

Chronic Low-Back Pain and Its Response to Custom-Made Foot Orthoses

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A new approach to treating chronic low-back pain with custom-made foot orthoses was investigated. The Quebec Back Pain Disability Scale was used to objectively assess the functional disability of 32 subjects at different times. Subjects in this prospective study experienced more than twice the improvement in alleviation of pain, and for twice as long, compared with subjects in a study using traditional back-pain treatment. The authors believe that the findings of this study may provide a new method by which patients with chronic low-back pain can be evaluated and treated. (*J Am Podiatr Med Assoc* 89(3): 109-117, 1999)

Chronic low-back pain is a medical problem throughout the world. Various studies have shown that this problem is characterized by partial remissions and frequent exacerbations of pain. Up to 70% of patients who develop disabling low-back pain will experience a repeat episode within 1 year of treatment.¹⁻³ Most care options address only acute flare-ups and are not useful for long-term management of pain. Surgical intervention has limited success, and is best performed for radiculopathic-type leg pain and not for pain specifically involving the lower back.^{4,5} The cost of treating low-back pain is in the tens of billions of dollars annually in the United States alone.^{6,7}

Podiatric physicians have long known that the use of foot orthotic devices can help alleviate low-back pain. The evidence was primarily anecdotal. A 1990 study found that 77% of patients demonstrated 50% to 100% improvement over a 2-year follow-up period when custom-made foot orthoses were used to correct subtle aberrations in their gait style.⁸ In 1993, in a two-part article, one of the authors of this article (H.J.D.) described the biomechanical relationship between gait style and lumbar stress.^{9,10}

DiNapoli et al⁸ and Dananberg^{9,10} have postulated

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that functional hallux limitus is a major gait abnormality that causes lumbar stress. Essentially, functional hallux limitus is the blockage of a rotational type of motion at the first metatarsophalangeal joint at the time when the joint should be dorsiflexing in the single-support phase of gait. This occurs despite the fact that normal range of motion at this joint is available in the nonweightbearing state. With functional hallux limitus, the first metatarsal is not stabilized against the ground and, therefore, the foot and body cannot pass directly over it. Ankle equinus is another example of this type of motion restriction. These two conditions have been collectively referred to as sagittal plane blockage.^{9,10} The purpose of this prospective study was to determine whether addressing sagittal plane blockage with custom-made foot orthoses and manipulation of affected joints could alleviate the chronic low-back pain that was experienced by the study participants.

Materials and Methods

The 32 subjects in this study were referred to the Podiatry Centers of New Hampshire between the summer of 1996 and the fall of 1997 for gait evaluation and custom-made foot orthoses to treat chronic low-back pain. Each subject had been treated unsuccessfully with several standard low-back treatment modalities, including skilled spinal manipulation,

physical therapy, therapeutic injections, and, in some cases, surgery, and were considered to be approaching the medical end point for their conditions. The inclusion criterion for this study was the presence of either chronic low-back pain or an acute episode of recurrent low-back pain. All patients had a long history of back pain; the types of pain included, but were not limited to, chronic sacroiliac joint pain, non-specific “mechanical” chronic low-back pain, spinal stenosis, and chronic radiculopathic pain related to intervertebral disk disease.

In order to objectively assess each subject’s back pain for intrasubject and intersubject comparisons, each subject was asked to complete the Quebec Back Pain Disability Scale questionnaire before treatment began (Time 1), after wearing the orthoses for at least 1 month (Time 2), and after wearing the orthoses for at least 6 months (Time 3). The Quebec Back Pain Disability Scale questionnaire is a self-administered questionnaire designed to assess the level of functional disability in patients experiencing back pain (Fig. 1). The scale has been shown by Kopec et al¹¹ to be an accurate measurement tool for clinical outcome studies when compared with the classic pain-measurement tests, the Roland, Oswestry, and SF-36 scales. The Quebec Back Pain Disability Scale questionnaire asks the subject to rate 20 general activities of daily living on a scale from 0 to 5, with 0 representing no difficulty and 5 representing the impossibility of performing the task. Therefore, a score of 100 would be the worst score and 0 would be the best. For each subject, the scores were converted to a mean pain score representing the sum of all of the numerical answers divided by the number of questions answered.

