Barefoot Running

The Effects of an 8-Week Barefoot Training Program

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Background: It has been proposed that running barefoot can lead to improved strength and proprioception. However, the duration that a runner must train barefoot to observe these changes is unknown.

Hypothesis: Runners participating in a barefoot running program will have improved proprioception, increased lower extremity strength, and an increase in the volume or size of the intrinsic musculature of the feet.

Study Design: Randomized controlled trial; Level of evidence, 2.

Methods: In this 8-week study, 29 runners with a mean age of 36.34 years were randomized into either a control group ($n = 10$) who completed training in their regular running shoes or to an experimental barefoot group ($n = 14$). Pretraining tests consisted of a volumetric measurement of the foot followed by a strength and dynamic balance assessment. Five subjects completed the pretests but did not complete the study for reasons not related to study outcomes. Participants then completed 8 weeks of training runs. They repeated the strength and dynamic balance assessment after 8 weeks.

Results: Significant changes from baseline to 8 weeks were observed within the barefoot group for single-leg hop (right, $P = .0121$; left, $P = .0430$) and reach and balance (right, $P = .0029$) and within the control group for single–left leg hop ($P = .0286$) and reach and balance (right, $P = .0096$; left, $P = .0014$). However, when comparing the differences in changes from baseline to 8 weeks between the barefoot and control groups, the improvements were not significant at the .05 level for all measures.

Conclusion: Although statistically significant changes were not observed between the pre- and posttest evaluations in strength and proprioception with the 8-week low-intensity barefoot running regimen, this does not necessarily mean that these changes do not occur. It is possible that it may take months or years to observe these changes, and a short course such as this trial is insufficient.

Keywords: running; barefoot; barefoot running; training

Since its inception in the 1970s, the modern running shoe has been altered many times to better allow the runner to more comfortably heel strike while running. The materials in the heels of the shoe are designed to absorb and dissipate the amount of energy that is transmitted to the hips and knees of runners.[22] Several recent publications indicate that the heel-strike gait pattern produces ground reaction forces much greater than a forefoot-strike pattern, with potentially deleterious effects on the ankle, knee, hips, and spine.[14,20]

Many runners have therefore become interested in the idea of barefoot running. Running barefoot or running in a classic track racing flat results in a running technique where the forefoot strikes the ground first, followed by contact of the heel and subsequent toe-off with the forefoot.[17] This mechanism uses the muscles and suspensory ligaments of the foot to diminish the transient initial impact force, almost to 0, while the overall ground reaction force of the foot striking the ground remains the same. In addition, it has been suggested that barefoot running is an evolutionary adaptation of the human foot; it has been hypothesized that this is a more advantageous pattern than a heel-strike pattern.[14] There has been a dramatic increase in the number of runners interested in running barefoot or in a shoe that mimics barefoot running, commonly referred to as a minimalist shoe.[19] It has been theorized that running barefoot strengthens the foot and the muscles of the lower leg and improves proprioception.[13]

The duration of time that a runner must train to obtain improvement in strength and proprioception through barefoot running is unknown. We therefore conducted an 8-week study to investigate this. We hypothesized that runners participating in a barefoot running program will have improved proprioception, increased lower extremity strength, and an increase in the volume or size of the intrinsic musculature of the feet.

MATERIALS AND METHODS

After approval by the Human Subjects Committee at our institution, a total of 29 runners between the ages of 17 and

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TABLE 1
Demographic Data of the 2 Groups

	Control Group	Barefoot Group
Average age, y	39.7	35.5
Running experience, y	9.7	7.5
Weekly distance, km	16.96	14.69
Preparticipation injuries	Shin pain, calf strain, knee pain, foot pain	Iliotibial band syndrome, hip abductor strain
Barefoot running experience	1 runner (minimal)	1 runner (minimal)

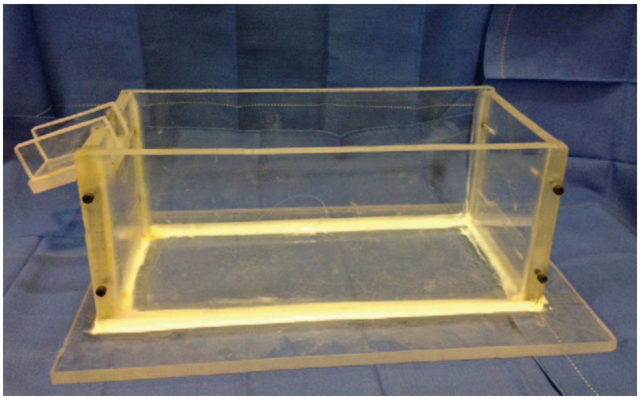

Figure 1. A Plexiglas box was constructed to conduct volumetric measurement of the foot by water displacement.

