

## [ Athletic Training ]



# Suspected Mechanisms in the Cause of Overuse Running Injuries: A Clinical Review

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**Context:** Various epidemiological studies have estimated that up to 70% of runners sustain an overuse running injury each year. Although few overuse running injuries have an established cause, more than 80% of running-related injuries occur at or below the knee, which suggests that some common mechanisms may be at work. The question then becomes, are there common mechanisms related to overuse running injuries?

**Evidence Acquisition:** Research studies were identified via the following electronic databases: MEDLINE, EMBASE PsycInfo, and CINAHL (1980–July 2008). Inclusion was based on evaluation of risk factors for overuse running injuries.

**Results:** A majority of the risk factors that have been researched over the past few years can be generally categorized into 2 groups: atypical foot pronation mechanics and inadequate hip muscle stabilization.

**Conclusion:** Based on the review of literature, there is no definitive link between atypical foot mechanics and running injury mechanisms. The lack of normative data and a definition of typical foot structure has hampered progress. In contrast, a large and growing body of literature suggests that weakness of hip-stabilizing muscles leads to atypical lower extremity mechanics and increased forces within the lower extremity while running.

**Keywords:** running; injuries; cause; prevention

Although runners often sustain acute injuries such as ankle sprains and muscle strains, a majority of running injuries can be classified as cumulative micro-trauma injuries (ie, overuse injuries).<sup>13,56</sup> Running is one of the most widespread activities during which overuse injuries of the lower extremity occur. Various epidemiological studies have estimated that anywhere from 27% to 70% of recreational and competitive distance runners sustain an overuse running injury during any 1-year period.<sup>2,26,32,35,38,53,64</sup> The runners in these studies vary considerably in their running experience and training habits, but they generally run at least 20 to 30 km per week and have been running consistently for at least 1 to 3 years.

The knee is the most common site of overuse running injuries, accounting for close to 50% of all injuries.<sup>7,51,54,59</sup> A recent systematic review and meta-analysis reported that the knee was the most common site of musculoskeletal injury for runners.<sup>61</sup> According to a clinical study of more than 2000 injured runners, the most common knee condition is patellofemoral pain

syndrome (PFPS), followed by iliotibial band syndrome (ITBS), meniscal injuries, and patellar tendinitis.<sup>59</sup> Injuries to the foot, ankle, and lower leg—such as plantar fasciitis, Achilles tendinitis, and medial tibial stress syndrome (also known as *shin splints*)—account for almost 40% of the remaining injuries, whereas less than 20% of the running injuries occur superior to the knee. Although few overuse running injuries have an established cause,<sup>5</sup> more than 80% of these injuries occur at or below the knee, thus suggesting that some common mechanisms may be involved.

The cause of these injuries is multifactorial and diverse,<sup>38,54,61,62</sup> and several identifiable factors may predict who is at risk.

## EVIDENCE ACQUISITION

For the purpose of this clinical review, research studies were identified via the following electronic databases: MEDLINE, EMBASE, PsycInfo, and CINAHL (1980–July 2008). Included

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studies were directly related to risk factors for overuse. The following keywords were used: *running, injury, mechanics, and knee* (resulting in 283 articles). Criteria for screening included (1) running injuries in long-distance runners, (2) a minimum of 20 km per week, (3) recreational or competitive runners but not elite, and (4) epidemiology (prevalence, incidence) or etiology (determinants). Two reviewers categorized the studies to determine whether a majority identified common risk factors. As such, risk factors were generally categorized into 2 groups: atypical foot pronation mechanics and inadequate hip muscle stabilization.

## FOOT PRONATION MECHANICS

Pronation is a combination of ankle dorsiflexion, rearfoot eversion, and forefoot abduction, and it occurs during the first half of the stance phase in running. Excessive rearfoot frontal plane motion (eversion) influences lower extremity mechanics via tibial rotation.<sup>11,36,39,65</sup> During the first half of the stance phase, the calcaneus everts and the head of the talus internally rotates.<sup>24,34</sup> The tibia internally rotates with the talus, owing to the tight articulation of the ankle joint mortise.<sup>24,34</sup> In weight-bearing activities such as running, there is a direct relationship between degree of pronation and internal tibial rotation (ie, for runners who exhibit a heel-toe footfall pattern).<sup>12</sup> Pronation is a necessary and protective mechanism during running; it allows impact forces to be attenuated over a long period. Researchers have suggested that a higher level of pronation is favorable during running, if it falls within normal physiological limits and does not continue beyond midstance.<sup>22,58,66</sup> After midstance, it is necessary for the foot to become more rigid and supinate in preparation of toe-off (ie, the tibia and talus externally rotate and the calcaneus inverts). As such, the rearfoot inverts and the tibia externally rotates.<sup>24,34</sup> Severe overpronators, or runners who exhibit prolonged pronation, may be at an increased risk of injury because of the potentially large torques generated within the lower extremity and the subsequent increase in internal tibial rotation.<sup>3,20,39,42,43</sup> Specifically, the tibialis posterior and soleus muscles function to minimize these torsional forces within the shank and ankle complex.<sup>45</sup> If these forces are experienced within the knee or hip joints, then the hamstring and deep external rotator muscles must concomitantly contract to control the subsequent torsional forces, respectively.<sup>45</sup>

