CAUSE OF PRONATION IN RACE WALKING

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Walking and race walking are gaining acceptance as forms of fitness and recreation. A recent survey conducted by the Gallup Organization for the American Podiatry Association and Scholl, Inc. found that walking was the most popular form of exercise for one-third of the respondents with 63% walking daily.[1] A main reason for race walking's popularity according to Subotnick (1977) and Sheehan (1978) is that race walking is virtually injury free when compared to running.[2, 3] Walking and race walking may serve as an attractive, safe, and adequate form of aerobic fitness.

Competitive race walking has been part of the Olympic athletics program since 1908.[4] Race walking is a part of major national and international competitions throughout the world. Distances range from one to thirty-one miles and are contested by both men and women.

The International Amateur Athletic Federation governs the conduct of race walking and defines race walking by a rule that states:

> Race walking is a progression by steps so taken that unbroken contact with the ground is maintained. The advancing foot of the walker must contact the ground before the rear foot leaves the ground. During the period of each step, in which a foot is on the ground, this leg shall be straightened (i.e. not bent at the knee) for at least one moment.[5]

PRONATION AND FOOT MECHANICS

Normal walking and race walking follow the same gait mechanics. Race walking movements are more exaggerated to gain speed, efficiency, and maintain balance. Murray (1983) demonstrated increased stride length and cadence and increased amplitudes of most movement patterns of the trunk and upper and lower limbs.[6] The foot in normal gait functions as follows:

1. As a mobile pronating adaptor to absorb shock and adjust to changes in terrain.

2. A decelerator of vertical force at heel contact.
3. A rigid supinating lever for propulsion.
4. A transverse plane translator of motion of the foot to the leg and vice versa.[7]

Root (1971) defines pronation as a complex triplane motion consisting of simultaneous movement of the foot or part of the foot in the direction of abduction, eversion, and dorsiflexion.[8] Pronation is a normally occurring motion in gait and stance. It occurs primarily at the talo-calcaneal joint of the foot (a.k.a. the subtalar joint). The subtalar joint has three articular facets that give rise to the triplane motion. The subtalar joint axis deviates 16° from the saggital plane and 42° from the transverse plane. Pronation also occurs in the forefoot at the talo-navicular and calcaneo-cuboid joints (a.k.a. the midtarsal joint). The midtarsal joint has two axes of motion. The oblique axis deviates 52° from the transverse plane and 57° from the saggital plane. The longitudinal axis deviates 15° from the transverse plane and 9° from the saggital plane.

When the body weight transfers to the support leg at heel contact through midstance, the entire supporting leg internally rotates with translation of this rotation force occurring at the subtalar joint of the foot. The foot reacts by pronating to absorb shock and adapt to the terrain. The arch of the foot flattens while the heel everts or rolls inward toward the midline of the body. As the full weight of the body passes onto and over the foot, pronation of the midtarsal joint occurs resulting in abduction of the forefoot and locking of the midtarsal joint. This adds further stability of the foot needed to prepare the foot for propulsive toeoff.

Abnormal pronation of the foot is pronation occurring beyond the normal amount of pronation needed by the foot to function in gait. Excessive pronation can occur in any period of gait and may occur at a time when the foot should not be pronating (i.e. supinating for toeoff). Most abnormal pronation is compensatory in nature and is a result of accommodative changes for structural or functional distortion.[9] In summary, the foot will pronate for normal locomotion and, in addition, will pronate even more to compensate for any present deformity.

Causes for abnormal compensatory pronation within the foot structure are:

1. Forefoot varus (the leading cause)
2. Dorsiflexion of the fifth ray
3. Forefoot valgus
4. Plantarflexion of the first ray

5. Rearfoot varus
6. Ankle equinus

Compensatory pronation of the foot is not limited to structural problems within the foot. Tibial varum, internal tibial and femoral torsions, muscle imbalance, and neurologic disease may also cause compensatory pronation.

Once the cause of pronation is identified through biomechanical evaluation and gait analysis, appropriate therapy can be instituted to control the compensatory pronation. This includes strengthening and stretching exercises, functional orthoses, and proper shoegear.

METHODS

A group of ten elite class race walkers living at the United States Olympic Training Center were used as subjects. Two walkers were members of the 1980 Olympic team, four competed for the United States abroad, and four had won or ranked in national championships. All are in training for the 1984 Olympic Trials.

Background information was gathered by interview and included age, years of competition, running background, types of shoes worn, and previous and current injury problems. Each candidate was examined visually for ranges of motion at the subtalar joint, midtarsal and ankle joints, as well as visualizing tibial varum and limb length discrepancies. The results were recorded.

