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**A pathomechanical  
paradigm for treating  
the injured runner**

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# A pathomechanical paradigm for treating the injured runner

**Richard W. Willy,**  
PT, PhD, OCS  
Department of Physical Therapy,  
East Carolina University,  
Greenville, NC

**Corresponding Author:**  
Richard Willy, PT, PhD  
Assistant Professor  
Department of Physical Therapy  
College of Allied Health Sciences  
East Carolina University  
Greenville, NC 27834 USA  
Mail stop: 668 Allied Health

email: willyr@ecu.edu

## Abstract

Pathological mechanics are thought to play a role in many common running injuries. A review of the biomechanical literature reveals that a given running injury may be associated with multiple faulty running mechanics. Traditional rehabilitation programs have focused their efforts on addressing the injured anatomical structure. By focusing rehabilitation programs on correcting the pathomechanics of an injury, outcomes may be improved. Since the underlying faulty mechanics have been addressed, risk of reinjury may also be decreased. In this article, a pathomechanical paradigm for the treatment of the injured runner is introduced. Emphasis is placed on recognizing the most common types of faulty running mechanics often encountered in the clinical setting and their implications for injury. Finally, suggested treatment techniques are described.

## Introduction

Endurance running is one of the most popular and is enjoyed across the lifespan. Unfortunately, running is associated with a high injury rate with 19-79% of runners sustaining an injury each year.<sup>31</sup> Injuries to the knee and lower leg represent nearly 2/3rds of all running-related injuries, with patellofemoral pain (PFP), iliotibial band syndrome, plantar fasciitis and tibial stress fractures being among the most prevalent.<sup>30</sup> High recurrence rates for many of these overuse injuries suggest that traditional treatment regimens lack a

certain aspect that may be critical for long term success.

In addition to structural and training-related risk factors, pathomechanics are thought to contribute to the development of running injuries. Abnormal running mechanics may result in pathological levels of loading on anatomic structures, resulting in overuse injury. Failure to address the underlying faulty running mechanics, if present, may contribute to the high rate of recurrence that is often associated with many running-related injuries.<sup>16, 42</sup> Adopting a pathomechanical paradigm may be beneficial when treating many running-related injuries.<sup>16, 28</sup> In a pathomechanical model, faulty mechanics, rather than injured anatomical structures, are the focus of clinical assessment and treatment programs.<sup>28</sup> A pathomechanical paradigm is particularly well suited to the treatment of running clientele as most running-related injuries have multiple potential biomechanical causes.

The ability to conduct a thorough and accurate running gait analysis is paramount to successful implementation of a pathomechanical approach for rehabilitation of the injured runner. A fully instrumented gait analysis, using a 3-dimensional motion capture system, is considered the gold standard for evaluating running gait. These systems are expensive and require a highly specific skill set to operate and, consequently, are rarely seen in the clinical setting. In addition, the amount of information provided by these systems can prove

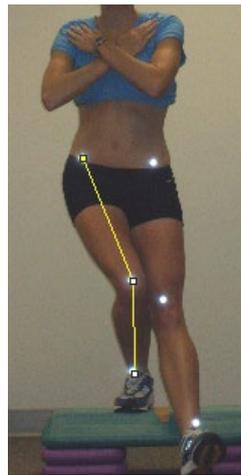
overwhelming for the clinician and runner alike. A skilled clinical gait analysis, using a standard video camera and treadmill, can provide the necessary information to implement a pathomechanical paradigm for the treatment of most common running injuries. Despite some differences with overground running, a treadmill is a valid tool for clinical gait analysis with respect to joint kinematics and kinetics.<sup>8, 40</sup> During treadmill running, a less inclined foot and a slightly shorter stride are present when compared with overground running.<sup>8</sup> These differences may be important considerations when evaluating certain running mechanics. In this article, a basic classification framework is described for the most common pathomechanics associated with the many prevalent running injuries. Specifically, this article will discuss medial collapse mechanics,<sup>27</sup> overstriding,<sup>5, 12</sup> crossover gait<sup>3</sup> and their associated running-related injuries. Clinical assessment techniques and suggested treatment strategies are discussed for each of these faulty running patterns. Overall, the intent of this article is to describe the basis for a theoretical model designed to assist clinicians in the treatment of the injured runner.