The mean pain scores at different times were then compared in order to measure the increase or decrease in each subject’s back pain. Two time periods were evaluated: The first period, called the initial phase, is that from the pretreatment pain assessment to the assessment at least 1 month after dispensing the orthoses. The second period, or follow-up phase, is that from the pretreatment assessment to the assessment at least 6 months after dispensing the orthoses. The degree of improvement or worsening in the initial phase was measured by subtracting the mean pain score at Time 2 from the mean pain score at Time 1; the degree of improvement or worsening in the follow-up phase was measured by subtracting the mean pain score at Time 3 from the mean pain score at Time 1. Twenty-three of the original 32 subjects completed the final survey and follow-up phase.

The Student’s *t*-test was used to determine whether there was a statistically significant difference between scores in the initial and follow-up phases of

The Quebec Back Pain Disability Scale

This questionnaire is about the way your back pain is affecting your daily life. People with back problems may find it difficult to perform some of their daily activities. We would like to know if you find it difficult to perform any of these activities listed below because of your back. For each activity there is a scale of 0 to 5.

- 0 — not difficult at all
- 1 — minimally difficult
- 2 — somewhat difficult
- 3 — fairly difficult
- 4 — very difficult
- 5 — unable to do

Please choose one of the above response options for each activity (do not skip any activities) and write your response on the line provided.

Today do you find it difficult to perform the following activities because of your back?

- _____ 1. Get out of bed.
- _____ 2. Sleep at least 6 hours.
- _____ 3. Turn over in bed.
- _____ 4. Travel 1 hour in a car.
- _____ 5. Stand up for 20 to 30 minutes.
- _____ 6. Sit in a chair for 4 hours.
- _____ 7. Climb one flight of stairs.
- _____ 8. Walk a few blocks.
- _____ 9. Walk several miles.
- _____ 10. Reach up to high shelves.
- _____ 11. Throw a ball.
- _____ 12. Run two blocks.
- _____ 13. Take food out of the refrigerator.
- _____ 14. Make your bed.
- _____ 15. Put on socks (panty hose).
- _____ 16. Bend over a sink for 10 minutes.
- _____ 17. Move a table.
- _____ 18. Pull or push heavy doors.
- _____ 19. Carry two bags of groceries.
- _____ 20. Lift 40 pounds.

Figure 1. The questionnaire that was completed by patients in this study. (Reprinted with permission from Kopec et al.¹¹)

the study. The *P* values for the phases were subsequently calculated.

The initial clinical examination consisted of two parts: a physical examination, which was used as a screening tool to assess foot and ankle joint ranges of motion, muscle strength, and limb-length discrepancy, and a brief visual assessment of gait. Ranges of motion of the ankle joint, subtalar joint, midtarsal joint, and first metatarsophalangeal joint were evaluated qualitatively according to the method described by Root et al.¹² The amount of dorsiflexion at the first metatarsophalangeal joint was further assessed in the loaded position as described by Dananberg et al.¹³

The diagnosis of hallux limitus was made when hallux dorsiflexion in the unloaded state was significantly less than 65°. Functional hallux limitus was given as the diagnosis when the amount of dorsiflexion available at the first metatarsophalangeal joint was normal (65°) in the unloaded state and was markedly decreased in the loaded state. Other clinical signs of functional hallux limitus or hallux limitus were noted, including callus under metatarsals 2 through 5, exostoses at the first metatarsal head or at the first metatarsocuneiform joint, excessive lateral shoe wear, hyperextension of the hallux interphalangeal joint, or pinch callus at the medial hallux. Ankle equinus was defined as less than 10° of ankle dorsiflexion with the knee fully extended.¹²

Manipulations at the first metatarsophalangeal joint, ankle, and fibular head were performed to increase range of motion when appropriate. Criteria for manipulation have been described previously.¹³

Manual muscle testing of the lower-leg muscles was performed as described by Walther,¹⁴ and any muscle weakness was noted. Limb length was assessed by examining whether the hips were level by palpating the subject's anterosuperior iliac spines and posterosuperior iliac spines.

