UNIVERSITY OF TARTU

Institute of Exercise Biology and Physiotherapy

Marii Sernjuk

How can a recreational runner benefit from transitioning to minimalist running shoes and how to do it safely?

Minimalistlike jooksujalatsite kasutuselevõtu mõju ja ohutus harrastusjooksjale

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Supervisor:

MSc, J Jürgenson

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ABBREVIATIONS

FFS- forefoot strike

GRF- ground reaction force

MFS- midfoot strike

MRI- magnetic resonance imaging

RFS- rearfoot strike

SPECT-CT- Single photon emission computed tomography and computed tomography

VFF- Vibram FiveFingers

1. INTRODUCTION

Evolutionarily humans are endurance runners and have been running for millions of years, but the intervention of primitive shoes dates back to only 40,000 years ago (Murphy et al., 2013), leaving plenty of time for our ancestors to practise barefoot running: a rising trend among athletes and recreational runners.

Since the publication of Christopher McDougall's *Born to Run: A Hidden Tribe, Superathletes, and the Greatest Race the World Has Never Seen* in 2009 barefoot and minimalist running have become increasingly popular. According to Rothschild's survey from 2012, conducted among recreational runners in USA, *Born to Run* was the most commonly reported book used as a resource for transitioning to barefoot or minimalist running.

Similarly, the author of this thesis first learned about barefoot running via that book. But, since barefoot running turned out to be rather extreme in the Northern-Europe climate, the conditions led to experimenting with various minimalist running shoes and to the desire – if not necessity- to find out more on the subject.

By now nearly every major footwear company has launched some type of a minimalist shoe, already in 2011 minimalist shoes formed 8% of total running shoe sales in North America (Footwear Insight, 2015). Amongst runners Vibram FiveFingers (VFF), Nike Free, Saucony Kinvara and New Balance Minimus have been the most popular shoes marketed as minimalist by their manufacturer (Rothschild, 2012).

Unfortunately no innovation in footwear design has so far managed to decrease the rate of running related injuries. Runners are prone to repetitive stress injuries due to the simple fact that they strike the ground approximately 600 times per kilometre (Lieberman et al., 2010). An increase in the popularity of endurance running has incurred an increase in running related injuries (Daoud et al., 2012). Further research is required to examine, whether barefoot running, or mimicking it with minimalist footwear, could break the cycle.

In the midst of it all, athletes and healthcare professionals are overwhelmed by the multiple new choices and rapidly changing trends in running footwear, while scientists are desperately looking for evidence for the claims advertised by footwear companies.

The aim of this thesis is to give an overview of the three running conditions: barefoot, minimalist and shod. As well as, to introduce the various types of minimalist footwear, define their advantages and disadvantages and to give practical recommendations on how to transition to minimalist running safely.

Key words: barefoot running, minimalist running, running shoes, running related injuries.

Märksõnad: paljajalu jooksmine, minimalistlikud jooksujalatsid, jooksuvigastused.

2. BAREFOOT RUNNING

2.1. Biomechanics

In order to discuss the barefoot running style some fundamental concepts –mostly biomechanics- must first be explained. The running gait cycle for one leg consists of the stance phase, early float, mid swing and late float phase (Figure 1) (Lohman et al., 2011). The stance phase is characterized by a forefoot, midfoot or rearfoot striking pattern, which is important when comparing barefoot to shod running. Terms such as shod or cushioned are used with regards to a conventional running shoe, also known as a traditional or a modern running shoe. The forefoot strike (FFS) runners make initial contact with the distal metatarsal area and then continue to lower the heel, but the rearfoot strike (RFS) runners land heel first and then lower the metatarsal area. The most confusing of the three- the midfoot strike (MFS) runners are counted for landing the entire foot on the ground almost simultaneously (Lieberman et al., 2010).

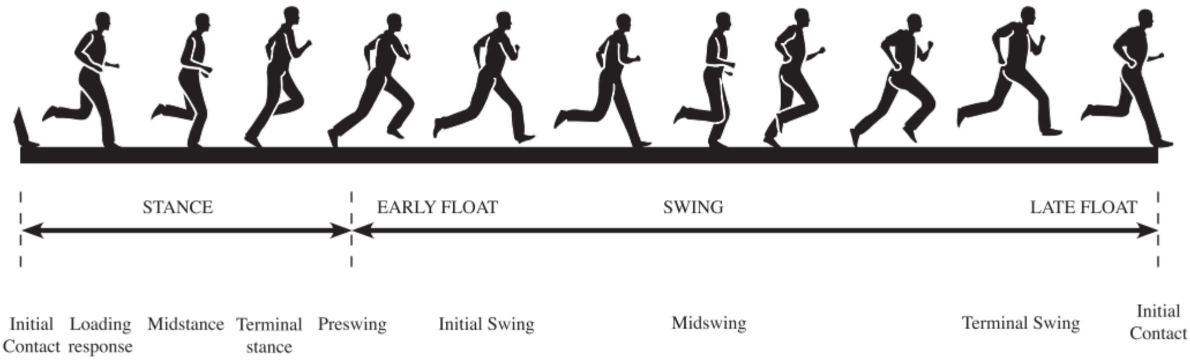

Figure 1. Phases and periods of the shod running cycle (Lohman et al., 2011).

Habitually barefoot runners are found to adopt the FFS or MFS pattern, while the habitually shod runners use the RFS pattern due to the shock-absorbing effect of a cushioned sole. This, of course, accounts for shod endurance runners as sprinters mostly FFS (Lieberman et al., 2010). RFS runners demonstrate a dorsiflexed ankle position during terminal swing and early stance phase, in contrast, FFS runners have a more neutral ankle position during terminal swing and a plantarflexed ankle during foot contact (Arendse et al., 2004; Lieberman et al., 2010). On average FFS runners display a 6° greater knee flexion at foot contact, which alongside with the plantarflexed ankle lessen the activity of the often problematic tibialis anterior and vastus medialis muscles compared to RFS runners (Yong et al., 2014).