56 years (mean age, 36.34 years) who provided written informed consent were randomized into either a control group who completed the training in their regular running shoes or to an experimental barefoot group who ran barefoot. Initially, 14 runners were randomized to the control group, and 15 were randomized to the experimental barefoot group. Five subjects completed the pretests but did not complete the study for reasons not related to study outcomes, which left a total of 24 participantss (13 females and 11 males). There were 10 runners in the control group and 14 runners in the experimental barefoot group that completed the entire study protocol. The inclusion criteria were as follows: experienced runners, age between 14 and 65 years, able to run at least 10 miles weekly, able to run for at least 45 minutes at a time, able to attend the required study sessions for an 8-week time period, free from injury and cardiovascular pathology, and medically cleared to participate in physical activities. The exclusion criteria were as follows: inability to run the prescribed distances, inability to attend the required study sessions for an 8-week time period, a recent lower extremity injury, not medically cleared to participate in physical activities, and presence of any cardiovascular pathology. Demographic data are presented in Table 1.

The pretraining tests consisted of a volumetric measurement of the foot followed by a strength and dynamic balance assessment. A custom-made Plexiglas (Arkema, Colombes, France) box was fashioned to carry out the volumetric assessment (Figure 1). This assessment was completed by measuring the volume of water displaced by the foot when it was submerged to the level of the malleoli in the Plexiglas box.[20,24] A single measurement of the amount (in milliliters) of water displaced was taken of each foot and recorded. The participants were instructed not to run or do other vigorous activity prior to attending the pre- and posttest, as this could in theory affect the volume of the foot. Then, following a 5-minute stationary bicycle warm-up without resistance, the participants commenced strength, dynamic balance, and stability testing performed by a blinded physical therapist. The testing consisted of 5 different tests: (1) single-leg balance, (2) reach for distance, (3) single-leg hop, (4) single-leg hop on a trampoline, and (5) vertical jump. The first test performed was the single-leg balance and reach for distance. The participant must reach out as far as possible with 1 leg while balancing on the other. It was repeated 3 times on each foot, and an average distance was recorded. This test measures dynamic stability and balance as well as eccentric quadriceps and gastrocnemius/soleus complex control.[12] Then, they performed a single-leg hop for distance. This was performed by hopping as far as possible in a single hop from the stationary opposite foot. This was repeated 3 times on each foot, and an average distance was recorded. The single-leg hop measures quadriceps power as well as dynamic stability.[7] Next, they completed heel raises to fatigue. The participants had to keep pace with a metronome set at 80 beats per minute. Fatigue was defined as an inability to keep pace with the metronome. The heel raise test measures gastrocnemius/soleus complex strength and endurance.[10,15,16] They then performed a single-leg hop test on a trampoline for maximum repetitions in 30 seconds. Again, this test was repeated 3 times on each foot, and the average number of hops was recorded. This test measures dynamic quadriceps and the gastrocnemius/soleus complex strength and endurance.[7] Finally, the participants did a standing vertical jump with double limb take-off. This was measured using the Vertec vertical leap measurement device (Vertec Corp, North Easton, Massachusetts, USA). This was repeated 3 times, and the average vertical leap was recorded. The standing vertical leap measures concentric strength of the hip extensors, quadriceps, and gastronemius/soleus complex.[25] The foot-strike pattern was not evaluated in this study because it would be extremely difficult to perform foot-strike analysis on a grass surface. Performing a foot-strike analysis on a treadmill would not indicate whether the participants would have adopted the forefoot strike while running on grass; therefore, this measurement was not included.

The participants then completed 8 weeks of training runs. These runs were performed 2 times per week on a grass surface. A grass surface was selected because of the potential injury risk to the participants. Each week they completed an interval run and a steady state run. All