Because of space considerations at the time of the initial visit, a brief visual examination of each subject's gait was performed only in the frontal plane; the subject was viewed walking up and down a hallway. Additional evidence of any limb-length discrepancy such as head tilt, shoulder drop (usually on the same side as the longer limb), limited arm swing (usually on the same side as the longer limb) and hip drop (usually on the same side as the shorter limb) could be observed at this time. Other gait aberrations such as an early heel-off or an abductory twist could also be observed during this evaluation. Tape was applied to the subject's foot in a modified low-Dye style as described previously¹³ and/or an Aliplast (AliMed Corp, Dedham, Massachusetts) heel lift was inserted in the shoe of the taped foot. The gait examination was repeated to assess whether a more symmetrical gait was achieved (by such evidence as an increase in arm swing, longer stride, decreased shoulder drop, and diminished abductory twist). The subject was asked to wear the tape for 2 to 3 days if it had been applied, and/or to use the Aliplast heel lift in the shoe of the shorter limb. This completed the initial examination and treatment protocol.

In order to initiate orthotic treatment, each subject was asked to return for an intensive clinical examination, dual-direction slow-motion video assessment, and in-shoe pressure analysis with the F-Scan system (Tekscan, Boston, Massachusetts). Compensatory

motions were qualitatively identified in the frontal and sagittal planes using the video analysis. Some of the compensatory motions of sagittal plane blockage that were observed in gait were early or delayed heel-off, early knee flexion, circumduction-type gait, diminished arm swing, abductory twist, decreased hip extension, flexion of the torso during gait, and lateral trunk bend and upper-body sway. Each subject's gait was then objectively examined for symmetry, excessive force levels, and efficiency of weight transfer during the single-support phase by using the diagrams and graphs generated from the in-shoe pressure data.

A complete description of pressure analysis in gait is beyond the scope of this article, but a general set of rules for this includes the following: The time in 20-millisecond intervals of the entire contact duration of each foot is determined. The timing and symmetry of left and right heel lift are examined. The center of pressure course is reviewed to determine whether weight flow is excessively medial or lateral, and, if direction of flow changes, at what point in the step this takes place. Should the loads under the first metatarsal be too low, then the size of the first-ray cutout in the future orthosis is increased. In addition, the force-versus-time graphics are carefully examined for shape and symmetry. The normal central depression on these graphs should be approximately 20% to 25% lower than the peak heel-load levels. If this area is excessively deep or too shallow, or if marked variations between the two are evident, a determination of how these differ is made. Pressure analyses must be combined with video analyses, as the findings of each are significant in the interpretation of a patient's gait.

The combined information from the pressure and video analyses coupled with the clinical examination findings provided the basis for prescribing and modifying an orthotic test device. This test device was made from an impression taken with the subject in a semiweightbearing stance; the device was made of an Aliplast-Nickelplast (AliMed Corp, Dedham, Massachusetts) lamination. The device was ground and posted to a standard podiatric-style orthotic device, although rearfoot posting was used very selectively and only in cases in which early medially deviated center of pressure motion was verified.

Once the test devices were fabricated and placed in the patients' shoes, the in-shoe pressure analysis examination was repeated. Changes in symmetry, direction, and timing of loads were then evaluated. An attempt was made to alter gait parameters to acceptable levels by orthotic modifications that included but were not limited to standard cutouts, bidirectional cutouts, first-ray cutouts, heel lifts, load-dampen-

ing lifts (PPT, Langer Biomechanics Group, Deer Park, New York), and forefoot and rearfoot postings. The testing was completed when appropriate findings were demonstrated by changes in the pressure analysis data. Subjects underwent a repeat dual-direction video examination to assess visual gait changes and ensure improved status.

The ability of the hip joint to extend during the single-support phase of gait is restricted in the presence of any (or all) of the sagittal plane blockages. Normal hip-joint extension is approximately 15° at the end of the single-support phase. Extension less than 15° can be assumed to be abnormal, although there is certainly a range ($\pm 5^\circ$) in which extension motion can be viewed. Knee flexion or failure of the ipsilateral knee to reach full extension prior to opposite heel strike is the marker for improper hip extension. It is important that during the gait cycle the limbs be viewed as interconnected parts of the whole rather than as two unrelated and independent structures.

