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The Effect of Footwear Habits of Long-Distance Runners on Running Related Injury: A Prospective Cohort

Abstract: Every year, about 60% of distance runners will suffer a running-related injury that not only temporarily affects their training, but can also have long-term psychological and physical effects. Following recent publications, barefoot running has gained attention for its claim to reduce running related injury and promote a natural running stride. This study directly compares injury rates between barefoot and shod runners and for the first time quantitatively evaluates the risk present in transitioning from shod to barefoot running. The following question will be examined: How does footwear habit (barefoot, transitioning or shod) affect the injury rates of long distance runners? A series of surveys were emailed to participants to record running habits and injuries suffered over a course of twelve weeks. The data supported that runners transitioning from shod to barefoot running had the highest prevalence with an average of 32% of its runners in an injured state each week. Shod runners had the lowest prevalence with 21% and barefoot runners (prevalence of 29%) were in the middle. Furthermore, relative risk calculations, which are based on a ratio of prevalence, showed that barefoot runners are 1.35 times as likely to suffer and injury as shod runners. Transitioning runners are 1.48 times as likely as shod runners to suffer an injury. This study supports that shod running presents the lowest risk of injury for distance runners. Despite recent speculation, barefoot running in industrialized countries does not appear to reduce running related injury. Thus it is not recommended that healthy runners transition to barefoot running for the sole purpose of reducing injury risk.

Introduction

Long distance running is known to have a number of health benefits. The aerobic exercise can reduce the risk of obesity, heart disease and diabetes. However, every year, approximately 55-60% of runners will suffer a running related injury (Malone, 2008). These injuries not only interrupt training and daily exercise, but can also cause lasting physical and psychological effects. These effects can make running significantly less enjoyable and thus act as a deterrent to distance running. Given the negative impact and high frequency of injuries, factors that could prevent injury would be beneficial to a large number of people.

Over the past few years, barefoot running has gained prominence through a number of media sources. It claims to promote a natural running stride and reduce the risk of injury by utilizing the body's natural running mechanisms. There has been speculation that long distance running was beneficial to our hunter ancestors, who would have run barefoot or in simple sandals. When nations industrialized, shoes were adopted as a form of protection. Shoe technology has become a large business now. But barefoot running still occurs in many third world countries. Many prominent elite African runners started as barefoot runners. These speculations and observations have been supported by other research that looks specifically at biomechanics. However, very few studies directly assess the injuries related to the barefoot running habit. Furthermore, no other study evaluates the risks associated with transitioning from shod running to barefoot running, which would be the case for the majority of runners in developed nations.

Barefoot running is believed to provide a number of biomechanical advantages that are inhibited by the modern running shoe. Almost all running shoes have a thick heel to provide extra cushioning but also disrupt the natural foot positioning. High heel shoes are known to cause knee problems and therefore the one inch increase of running shoe heels would also increase knee pressure. Furthermore, the increased heel height reduces the propulsion efficiency of the leg by shortening the Achilles tendon which inhibits the stretch reflex of the tendon. The decrease in tendon length also reduces its ability to pull on the heel, which causes a flattening of the arch. Furthermore, the elevated toe box reduces the ability of the metatarsals to efficiently grip and lever the foot against the ground (Driscoll, 2003).

The shoe was originally adopted to protect a person's feet as nation's industrialized from dirt and grass to asphalt and concrete. Since, then a number of companies (Nike, Asics, Saucony) have built off the shoe business promoting specialized running shoes with support and cushion. Recent studies have challenged the benefit of the shoe, citing that the additional support enables imbalance problems in the foot to worsen. There has been speculation that the supportive qualities of the shoe eliminate the need to develop key foot muscles that maintain natural balance and stability in the foot. Barefoot running helps strengthen muscles in the feet and utilize soft tissue to create natural stability and force absorption (Warburton, 2001). Prior research has reported that expensive running shoes account for twice as many injuries as inexpensive shoes (Warburton, 2001). Furthermore, sources cite that additional cushioning does not decrease impact forces, although accurate measures of impact force have been difficult to record due to spatial and frequency domains (Shorten, 2002). Regardless, the weight of the extra cushioning is responsible for decreasing running efficiency by approximately 4%. The cushioning also inhibits sensory feedback while barefoot running increases sensory feedback allowing the body to adapt and land lightly (Warburton, 2001).

Despite speculated benefits, barefoot running remains rare in industrialized countries. Cuts and other surface wounds remain as a large deterrent to barefoot running. The National Federation of State High School Associations requires athletes to wear shoes for Track and Field and Cross Country (Driscoll, 2003). However, barefoot and minimalist running has gained attention in the last few decades due to recent media publications and scientific studies. As a result, shoe companies are producing minimalist shoe models which involve less support and cushioning. Other companies have released sandal-like shoes which are suppose to model barefoot running except with protection against surface wounds.