8-Week Barefoot Training Schedule
Warm-up: Jumping jacks (10), forward-walking lunges (10 steps), reverse-walking lunges (10 steps), mountain climbers (10), and easy jogging (3 minutes).
Week 1: **Run 1:** 10 intervals of 50-m runs and 50-m walks. **Run 2:** 0.8-km run.
Week 2: **Run 1:** 4 intervals of 400-m runs with 4-minute rests. **Run 2:** 1.6-km run.
Week 3: **Run 1:** 5-minute run, 2.5-minute walk, 6-minute run, 3-minute walk, 7-minute run, cool down. **Run 2:** 1.6-km run.
Week 4: **Run 1:** 9 intervals of 1-minute run and 1-minute walk. **Run 2:** 1.6-km run.
Week 5: **Run 1:** 3 rounds of intervals of 200, 400 m. Rest 2 minutes between intervals. **Run 2:** 2.4-km run.
Week 6: **Run 1:** 1-minute ladder: run 1 minute, rest 1 minute, 50-second run, 50-second walk, 40-second run, 40-second walk, 30-second run, 30-second walk, 20-second run, 20-second walk, 10-second run, 10-second walk, then work back up to 1 minute on and 1 minute rest. **Run 2:** 3.2-km run.
Week 7: **Run 1:** 7 intervals of 2-minute runs and 1-minute walks. **Run 2:** 4-km run.
Week 8: **Run 1:** 4-minute run, 3-minute walk, 2-minute run, 30-second walk, 1-minute run, 3-minute walk, 2-minute run, 30-second walk, 4-minute run. **Run 2:** 4.8-km run.
Cool-down: 3 minutes of easy walking.

Figure 2. The 8-week training schedule.

participants had minimal or no experience running barefoot. Therefore, the training protocol was intentionally designed to be relatively low intensity to prevent injury in the runners. The distance of the runs increased gradually each week in both the interval run and the steady state run. See Figure 2 for additional details of the 8-week schedule. Their activity outside the study runs was not restricted; however, it was documented. All participants completed at least 13 of 16 runs at the end of the study.

At the completion of the 8-week training schedule they returned to the clinic and repeated the same testing procedures. All pre- and posttesting of strength, dynamic balance, and stability testing was performed by the same blinded physical therapist.

Statistical analyses were based on the average of 3 repetitions from each foot for the measurements of reach/balance, single-leg hop for distance, and vertical jump, while a single measurement was used for the timed single-leg hop, heel raise, and volume of water displaced. A pair test, 2-sample t test, and analysis of covariance was used when appropriate to evaluate the level of significance in changes from pre- to posttraining and the differences in changes from pre- to posttraining between the control and training groups. All analyses were performed on an intention-to-treat basis, and no multiple comparison adjustments were made. Each leg was measured independently because in previous studies where we evaluated foot strike with infrared markers, we noted that there was great variability between the right and left foot in the same runners in terms of heel strike (ie, a runner would heel strike with the right foot and forefoot strike with the left).

RESULTS

Initially, 29 patients underwent pretesting and 24 patients underwent posttraining testing. No significant differences were found in all of the pretraining measurements between those who completed and those who did not complete the study. Analyses were therefore based on 24 runners and 48 feet. Furthermore, all of the pretraining measurements were similar between the barefoot and control groups. There were no differences between the control and barefoot groups for the right ($P = .88$) or left foot ($P = .56$), indicating that the randomization process was valid.

In the control group, the reach and balance test demonstrated an average increase of 11.7% on the right and 11.2% on the left. In the experimental group (barefoot), the increase in reach was 9.1% on the right and 4.6% on the left. The increased percentage change from pre- to posttesting was found to be significant for both left ($P = .0014$) and right feet ($P = .0096$) within the control group, and for the right foot only within the experimental group ($P = .0029$). There were no significant differences between the control and barefoot groups in the increased percentage change from pre- to posttest for the right ($P = .59$) or left foot ($P = .10$).

In the control group, the single-leg hop for distance test demonstrated an increase of 3.6% on the right and 5.3% on the left. In the experimental group, the increase was 3.2% on the right and 0.3% on the left. The percentage change in single-leg hop for distance from pre- to posttesting was not found to be significant within each group for both left and right feet. There were no significant differences between the control and barefoot groups in the percentage change from pre- to posttest for the right ($P = .95$) or left foot ($P = .19$) for the single-leg hop for distance test.

In the control group, the single-leg hop for time demonstrated an increase of 5.6% on the right and 10.4% on the left. In the experimental group, the increase was 16.5% on the right and 8.1% on the left. The increased percentage change in maximum single-leg hops for time from pre- to posttesting was found to be significant for both left and right feet within the barefoot group ($P = .04$ and $P = .01$, respectively), and for left foot only within the control group ($P = .02$) for the single-leg hop for time test. There were no differences between the control and experimental groups in increased percentage change from pre- to posttest for the right foot ($P = .28$), the left foot ($P = .68$), or for the average between the left and right feet ($P = .83$).