Regarding to gait cycle differences between the two conditions, stride length and stride frequency are also worth noting. Besides the ankle being 82% less dorsiflexed at footstrike during barefoot running the comparison between the barefoot condition and a conventional running shoe has resulted in 2.4% shorter stride length and 2% higher stride frequency (Bonacci et al., 2014).

Another commonly evaluated measure in running biomechanics is the ground reaction force (GRF), the magnitude of which depends on several variables: stride length, running speed, shoe characteristics, inclination, and stiffness of the ground surface (Lohman et al., 2011). The barefoot runner's FFS creates smaller collision forces leading to a smaller GRF relative to shod runners. Plus the FFS runners have a shorter stance phase: lower ground contact time results in smaller peak forces (Murphy et al., 2013).

2.2. Running performance

The training regimes of athletes involved barefoot training long before the invention of minimalist footwear, because it improves overall muscle strength, as well as, strengthens the foot core system (Squadrone & Gallozzi, 2009).

One of the many purposes of the strong longitudinal arch of the foot is to store and release elastic energy during running. Barefoot running improves this mass-spring mechanics as FFS and MFS enable the arch to stretch passively during the entire first half of stance. Whereas, RFS passively stretches the arch only in late stance, when the forefoot has also reached the ground (Lieberman et al., 2010).

It has been found that frequent strides and loss of the mass of the shoe may have a positive effect on running performance (Rothschild, 2012). Running in conventional running shoes increases oxygen consumption 5.7% overgound and 2.0% on a treadmill when compared to running barefoot (Hanson et al., 2011). In addition, higher step rate during running increases muscle activity in the gluteal region, which may be beneficial for preventing muscle imbalances (Chumanov et al., 2012).

2.3. Common injuries

Common running related injuries include plantar fasciopathy (Figure 2, C), stress fractures, Achilles tendon injuries (Figure 2, F) (Pelletier-Galarneau et al., 2015) and patellofemoral pain syndrome (Bonacci et al., 2013). These musculoskeletal injuries are referred to as overuse injuries, hence sustained from repeated wear and tear of the lower limb (Hreljac, 2004). 37% of all the recorded running injuries are located at or below the knee (Taunton et al., 2002). 56.6% of elite runners have experienced an Achilles tendon overuse injury, 46.6% have sustained anterior knee pain, 35.7% have had a medial tibial stress syndrome and 12.7% plantar fasciopathy (Knobloch et al., 2008).

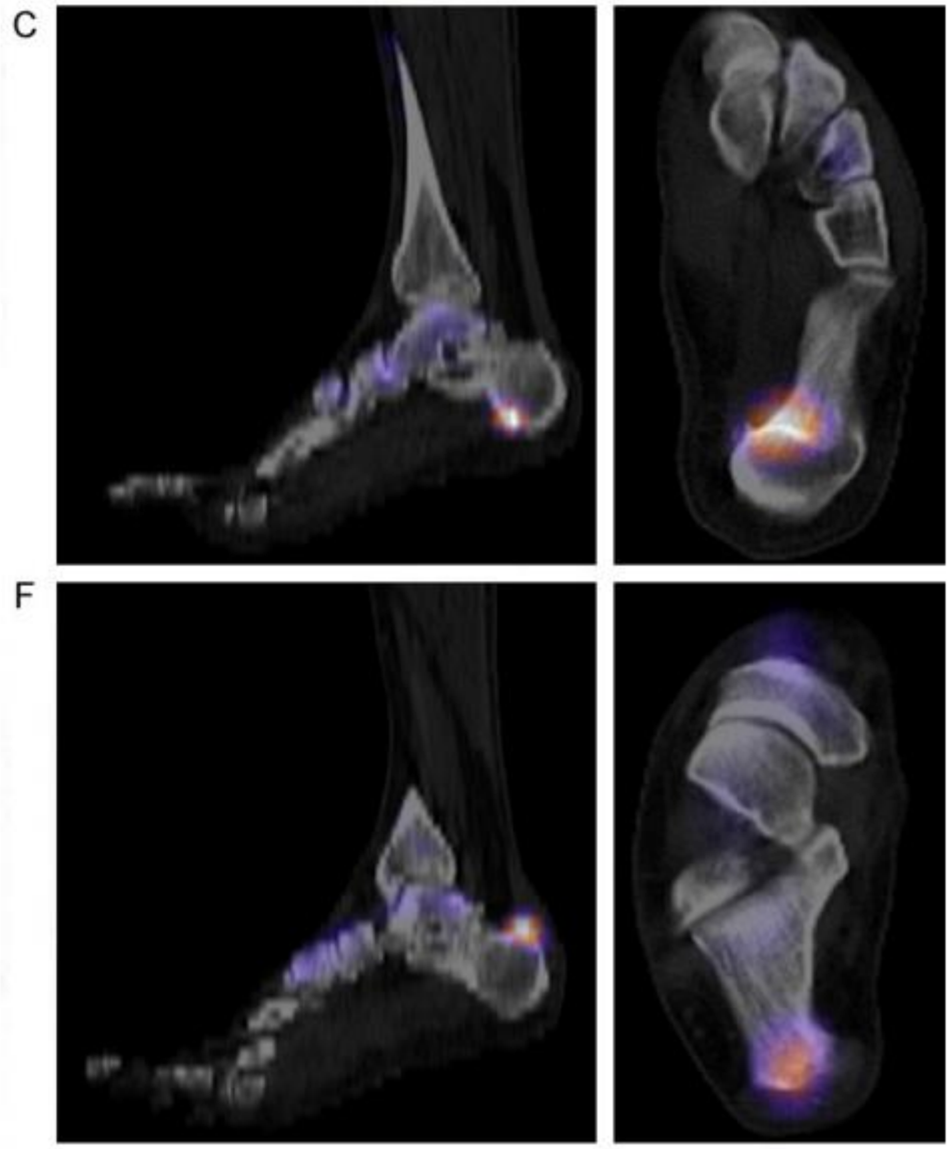

Figure 2. Single photon emission computed tomography (SPECT) and computed tomography (CT) images of the sagittal and axial planes show increased activity of blood flow at the

calcaneal tuberosity indicating a plantar fasciopathy (C). SPECT-CT images of the sagital and axial planes show increased uptake of radioactive material at the Achilles tendon insertion in the calcaneus, indicating an Achilles enthesopathy (F) (Pelletier-Galarneau et al., 2015).