The study addresses the following research question: How does footwear habit affect the injury rates of long distance runners? In evaluating this question, I hypothesized that the barefoot runners will have the lowest injury rate because barefoot running utilizes the body's natural adaptations to divide and absorb stress and strain from the impact of running. Furthermore, I think the transitioning group will have the highest rate of injury because the muscles and tendons are not yet strengthened and are therefore still prone to imbalances yet lack the artificial support. The null hypothesis states that there will be no difference between the injury rates of the three groups. A prospective cohort was chosen for this study in order to look at the exposure of various footwear habits and then track those who developed injuries. Prospective cohort studies are advantageous in establishing temporal relation and can help prevent later recall bias. A cohort study was much more feasible than a case control study due to the number of other variables that would necessary in pairing samples.

The study involved contacting local running clubs, stores and prominent individuals in the community to spread the word of the study. The criteria for participants specified persons between the ages of 16-70 who ran at least an average of 10 miles per week and is not participating in high school or collegiate sports. My primary concern when gathering participants was the sample size. In order to overcome the number of confounding variables involved, a large sample size would be ideal. This would hopefully allow comparisons within similarities of confounding variables in order to draw conclusions about the specified variable (footwear habit). The study involved runners who volunteered to record and submit surveys of their running habits for 12 weeks. Runners who emailed the address specified for this project were considered valid subjects if they met the above criteria. This limited the sample population to runners who had regular access to the internet. Also, the selection of samples tended to represent those who were involved in the running community.

The study involved two surveys. The Entrance Survey records background information of factors that might increase the risk of injury. The Bi-weekly Survey records the running habits and injuries of the runner every two weeks. Each participant was requested to fill out 6 bi-weekly surveys in subsequent weeks. By filling out each survey, the participant agreed to the anonymous use of the data recorded in the survey. Both the surveys were approved by my advisor as a source to collect data. A twelve-week duration was chosen to give sufficient consideration to variations in training cycles.

Each runner was placed into one of the three groups (barefoot, shod and transitioning) based on their current running habit. No runners were requested or pressured to run in footwear differing from their present habit. The barefoot group is defined by runners who run either exclusively barefoot or exclusively in minimalist shoes for at least the past 4 months. The use of the term “barefoot” in this study refers to both pure barefoot running and minimalist shoe running. Minimalist shoes are defined as footwear with no intention of providing support or cushioning, but merely offers surface protection for the feet. The transitioning group is defined by shod runners who have the goal of running barefoot or minimalist and are currently either running in both shoes and barefoot or have switched to barefoot running in the past four months. The shod group is defined by runners who wear standard running shoes and have no intention of running exclusively barefoot.

The primary measure of the study is the injury rate of the runners. Every two weeks, based on the data submitted, two values will be recorded: the number of new injuries and the number of days that the runner was in an injured state. Injury was defined as physical damage that persists throughout the duration of the run and could potentially cause long-term harm. Soreness and exhaustion were not recorded as injuries, because they are more directly associated with phases of training. Secondary features such as injury diagnosis, treatment and rest were also recorded. The main variable measured in this study is the number of days that a runner was in an injured state (a value referred to as prevalence).

The data will be analyzed to compare the injury rates between the three groups and address the confounding variables present. The prevalence of injury in the three groups will be compared using ANOVA tests to determine the significance of the difference. I hypothesized that the transitioning group will have a higher risk of injury due to the fact that the body at that time will be adapting to strengthening smaller muscles. Furthermore, the transitioning phase is a temporary state. Therefore, the transitioning group will be evaluated separately. The barefoot and shod group will be compared directly using t-tests to determine the significance of any difference between the two permanent footwear habits. The transitioning group will then be assessed to evaluate risks of transitioning in light of potential benefits of barefoot running.

In order to draw significant comparisons between the three running habits, the effect of the confounding variables needs to be considered. The following variables will be measured: gender, age, BMI, number of races, years running, pace, prior injury, mileage, cross training and running surface. For each group, the average and standard deviation will be calculated for each variable and then compared. Furthermore, when possible, a Peasron's r-value will be used across each group individually to determine the correlation between the particular variable and injury prevalence.

Results:

Data:

Collected between: July 11, 2010 to December 3, 2010.