Excessive pronation, pronation velocity, and time to maximum pronation have often been implicated as contributing factors to overuse running injuries.<sup>5,27,28,41,42,54</sup> In many studies, a static evaluation of pronation was conducted on injured runners, with the results suggesting that injured runners were more often overpronators when compared to uninjured runners. However, minimal and conflicting experimental evidence supports excessive foot pronation as a contributing factor in the cause of injuries. The majority of these studies were cross-sectional. One study partially supported the speculation regarding a cause-and-effect relationship between foot pronation and injury; it reported that groups of injured runners, when compared to a control group comprising uninjured runners, exhibited greater maximum

pronation angles and had greater maximum pronation velocities.<sup>43</sup> The results were evident in a group who had medial tibial stress syndrome. Viitasalo and Kvist<sup>63</sup> reported similar results when comparing runners with medial tibial stress syndrome to an uninjured control group during barefoot running. However, contradictory results were found in a study in which runners who had never sustained an overuse injury exhibited greater pronation velocity and greater touchdown supination angle when compared to runners who had sustained an overuse injury.<sup>23</sup> Messier et al<sup>45</sup> compared runners with PPPS to an uninjured control group<sup>42</sup> and found no differences in any rearfoot variables. Thus, the relationship between rearfoot position and running injury susceptibility is not clear given these retrospective cross-sectional design studies.

Unfortunately, only 2 prospective studies have been conducted to investigate the link between foot mechanics and overuse injuries. Willems et al<sup>67,68</sup> evaluated lower leg pain in a group of 400 physically active young individuals. Plantar pressure measurements and 3-dimensional rearfoot kinematic data were collected, and participants were followed for 1 academic year. Seventy-five injured runners were identified, and their data were compared to those of 167 noninjured runners. The injured runners exhibited significantly prolonged rearfoot pronation, increased medial foot pressure, and accelerated reinversion when compared to controls, thus suggesting that atypical foot pronation is a contributing factor in the cause of running-related injuries. In contrast, Thijs et al,<sup>60</sup> using plantar pressure measurements, examined gait-related risk factors for patellofemoral pain in a group of 84 officer cadets over the course of a 6-week basic military training period. Thirty-six cadets developed patellofemoral pain and were therefore compared to the remaining 48. Compared with the control group, the injured group exhibited a supinated heel strike position and reduced pronation (greater lateral contact pressure). Thus, the only 2 prospective studies conducted to date provide conflicting results: one suggests that excessive foot pronation mechanics are related to injury development, whereas the other suggests that reduced foot pronation mechanics are the culprit. Based on these data and the contradictory results derived from the various retrospective cross-sectional studies outlined previously, no definitive answer can be put forth regarding potential running-related injury mechanisms and excessive foot pronation.

## ESTABLISHING THE TYPICAL FOOT

The range of physiological foot pronation has not been established. Several investigators have based selection of participants on relatively arbitrary criteria. Mündermann et al<sup>46</sup> classified 20 runners as overpronators on the basis of a 2-dimensional standing rearfoot-shank angle greater than 13° (see Figure 1). This value was based on work by Clarke et al,<sup>6</sup> who averaged the maximum pronation angle from 9 studies conducted between 1978 and 1983. The average angle when running was 9.4° (± 3.5°), with a maximum pronation of 13° or greater labeled *excessive*.



Figure 1. Right, markings to bisect the long axis of the shank and rearfoot; left, goniometric measurement of standing rearfoot-shank angle (left foot shown).

McClay and Manal<sup>40</sup> investigated lower extremity mechanics for a group of 20 recreational runners exhibiting normal<sup>6</sup> rearfoot mechanics. Participants for this study were selected using a dynamic assessment of 2-dimensional peak rearfoot-shank angle between 8° and 15° while running on a treadmill.

Cheung and Ng<sup>3</sup> identified 22 overpronators on the basis of a dynamic 3-dimensional rearfoot angle greater than 6° while running. Genova and Gross<sup>19</sup> classified 8 overpronators on the basis of a standing rearfoot-shank angle greater than 10°. <sup>29</sup>

Cornwall and McPoil<sup>8</sup> reported a measure of 6.3° ( $\pm$  4.0°) for static rearfoot-shank angle from 82 participants. Sobel et al<sup>55</sup> reported a similar measure of 6.07° ( $\pm$  2.71°) for 88 adults, whereas Kendall et al<sup>31</sup> reported an average angle of 6.10° ( $\pm$  2.58°) in 221 runners. Based on these large samples, a static rearfoot-shank angle of 6.00° ( $\pm$  3.00°) could be considered normal and thus an appropriate measure for screening.