The frequency of the patellofemoral pain syndrome among runners is so high that it is often simply called the runner's knee: representing approximately 20% of all running injuries (Lohman et al., 2011). Over-pronation (eversion) of the heel at foot strike is associated with the patellofemoral pain syndrome, this mal-alignment occurs more among shod than barefoot runners (Murphy et al., 2013). Bonacci et al., (2014) proved that unlike shod running, barefoot running induces a decrease in the peak patellofemoral joint stress and suggested to use barefoot running as part of a treatment plan of the patellofemoral pain syndrome.

Furthermore, it is now believed that stiff soles and arch supports in running shoes may cause plantar fasciopathy. These traits of extra support reduce the strength of foot muscles, and therefore place greater stress loads on the plantar fascia via over-pronation (Lieberman et al., 2010).

Up to 80% of shod endurance runners RFS (Lieberman et al., 2010), making initial ground contact with the heel. The collision of the heel with the ground generates an impact of two to four times body weight. Normally, the fat-filled elastic heel pad functions to dissipate stresses during impact phase, but after excessive and repetitive stresses the heel pad degenerates and may provoke pain at the medial calcaneal tubercle. Even though, shoes provide a larger contact area, hence a lower peak pressure under the heel, according to Chen & Lee (2015) „stress concentrations still exist in the heel pad" (Chen & Lee, 2015).

2.4. Injury prevention

Although, there are insufficient research studies regarding injury rates in shod versus barefoot populations, biomechanical analysis refers to a possible contrast (Rothschild, 2012). Not only barefoot running, but any barefoot activity has the quality to spare the plantar fascia from impact forces by activating the foot intrinsic muscles and controlling impact loads. In third world countries, where the barefoot state is rather inevitability than a choice, there are less chronic injuries to bone and connective tissue (Robbins & Hanna, 1987). Among unshod populations lower extremity osteological modifications are not as frequent as in shod populations (Zipfel & Berger, 2007).

Thanks to its MFS to FFS pattern the barefoot running style can potentially reduce impact related injuries, because it allows the plantar flexors to preactivate to a greater degree before the impact (Rothschild, 2012). The direct contact with the ground, hence the increased sensory feedback also stimulates the activation of the intrinsic foot musculature and allows shock absorption (Robbins & Hanna, 1987). Rothschild (2012) concludes in her survey analysis that „barefoot running replaces the external, passive support of a shoe and with internal, active support by the foot musculature".

2.5. Limitations

Despite the evident advantages of barefoot running, there are a few disadvantages to be considered before discarding footwear. Even though skin on the soles of the foot is thicker, stronger and more resistant to bruises than skin elsewhere on the body there may not be suitable surfaces in developed countries for barefoot training: harmful stones, glass, needles and nails are inescapable (Squadrone & Gallozzi, 2009). Extreme climate conditions of different regions also affect barefoot running as they form the terrain: neither do too hot or too cold surface temperatures support barefoot activities (Rixe et al., 2012).

Minimizing the supportive features of running shoes may reduce pain and prevent injuries, but may also worsen a previous injury. Thus, in the occurrence of a pre-existing injury or a pain syndrome runners might consider using orthotic devices in cushioned running shoes as a short-term solution. Orthotic devices are thought to reduce perceived pain and provide greater ankle stability (Murphy et al., 2013). A short 4 week treatment plan has shown that individually fitted, semi rigid insoles reduce pain during activities of daily life, as well as running-specific pain in most patients with unilateral chronic Achilles tendinopathy. This short-term treatment option could be considered, when running mileage cannot be reduced (Mayer et al., 2007).

3. MINIMALIST RUNNING SHOES

3.1. Definition

There are many definitions in the literature for minimalist running shoes also known as barefoot shoes, which is why the author finds it necessary to clarify what are considered as minimalist running shoes in the frames of this work.

The absence of a specific definition has led to a general agreement that presents minimalist running shoes with the following requirements: less structure and mass, a reduced heel-toe drop or more flexible than a conventional running shoe (Hamill et al., 2011).

As a result of an ambiguous term and a fast growing market, the minimalist category can be subdivided into three large groups: firstly low-heel and reduced heel-toe drop shoes (e.g. New Balance® Minimus™, Vibram® FiveFingers®, Merrell® Barefoot™), secondly shoes with a slightly thicker sole and minor cushioning (e.g. Nike® Free™), and thirdly shoes that are very similar to a traditional racing flat, yet named minimalist (e.g. Brooks® Pure™, Saucony® Kinvara®) (Squadrone et al., 2014).

The use of various types of minimalist shoes in research studies has brought forth contradictional information about the efficacy of minimalist running shoes in imitating the barefoot running style.

3.2. Classification

As to classify these shoes on the basis of their efficacy to imitate barefoot running patterns and to elicit biomechanical changes which differentiate them from conventional running shoes Squadrone et al., (2014) conducted a study, where they compared six different minimalist shoes to a conventional running shoe and the barefoot condition. All fourteen participants of this study were RFS runners and all had a previous training experience in minimalist shoes. The minimalist shoes tested in this study were: Newton Running® MV2, New Balance® MR00GB, Nike® Free™ 3.0V4, Inov8® Bare-X™ 200, Vibram® FiveFingers® (VFF) Seeya™ and Saucony® Kinvara™ 2.