The prescription for the permanent orthoses included all of the modifications that were objectively found to improve gait mechanics. All gait analyses were performed and orthotic prescriptions were written by the same clinician (H.J.D.). Patients wore the test devices while waiting for the permanent devices to be dispensed. Normal orthotic follow-up was provided for both test and permanent orthoses.

Results

Thirty-two subjects originally participated in the study; the average time that elapsed between Time 1 and Time 2 was 2.5 months. Only 23 subjects completed the final questionnaire, doing so between 6 months and 23 months after the original questionnaire date; the average time that elapsed between Time 1 and Time 3 was 13.8 months. Four of the subjects could not be reached for follow-up because they had relocated. One subject was eliminated in the follow-up phase because she had breast-reduction surgery; therefore, any decrease in back pain could not be attributed solely to the orthotic care. One subject did not participate in the follow-up phase because she did not wear the orthoses. She claimed that they did not fit into her sandals, which were the only shoes she wanted to wear. Three of the subjects could not be reached despite numerous phone calls and mailings asking them to participate in the follow-up phase of the study.

The age range of the subjects in the initial phase was 20 to 73 years (average age, 57 years). There were 17 (53%) male and 15 (47%) female participants. The age range of the subjects in the follow-up phase

was 37 to 65 years (average age, 47 years). There were 14 (61%) male and 9 (39%) female participants. Table 1 lists the self-reported diagnoses of the subjects in this study.

In the initial phase of the study, the participants had a statistically significant improvement in alleviation of pain, with a mean reduction of 0.66 and a standard deviation of 0.78 in the disability score; 84% (27) of the 32 patients experienced improvement. The subjects in the follow-up phase of the study experienced a statistically significant improvement in alleviation of pain, with a mean reduction of 0.66 and a standard deviation of 0.92, after an average of 13.8 months of orthotic treatment. Within this subset of subjects, the mean improvement after the initial phase of the study was 0.66, with a standard deviation of 0.72 (Table 2). Furthermore, all of the patients participating in the study had at least one pedal source of sagittal plane blockage (Table 3). Thirteen of the 32 (41%) subjects in this study had back pain resulting from accidents or injuries for which they were seeking monetary compensation; interestingly, of those 13, only 3 showed no improvement.

The results of the present study can be directly compared with results obtained in a previous back-pain study that used the Quebec Back Pain Disability Scale. Kopec et al¹¹ used the Quebec Back Pain Disability Scale to evaluate changes in back pain in 178 subjects undergoing standard back-pain treatments at physical therapy clinics, at a physiatry center, and in family group practices. The interval between Time 1 and Time 3 in the study by Kopec et al ranged from 2 to 4 months. Almost 40% more patients in the follow-up group of the orthotic study showed improvement, as indicated by differences between the Time 1 and Time 2 scores, as compared with the study by Kopec et al. Furthermore, this improvement was nearly two times as great as that of the patients treated with traditional back-pain care (0.66 for the follow-up subjects in the orthotic study *versus* 0.38 for the population of the Kopec et al study) (Table 2).

Table 1. Subjects' Self-reported Diagnoses

Diagnosis	Number of Subjects
Spinal stenosis	1
Fibromyalgia	1
Disk herniations	5
Generalized chronic low-back pain	32
Traumatic injury	14
Sacroiliac dysfunction	4
Sciatica	9

Note: Some subjects reported more than one diagnosis.

Table 2. Average Mean Pain Scores and Change in Scores over Time for the Orthotic Study and the Study by Kopec et al¹¹

Subjects	Time 1 Score	Time 2 Score	Difference (Time 1 minus Time 2)	Time 3 Score	Difference (Time 1 minus Time 3)	Paired <i>t</i> -test	<i>P</i>
All (N = 32)	2.42	1.80	0.66	NA	NA	-3.10 ^a	.0025
Follow-up (N = 23)	2.37	1.71	0.66	1.74	0.66	-2.52 ^b	.01
Kopec et al (N = 178)	2.40	NA	NA	2.02	0.38	NA	NA

Abbreviation: NA, not applicable.

Note: The average mean pain scores in the study by Kopec et al were normalized for accurate comparison with the results of the current study. The interval between Time 1 and Time 2 for all subjects in the current study averaged 2.5 months, and the interval between Time 1 and Time 3 for the Kopec et al study ranged from 2 to 4 months. The interval between Time 1 and Time 3 for follow-up subjects in the current study averaged 13.8 months. The Time 2 score for the Kopec et al study is not reported because it was recorded within 1 week of Time 1.

