Running-related injury prevention through barefoot adaptations

STEVEN E. ROBBINS and ADEL M. HANNA

Human Performance Group,
Concordia University Civil Engineering Department,
Montreal, Quebec H3G 1M8, CANADA

ABSTRACT

ROBBINS, S. E. and A. M. HANNA. Running-related injury prevention through barefoot adaptation. Mod. Sci. Sports Exerc., Vol. 19, No. 2, pp. 148-156, 1987. A number of reports indicate an extremely low running-related injury frequency among barefoot populations in contrast to reports about shod populations. It has been hypothesized that the adaptations which produce shock absorption, an inherent concomitant of barefoot activity and a mechanism responsible for the low injury frequency among shod populations, are related to deflection of the medial longitudinal arch of the foot on loading. It is also hypothesized that the known stability of the shod foot does not deflect without failure. Recent studies of runners have consumed considerable interest. The adaptive pattern of the medial longitudinal arch of the foot due to increased barefoot weight-bearing activity. Changes occurred in the arch of the longitudinal arch which allowed deflection of this arch on loading which substantiated the hypothesis. The evidence suggests that sensory feedback from the arch is a possible reason for applied statically. Other physiologically similar sports such as bicycling and cross country skiing subject the lower extremities to similar net loads, but the rate of loading is lower. Lower extremity injury is so uncommon in such sports that it has not been identified as a significant problem.

Despite the modern engineered running shoe, a sports medicine clinic reported a large series of running-related injury referrals with an average weekly mileage at the time of injury of 19 miles for women and 27 miles for men (9). Practitioners of sports medicine have observed injuries in runners using every shoe model available. The above reports can hardly be considered an endorsement of the modern running shoe as a protective device. These data have lead the authors to suspect that the basic assumptions used in running shoe design are incorrect.

This high injury frequency in sports involving running and jumping has lead many to conclude that the lower extremities and particularly the foot to be of a poor design, an unusually fragile structure unable to sustain the use associated with running without injury, thus requiring additional protective devices (22). The foot of the normally shod individual is described as rigid, i.e., the main bony arches are unable to yield on normal loading. Relatively unyielding connective tissue appears to sustain the foot arches (1). The intrinsic

Figure 1—Graphic presentation of the hypothesis formulated by the authors.

149

running-related injuries

Injuries thought to be due to impact transmission

Rear foot
Medial subtalar
Midfoot
Metatarsal

dysfunction

Dysfunction

High level of impact transmission injuries

Diminished impact transmission injuries

Magnitudes of peak
foot bone vibrations

Barefoot Shock Absorbent
System

Shod Rigid System

Direct contact with nature
low bone transmission

(3) shows extremely low vibrations little or no foot shock absorption.

Lack of density feedback
foot touchdown produces rigid
surface with high vibrations,
foot shock absorption.

inadequate

underveloped countries indicate the rarity of lower extremity injury in such populations.

1) A West German trained physical education instructor has trained literally hundreds of barefoot people in sports involving running and jumping over a period of many years. He is unable to recall a single impact-related lower extremity injury in this population.

2) Reports from countries where both barefoot and shod population co-exist, as in Haiti, indicate high rates of lower extremity injury only in the shod population. Barefoot weight-bearing is considered by many Haitians to induce resistance to lower extremity injury.

3) In countries where people have spent part or all of the year barefoot, as in the West Indies or certain countries in Europe and Asia, there is little evidence of nor reports of frequent impact-related lower extremity injuries.

4) A paradox is presented of lower extremity fragility associated with the wearing of protective footwear and relative resistance to injury in the barefoot or unprotected state. To explain this paradox, the authors hypothesized that there exist adaptations associated with barefoot activity that provide impact absorption and protection against running-related injuries. An adaptation involving foot arch deflection on loading is hypothesized to be an important adaptation providing impact absorption. In contrast, it is hypothesized that the known rigidity of the shod foot may explain the reported high injury frequency in North American runners (Fig. 1).
Finally, it is hypothesized that the traditionally shod foot of the North American is capable of rehabilitation of the internal foot structure (intrinsic musculature), a subject which has been ignored by investigators. The investigation which is reported here examines changes in force-deflection characteristics of the main longitudinal arch (medial) of the foot associated with increased barefoot weight-bearing activity among typical North American recreational runners.

**MATERIALS AND METHODS**

**Equipment development.** Traditional force platforms give net readings at the skin-platform interface. No information is obtained as to how any substructure such as the arched systems of the foot contribute to this net result, an assessment of its contribution to the modification of vertical force transmission. A platform was developed that could obtain reliable measurements of force-deflection characteristics of the arched substructures internal to the foot. With this device, a reference point is used which is approximately equidistant to the ends of the longitudinal and the transverse arches of the foot. A ball and socket type joint is placed under the platform at this point so that when the platform is balanced, there is repeatable loading on either side of the arch to be examined. Normal load is controlled by means of a spring balance. Foot positioning on the platform is aided by the use of easily ascertained bony landmarks on the perimeter of the foot, and with the aid of a matrix which is permanently fixed to the surface of the platform (Figs. 2 and 3).