The Effect of Footwear habits on the Incidence and Prevalence of Running-Related Injury in Specified populations						
Uncertainty: Variable based on the number of runners recorded per week						
	Barefoot		Transitioning		Shod	
Week	Incidence	Prevalence	Incidence	Prevalence	Incidence	Prevalence
1	0.37	0.37	0.45	0.45	0.40	0.40
2	0.32	0.37	0.27	0.27	0.10	0.30
3	0.25	0.44	0.33	0.33	0.29	0.29
4	0.20	0.33	0.38	0.75	0.13	0.50
5	0.21	0.36	0.50	0.50	0.00	0.14
6	0.00	0.29	0.00	0.25	0.00	0.17
7	0.17	0.17	0.25	0.25	0.17	0.17
8	0.25	0.33	0.00	0.25	0.00	0.00
9	0.17	0.33	0.00	0.33	0.00	0.17
10	0.09	0.36	0.00	0.33	0.00	0.17
11	0.10	0.30	0.33	0.67	0.00	0.00
12	0.50	0.80	0.50	1.00	0.00	0.00
Average	**0.23**	**0.37**	**0.24**	**0.41**	**0.12**	**0.22**

Figure 1: Incidence denotes the number of new injuries each week. Prevalence denotes the total number of persons injured each week. All statistics are given as a ratio of the total number of people (in the group) to account for different group sizes and different numbers of data submitted each week.

The table above includes all reported injuries. The table below includes "major injuries," which is defined as pain associated with potentially long-term physical effect. Major injuries do not include soreness and blisters which may be related to variance in training patterns and weather. For this reason, the analysis uses the data of major injuries. However, because the distinction between the two is subjective, both sets of data were included to show that similar trends exist between both data sets.

The Effect of Footwear habits on the Incidence and Prevalence of Major Running-Related Injury in Specified populations						
Uncertainty: Variable based on the number of runners recorded per week						
	Barefoot		Transitioning		Shod	
Week	Incidence	Prevalence	Incidence	Prevalence	Incidence	Prevalence
1	0.11	0.11	0.21	0.21	0.40	0.40
2	0.32	0.37	0.14	0.14	0.10	0.30
3	0.31	0.44	0.27	0.27	0.29	0.29
4	0.07	0.40	0.20	0.40	0.13	0.50
5	0.21	0.36	0.20	0.20	0.00	0.14
6	0.00	0.29	0.00	0.20	0.00	0.17
7	0.17	0.17	0.40	0.40	0.17	0.17
8	0.08	0.25	0.00	0.40	0.00	0.00
9	0.00	0.25	0.00	0.50	0.00	0.17
10	0.00	0.27	0.00	0.50	0.00	0.17
11	0.10	0.20	0.00	0.50	0.00	0.00
12	0.20	0.40	0.33	1.00	0.00	0.00
Average	**0.14**	**0.29**	**0.17**	**0.32**	**0.11**	**0.22**

Qualitative data: Injuries recorded include the following: plantar fasciitis, aching, shin splits, cuts, scrapes, bruises, fractures, Iliotibial band syndrome, Achilles tendonitis, inflammation. On the bi-weekly surveys, it was hard to distinguish between rest days due to injury and rest days that were simply part of a training program Even though the number of days of rest was also recorded, due to inconsistencies between reporting and difficulty separating rest days and injury rest days, the information was not included in the analysis.

Analysis:

From the data presented above, the transitioning group is associated with the highest risk of injury. However, unlike the barefoot and shod groups, the transitioning state is a temporary phase. Therefore, it is illogical to compare it to the other two permanent states. The Barefoot and Shod running conditions will be compared and then the transitioning state will be evaluated.

Prevalence was the main evaluation of injury as it was based on the number of runners who were in an injured state not simply a new injury (which would not include an injury from a prior week). Thus prevalence to some extent also evaluates the magnitude of the injury and the impact on training.

Barefoot Running versus Shod Running:

Effect of Barefoot versus Shod Running on Injury Rates over 12 weeks			
	Units of measure: persons	Units of Measure: Percent of the group injured	
Footwear	**Number of Participants**	**Average**	**Standard dev.**
Barefoot	19	29.3	10.3
Shod	10	21.7	15.8

The injury rate was measured by the percent of the group that was injured each week. Not all participants submitted all 12 weeks of data. Thus to account for the different number of participants (per group and per week) all injury rates are given as percents of number of people who submitted data that week (for the respective group). The overall average for the group was calculated based on the total number of injuries and the total number of weeks of submitted data (for each group). From the table above, the barefoot group had a higher percent injured on average each week. The standard deviation is fairly high because the percent injured varied from week to week as shown below.