^a For Time 1 versus Time 2.

^b For Time 1 versus Time 3.

Table 3. Percentage of Subjects with Sagittal Plane Blockages and Limb-Length Discrepancies

Condition	All Subjects (N = 32)	Follow-up Subjects (N = 23)
Functional hallux limitus	91	83
Bilateral functional hallux limitus	88	74
Ankle equinus	91	91
Bilateral ankle equinus	47	74
Functional hallux limitus and ankle equinus	82	87
Limb-length discrepancy	84	74
Functional hallux limitus or ankle equinus	100	100

Most important, however, this improvement was demonstrated over a time period that was more than twice as long as that in the study by Kopec et al (2 to 4 months was the follow-up time in the standard treatment study, as compared with an average of 13.8 months in the orthotic study).

Discussion

Many studies that have been conducted on low-back pain address the structural components of the lumbar spine and related muscles.^{2, 4, 5, 15, 16} Many patients with low-back pain, however, have little or no pathology revealed by scans of the lower back and/or x-ray studies. The purpose of this outcome study was to examine whether the pain experienced by these patients was due to a repetitive injury to the lumbar spine through faulty gait mechanics. It would appear from the results of this study that a significant por-

tion of low-back pain symptoms are related more to the abnormal stresses applied during the gait cycle than to specific anatomic abnormality of the spine itself. In workers' compensation claims, the success of treatment is determined by how rapidly an employee can return to the activity level that his or her job demands. If, however, the job involves even minimal weightbearing activity, inability to return to work is common and is attributed to such things as the specific back problem, worker dissatisfaction, and litigation, rather than to the weightbearing activity.^{5, 12, 17} If gait style is at fault but is not identified as a primary cause of the relapse, erroneous conclusions are made about the etiology of low-back pain.

A gait-related perspective on chronic low-back pain provides a model that is highly consistent with the natural history and frequent symptom recurrence typical of this disorder. Perhaps the most significant finding of this study is that of long-term improvement in alleviation of pain. Prior studies have shown that up to 70% of patients experiencing a disabling attack of low-back pain will have a repeat episode within 12 months.¹⁻³ In the patients in the orthotic study, the average pain level of 2.42 at Time 1 was reduced to 1.74 at Time 3 (13.8 months). This compares with an average pain level of 2.02 at 2 to 4 months for standard methods of care. Thus it appears that examining and, specifically, treating the gait of these patients is crucial to maintaining long-term improvement.

Gait Style and Chronic Low-Back Pain

The gait cycle represents a rhythmic series of events. The average step lasts only 700 to 800 milliseconds. Podiatric physicians customarily divide the gait cycle into the periods of contact, midstance, and propul-

sion, but this may not provide a good understanding of the movement process. A better way to perceive the application of stress would be to view movement not in terms of a single foot action such as heel strike, midstance, and toe-off, but rather as it relates to specific mechanical events that incorporate activity from both right and left limbs. The authors suggest that the gait cycle and its pathomechanics are best understood in terms of three separate phases related to limb support: initial double-limb support (20%), single-limb support (60%), and terminal double-limb support (20%).

Forward movement occurs predominantly during the single-support phase of gait. With both feet on the ground in the initial and terminal double-support phases, the ability to move forward is obviously limited. Over the course of millions of years of evolution, humans have learned to use gravity to their advantage in order to be efficient in the gait process. The power for forward propulsion comes from the swing limb pulling the body's center of mass upward and forward.^{18, 19} Once the center of mass reaches the highest point above the support surface in the middle of the single-support phase, the potential energy stored in this process is returned as kinetic energy as the center of mass gravitates forward and downward. As the center of mass advances, the weight-bearing limb naturally extends out from under the pelvis, and the combination of these movements creates a relative thrust against the support surface and results in continued forward motion. Understanding how the swing phase occurs forms the basis for understanding lumbar stress during the gait cycle.