## Medial collapse mechanics

Medial collapse is perhaps the most common faulty running mechanic, particularly among female runners (FIGURE 1). Excessive hip adduction, hip internal rotation, and contralateral pelvic drop result in a knee in apparent valgus, collectively



**Figure 1:** Medial collapse mechanics at midstance. Note the excessive contralateral pelvic drop and hip adduction. Clinically, close proximity of the medial femoral condyles at midstance, as above, generally indicates excessive hip adduction of the stance limb.



**Figure 2 :** Measurement of the Frontal Plane Projection Angle (FPPA) during a stepdown maneuver. ImageJ (www.NIH.gov Bethesda, MD USA) was used to obtain an FPPA measurement of  $-21^\circ$ . A negative FPPA measurement is indicative of medial collapse. The same methodology is used to measure FPPA during running.

known as medial collapse.<sup>27</sup> While primarily seen in female runners, medial collapse mechanics should not be considered sex-exclusive.<sup>41</sup> Medial collapse mechanics apply added stresses and forces to several anatomical structures, potentially resulting in overuse injury. Medial collapse mechanics have been identified as possible mechanisms for the development of PFP<sup>23, 29, 34</sup> and iliotibial band syndrome in runners.<sup>9, 11, 22</sup> Excessive hip adduction and hip internal rotation increase the dynamic quadriceps angle, increasing the lateral vector acting on the patellofemoral joint.<sup>13, 14</sup> Additionally, contralateral pelvic drop and hip adduction motions are thought to increase strain in the iliotibial band.<sup>11</sup> Excessive hip adduction and internal rotation may also engage cam or pincer morphologies of the femoroacetabular joint, potentially contributing to femoroacetabular impingement and acetabular labral tears.<sup>1</sup> Medial collapse also results in uneven loading of the long bones of the lower extremity. Specifically, a knee in dynamic valgus will shift loading to the lateral aspect of the tibiofemoral joint leading to bending moments applied to the femur and tibia.<sup>26</sup> Tension on the medial aspects of the femur and tibia may result. Interestingly, female runners with a history of tibial stress fractures tend to run with medial collapse mechanics.<sup>26</sup>

Clinically, there are several methods to evaluate medial collapse mechanics. The frontal plane projection angle (FPPA) of the knee is a 2-dimensional evaluation technique readily performed in the clinic, requiring only a standard video camera and software to quantify joint angles (FIGURE 2).<sup>35, 36</sup> Many open source applications for tablet and handheld computers are now available and allow the clinician to measure FPPA conveniently in the clinic. To measure FPPA, an angle is obtained by the intersection of two lines: a) a line between the

anterior inferior iliac spine and the midpoint of the tibiofemoral joint, and b) a line between the center of the ankle mortis and the tibiofemoral joint.<sup>35</sup> Despite the ease in measuring FPPA, it has only moderate correlations with any single 3-dimensional measure of joint motion.<sup>35</sup> Caution is urged when directly comparing the results of the 2-dimensional measure of FPPA with 3-dimensional measures obtained in research gait laboratories. Rather, FPPA is a composite measure with inputs that occur in different proportions from hip adduction and internal rotation, and knee abduction and external rotation.<sup>35</sup> Despite this limitation, FPPA is a repeatable measure (intraclass correlation coefficients = .72-.91),<sup>20, 36</sup> and is a useful clinical tool to quantify changes in dynamic alignment of the lower extremities. A more subjective measurement is to visually assess the distance between the medial femoral condyles at midstance using a posterior full body view. Clinicians often consider a runner to have medial collapse mechanics when the medial femoral condyles appear to touch, or nearly



touch during the swing phase. Regardless of the assessment technique used, individuals who demonstrate medial collapse during running tend to move in the same manner during other tasks such as jumping, single leg squatting and step descent.<sup>29, 34, 41</sup> Therefore, evaluation of medial collapse mechanics during other movement tasks is comparable to running if a treadmill is not readily available.