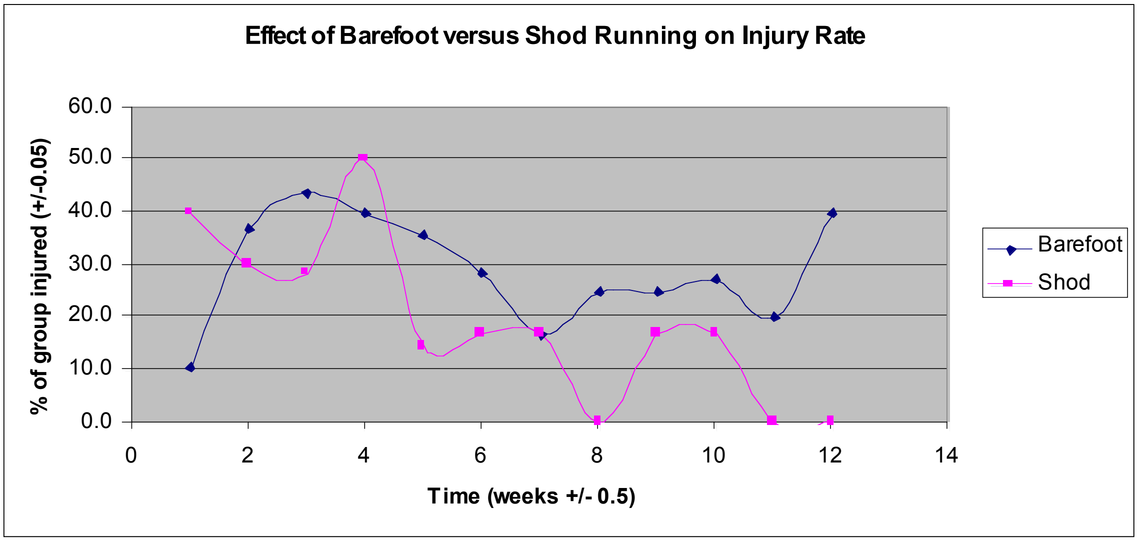

Figure 2: A graph of prevalence (% of persons in an injured state) in the barefoot and shod group over the twelve weeks.

Even though there were a few week when the shod group had a higher prevalence, in general, the shod group usually had a lower percentage of injured group members.

T-test: 0.077

A t-test was used to determine if there was a significant difference between the barefoot and shod group. A p-value of 0.077 indicates that there is 92.3% certainty that the difference between the groups is significant and not due to chance. This indicates a strong trend but the value is not high enough to reject the null.

The relative risk between the two values can be calculated in a cohort study:

Relative risk is defined as:

$$\frac{Number\ injured\ in\ \text{var}iable\ group}{Number\ injured\ in\ control\ group} = 1.35$$

The average prevalence value over the twelve weeks was used to ensure that differing population sizes did not skew the calculation. Based on this statistic, barefoot runners are 1.35 times more likely to suffer an injury than shod runners. However, relative risk values often need to be above 3 or 4 to be considered significant enough to link causation.

Barefoot running appears to be associated with a greater risk of injury. On average 29.3% of the barefoot group was injured each week. The shod group had an average of 21.7% injured each week. Furthermore, a t-test (p-value: 0.77) indicates that we can be fairly confidence that a difference between the two groups exists but the value is not high enough to reject the null. From both the graph and standard deviation, there is a large variation of injury each week. This may be due in part to variation in training cycles (i.e. mileage, races).

Evaluation of Transitioning:

Effect of Barefoot versus Shod Running on Injury Rates over 12 weeks			
	Units of measure: persons	Units of Measure: Percent of the group injured	
Footwear	**Number of Participants**	**Average**	**Standard dev.**
Barefoot	19	29.3	10.3
Shod	10	21.7	15.8
Transitioning	16	32.1	23.1