After the laboratory tests the analysis revealed that the Inov8, New Balance and VFF shoes elicited a more anterior foot strike pattern than the other minimalist shoes with the average mean difference of ~ 30% or ~ 1.6 cm. These shoes were also characterised by a less dorsiflexed foot (~ 35%) at initial contact, which can be explained by a less elevated heel (Squadrone et al., 2014). An ultrathin sole means less material to prevent possible heel pain at impact, resulting in a more midfoot contact and a plantarflexed foot position (Lieberman et al., 2010).

On the basis of stride frequency, stride length and step time the minimalist shoes appeared to form two subgroups: (1) Newton Running and VFF shoe, and (2) Saucony, Nike, New Balance and Inov8 shoe. Stride frequency was ~ 15% higher, stride length ~ 15% and step time 18% lower in the first group (Squadrone et al., 2014).

Previous studies (e.g. Squadrone & Gallozzi, 2009) have also reported higher stride frequencies when runners transition from conventional running shoes to minimalist ones. Reduced stride length decreases impact characteristics, possibly due to the centre of mass lying more directly over the foot strike not on the heel extended in front of the runner (Kerrigan et al., 2009). A more extended knee is believed to increase landing stiffness (Farley et al., 1998) and knee range of motion, the latter results in greater contact time as was seen in the shoes with a higher heel stack (Squadrone et al., 2014). Greater contact time in high-heel shoe conditions generates higher peak forces and therefore a higher GRF (Murphy et al., 2013). Contact time was the shortest with VFF and New Balance shoes (Squadrone et al., 2014). Further foot strike, spatio-temporal stride and kinematic variables for the different foot conditions are available in Table 1 and Table 2.

On the whole, it was concluded that some models (VFF Seeya, New Balance MR00GB and Inov8-X 200) are more effective in inducing adjustments characteristic to barefoot running than others (Newton Running MV2, Saucony Kinvara 2, Nike Free 3.0V4). RFS runners responded most prominently to low-heel minimalist shoes by adapting to a more MFS pattern. The purpose was to define minimalist as the quality of imitating barefoot running conditions, so according to this study the most essential requirements for a minimalist shoe are extremely low heel height and reduced shock absorption ability (Squadrone et al., 2014).

In addition to low-heel, reduced heel-toe drop, lightweight and high sole flexibility Rixe et al., (2012) suggest that true minimalist shoes should have an expanded toe box like the VFF. Footwear, which meets these criteria, allows the wearer to imitate the barefoot running style while protecting the feet from acute puncture wounds, severe surface temperature and infections (Rixe et al., 2012).

In terms of making this work more easy to follow, from here on the low-heel minimalist shoes, which according to Squadrone et al. (2014) proved to be more effective in replicating the barefoot condition (e.g.VFF Seeya, New Balance MR00GB and Inov8-X 200) will be referred to as 'true' minimalist shoes and the less effective slightly cushioned shoes (e.g. Newton Running MV2, Saucony Kinvara 2, Nike Free 3.0V4) will be named 'potential' minimalist shoes.

Table 1. Mean values of biomechanical variables for different true minimalist shoes. (Squadrone et al., 2014).

Foot strike, spatio-temporal stride and kinematic variables.	Barefoot	VFF Seeya	Inov8 Bare-X 200	New Balance MR00GB	Cushioned shoe
Strike index (%)	27.0	25.5 #	24.5 #	25.4 #	18.6 *
Foot angle at contact (°)	7.3	6.9 #	7.6 #	8.0 #	12.1 *
Stride frequency (step/min)	86.8	85.4 *#	83.6 *	84.1 *	83.4 *
Stride length (m)	2.30	2.34 *#	2.38 *	2.37 *	2.38 *
Step time (ms)	346	352 *#	358 *	357 *	358 *
Contact time (ms)	234	238 *#	246 *#	242 *#	251 *
Stride angle (°)	73.2	72.6	73.4	74.3	74.5
Overstride angle (°)	7.2	8.1	7.7	7.5	8.6
Knee contact angle (°)	163.8	165.1	164.5 #	165.2	166.6 *
Peak stance knee flex angle (°)	138.8	138.5	137.9	138.2	137.5
Knee ROM stance phase (°)	25.1	26.7 #	26.6 #	26.9 #	29.0 *
Hip vertical displacement (mm)	8.0	8.2 #	7.8 #	7.3 #	10.8 *
Variables significantly similar to barefoot (n)	-	8	8	8	-
Variables significantly different from cushioned model (n)	-	8	6	5	-

Notes: *Significantly different from barefoot. # Significantly different from the cushioned shoe. In this study „significance was accepted at P < 0.05 level" (Squadrone et al., 2014).

Table 2. Mean values of biomechanical variables for different potential minimalist shoes. (Squadrone et al., 2014).

Foot strike, spatio-temporal stride and kinematic variables.	Barefoot	Newton Running MV2	Saucony Kinvara 2	Nike Free 3.0V4	Cushioned shoe
Strike index (%)	27.0	21.0 *	19.6 *	19.9 *	18.6 *
Foot angle at contact (°)	7.3	10.7 *	11.8 *	12.3 *	12.1 *
Stride frequency (step/min)	86.8	84.9 *#	84.0 *	83.7 *	83.4 *
Stride length (m)	2.30	2.35 *	2.37 *	2.38 *	2.38 *
Step time (ms)	346	354 *#	357 *	358 *	358 *
Contact time (ms)	234	247 *#	250 *	252 *	251 *
Stride angle (°)	73.2	74.2	73.3	72.5	74.5
Overstride angle (°)	7.2	8.8	8.6	8.5	8.6
Knee contact angle (°)	163.8	165.4	165.6	166.3 *	166.6 *
Peak stance knee flex angle (°)	138.8	138.0	137.6	137.4	137.5
Knee ROM stance phase (°)	25.1	27.4 *	28.0 *	28.9 *	29.0 *
Hip vertical displacement (mm)	8.0	9	11.5 *	10.8 *	10.8 *
Variables significantly similar to barefoot (n)	-	5	4	3	-
Variables significantly different from cushioned model (n)	-	3	0	0	-

Notes: *Significantly different from barefoot. # Significantly different from the cushioned shoe. In this study „significance was accepted at P < 0.05 level“ (Squadrone et al., 2014).

