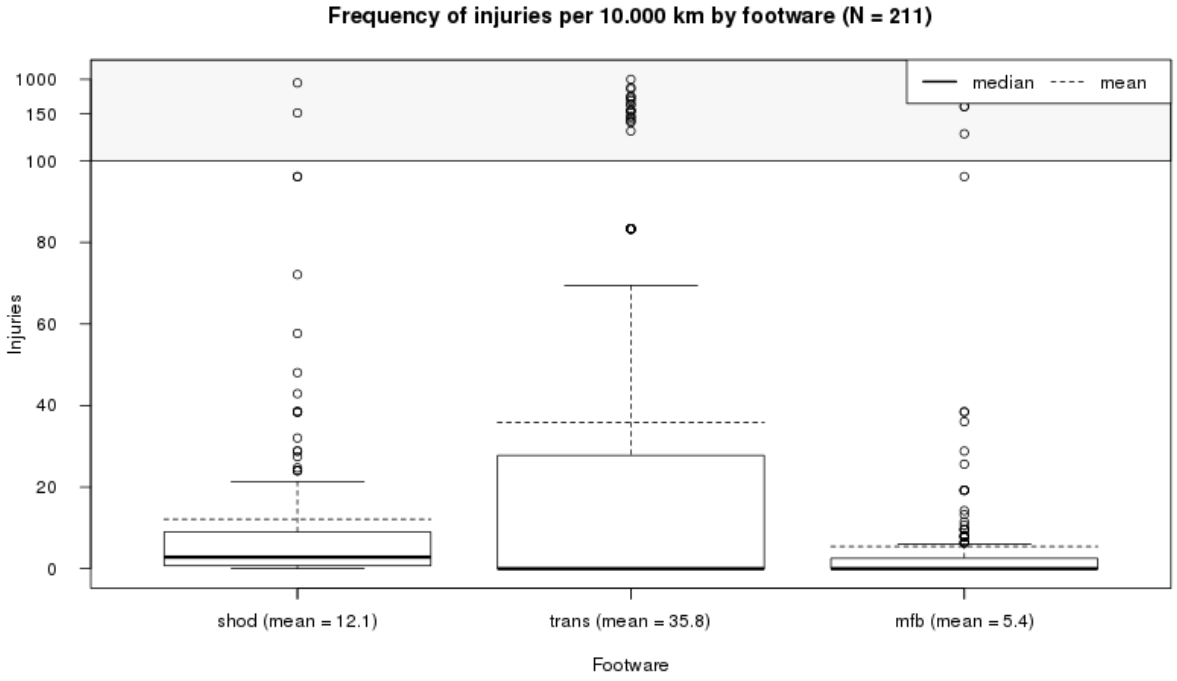

Figure 5: Box plots of running injuries in the three phases. Compare to the graphic in [Lieberman1]

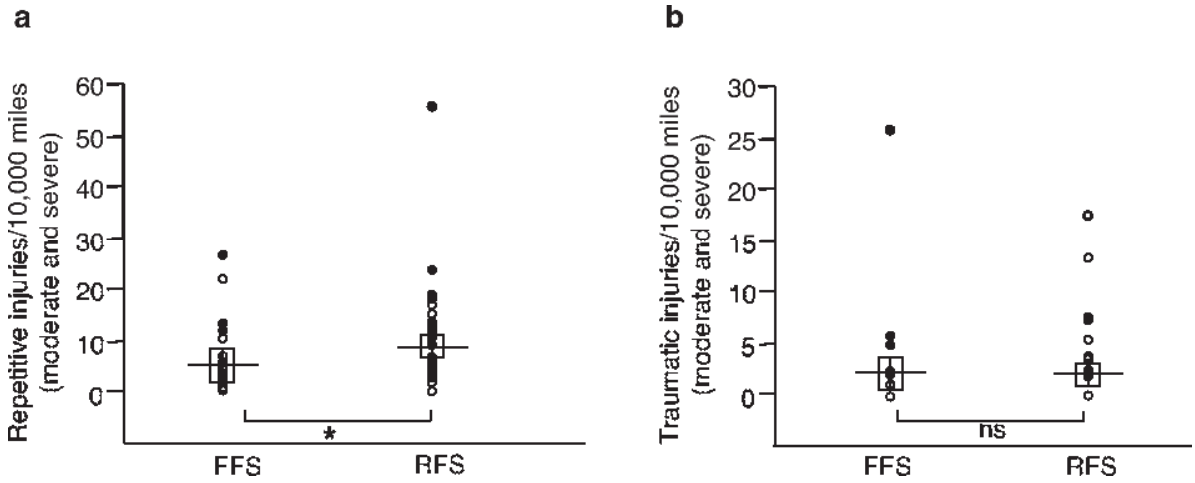

Figure 6: Injury rate per 10.000 miles for forefoot (FFS) and rearfoot strike (RFS) reprinted from [Lieberman1] with permission. Boxes indicate mean and SE. (Lieberman's rates are per miles, ours per km).