ANOVA: 0.02

T-test (Shod and Transitioning): 0.06

T-Test (Barefoot and Transitioning): 0.17

Relative Risk (Shod and Transitioning): 1.48

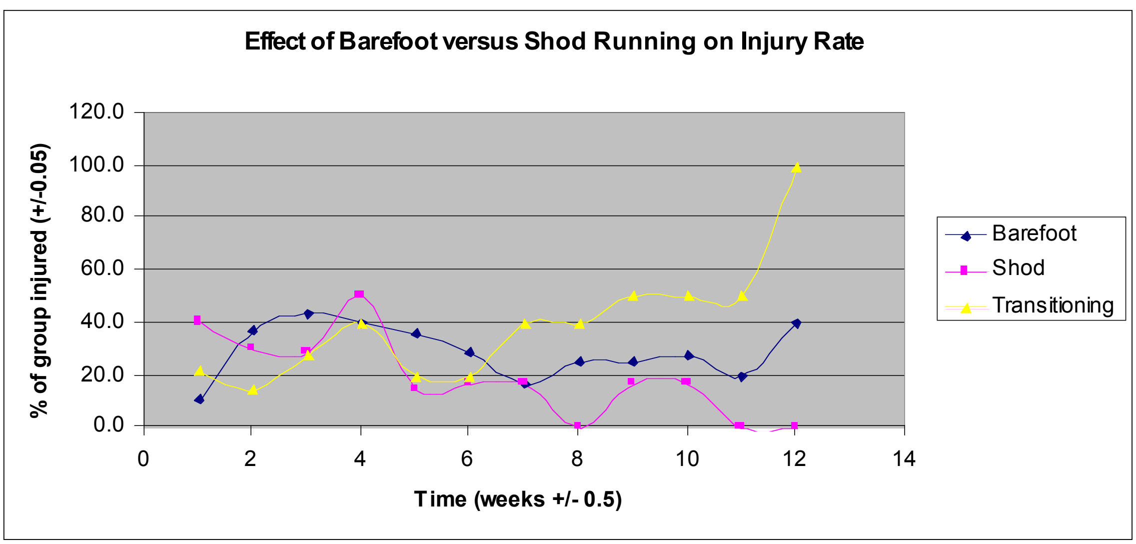

Figure 3: A graph of the prevalence (% of runners in an injured state) of the barefoot, transitioning and shod group over the 12 weeks.

Towards the latter end of the study the injuries in the transitioning group increases significantly. This may be due to a decrease in sample size or an increase in injuries as the transitioning process progressed. An ANOVA test with a p-value of 0.02 indicates that there is a 98% certainty that the difference between the three groups is significant. This is sufficient certainty to reject the null, which supports that there is difference between the three groups. However, comparing groups individually in pairs of two is not as certain (as mentioned in the previous section). A t-test between the transitioning group and shod group resulted in a p-value of 0.06, indicating that there is 94% certainty that the difference between the groups is significant. Thus the null hypothesis cannot be rejected. Relative risk indicates that the transitioning group is 1.48 times as likely to suffer an injury as the shod group. A t-test between the transitioning group and barefoot group resulted in a p-value of 0.17, which indicates 83% confidence that the difference between injury rates in significant. Similar to the barefoot and shod comparison, the injury rates between the groups are not significantly different between any of the two groups, but as a whole the three groups are statistically different.

Confounding Variables:

Given the nature of running injuries, there are a number of confounding variables that make it near impossible to determine causation (especially with a limited sample size). However, the following section attempts to examine major variables and the possible effect they had on the injury difference seen between the barefoot, transitioning and shod group.

The following confounding variables will be assessed:

- Mileage
- Gender
- Age
- BMI
- Running Surface
- Prior Injury

The critical value of the Pearson correlation coefficient indicates the level of significance. For the barefoot group, based on 19 runners, a value of 0.48 is necessary for 95% confidence. For the transitioning group, based on 16 runners, an r-value of 0.52 is necessary for 95% confidence. In the shod group, based on 10 runners, an r-value of 0.68 is needed for 95% confidence. The Pearson correlation test calculates the strength of the correlation between two variables.

Mileage:

Higher mileage often increases the rate of injury. Running causes microscopic tears in muscles. When the body repairs these tears, it forms scar tissue, which is stiff and unable to stretch. As a result, this scar tissue leads to tight muscles, which are less capable of absorbing shock and also can lead to muscle imbalances (Weisenfeld, Burr, 1981). Increasing mileage increases the number of microscopic tears and therefore scar tissue.

Effect of Mileage on Injury Rates over 12 weeks			
	Average Mileage (+/- 0.5 miles)	Standard Dev.	Correlation to injury (r-value)
Barefoot	26.1	20.9	-0.22
Transitioning	29.7	29.8	-0.01
Shod	26.7	15.1	-0.74

The average mileage of the three groups was between 26-30 miles per week. The average mileage of the three groups is relatively similar. The large standard deviation again indicates a wide variance in training programs, which cannot be controlled. Furthermore, the occurrence on an injury will typically affect training, which would also cause mileage to fluctuate. An ANOVA test resulted in a p-value of 0.34 which indicates that there is speculation of some difference between the mileages of the three groups, but it is not significant. Furthermore, a Pearson correlation test returned negative r-values that higher mileage was weakly associated with lower injuries. This again may be due to the cause-effect conundrum, in which the presence of the injury is decreasing the mileage. In the barefoot and transitioning group, this correlation was statistically insignificant. However, in the shod group, there is close to 98% confidence that higher mileage is associated with fewer injuries. This indicates that mileage likely played a role in the injury rates of the shod group, but the cause-effect relationship is unclear. As a whole, due to the low correlation in the barefoot and transitioning group as well as the insignificant ANOVA test, mileage played a minor role in influencing the injury differences between the three groups.