4. COMPARISON OF RUNNING SHOES

4.1 True versus potential minimalist shoes

Although, shortly discussed in the previous chapter, the importance of differentiating various types of minimalist shoes will herein be further explained. Namely, how different types of minimalist shoes appear to reproduce different aspects of the barefoot condition (Nigg, 2009).

In a study by Bonacci et al. (2013) the researchers examined the NIKE Free 3.0, which was categorized as a potential minimalist shoe earlier in this paper. The NIKE Free was set against the barefoot condition, a lightweight racing flat (NIKE LunaRacer2) and a conventional running shoe, with the purpose to assess if running biomechanics are similar in minimalist and barefoot conditions. The racing flat, that has been commonly used by runners for many years, was included to detect the differences between the racing flat and a potential minimalist shoe, if any.

Twenty-two highly trained habitually shod runners performed ten overground running trials in all four conditions. Results showed stride length and frequency differences between barefoot and all shod conditions, but not between the minimalist shoe and the racing flat. For most kinematic and kinetic variables at the knee and ankle, the testing displayed differences between barefoot and all shod conditions, but not across the shod conditions (Bonacci et al., 2013).

The authors draw a conclusion that the NIKE Free minimalist shoe is unable to sufficiently replicate the biomechanics of barefoot running. Although labelled minimalist, the NIKE Free 3.0 still has a 17 mm thick heel that affords considerable cushioning (Bonacci et al., 2013), which reduces the feeling of discomfort at heel contact and encourages the runner to land with a dorsiflexed ankle (Lieberman et al., 2010).

When describing the limitations of their study the authors recognise that due to the different constructions of minimalist shoes the results of this study should not be fully extrapolated to less cushioned low-heel minimalist shoes (Bonacci et al., 2013).

Similarily, Squadrone and Gallozzi's research from 2009 assessed whether the VFF Classic, named a true minimalist shoe by the current author, is effective in mimicking barefoot running conditions**.** To avoid the subjects having a weakened foot musculature or reduced proprioceptive sensitivity from long-term footwear use (Stiff & Verkhoshansky, 1999), only experienced barefoot runners were recruited to this study.

Eight healthy runners participated by running on an instrumented treadmill in three different conditions: barefoot, with the VFF Classic and with a conventional running shoe. After analysing the three conditions the authors reported, that the tested minimalist shoe enables the following benefits of barefoot running: FFS pattern, lower ground contact time, higher step rates and lower peak impact forces than with a conventional running shoe. It also appeared that running with VFF decreased oxygen consumption 2.8% in comparison to a conventional running shoe (Squadrone & Gallozzi, 2009).

The VFF Classic has a 3.5 mm rubber sole, is lightweight (148 g) and has very limited cushioning (Bonacci et al., 2013). The authors concluded that the VFF effectively replicate the barefoot condition while providing a layer of protection (Squadrone & Gallozzi, 2009).

Before making definite conclusions there are some methodological differences between the two reported studies (Bonacci et al., 2013; Squadrone & Gallozzi, 2009) that must be considered. Firstly, the participants were accustomed to different conditions: habitually shod versus habitually barefoot. Secondly, the participants ran on different surfaces: overground versus treadmill. Thirdly, the sample sizes of the experiments varied significantly: twenty-two versus eight participants. Unfortunately these differences are inevitable due to the limited number of studies available on the subject.

4.2 Conventional running shoes

Many authors, including Rixe et al. (2012) and Kerrigan et al. (2009), have stated that despite the popularity of a conventional running shoe there is no scientific evidence to confirm its potential to reduce injury or to promote long-term heath in runners. Although, footwear companies are developing specific running shoes and orthotic insert for variable arches and foot shapes, e.g. motion control footwear for *pes planus*, cushioned footwear for *pes cavus* and stability footwear for normal arches (Rixe et al., 2012), injury rates among endurance runners have not decreased over the past 30 years (Fields et al., 2010).

The construction of a conventional running shoe includes cushioning and an elevated heel (~8-16 mm) made of foam or other compliant material. This additional support may lead to a decrease in tissue tolerance to mechanical stress and excessive foot pronation, which tenses the deltoid ligaments and medial fascia of the foot (Murphy et al., 2013).

The cushioning and the elevated heel of a conventional running shoe reduce the magnitude of the vertical GRF at footstrike, which would normally cause discomfort

(Lieberman, 2012). However, at midstance, when the GRF, joint moments and contact forces are at their peak, the fore mentioned reducing factors have little influence (Bonacci et al., 2014). Higher rates of peak vertical GRF during footstrike interrelate with injury (Kernozek et al., 2014), thus the importance of the barefoot runner's FFS pattern, which decreases the peak GRF during impact serving the same purpose as the shoe with the additional benefit of also reducing peak joint moments at midstance (Bonacci et al., 2014).

Since the conventional running shoe eases discomfort in the rearfoot area during contact, it can be postulated that the conventional running shoe predisposes the use of RFS (Lieberman et al., 2010). Runners who naturally utilize the RFS pattern reported 54% incidence of running related injury annually compared to non-RFS runners' 31% (Goss & Gross, 2012). Moreover, the same authors found that runners who wear conventional running shoes are 3.41 times more prone to experience a running related injury than runners who choose to wear minimalist shoes (Goss & Gross, 2012).