During stance, the knee and hip reach a fully extended position by the termination of the single-support phase. As terminal double support begins, the weightbearing limb must initiate the preswing phase while the opposite limb is undergoing the heel contact through ground adaptation (ankle plantarflexion) phase. During this preswing period, the fully extended position created during the single-support phase yields to a reversal of motion, which includes flexion of both the hip and knee joints combined with rapid plantarflexion of the ankle and dorsiflexion of the metatarsophalangeal joints of the foot, allowing the trailing limb to accelerate forward in preparation for toe-off.²⁰ The preswing motion is critical for normal swing-phase activity. The laws of conservation of momentum dictate that a powerful and efficient swing phase is easily created when the limb has developed adequate speed just prior to toe-off. Failure to reach sufficient preswing speed will therefore make it more difficult for the muscles to accelerate the swing limb at the moment toe-off occurs (Fig. 2).²¹

Any limitations to hip extension during the single-support phase and prior to the preswing phase result in a loss of range about which hip flexion motion necessary for the preswing phase could originate. This is analogous to hitting a pool ball without drawing back on the cue, or trying to throw a forward pass with a football without first pulling back the throwing arm. Without sufficient "windup," the creation of each subsequent swing phase would either strain the structures associated with hip flexion or require some type of assistance process for efficient and timely action. The neurologic motor-control aspect of swing-phase activity has been shown to be instinctive and therefore "hard-wired" in the central nervous system.²² This indicates that the preswing phase will begin irrespective of the preswing limb's position. If the limb is not in its proper position, the act of swing-phase initiation could cause repetitive stress to the muscles, their origins, and/or their insertions, the structures that perpetuate this activity during thousands of cycles per day. The iliopsoas muscle represents the primary hip flexors at toe-off, and is known to originate from the lumbar spine, disks, vertebral septa, and iliac crest. Failure of proper extension during the single-support phase causes overuse of the iliopsoas muscle, which could become a major etiologic factor in chronic low-back pain.

The ability of the center of mass to move up and over the weightbearing limb is directly related to the ability of the foot to allow efficient and timely sagittal plane motion. Each step requires that the center of mass advance from behind the weightbearing foot to in front of the weightbearing foot; therefore, the pivotal activity in the sagittal plane permitted by the foot is essential for proper gait mechanics. This is analogous to a wheel rotating about its axis: The rim of the wheel rotates in a circle around the hub. The foot serves as an axis, allowing the center of mass to revolve around the foot as though it were the rim. Any restriction of this sagittal plane motion during the single-support phase (ie, sagittal plane blockage) represents a primary gait abnormality and will block the proper timing sequence of extension of the proximal joints.²³

Perry²⁰ has shown that a series of three "rockers" exist within the foot. These sites—the round underside of the calcaneus, the ankle joint (via dorsiflexion), and the metatarsophalangeal joints (via dorsiflexion)—form a progressive series of locations about which sagittal plane motion occurs (Fig. 3). Failure of any of these sites to permit sagittal plane motion in a timely fashion can represent a sagittal plane blockage.²⁴ The underside of the calcaneus is rarely involved in this blockage unless trauma to the



Figure 2. A, Example of appropriate positioning of the right lower extremity in the early preswing phase. There is 15° of hip extension of the limb and the knee is in full extension and fully locked. Heel-off is evident with ankle plantarflexion. The metatarsophalangeal joints are dorsiflexed 25° to 30°. The swing phase is properly prepared with the joints in these positions. B, From the fully extended position, the hip and knee rapidly flex while the ankle plantarflexes and the metatarsophalangeal joints dorsiflex. These late preswing motions permit acceleration of the limb so that at toe-off the iliopsoas muscle acts on a limb that is already in motion. Failure of the preswing mechanism prevents the limb from achieving adequate speed for toe-off and results in the iliopsoas muscle working harder to accelerate the limb.

heel bone has created an anatomic abnormality. Generally, the ankle and metatarsophalangeal joint represent the most common blockage sites. These blockages can occur either singly or in combination with each other and may include ankle equinus, forefoot equinus, and, most commonly, structural or functional hallux limitus.

Motion of the trailing, weightbearing preswing limb will be adversely affected if any or all of the previously mentioned sagittal plane blockages are present. The natural tendency to extend the hip is progressively lost, resulting in a compromised position about which preswing, toe-off, and, finally, the swing phase itself are initiated.