A detailed biomechanical evaluation of the foot to leg relationship followed the visual exam. Degrees of inversion-eversion, rearfoot neutral position, forefoot varus or valgus, ankle dorsiflexion, and tibial varum were measured with tractograph, goniometer, and a special rearfoot measuring device. Plaster bandage cast impressions were made of both feet based on the method described by Root[10] to capture the forefoot to rearfoot relationship with the subtalar joint in its neutral position.

Finally eight pairs of functional orthotics were fabricated by an orthotic technician for the candidates based on data gathered and demonstrated need.

RESULTS

The average age of the walkers surveyed was 24.8 years with the youngest being 20 and the oldest 29. The average number of years competing was 7.5 years with a range from 4 to 18 years. Nine of the ten walkers came from a stronger walk training background than a running background. (The exception was a candidate who walked late in his career but had a 2:36 marathon best.) Walking shoes consisted of a diversity of brand training and race shoes (Table One).

TABLE ONE

Shoes Used for Race Walking

Training	Racing
Nike Elite Classic	Mizuno Prototype
Nike Waffle Racer	Nike El Viento
K-Mart Jogging Shoes	Nike American Eagle
Kangaroo '84 Walker	Nike Prototype
Tiger Volleyball Shoes	Tiger Jayhawk
	Kangaroo Comet
	Adidas Race Walking
	Adidas Adistar Racer

Injuries and pains were experienced by all the walkers during their careers and were of the overuse type. The overall nature of the injuries were not severe enough to restrict or lose time training (Table Two).

TABLE TWO

Injuries Sustained by Race Walkers

Popliteal Space Cyst
Shin Splints
Posterior Tibial Tendonitis
Popliteal Tendonitis
Sacral-Iliac Pain
Back Pain
Anterior Tibial Tendonitis
Hip Pain
Plantar Fasciitis
Gluteal Muscle Strain
Achilles Tendonitis
Blisters

Visual examination of position and ranges of motion demonstrated forefoot varus and rearfoot varus in all ten candidates, with subtalar joint range of motion being adequate. Ankle motion and dorsiflexion were normal. Tibial varum was found in eight of the ten candidates. No significant limb length differences were found.

Degrees of rearfoot varus around the subtalar joint neutral position ranged from 0° to 4° varus in nine of the ten candidates. Degrees of dorsiflexion of the foot on the leg ranged from 10° to 15° in all ten. Tibial varum (bowing) ranged from 3° to 8° in all ten candidates.

The forefoot varus value exceeded accepted normal values (Norm = 0° to 2°) in all ten walkers. The walkers' values ranged from 5° to 10° varus. All other values measured for rearfoot varus, dorsiflexion, and tibial varum were within normal limits. None of the walkers examined demonstrated forefoot valgus or a normal forefoot position (Table Three) (Figure One).