Gender:

Anatomical differences due to age and gender also play a role. Females are reported to have a larger hip width to femoral length ratio which increases the likelihood knee and shin injuries Also differences in foot width and hormones may contribute to back pain, thigh injuries and ligament damage in females (Ferber, 2003).

Effect of Gender on Injury Rates				
	Male to Female ratio	Male (Prevalence)	Female (Prevalence)	T-test (between male and female)
Barefoot	15:4	0.32	0.19	0.34
Transitioning	8:7	0.26	0.36	0.26
Shod	7:3	0.28	0.12	0.18

The gender distribution is not as even as preferred. Yet despite this difference, t-tests indicate that there was not a significant difference between injury rates in males and females. The injury rates of males tended to be higher than females, but this was not consistent across all three groups. According to prior research, the major difference between male and female is the location of injury. However, due to uncertainties associated with the exact diagnosis of an injury, it is difficult to assess differences in injury type or location. Compare male to male and female to female

Age:

As humans age, bone loss can lead to a greater risk of stress fractures and muscles are slower to repair.

Effect of Age on Injury Rates over 12 weeks			
	Average Age (+/- 0.5 miles)	Standard Dev.	Correlation to injury (r-value)
Barefoot	41.5	8.2	-0.37
Transitioning	44.1	11.1	0.23
Shod	44	13.1	-0.31

ANOVA: 0.73

The average age ranges from around 41-44. An ANOVA test resulted in the p-value of 0.73 showing the difference between ages of the three groups is not statistically significant. The Pearson correlation test indicated that a trend between age and injury may be present, but not significant. Secondly, again the trend is not consistent across all three groups. This inconsistency and the similar averages, suggests that age did not have a major effect on the difference in injury rates across the three groups.

BMI:

The impact force due to gravity when the foot strikes the ground is usually absorbed by the tendons and joints in the leg. However, increased BMI or body mass will increase the impact force which increases stress on these joints (especially the knee).

Effect of BMI on Injury Rates over 12 weeks			
	Average BMI (+/- 0.5 miles)	Standard Dev.	Correlation to injury (r-value)
Barefoot	23.4	3.42	0.37
Transitioning	21.6	1.87	-0.58
Shod	23.9	2.48	0.01

The transitioning group had the lowest BMI, but overall the BMI's were relatively similar. The barefoot and transitioning group showed some trends between BMI and injury, but the trends were in opposite direction which would likely indicate that the correlation was due to different factor.

Running Surface:

Softer running surfaces can aid in the absorption of impact force, but also requires more effort from the muscles and can strain the Achilles tendon (Bloom). Harder surfaces increase impact forces, but provide a solid, even and accessible surface for running (Bloom, Smythe, 2002). Moderate surfaces provide a good middle between the two but often can be uneven, which can lead to ankle injuries.

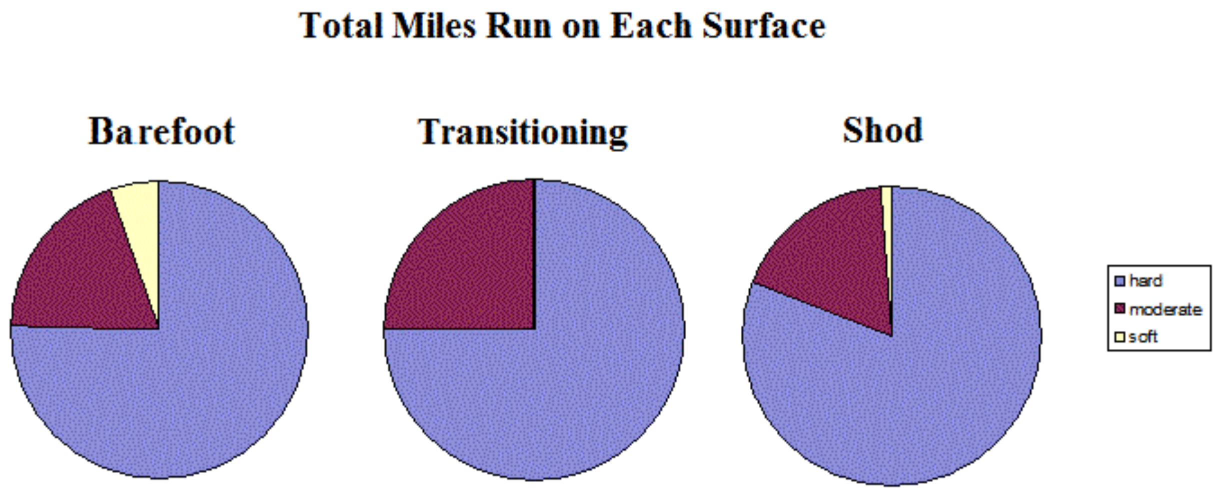

Figure 4: Pi charts representing the fraction of miles run on each type of surface. Hard Surfaces: asphalt and cement. Moderate surfaces: dirt, trail, tarmac and treadmill. Soft surfaces: grass and sand.