The platform was constructed of rigid wood and plastic. Two bubble type levels were inserted perpendicular to each other and parallel to the main axes (Fig. 3). The central reference point was positioned over a ball and socket type joint (Fig. 3). The subject is required to balance with respect to the levels and to obtain standardized load prior to obtaining the X-ray. The platform was used to obtain radiographs in the lateral position on weight-bearing (Figs. 4 and 5).

**X-ray techniques.** Lateral radiographs were obtained during relaxed barefoot weight-bearing. The cassette was located parallel to the long axis of the platform in a vertical position or position for horizontal beam lateral view radiographs (Figs. 4 and 5). The X-ray machine used was a Picker single-phase type. The cassettes used were Dupont Rare Earth Extremity Extreme Detail. The machine settings were approximately 100 mA and 50 kV with a 1/320 s exposure time.

**System repeatability.** The repeatability of the system was determined by overall foot weight-bearing imprint length measurements. Serial X-rays in the number required to determine repeatability was considered to be of limited advantage over the imprints and of possible risk to the subjects. The high degree of repeatability of the technique is evidenced by serial recordings. The standard deviation was under 0.5 mm, which was the limitation of the measuring instrument. A change of greater than 1 mm should be considered significant.

**Subjects.** The subjects consisted of 17 volunteer recreational runners. There were 14 men and 3 women. The controls were a sub-group of the volunteers who entered the study as the others, but were unable to increase their barefoot weight-bearing activity for reasons of inconvenience or time constraints. The subjects were asked not to significantly alter their running mileage. The subjects were all informed by standards of the Declaration of Helsinki of the World Medical Association.

**Experimental period.** The subjects recorded a detailed running history with emphasis on footwear, injuries, and barefoot weight-bearing activity prior to the experiment. The subjects were all instructed about the maintenance of a "training log," which recorded the duration and type of barefoot weight-bearing activity during each day of the experiment.

The subjects were told to increase barefoot weight-bearing activity as much as possible both at home as well as outdoors. Barefoot running and walking were encouraged. The investigators recommended that this activity be increased gradually over a period of several weeks. The duration of the experiment was explained to be approximately 4 months. Foot data were collected prior to the experiment, consisting of foot imprints taken during relaxed barefoot weight-bearing with applied normal loads of 15 and 45 kg for men and 15 and 45 kg for women, and X-rays which were taken at the heavier load only.

**Data analysis.** The lateral X-rays taken during relaxed barefoot weight-bearing were analyzed by a radiologist. The distance was measured from the medial tubercle of the calcaneus to the most distal point of the first metatarsal head (Fig. 6). All experimental subjects were required to perform greater than 1 h of increased barefoot activity daily.

**RESULTS**

**Medial longitudinal arch span.** A positive change is indicated by significant (1 mm) shortening of the medial longitudinal arch with increased barefoot weight-bearing activity, or lengthening with cessation of increased barefoot weight-bearing activity (Figs. 7 to 10). Of 18 readings from the experimental group, 13 changed positively, two changed negatively, and three did not change (P < 0.05). Of the controls, one changed positively and 10 changed negatively (P < 0.05). The trend toward decreased span was present without respect to the height of the arch prior to the experiment.
nor the subject's age, sex, running mileage, or footwear. The mean change for the experimental subjects was +4.7 mm. The mean change for the controls was −4.9 mm.

**DISCUSSION**

Electromyographic studies have repeatedly confirmed that there is no tonic activity of the intrinsic muscles of the foot during relaxed weight-bearing in normally shod volunteers (1). The experimental changes of shortening of the medial arch and load redistribution to the digits can only be explained by an activation of this normally inactive musculature associated with increased barefoot weight-bearing activity. The progressive change over 2 and 3 months is also consistent with skeletal muscular conditioning. The data clearly demonstrate that the normally shod foot is capable of rehabilitation of foot musculature. While the demonstrated adaptation has been shown to exist in the laboratory setting while standing on a platform, the question remains whether this adaptation is actually used in vivo when running, walking, standing, and jumping. Technically, it would be very difficult to obtain X-rays of the arches of the foot when running, in order to display this adaptation. However, the following information strongly supports the use of this adaptation in vivo. Reports confirm that, in traditionally barefoot populations, the foot appears highly arched when unloaded and flattens considerably when loaded (22, 26). This
### Table: Pre- and Post-Training Data

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<tr>
<td>Total Area</td>
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### Figure 10: Sample comparison

- Male control subject. See Figure 8.

### Running-Related Injuries

- Diminished sensitization of foot, which can be understood as a lack of sensitivity to environmental cues.
- The condition is common in athletes and can be due to repetitive stress injuries.
- The injury involves the skin and subcutaneous tissue, leading to pain and discomfort.

### References

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