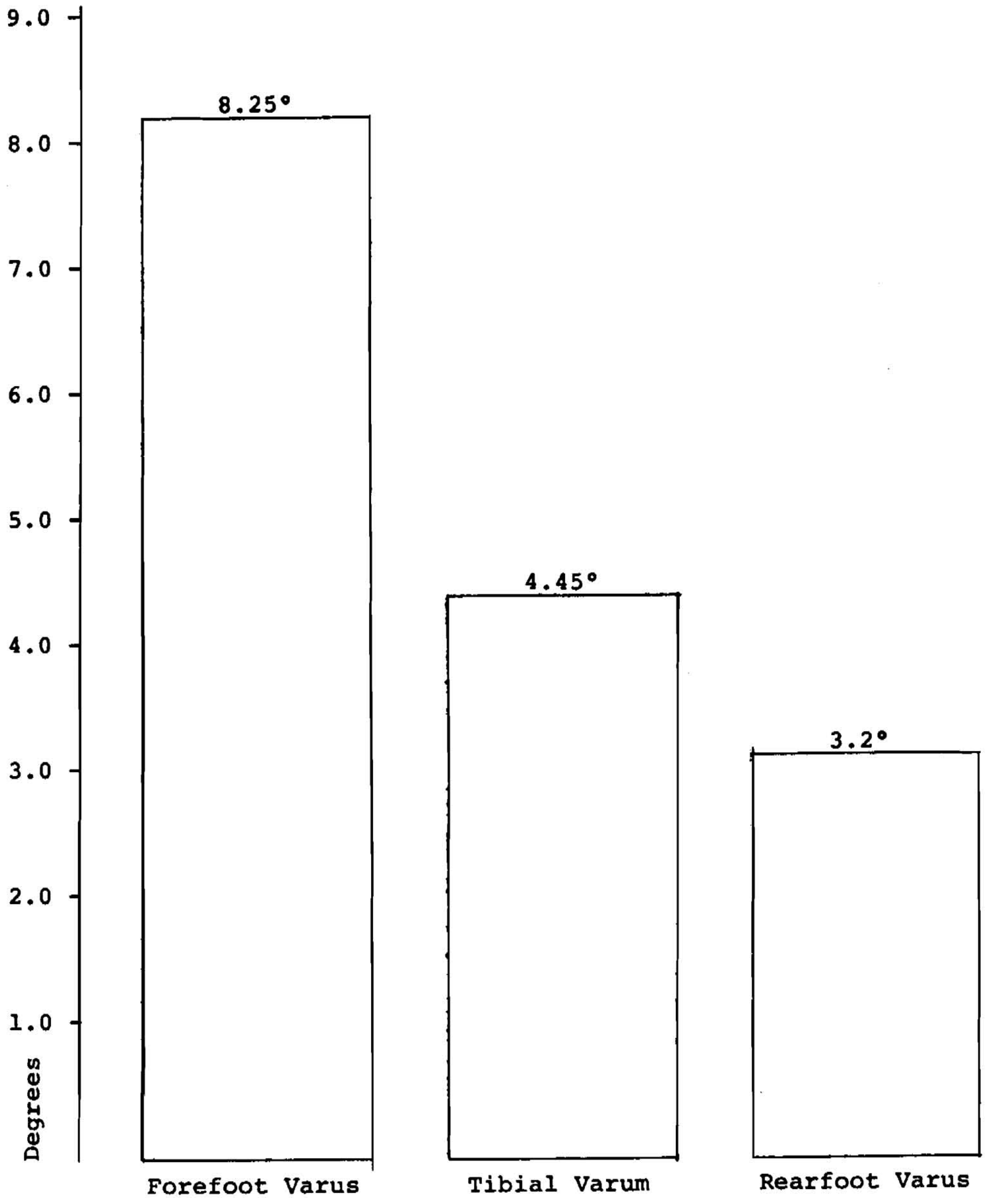
TABLE THREE

Biomechanical Data on Pronation

Candidate		Forefoot Varus		Rearfoot Varus		Tibial Varum	
		Left	Right	Left	Right	Left	Right
1.	FK	8°	7°	2°	1°	4°	4°
2.	LJ	10°	8°	2°	2°	0°	0°
3.	SS	8°	10°	4°	1°	8°	8°
4.	RM	7°	6°	2°	3°	4°	4°
5.	MM	10°	10°	4°	2°	3°	3°
6.	TL	10°	9°	3°	3°	5°	5°
7.	ME	10°	8°	5°	3°	4°	6°
8.	JH	7°	5°	10°	0°	5°	4°
9.	DC	7°	5°	2°	0°	3°	3°
10.	SP	10°	10°	8°	7°	8°	8°

FIGURE ONE

Averages of Rearfoot Varus, Forefoot Varus, Tibial Varum



DISCUSSION

The most important aspect of human locomotion is the interface of the foot and the ground. All the forces generated by the body to enact propulsive locomotion are transmitted through the foot to the ground and vice versa. The function of the foot around it axes of motion and joint position result in a stable and efficient gait. Abnormal and excessive pronation result in instability, less propulsion, and potential overuse injury of the entire lower extremity because of excessive torque and malalignment of body segments.

The most common etiology of pronation is forefoot varus deformity of the foot. Forefoot varus causes extensive abnormal pronation of the foot. Root et al. defines forefoot varus as an inversion of the forefoot from the ground when the individual is standing with the rearfoot in neutral position.[9] The compensation takes place by the rearfoot everting (unlocking of the subtalar joint) and allowing the forefoot to evert until the medial side of the foot can contact the ground. When full weight is placed on the foot, vertical ground reactive forces come against the lateral aspect of the forefoot causing the forefoot to evert parallel to the ground. This motion of compensation is only possible when the subtalar joint pronates. Therefore, an abnormal position of the forefoot causes the entire foot to pronate.

Forefoot varus can result in the most common cause of abnormal pronation. The abnormal pronation is maintained throughout the stance phase of gait and prevents normal supination of the foot during toeoff. When all available subtalar joint pronation is used to compensate for forefoot varus, no subtalar joint pronation is available to fulfill the requirements of normal locomotion.[9]

Rearfoot varus is primarily a heel contact pronator and results in no major symptomatology. On the contrary, forefoot varus related pronation creates an unstable foot plant and may lead to major symptomatology such as overuse injury and poor performance.