5. TRANSITIONING TO MINIMALIST SHOES

5.1 Complications

Minimalist running puts higher impact forces on the forefoot and midfoot area, which has resulted in reports of metatarsal stress fractures (Giuliani et al., 2011). Females are more prone to stress fractures than males, therefore females must make sure to transition to minimalist running shoes particularly slowly (Ridge et al., 2013). Also, when first undertaking the FFS pattern the increased work in the triceps surae muscle causes muscle soreness for the majority of runners (Bonacci et al., 2013). If, for some reason, a runner is unsuccessful in switching to the FFS pattern and utilizes the RFS pattern without the shock-absorbing sole of a conventional running shoe, forces equal to 1.5-3 times body weight will be absorbed by the heel (Lieberman et al., 2010). This can cause running related injury to the structures of the heel (Ridge et al., 2013).

Another possible source of injury during the transitioning period is the mismatch between the striking pattern and the footwear design. Long-term RFS runners switching to footwear developed for FFS and MFS runners without any training or guidance is a risk factor for repetitive stress injuries to the foot and ankle (Giuliani et al., 2011).

In order to prevent potential complications runners must not rush the transitioning from a conventional running shoe to a true minimalist shoe, it is a process that requires caution and patience (Rixe et al., 2012).

5.2 Recommendations

Rothschild (2012) has described minimalist running as a recommended phase before transitioning to barefoot running. But as the running pattern for barefoot and true minimalist shoes is considered biomechanically analogous (Squadrone et al., 2014), and the amount of studies examining the adaptation period is very limited, it is recommended, based on the available information and literature search, to follow the instructions given below in both cases: either transitioning to barefoot or minimalist running.

Replacing or discarding shoes is only the first step towards permanently changing one's striking pattern. Although, RFS runners, who have grown up wearing shoes, automatically decrease dorsiflexion at initial contact approximately 7-10° when first trying barefoot running, they predominantly use the RFS pattern even on hard surfaces (Lieberman et al., 2010).

Thus, running with new shoes or on a new surface should be treated as high-intensity days that are followed by lower intensity ones. Muscles that act on the lower leg, ankle and foot will need more time to recover to avoid overload: post workout meals rich in protein and carbohydrates also help to speed recovery (Rixe et al., 2012). Strengthening exercises for the musculature in the foot are advised before discarding cushioned footwear (Ridge et al., 2013).

A 2-week strength training programme for the foot musculature is freely accessible on the VFF homepage. The programme involves seven exercises: heel raise, toe grip, dorsi/plantar flexion, toe spread/tap, exaggerated eversion/inversion, grabbing a towel with toes, and barefoot walking (or in VFF) for one- to two-hour periods. It is recommended to perform the exercises for 20 repetitions in 3 sets, 3-5 times per week for 2 weeks before wearing VFF for running (VFF1, 2015).

The time span of a full transition is individual for each runner and thus cannot be outlined in terms of days or weeks (Rixe et al., 2012). One of the few available studies on transitioning to true minimalist shoes by Ridge et al. (2013) assessed structural lesions in recreational runners during a 10 week adaptation period. Runners were instructed to gradually replace some mileage in conventional running shoes with mileage in VFF according to the recommendations published on the VFF Web site. The instructions currently available on the Web site may differ from those used in the study noted, but are nevertheless brought in Table 3.

During the first week participants ran one 1-2 mile run in the VFF and from the second week they added one 1-2 mile run per week up to the fourth week, during which they were allowed to add more mileage if they wanted, but not less. So during the tenth week they would run 10 or more miles in the VFF. All participants documented their workouts, including any foot or leg pain. Of the 19 participants, who tested the VFF, 10 had increased magnetic resonance imaging (MRI) signal intensity in some bone of their feet that refers to either a subfracture bone marrow edema or a stress fracture (only two experienced stress fractures) (Ridge et al., 2013).

However, increases in bone marrow edema correlate with added stress and have also been found in inexperienced runners who trained in conventional running shoes for 7 sequential days (Trappeniers et al., 2003). Even though, the injured and non-injured participants ran the same mileage in VFF, the injured runners ran more in conventional shoes in addition to the minimalist running, which also could have contributed to injury (Ridge et al., 2013).

As most runners are unable to receive a MRI scan after undertaking minimalist running, the presence of any pain should be taken with care and running should be limited (Ridge et al., 2013). If the pain persists seeking medical advice is highly recommended (Rixe et al., 2012). As far as injury prevention is concerned the most important aspect to take into account when transitioning to minimalist running is the rate of transition (Ridge et al., 2013).

Table 3. Instructions for transitioning to VFF (VFF1, 2015).

Weeks 1 and 2	Weeks 3 and 4	Weeks 5 through 12	Weeks 13 and on
Foot training 3-5x/week.	Warm up with foot training. Gently stretch your calves and arches.	Warm up with foot training. Gently stretch your calves and arches.	Warm up with foot training. Gently stretch your calves and arches.
Wear FiveFingers for 1 to 2 hour intervals per day (simple day-to-day activities: sitting, standing walking, etc.).	Run 10% - 20% of your normal running distance no more than once every other day.	Each week, increase your running by no more than 10% of your distance from the previous week. Continue to run more than once every other day.	At this stage you may be able to experiment with your distance, speed, and frequency. Continue to gradually increase your distance, but listen to your body every step of the way.
	Practice foot stretching and self-massage, include calf massage as part of this recovery process.	After each run, practice foot stretching and self-massage. Include calf massage as part of this process.	After each run, practice foot stretching and self-massage. Include calf massage as part of this process.

6. SUMMARY

The aim of this thesis was to research the differences between the following running conditions: barefoot, minimalist and shod. Meanwhile, the characteristics of various minimalist shoes were analysed, their advantages and disadvantages were listed through the eyes of a recreational distance runner in a climate of four seasons. Based on the received information practical recommendations were given in the matter of transitioning to minimalist footwear without or with minimal complications.