Neuromuscular therapies often target the hip abductor and external rotator musculature in an effort to improve control of the motions associated with medial collapse mechanics. The short term outcomes of hip strengthening programs are promising for the treatment of the PFP and iliotibial band syndrome.<sup>6, 10, 21</sup> However, there is no evidence that hip strengthening actually reduces medial collapse mechanics.<sup>38, 43</sup> These findings may have long term implications for the success of hip strengthening programs for the treatment of injuries with a medial collapse mechanic.

There is a growing body of evidence that deficits in neuromuscular control may be related to running injuries associated with medial collapse mechanics. Willson and colleagues recently reported that medial collapse mechanics are correlated with deficits in neuromuscular control of the gluteal musculature in runners who exhibit medial collapse mechanics.<sup>37</sup> Additionally, a recent systematic review found evidence that females with PFP demonstrate delayed onset and shorter duration of activation of the gluteus maximus and medius during step negotiation and running.<sup>2</sup>

**Figure 3 :** Mirror gait retraining session with a runner with patellofemoral pain related to medial collapse mechanics.

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Consequently, interventions that target neuromuscular control deficits of the gluteal musculature may be successful in addressing medial collapse mechanics. Gait retraining, a systematic neuromuscular reeducation of gait patterns, has shown promise at reducing medial collapse mechanics. In two recent reports, female runners with patellofemoral pain were verbally cued to “squeeze” their gluteal musculature to reduce medial collapse mechanics during 8 treadmill training sessions.<sup>24, 42</sup>

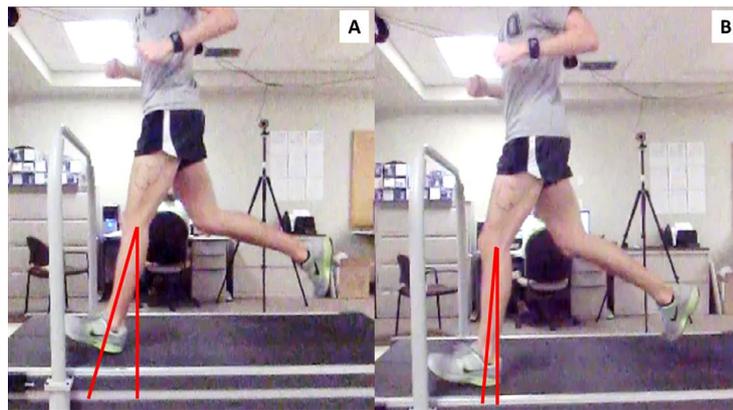
Feedback on medial collapse mechanics was provided by either a real time motion capture system<sup>24</sup> or a full length mirror placed in front of the treadmill (FIGURE 3). Runners in both studies reduced their medial collapse mechanics while reporting significant reductions in pain and improved overall knee function. These preliminary studies suggest that gait retraining may have promise at reducing in symptoms and medial collapse mechanics. It is also noteworthy that the mirror retraining and the real time feedback studies produced equivalent results in both symptoms and improvements in medial collapse mechanics. Thus, the technique in the mirror retraining study transfers readily to the clinical setting whereas most clinics lack the access to a motion capture system to implement the real time kinematic technique.