A possible cause of the increased forefoot varus angle seen in race walkers may be a secondary adaptive change to overdevelopment of the anterior tibial muscle group of the leg. At toeoff the anterior tibial muscle group acts as an accelerator to dorsiflex the foot on the ankle to facilitate ground clearance during the swing phase of gait.[10] Race walkers have a lower ground clearance of the swing phase than runners do. In race walking, one foot must be on the ground at all times including swing phase. In running, both feet are off the ground during swing phase providing for more than adequate ground clearance.

At heel contact, the anterior tibial muscle group acts as a decelerator to prevent the foot from slapping the ground. Since heel contact is deliberate and forceful to comply with the rules of race walking, the anterior tibial muscles are exercised harder than in normal walking. A hypertrophy of the muscles may take place. Cases of anterior tibial compartment syndrome have been reported in several world class British race walkers with two cases requiring surgery.[11]

The goal in treating symptomatic forefoot varus is to limit the excess eversion of the forefoot at the point in gait where the compensation takes place. When indicated based on the amount of forefoot varus degrees present ($>4°$), a semi-rigid foot orthoses is used.

The orthoses is fabricated to the contours captured in the impression casts and extends from the heel to the metatarsal-phalangeal joints. The foot is supported on this plastic platform. Elevations on posts are built into the orthoses at the heel and forefoot to act as controlling planes to limit rearfoot and forefoot excess motion. The forefoot post controls forefoot varus by effectively holding the forefoot in varus position and not allowing the forefoot to evert abnormally resulting in abnormal pronation of the entire foot. The forefoot post effectively brings the ground up to the foot, supporting the varus deformity, and does not allow the foot to travel to the ground creating instability.

A specific orthotic was fabricated for the race walkers taking into consideration tolerance of the orthotic during long hours of training, hardness of the orthotic, and fit of the orthotic in the walking shoe.[12]

The material used to fabricate the orthotics was polypropylene. A 3/16 inch thickness was used to offer more control. This thickness is thicker than usually used for runners. Unlike the runner who strikes the ground at 3 to 4 times his body weight, the walker strikes at 1 1/2 times and requires less shock absorption. The walker can use a thicker and less flexible material to get the most possible control.

The orthotics were "streamlined" to better fit the narrow last of a race walking shoe. This was accomplished by building the forefoot varus correction directly into the orthotic instead of adding an external material to the orthotic. This gives the orthotic a lower profile and fits in the shoe better.

REFERENCES

1. APA Report: Attitude Study on State of Nation's Feet. Vol. 4 No. 10. October 15, 1983. Washington, D.C.

2. Subotnick, S.: The Running Foot Doctor. World Pub. Mountain View, Calif. :98-103, 120, 1977.

3. Sheehan, G.: Dr. Sheehan on Running. Bantam Books, New York. :32-33, 1978.

4. Rudow, M.: Race Walking. World Pub. Mountain View, Calif. :7-9, 1975.

5. I.A.A.F. Walking Committee: Guidance for Walking Judges, 1972.

6. Murray, M. P.; Guten, G. N.; Mollinger, L. A.; Gardner, G. M.: Kinematic and electromyographic patterns of Olympic race walkers. Am J Sports Med 11:68, 1983.

7. Schoenhaus, H.: Pathomechanics. Unpublished. :5, 1977.

8. Root, M.; Orien, W.; Weed, J.; Hughes, R.: Biomechanical Examination of the Foot. Clinical Biomechanical Corp. Pub., Los Angeles. :1:10, 1971.

9. Root, M.; Orien, W.; Weed, J.: Normal and Abnormal Function of the Foot. Clinical Biomechanical Corp. Pub., Los Angeles. :2:295-299, 1977.

10. Sgarlato, T. E.: A Compendium of Podiatric Biomechanics. Calif. College Pod. Med., San Francisco. :IX:347-349, 1971.

11. Young, C.: Personal communication. Jan., 1983.

12. Fry, J.: Construction of orthotics for race walkers. Unpublished, Oct., 1983.

ACKNOWLEDGMENTS

The author would like to thank Ronald Laird, U.S. Olympic Training Center walking coach; Leonard Jansen; U.S.O.C. Computer Services; the athletes; and the Pennsylvania College of Podiatric Medicine for valuable assistance in preparing this study.