Despite differences in footwear, all three groups showed similar distributions of miles across the three types of surfaces The majority of miles run were on hard surfaces, followed by moderate and then soft. The difference was likely due to availability. Based on the fact that the distribution of miles is fairly even across the types of surfaces, running surface likely only had minimal effect on the difference in injury between the three groups.

Prior Injury:

Almost all of the runners in this study had suffered a prior injury. Within each group, there was only one or two without a previous injury. This variable, regardless of confounding, is fairly evenly distributed across all three groups.

Discussion:

Contrary to recent speculation, the shod group had a lower injury rate than the barefoot group. A number of factors could account for this disagreement. This study assumes that four months would be sufficient time for a barefoot runner to adapt their running stride and strengthen foot muscles. The distinction between barefoot runner and transitioning runners is debatable. But even when the barefoot group was reduced to runners who had run barefoot for at least a year, the prevalence (0.39) was still higher than the shod group. The majority of current research addresses factors such as foot strike and cushioning in regards to barefoot running. However, this study did not record foot strike due to resource limitations. Research asserts that barefoot runners naturally switch to a more efficient foot strike out of comfort and preference. Furthermore, in industrialized nations, most people use shoes on a normal basis and thus their foot muscles lack the strength and stability of those who live completely without shoes. So even if they run without shoes, if their day to day activities are still performed without shoes the muscles may not strengthen properly.

Running shoes appear beneficial in cushioning the feet and protecting them from hazards. The results of this study reflect that the human body may not be designed to run barefoot on rock hard surfaces such as asphalt and concrete. Human phylogeny may favor barefoot distance running, but during that time of adaptation humans would have been running across earth not roads. The ability for tendons and joints to absorb the impact of striking the ground may not be developed sufficiently for impact of roads. The majority of serious injuries in the barefoot group were lower leg pain or fractures of small bones in the foot. The fractures in the foot were in most cases attributed to some acute injury. The metatarsal bones are the main shock absorbers in the foot (Sandler, 2010). In the barefoot and transitioning group, fractures of the metatarsals were the most common long-duration injury. Even if the human body helps absorb impact on a larger scale, the impact on small joints and bone may not be absorbed sufficiently. Barefoot running emphasizes the benefits of sensory feedback to make adaptations. However, small bones may not possess adequate durability to allow adaptation without suffering injury. Metatarsal fractures were present in both the barefoot and the transitioning group, but absent from the shod group.

Also each confounding variable may have played some role in influencing the data but never appeared as a significant trend. It is extremely difficult to account for confounding variables due to ethical restrictions. Furthermore, in seeking a larger sample size, specifying certain groups would have greatly limited the size and application of the study. In order to account for confounding variables, a stratified analysis of all the variable combinations is used. But given the number of variables present in running, a massive sample size (at least a couple thousand) would be necessary. The study presents the best method to account for possible confounding given the circumstances. The variables examined are not believed to have played a significant role in influencing the difference in injury rates between the three groups.

The development and strengthening of muscles in the transitioning group is likely responsible for the higher injury rate. Of the 19 muscles in the human foot, 12 connect to the leg, but walking in shoes only utilizes the tibialis anterior and triceps surae (Csonka, 2010). As a result, the other important muscles in the foot remain undeveloped. The arch is important in absorbing impact force and is supported by the posterior tibial muscle. Also, in barefoot running the toes are used to help propel the body and need the support of a number of flexor and extensor muscles. The plantar fascia ligament is crucial for maintaining balance, support and strength of the entire foot. Wearing shoes or prior use of shoes, can deform and atrophy these muscles and ligaments in order to make shod movement more efficient (Sandler, 2010). Without the support of shoes, barefoot running requires these muscles in order to function efficiently. The Achilles tendon, which connects the heel to the calf muscle, also must lengthen for barefoot running because there is no longer a raised heel. During the transitioning phase, runners are especially prone to overuse injuries because many of the small muscles are easily overworked and may not be capable of fully completing their job.