Running related musculoskeletal injuries are often associated with incorrect footwear, training errors and biomechanical factors like the GRF. As runners tend to choose their shoes on the basis of trend information, personal preference and the input of the store employee (Lohman et al., 2011), it is safe to say that the scientific material is yet to reach the crowds.

Due to the many factors influencing injury development besides footwear, taking up a certain strike pattern may not decrease injury rates for all runners (Murphy et al., 2013). Nor is it advised to switch to minimalist running without any consultancy (Giuliani et al., 2011) or with a pre-existing injury (Murphy et al., 2013). That is, only if acute damage to the feet can be avoided reducing the support by the footwear is suggested in order to stimulate the strengthening of the foot musculature (Rothschild, 2012).

Compared to shod running, the most evident advantage of minimalist running is the likely shift towards a more FFS pattern and thereby a decrease in collision forces (Squadrone & Gallozzi, 2009). The subsequent higher stride frequency alongside with the loss of shoe mass can have a favourable effect on running performance (Rothschild, 2012).

In order to see the desired change one must very carefully choose between the many types of minimalist running shoes. Low-heel, reduced heel-toe drop, lightweight and high sole flexibility make a minimalist shoe effective in replicating the barefoot style (Squadrone et al., 2014).

Before taking up running in minimalist footwear it is recommended to strengthen the foot musculature with exercises and walking in minimalist shoes or barefoot (VFF1, 2015). The transition ought to be done gradually and stopped if any pain is experienced (Ridge et al., 2013).

To summarise, it seems that according to the existing studies less is more in case of running footwear.

REFERENCES

1. Arendse RE, Noakes TD, Azevedo LB, Romanov N, Schwellnus MP et al. Reduced eccentric loading of the knee with the pose running method. Med Sci Sports Exerc 2004; 36: 272-277.
2. Bonacci J, Saunders PU, Hicks A, Rantalainen T, Vicenzino BT et al. Running in a minimalist and lightweight shoe is not the same as running barefoot: A biomechanical study. Br J Sports Med 2013; 47: 387-392.
3. Bonacci J, Vicenzino B, Spratford W, Collins P. Take your shoes off to reduce patellofemoral joint stress during running. Br J Sports Med 2014; 48: 425-428.
4. Chen WM, Lee PV. Explicit finite element modelling of heel pad mechanics in running: inclusion of body dynamics and application of physiological impact loads. Comput Methods Biomech Biomed Engin 2015; 18: 1582-95.
5. Chumanov ES, Wille CM, Michalski MP, Heiderscheit BC. Changes in muscle activation patterns when running step rate is increased. Gait Posture 2012; 36: 231-235.
6. Daoud AI, Geissler GJ, Wang F, Saretsky J, Daoud YA et al. Foot strike and injury rates in endurance runners: a retrospective study. Med Sci Sports Exerc 2012; 44: 1325-1334.
7. Farley CT, Houdijk HH, Van Strien C, Louie M. Mechanism of leg stiffness adjustment for hopping on surfaces of different stiffnesses. J Appl Physiol 1998; 85: 1044-1055.
8. Fields KB, Sykes J, Walker K, Jackson J. Prevention of running injuries. Curr Sports Med Rep 2010; 9: 176-182.
9. Footwear Insight. Less Shoe, More Sales, http://www.textileinsight.com/trendinsight/TREND%20INSIGHT%20PDFs/TI%20FWI%20JA11%20P40%3A41.pdf, 03.11.2015.
10. Giuliani J, Masini B, Alitz C, Owens BD. Barefoot-simulating footwear associated with metatarsal stress injury in 2 runners. Orthopedics 2011; 34: 320-323.
11. Goss DL, Gross MT. Relationships among self-reported shoe type, footstrike pattern, and injury incidence. US Army Med Dep J 2012; Oct-Dec: 25-30.
12. Hamill J, Russell EM, Gruber AH, Miller R. Impact characteristics in shod and barefoot running. Footwear Sci 2011; 3: 33-40.

13. Hanson NJ, Berg K, Deka P, Meendering JR, Ryan C. Oxygen cost of running barefoot vs. running shod. Int J Sports Med 2011; 32: 401-406.
14. Hreljac A. Impact and overuse injuries in runners. Med Sci Sports Exerc 2004; 36: 845-849.
15. Kernozek TW, Meardon S, Vannatta CN. In-shoe loading in rearfoot and non-rearfoot strikers during running using minimalist footwear. Int J Sports Med 2014; 35: 1-6.
16. Kerrigan DC, Franz JR, Keenan GS, Dicharry J, Della Croce U et al. The effect of running shoes on lower extremity joint torques. PM&R 2009; 1: 1058-1063.
17. Knobloch K, Yoon U, Vogt PM. Acute and overuse injuries correlated to hours of training in master running athletes. Foot Ankle Int 2008; 29: 671-676.
18. Lieberman DE, Venkadesan M, Werbel WA, Daoud AI, D'Andrea S et al. Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature 2010; 463: 531-535.
19. Lieberman DE. What can we learn about running from barefoot running: An evolutionary perspective. Exerc Sport Sci Rev 2012; 40: 63-72.
20. Lohman EB 3rd, Balan Sackiriyas KS, Swen RW. A comparison of the spatiotemporal parameters, kinematics, and biomechanics between shod, unshod, and minimally supported running as compared to walking. Phys Ther Sport 2011; 12: 151-163.
21. Mayer F, Hirschmüller A, Müller S, Schuberth M, Baur H. Effects of short-term treatment strategies over 4 weeks in Achilles tendinopathy. Br J Sports Med 2007; 41: 1-5.
22. Murphy K, Curry EJ, Matzkin EG. Barefoot Running: Does it prevent injuries? Sports Med 2013, DOI 10.1007/s40279-013-0093-2.
23. Nigg BM. Biomechanical considerations on barefoot movement and barefoot shoe concepts. Footwear Sci 2009; 1: 73-79.
24. Pelletier-Galarneau M, Martineau P, Gaudreault M, Pham X. Review of running injuries of the foot and ankle: clinical presentation and SPECT-CT imaging patterns. Am J Nucl Med Mol Imaging 2015; 5: 305-316.
25. Ridge ST, Johnson AW, Mitchell UH, Hunter I, Robinson E et al. Foot bone marrow edema after a 10-wk transition to minimalist running shoes. Med Sci Sports Exerc 2013, DOI: 10.1249/MSS.0b013e3182874769.
26. Rixe JA, Gallo RA, Silvis ML. The barefoot debate: Can minimalist shoes reduce running-related injuries? Curr Sports Med Rep 2012; 11: 160-165.