It is known that lumbar disk rupture occurs as a result of either an extremely high force applied to it, as in a fall from a height, or a low force that is repeatedly applied over a long period of time. Lumbar disks are quite strong under vertical loads, but they are rather weak under stress that is applied by rotation and lateral bending.²⁵ Kapandji²⁶ has shown that, if the femur is fixed and the psoas muscles activate, the lumbar vertebrae will move. He attributes this motion reversal to the psoas muscles' lumbar origin, femoral insertion, and subsequent vector, and describes the motion as lumbar rotation and lateral flexion, which are the known mechanical causes of lumbar herniations. Because many lumbar disk herniations occur following seemingly minor accidents, it has previously been surmised that there must be a gradual, unrecognized process that weakens the disk

over time, and the recognized minor accident becomes the "straw that breaks the camel's back."¹⁹ The adverse consequences for the lower back become obvious when one considers the difficulty of the psoas muscles in lifting a limb that is not already moving forward immediately before the limb enters the swing phase thousands of times per day.

When the limb in the preswing phase fails to undergo proper acceleration, the act of swing initiation is impeded. There appears to be a reflexive response to this inability to initiate adequate swing motion: the lateral trunk bend (Fig. 4).²⁷ This response occurs at the moment of toe-off and is toward the contralateral side. The lateral trunk bend appears to universally use the contralateral quadratus lumborum and hip extensors to "drag" the trailing side into motion. This is consistent with the clinical findings in patients with chronic low-back pain. They often exhibit low-back pain symptoms, particularly at the sacroiliac joint, on the same side as the sagittal plane blockage, and greater trochanteric bursitis, often with iliotibial band syndrome, on the opposite side. The patients also have chronic tightness of the quadratus lumborum and gluteal muscles. In addition, because the quadratus lumborum inserts into both the iliac crest and the iliolumbar ligament, its constant overuse can cause rotational stress to the L5 vertebra, further creating an environment for disk weakening. This would explain how minor injuries can create catastrophic disability. It would also explain why there is such a high recurrence rate of symptoms in patients with



Figure 3. Sagittal plane rocker sites of the foot (indicated by arrows). A, The round underside of the calcaneus provides the sagittal plane motion required for the heel-rocker phase of gait, which allows the forefoot to reach the ground (foot flat) following heel strike. B, Passive ankle dorsiflexion (ankle rocker) of at least 10° in the sagittal plane motion is required. This also allows the ankle joint to open up anteriorly and the fibula to translate anteriorly and superiorly, storing elastic energy for plantarflexion of the ankle, which occurs later in the step. C, Dorsiflexion of the metatarsophalangeal joints, particularly the first metatarsophalangeal joint, is coupled with the ankle plantarflexion at heel lift, thereby creating the sagittal plane motion that is necessary for the complete advancement of the body over the foot.



Figure 4. Lateral trunk bend. Limited hip extension of the right lower extremity increases the muscle power required to create the subsequent right-limb swing phase. This results in overuse of the affected (right) limb's iliopsoas muscle as well as the body's compensating by bending from the affected (right) side to the contralateral (left) side during the affected side's toe-off to attempt to “drag” the right limb into the swing phase.

low-back pain. If gait style is not addressed as a cause of low-back pain, sagittal plane blockage could become a perpetuating factor and create a chronically unstable lumbar spine, in spite of standard acute-care measures that treat the site of pain but do not alter the application of stress.

Conclusion

This outcome study shows the importance of examining gait style as a possible cause of chronic or acute recurrent low-back pain. Proper treatment with custom-made foot orthoses is more effective for improving symptoms of low-back pain than is treatment with standard care methods, and the symptoms remain improved for longer periods of time. Interceding in the pathomechanical process, which is a primary cause of low-back pain, reduces both the degree of pain and the rate of recurrence. Treatment by properly trained podiatric physicians and other clinical specialists can have a major effect on total costs of treating this entity, in terms of both treatment and

indemnity, as disability payments and time lost from work are nearly four times the cost of medical treatment in cases of low-back pain.

It is important to recognize that patients with chronic low-back pain do not limp because they hurt; rather, they hurt because they limp. Evaluation and correction of the gait style of these patients have positive results in terms of both symptoms and cost of care.

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