## INADEQUATE HIP STABILIZATION

The ability to dynamically stabilize the lower extremity during running may play a role in the cause of running-related injuries. For example, the gluteus medius muscle eccentrically controls hip adduction during the stance phase of gait, and the posterolateral fibers assist in eccentric control of hip internal rotation.<sup>45</sup> The deep external rotators of the hip (piriformis, quadratus femoris, etc) play a critical role in hip stabilization and primarily function to eccentrically control internal rotation of the hip during the stance phase of gait.<sup>10</sup>

Ireland et al<sup>25</sup> investigated the hypothesis of reduced hip muscle strength as a contributor to injuries and reported that, when compared to matched controls, female PFPS patients demonstrated 26% less hip abductor and 36% less hip external rotator strength. In addition, runners with ITBS

exhibited significantly weaker hip abductor muscle strength in the affected limb, when compared to the unaffected limb and to healthy controls.<sup>18</sup> Ten patients with PFPS exhibited 27% less hip abduction and 30% less hip external rotation strength on the injured limb, when compared to the contralateral limbs and to controls.<sup>52</sup> Injured runners also demonstrated significantly weaker hip abductor and hip flexor muscles, as compared to the noninjured limb and to the control group.<sup>47</sup> Cichanowski et al<sup>4</sup> reported significantly reduced hip abductor and external rotator muscle strength for a group of 13 PFPS patients, compared to the noninjured limbs and to controls. Finally, Kendall et al<sup>30</sup> investigated the influence of proximal and distal clinical measures between 60 runners with PFPS and 52 who served as noninjured controls. As such, 90% of the patients in the PFPS group exhibited significantly reduced hip external rotator, abductor, and flexor strength. These studies suggest a relationship among hip muscle weakness, side-to-side strength imbalances, and running-related overuse injuries.

Unfortunately, the relationship between hip mechanics and running-related injuries is not well understood. Noehren et al<sup>49</sup> examined differences in hip mechanics between runners who had sustained ITBS and those who had no knee-related running injuries. Compared to the control group, the ITBS group exhibited a significantly greater peak hip adduction angle and significantly greater frontal plane knee joint moments. Weakness of the hip abductor muscles may result in greater hip adduction, which may necessitate greater passive restraint from the iliotibial band and so result in the greater frontal plane knee joint moments while running. In support of Noehren et al,<sup>49</sup> Ferber et al<sup>15</sup> retrospectively evaluated 35 runners with a history of ITBS, who demonstrated significantly greater peak knee internal rotation angle and peak hip adduction angle when compared to 35 controls.

Several studies link common clinical variables, such as muscle strength, anatomical alignment, and the development of running-related injuries. Ferber et al<sup>17</sup> compared differences in kinematic and kinetic patterns of the hip and knee in 20 male and female recreational runners. Compared to men, women exhibited significantly greater peak hip adduction angle and hip frontal plane negative work, which may be the result of a greater pelvis width–femoral length ratio in women.<sup>21</sup> Female runners also demonstrated a significantly greater peak knee abduction angle and were in a more abducted knee position throughout stance. Malinzak et al<sup>37</sup> showed that female runners exhibit a significantly greater knee abduction angle throughout the stance phase of running, greater peak hip adduction, and hip internal rotation angle. The combination of greater hip adduction and knee abduction may be related to greater genu valgum<sup>1</sup> and increased Q angle<sup>21,33,44,50,70</sup> in women.

Fredericson et al<sup>18</sup> reported on the importance of hip abductor strengthening for participants experiencing ITBS. After participating in a 6-week intervention, 22 of 24 runners experienced a significant decrease in pain and a 35% to 51% increase in hip abductor strength. At a 6-month follow-up, there were no reports of ITBS recurrence. Ferber and Kendall<sup>16</sup> evaluated 284 consecutive patients with various musculoskeletal running injuries. Patients

were asked to report the average amount of pain they were experiencing while running, using a 10-cm visual analogue scale. A rehabilitation program was prescribed to improve hip abductor, flexor, and external rotator muscle strength. After 4 to 6 weeks of rehabilitation, 165 patients (58%) returned for follow-up assessment, among whom 89% reported at least a 50% improvement in pain. These results suggest that a hip strengthening rehabilitation program can be effective.

The current treatment of PFPS is usually not effective, and research has revealed that patients remain at risk for recurring bouts of pain.<sup>9,14,48,57,69</sup> Nimon et al<sup>48</sup> reported that 25% of PFPS patients continued to have significant knee pain over a 20-year period. Features were not identified that predicted which patients would not improve. Stathopulu and Baildam<sup>57</sup> found that 91% of PFPS patients continued to exhibit varying intensity of daily symptoms, 45% experienced pain at 4- and 18-year follow-up, and 36% stated that the pain restricted their physical activities. A study of 250 PFPS patients, who were surveyed an average 5.7 years after initial treatment, showed that 73% still experienced knee pain, 35% saw no change in symptoms, and 13% experienced increased pain.<sup>69</sup>

## CONCLUSION

Various epidemiological studies have estimated that up to 70% of runners sustain an overuse running injury each year. The knee is the most common site, accounting for approximately 50% of all running injuries. Risk factors can be categorized into 2 groups: atypical foot pronation and inadequate hip muscle stabilization.

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