27. Robbins SE, Hanna AM. Running-related injury prevention through barefoot adaptations. Med Sci Sports Exerc 1987; 19: 148-156.
28. Rothschild CE. Primitive running: A survey analysis of runners' interest, participation, and implementation. J Strength Cond Res 2012; 26: 2021-2026.
29. Squadrone R, Callozzi C. Biomechanical and physiological comparison of barefoot and two shod conditions in experienced barefoot runners. J Sports Med Phys Fitness 2009; 49: 6-13.
30. Squadrone R, Rodano R, Hamill J, Preatoni E. Acute effect of different minimalist shoes on foot strike pattern and kinematics in rearfoot strikers during running. J Sports Sci 2014, DOI 10.1080/02640414.2014.989534.
31. Stiff MC, Verkhoshansky YV. Supertraining 4th edition. Denver CO: Supertraining International, 1999.
32. Zipfel B, Berger LR. Shod versus unshod: The emergence of forefoot pathology in modern humans? Foot 2007; 17: 205-213.
33. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR et al. A retrospective case-control analysis of 2002 running injuries. Br J Sports Med 2002; 36: 95-101.
34. Trappeniers L, De Maeseneer M, De Ridder F, Machiels F, Shahabpour M et al. Can bone marrow edema be seen on STIR images of the ankle and foot after 1 week of running? Eur J Radiol 2003; 47: 25-28.
35. VFF1 (Vibram FiveFingers homepage). Getting Started: Foot Fitness Program, http://www.vibramfivefingers.it/education_why_barefoot.aspx, 03.11.2015.
36. Yong JR, Silder A, Delp SL. Differences in muscle activity between natural forefoot and rearfoot strikers during running. J Biomech 2014; 47: 3593-3597.

RESÜMEE

Minimalistlike jooksujalatsite kasutuselevõtu mõju ja ohutus harrastusjooksjale

Viimase viie aasta jooksul on nii harrastus- kui tippspordis populaarsust kogunud paljajalu ja minimalistlike jalatsitega jooksmine. Antud töös vaadeldakse erinevusi traditsiooniliste jooksujalatsite, minimalistlike jooksujalatsite ja paljajalu jooksmise vahel. Tutvustatakse mitmeid minimalistlike jooksujalatsite mudeleid ning selgitatakse välja, millised neist on kõige efektiivsemad imiteerimaks paljajalu jooksmist. Samuti sisaldab töö praktilisi soovitusi, kuidas minna üle minimalistlikele jooksujalatsitele võimalikult ohutult.

Vaatamata traditsiooniliste jooksujalatsite populaarsusele, pole siiani teaduslikult tõestatud, kas ja kuidas aitavad toestatud ja pehmendustega jalanõud ennetada jooksuvigastusi. Jooksujalatsite tootjad on viimase 30 aasta jooksul turule toonud lugematul hulgal erinevaid mudeleid, kuid vigastuste esinemissagedus ei ole langenud. Jooksjate seas esinevaid skeleti-lihassüsteemi vigastusi seostatakse treeningmetoodika vigade ja biomehaaniliste tegurite kõrval ka ebasobivate jalanõudega. Traditsiooniliste jooksujalatsitega joostes kulgeb algkontakt üle kanna, kuid paljajalu joostes kasutatakse maandumiseks kogu talda või pöida, mille tulemusena on hüppeliiges algkontaktil vähem dorsaafleksioon asendis, sammupikkus väiksem ja sammusagedus suurem. Nimetatud muutused vähendavad jooksjale mõjuvaid toereaktsioone ning võivad parandada ka jooksutulemusi. Kerged, õhukese ja elastse talla ning vähendatud kanna-varba kõrgusvahega minimalistlikud jooksujalatsid võimaldavad jooksjal imiteerida paljajalu jooksmist, kaitstes jalatalda akuutsete vigastuste, infektsioonide ja ekstreemsete temperatuuride eest. Seejuures peetakse uute jalanõudega jooksmist intensiivseks treeninguks, millega kohanemiseks on oluline anda organismile aega ja suurendada koormust järk-järgult. Kuna eesmärk on vigastust vältimine, siis on otstarbekas minimalistlike jalatsitega jooksmisele eelnevalt tugevdada jalalaba lihaseid harjutustega ning käia minimalistlike jalatsitega kõndimas. Soovitatavalt toimub üleminek treeneri või füsioterapeudi järelvalve all, võimaldades individuaalset lähenemist ja valukaebuste esinemisel kohest sekkumist.

Kokkuvõtteks võib öelda, et edasised uuringud on kindlasti vajalikud selgitamaks minimalistlike jooksujalatsite potentsiaali jooksuspordiga seonduvate vigastuste ennetamisel.

Lihtlitsents lõputöö reprodutseerimiseks ja lõputöö üldsusele kättesaadavaks tegemiseks

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How can a recreational runner benefit from transitioning to minimalist running shoes and how to do it safely? (Minimalistlike jooksujalatsite kasutuselevõtu mõju ja ohutus harrastusjooksjale)

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