#### Overstriding mechanics

Overstriding is operationally defined as taking longer strides than optimal for a given running velocity, resulting

in a lower running cadence (step rate) (FIGURE 4a). While easily measured, there is no established standard for optimal step rate. Step rate is highly individualized and is somewhat velocity dependent.<sup>12</sup> Nevertheless, overstriding mechanics may play a role in a number of running-related injuries. Individuals who run with sub-optimal stride rate exhibit a more extended knee at initial contact, reducing the knee’s ability to initially attenuate the impact forces that occur immediately after footstrike.<sup>12, 39</sup> A more pronounced heel strike occurs during overstriding. As a result, ground reaction force absorption occurs primarily through the highly dense calcaneus, resulting in elevated impact forces.<sup>12</sup> In contrast, running with increased step rate results in a more flexed knee at footstrike and reduced heelstrike pattern and lower impact forces (FIGURE 4b, 5).<sup>12, 39</sup>

The reduction of excessive impact forces during running may be an important consideration in the treatment of several common running injuries. For instance, runners with a history of tibial stress fractures have been shown to run with higher vertical loading rates of the vertical ground reaction force and higher tibial shock.<sup>19, 26</sup> Interestingly, the magnitude of impact forces seems to be more important than the number of cycles of impacts when addressing overstriding mechanics.<sup>7</sup> This finding supports the treatment strategy of reducing impact forces by increasing step rate, which reduces overstriding.<sup>12, 39</sup>



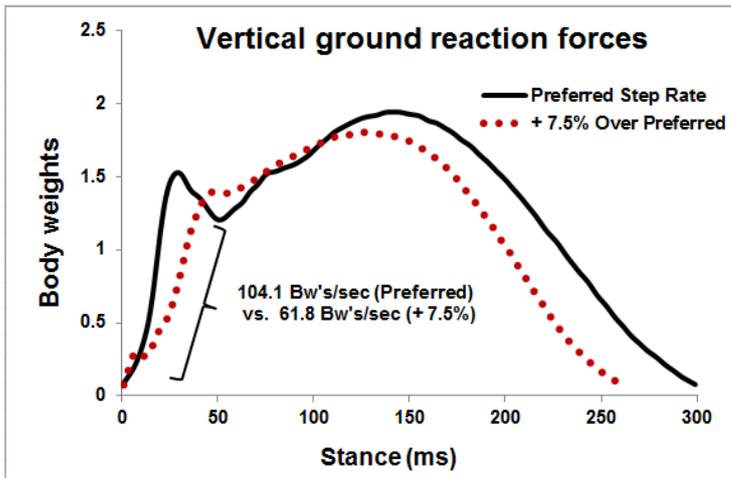
**Figure 4:**

A) Runner exhibited overstriding running mechanics. Note the extended knee at footstrike and the angle of the lower leg, with respect to vertical.

B) Running with 7.5% above preferred step rate. Note the changes in lower extremity kinematics, including increased knee flexion, a more vertical tibia, and a less-pronounced heelstrike. Adapted with permission from: Miller A, Willy RW. Retraining fixes faulty gait in injured runners. *LER*. 2013 5(6): 29-33.

Overstriding may also play a role in injuries to the patellofemoral joint. In runners who overstride, knee flexion velocity and the peak internal knee extension moment are elevated, resulting in increased knee power absorption and greater patellofemoral joint stress.<sup>12, 15, 39</sup> Interestingly, overstriding may also play a role in medial collapse mechanics. When a longer swing phase is adopted, activation of the gluteal musculature decreases during late swing phase.<sup>4</sup> As the gluteal musculature resist hip flexion, this decrease in neuromuscular activity may be necessary to facilitate a longer swing phase. This reduction in activity of the gluteus maximus and gluteus medius just prior to footstrike is perhaps significant as runners with excessive medial collapse often demonstrate the same altered neuromuscular control strategy.<sup>37</sup> Interestingly, hip adduction increases when step rate is decreased.<sup>12</sup> When these findings are taken together, overstriding may result in both greater patellofemoral stress and increased medial collapse mechanics.