Upon viewing the results of this study, the majority of participants said the results were as they had expected. There was a fair consensus that the transitioning group would have the highest risk of injury. However, barefoot and transitioning runners noted that it was often runners who had been plagued with injury when shod that decided to run barefoot. This was definitely supported in the data because all but one barefoot runner had a past injury. However, prior injury was pretty high in all three groups. In light of this study, most runners retained their running habit, noting that injury risk was not the only reason to choose barefoot running.

Conclusion:

The data from this study partially supports the hypothesis. The transitioning group did have the highest injury rate (both prevalence and incidence), but the shod group had the lowest of both injury statistics. The shod group had lower incidence and significantly lower prevalence of injury than both the transitioning and barefoot group. Given that the barefoot group did not have a lower prevalence than the shod group; it is difficult to evaluate the transitioning phase because there is no apparent benefit of barefoot running in regards to injury risk. Although, it is still useful to note, for those wishing to run barefoot, that the transitioning phase does present a greater risk of injury and thus careful planning of a training schedule is ideal when transitioning.

One of the strengths of this study is the measurement of injury in the transitioning group. The majority of runners in Western countries would have to transition from shoes in order to run barefoot. Thus this study not only compares barefoot and transitioning running, but also takes into account the possible risk in transitioning from one to the other. Also, the study addresses a fairly recent and upcoming running trend. Barefoot running has appeared in media sources with research to support the barefoot habit, but there is minimal consideration of shod running. This study attempts to address the possible overconfidence in barefoot running by directly collecting empirical evidence of injuries.

This study is not conclusive. It is difficult to conclude that one specific variable, amidst a number of other possible confounders, is responsible for injury. The data supports that shod running presents a lower risk for injury, but does not concluded that barefoot running will lead to injury. Based on this study, one should be cautious of media sources that solely praise barefoot running. For some people, barefoot running may involve fewer injuries. However, this is not necessarily true for all runners. From the data, barefoot running should not be adopted for the sole reason of injury prevention (especially if there are no major problems with the current footwear habit). However, other legitimate factors may motivate a switch to barefoot running. Ideally, one should keep in mind that a number of factors contribute to injury.

One of the major limitations of this study was finding participants and obtaining all twelve weeks of data. Many participants did not return all the surveys and as a result, their data reflects only a very short moment in time. Also unequal groups forced all data to be calculated per person. Although, this is not a huge error, for future studies it would be best to have an equal number of runners in each group and twelve weeks of data for all runners. The best way to do this would be to have direct contact, beyond email, with all participants. Another limitation of the study is the difficulty in precisely measuring the injuries because the study could not verify the diagnosis of injuries. The study is slightly limited by the fact that people likely did not record injuries based on the same exact definition.

Some unresolved questions that still exist are as follows. What is the connection between footwear habit and foot strike? To what extent do factors such as mileage, surface or gender alone contribute to injury or is it certain combinations of these factors? What is the effect of barefoot running as a cross-training exercise on injury rates?

In order to make this study more applicable to prior research, it would be useful to have biomechanical analysis of gait and running form. However, finding the resources to collect this information is extremely difficult. Prior to expanding the project, it would be useful to collect data on a local scale about the correlation between running mechanics in barefoot versus shod running. This could potentially be done with the cooperation of local running stores that have the equipment for this. Once the correlation is established, it could be used speculatively on a large cohort study.

In order to overcome some of the confounding variables such as mileage, races, and surface. One could select a sample from a specific training program (such as a marathon training club) because these groups present clear guidelines for mileage and workouts. Furthermore, if the club trains together, then the surface material would be constant for all runners. This would allow some confounding variables to be removed or reduced by the participant's own choice. However, the use of such sample decreases the application of the study to other groups or the general population.

In addressing the third question, a few shod participants noted that they occasionally ran very short distances (less than a mile) barefoot, but had no intentions of transitioning. These runners were placed in the shod group because barefoot running only accounted for a very small percentage of their total mileage. However, the number of people that this condition applies to is unknown. Also a separate study to specifically address this variable would be needed.

The results of this study support that shod running is associated with the lowest injury rates. On average, a greater percent of the barefoot group was injured than the shod group. Also, transitioning from shod to barefoot presented even greater percentages of injured runners. Thus, it is not ideal to switch to barefoot running solely for the purpose of reducing the amount of injury. Barefoot running was not associated with lower injury rates and the process of transitioning, at least temporarily, increases the risk of injury. Other factors such as a more natural stride or a connection with the earth are separate issues not addressed by this study. Furthermore, the data in this study suggests that a large-scale research project with greater numbers and detail could benefit the strength of the conclusions. I think there is reasonable evidence to believe that with additional participants, confounding variables can be overcome to draw significant conclusions about injury rates associated with barefoot, transitioning and shod running.

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