Discussion

It is important to point out that – unlike in clinical trials or epidemiological studies – we have neither obtained a signed written informed consent (the participants have just read the explanation and have then decided to fill in the questionnaire) nor any information about demographics (apart from sex) and no trusted third party (such as a hospital/physician with a link list that links patient ID with the actual name/address etc.) that would allow to identify an individual.

Bias cannot be controlled/estimated. On the other hand there is increasing evidence that this kind of "uncontrolled" data may have a similar quality and may be used for research as those generated in "classical" studies. (Bove et al 2013). We do not see a clear expected direction for a bias in the transition phase. In this study we may argue that there is an underreporting of injuries in the shod phase (a special form of recall bias). This may be partially compensated by an underreporting of injuries in the MF/B phase as one may speculate that barefoot enthusiasts have a biased perception of what constitutes an injury.

Despite the potential bias, we do consider the finding about a reduction of injury risk during the barefoot phase, as compared to the shod phase, as relatively strong. This for the following reasons:

- The hypothesis has been fixed beforehand (based on the finding by Lieberman with different methods and most likely completely different individuals) and was again confirmed in the second block of the data.
- Since our ancestors were running barefoot, there is a strong theoretical argument from evolutionary biology why this is plausible: as laid out in Lieberman's review [Lieberman2] there must have been a very strong selection pressure on minimizing the risk of running injury per distance.

The other finding, the concerning increase of injury risk in the transition phase, is an even more solid finding, as it should be considered to be an equivalent of a "safety signal" in a clinical trial. The burden is not on us to show that the true effect size may be smaller than we report. The existence of the problem is well-known and broadly discussed.

The increased weekly mileage after successful completion of the transition phase is a plausible consequence of the increased "fun" in running barefoot (informal conclusion from analyzing the free text comments).

We have on the one hand confirmed a quantitative estimate of the reduction of injury rate when running MF/B. On the other hand we have quantitative estimates for the

dramatic increase in injury risk when changing footwear (and indirectly the running style). Informal review of the free text filled in the questionnaire (available freely at XYZ) shows that “doing too much too fast” is probably the most important reason for this.

Conclusion

“Crowd sourcing” using social networks are an interesting way to generate new evidence in a faster and cheaper way, when compared to standard clinical trials or epidemiological studies; data of sufficient quality can be generated in a very small amount of time.
The risk of injury during the transition phase in the group of responders (“crowd sourcing“) is considerably higher compared to habitually running either shod or barefoot/minimal footwear, even with an optimistic rating of injuries during shod running. However there is a relevant risk of bias. Our data seem to confirm the need of special guidance to the runner, especially in the transition phase, to reduce the incidence of injuries. Future research into the right “dosage” of barefoot/minimal footwear running in the transition period is warranted. It is well known that MF/B runners have a higher step frequency. Therefore we have to conclude that there must be a strong beneficial effect on injury rate per step in case of trained BF/M runners. In a recent article [Lenhart], the beneficial effect of increased step frequency has been highlighted (partly linked to a change in the knee flexion angle) in a way that this is another potential partial explanation for the effect we saw. Changing the footwear to MF/B is typically associated with changing the running style – here an increase in step frequency – which in turn has a beneficial impact on the injury risk.
The reasons for the protective effect warrants further research, probably involving mobile accelerometry to generate ecologically valid data in combination with high-quality controlled laboratory research on forces and shock waves.

Careful description of case studies about running injuries related to a change on footwear/running style will also be an important element to further inform the direction of future research.

We speculate that special adaptations - which may take years and thousands of kilometers to become effective - of the neuromuscular control play a major role, very similar to the thousands of hours a person needs to play and practice playing the piano before becoming a musician.

We close with the quote:
"How one runs probably is more important than what is on one's feet, but what is on one's feet may affect how one runs." ~Dr. Daniel Lieberman*

Acknowledgements

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