Clinicians who suspect overstriding often note a more extended knee, a less vertical lower leg, and a more pronounced heelstrike at initial ground contact. Often, footstrikes are more audible in runners who overstride. While adopting a mid-foot or even a forefoot strike pattern is often suggested to reduce overstriding, considerably greater loading of the plantarflexors results.<sup>32</sup> Therefore, deliberately transitioning to a



**Figure 5:** The vertical ground reaction force curves of two stance phases of the runner in Figure 4 while running at preferred step rate (Fig. 4a) and at 7.5% over preferred step rate (Fig. 4b). Note the large reduction in the average vertical load rate, which is calculated as the rate of rise in the middle 60% of the vertical ground reaction force curve between foot strike and the vertical impact peak (the first peak). Adapted with permission from: Miller A, Willy RW. Retraining fixes faulty gait in injured runners. *LER*. 2013 5(6): 29-33.

non-heelstrike pattern may be unwise as injury to the plantarflexors may result. In contrast, gait retraining programs that cue an increase in step rate have shown promise without causing a large increase in plantarflexion power absorption.<sup>39</sup> Recent reports have shown that cueing a 5-10% increase in step rate reduces impact forces, knee power absorption and patellofemoral joint stress.<sup>12, 15, 39</sup> Feedback on step rate can be provided by manually counting a runner's steps, using a metronome, matching step rate to music, or using an accelerometer-based feedback system. Several commercial devices that provide real time feedback on step rate are now available.



### Crossover running mechanics

Recently, running with an excessively narrow step width, also known as crossover running, has garnered increased attention. Crossover running has a profound effect on the frontal plane mechanics of the hip, knee, and rearfoot. A narrow step width necessitates increased hip adduction by moving the foot medially relative to the body's center of mass.<sup>3</sup> By placing the foot medial to the midline of the body, the knee varus moment increases.<sup>3</sup> Elevated values of hip adduction and the knee varus moment increase strain of the iliotibial band, potentially contributing to the development of iliotibial band syndrome.<sup>18</sup> Additionally, modulation of elevated knee varus moments may be an important consideration in runners with medial compartment osteoarthritis. Crossover mechanics also necessitates increased rearfoot eversion to achieve a plantigrade foot.<sup>3, 25</sup> As rearfoot eversion increases, so does tibial internal rotation ( $r=0.84$ ),<sup>25</sup> leading to an increase in torsional loading of the tibia.<sup>17</sup> Bone is weakest under torsional loading. Hence, it is not surprising that runners with a history of tibial stress fractures often demonstrate high levels of torsional loading.<sup>26</sup>

**Figure 6:**

Crossover running mechanics in midstance in an individual with iliotibial band syndrome. Note that greater than 25% of the width of the heel is medial to a vertical line extended inferiorly from the 5th lumbar vertebra. Also, note the increased rearfoot eversion that is likely due to the crossover mechanic.

The crossover running mechanic is easily evaluated during a clinical gait assessment using the posterior view. With the gait analysis video paused in midstance, a vertical line can be extended inferiorly from the midline of the 5th lumbar vertebra.<sup>33</sup> At the East Carolina University Running Assessment Clinic, we consider a runner to have crossover mechanics if greater than 25% of the width of the heel is medial to this vertical line at the point of midstance (FIGURE 6)

Little is known as to why runners adopt a crossover running pattern. As excessive hip adduction is a component of crossover running, deficits in neuromuscular control of the hip and trunk musculature may be at fault. Clinically, runners who demonstrate a crossover gait pattern respond well to a structured proximal strengthening and gait retraining program. Clinicians may provide visual cueing to increase step width by placing a piece of tape running lengthwise on the front of a treadmill. A full length mirror is placed directly in front of the treadmill so that the runner does not need to look down when learning to avoid crossing over the piece of tape. Alternatively, gait retraining to cue an increase in step width can be done outside the clinic by instructing a runner to straddle 2 lanes on a running track.

### Conclusion

There is a growing body of evidence supporting a pathomechanical paradigm for the evaluation and treatment of injured runners. In this article, we have described how this type of model can be readily adopted to the clinical setting for the treatment of the most common types of faulty running mechanics. Adopting a pathomechanical paradigm for the treatment of injured runners may result in improved long term outcomes for the most prevalent running injuries.

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