In the control group, the increase in vertical leap was 5.9%. In the experimental group, the increase was 2.6%. The increased percentage change in vertical leap between pre- and posttesting within the control or experimental group was not found to be significant ($P = .09$ and $P = .47$, respectively). The increased percentage change in vertical leap was not significant in pre- and posttesting between the control and barefoot groups ($P = .52$).

In the control group, the percentage change in heel rises decreased by 2.3% on the right and also decreased by 1.5% on the left. In the experimental group, there was an increase of 4.6% on the right foot and a decrease of 1.6% on the left. No significant changes in number of heel raises completed were noted between pre- and posttesting for left or right feet within the control or experimental groups. There were also no differences between groups in the percentage change from pre- to posttest for right ($P = .54$) or left foot ($P = .99$).

In the control group, the percentage change in the volume of the foot was noted to decrease by 0.2% on the right and by 3.3% on the left. In the experimental group, there was an increase of 1.2% on the right and 0.3% on the left. No significant changes in the volume of the foot from pre- to posttesting were observed for right or left feet within the barefoot or control groups. There were no differences between the control and barefoot groups in the percentage change from pre- to posttest for the right ($P = .67$) or left foot ($P = .4426$).

There was 1 injury to report out of the 2 groups. A runner in the barefoot group developed pain in her posterior tibialis tendon following the second run of the seventh week. She was unable to complete the 2 runs in the eighth week; however, she did complete a total of 13 of 16 runs. She was able to perform the posttest procedures without pain and was therefore included in the final data analysis.

DISCUSSION

To our knowledge, this is the first study of its type evaluating the effects of a barefoot running training program. Previous studies have evaluated barefoot running at a single point in time.[‡] Although we did not observe statistically significant changes between the pre- and posttest evaluations, this does not necessarily mean that these changes do not occur.

Significant changes from the baseline to 8 weeks were observed within the barefoot group for single-leg hop (right, $P = .01$; left, $P = .04$) and reach and balance (right, $P = .003$) and within the control group for single–left leg hop ($P = .03$) and reach and balance (right, $P = .009$; left, $P = .001$). However, when comparing the differences in changes from baseline to 8 weeks between the barefoot and control groups, the improvements were not significant at the .05 level for all measures. This may have been because of the training protocol as well as the participant's familiarity with the testing procedures. We did note that there was greater improvement in the right foot than the left. It is possible that this is because of foot dominance. The individual components of the testing protocol and their validity were based on recent physical therapy literature.

Our small sample size may have affected our ability to detect significant changes between the 2 groups. A post hoc power analysis indicated we would need 56 participants in each group to detect a significant difference between the 2 groups. To perform this study on a larger scale would be ideal. Participants were not compensated for their participation. We also allowed them to continue their regular training, whatever that may have been, outside of the study as long as it did not include barefoot running. Ideally, participants would only complete runs associated with the study and would refrain from lower extremity strength training during the study period.

The current climate of running footwear is moving more toward a minimalist approach that is somewhat driven by the consumer but supported by little scientific evidence. The data presented here do not necessarily indicate that the trend toward running barefoot or in minimalist footwear is wrong. It is possible that it may take months or years, or perhaps a program that is more intense or longer in duration, to effect any changes in runners. Ours was designed as an 8-week program to attempt to define a minimum amount of time needed to observe the desired effects of a barefoot running program. Our program was of relatively low intensity. As stated, our runners had little or no barefoot running experience, and injury to them was a concern. One of our runners sustained an injury to the posterior tibialis even with the low-intensity design. A higher intensity program would likely need to be much longer in duration to allow the runners to incrementally increase the intensity without increased risk of injury. However, the duration of our program is akin to those used for many short-season running athletes, such as high school track, cross-country, or football. Many programs have their athletes run barefoot on grass or other soft surfaces several times a week. Our results demonstrate that this may not produce an appreciable improvement in the athlete's strength, proprioception, dynamic balance, or a change in the size of the intrinsic foot musculature indicated by measurement of the volume of the foot, but may put them at risk of injury. It is also possible that the benefits of barefoot running are not related to increased strength, improved dynamic balance, or improved stability, but instead are related to the global biomechanical changes that occur in the running gait when running barefoot.

This is important information for runners attempting to add barefoot training, as this type and short duration of 8 weeks of barefoot training may not provide them with the competitive edge or injury prevention they seek. Further studies are needed to evaluate how long-term barefoot training affects runners and the incidence of injuries.

[‡]References 1-6, 8, 9, 11, 14, 17, 18, 20, 21, 23.

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