The Effectiveness of Orthotics on the Biomechanics of Runners

A Literature Review

By

Cody Sauser

ID#1048

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Advisor: D. Robert Kuhn, D.C., DACBR, ART®

Abstract

Objective: To discuss how orthotic devices placed in shoes can alter the biomechanics of the lower extremity while running and possibly prevent injury and decrease symptoms of pain from injury.

Data Collection: A computer search of literature from the databases of pubmed, mantis, and Google was performed and the corresponding literature was collected from the learning resource center at Logan College. Special emphasis was placed on the biomechanics of runners affected by orthotics.

Results: Foot orthotic devices do alter the biomechanics of the lower extremity. Results differed depending on what type of orthotic was used, how it was prescribed, and what is was prescribed for. Orthotic devices did alleviate symptoms in people with lower extremity injuries, but no correlation was made between foot type and injury.

Conclusion: More studies need to be performed with custom molded orthotics and how they affect lower extremity kinematics.

Key Indexing Terms: Orthotic; biomechanics; kinematics; patellofemoral pain syndrome.

Introduction

Foot orthotics has been used in clinical settings for many years (1). Mostly they have been prescribed for people with abnormal lower extremity mechanics that can predispose to injury (28), they have been prescribed for people with low back pain (5,9,33), and they have even been prescribed for healthy patients and used as a form of prevention of injury (7,10,11,15,17,27,29,30,39,43). Although this review will give some reference to the literature that is applied to the use of orthotics in healthy populations, it will focus mainly on research that was done in previously injured people and more specifically how orthotics may affect running.

The literature referenced in this paper will cite research that uses mainly two different types of orthotics. To better understand the results of research a brief explanation of what orthotics are is warranted. There are many people who think that orthotics are simply arch supports. The fact is orthotics are inserts that are placed in the shoe and is intended to correct an abnormality in walking or correct a structural default that may predispose a person to injury (27,30,35,45). There are three main types of orthotics. Those types of orthotics are called rigid, semi-rigid, and soft. The rigid orthotics are functional in nature and are used to guide and/or restrict the motion of foot joints. Soft orthotics are used more for comfort, shock absorption, and balance. Semirigid orthotics are used primarily for balance and are prescribed mostly to athletes (42).

Also, before discussing the results of the literature, a brief discussion of the biomechanics of the lower extremity during gait is necessary. When the leg externally rotates the heel inverts and the forefoot spinets during the stance phase of gait. When the gait cycle moves from mid-stance to toe-off the leg internally rotates, the heel everts, and the forefoot pronates. The longitudinal arch of the foot is acted on mainly by three muscles. The tibialis posterior, peroneus longus, and tibialis anterior. The tibialis posterior is responsible for flexing the midfoot and the tibialis anterior decelerates the foot as it strikes the ground to prevent slappage gait. The muscle activity during gait is as follows: The tibialis anterior contracts eccentrically from heel strike to foot flat while the gastrosoleus complex is quiet. The gastrocsoleus complex contracts eccentrically during foot flat while the tibialis anterior is quiet. The gastrocsoleus complex contracts concentrically during heel rise and the tibialis anterior is quiet. The only difference in this cycle during running and during walking is that at some point during running, weight is not being borne on either leg resulting in much more force during heel strike (32).

The purpose of this paper is to review the research that mainly focuses on the efficacy of orthotics when given to runners with injuries (8,12,16,44), given to prevent injury (17,27-29,39,43,45) and how different types of foot orthoses affect lower extremity biomechanics (43).

Methodology

The primary research databases used for this review are pubmed, mantis, and Google. Also, on Google a search was done for websites using keywords such as orthotics, the effects of orthotics, lower extremity biomechanics, and history of orthotics. The research for this literature review was done at Logan College of Chiropractic at the computer lab inside the learning resources center. Research articles were searched for online and once they were listed the corresponding scientific journals were then pulled from the journal section of the learning resource center. The journals were read and selected according to relevancy. All articles that focused on children were immediately removed as this paper's focus is on the research performed on adults. The articles mentioning children that were not removed had either some correlation with adult studies or referenced a very common injury that occurs in runners. Most articles that were selected were written no more than twenty years ago. This search was conducted over a five-week period dating from July 3, 2005 to July 24, 2005, and from October 3, 2005 and concluded on October 13, 2005.

While on pubmed the word orthotics was entered, then history of orthotics, and lower extremity injuries. Next, a Boolean search was done using orthotics AND biomechanics, orthotics AND low back pain, orthotics AND patellofemoral pain syndrome. The journal articles that were obtained from this database were read and many of the articles that were cited in those papers were also used for this one.

Results

The results of this review show many aspects of orthotics. They discuss how different types of orthotic prescriptions may be more appropriate than others and how they affect lower extremity kinematics. There are several kinematic factors that predispose a runner to injury. Some of those factors are foot eversion and eversion velocity (26), increased internal tibial rotation (31), increased impact peak and loading rate of the vertical ground reaction force (18), increased ankle inversion moments (24), and increased knee abduction and external rotation moments (40). Munderman, et al discussed the topic of which was more successful, custom-molding or posting (28). These are two different ways of fitting orthotic devices. Molding usually consists of a neutral shell that is fabricated by molding it to a subject's foot. Posting is simply a way of adding material to the medial or lateral side of orthotics. Their study showed opposite results for each one. They showed that the biomechanics of runners do change when using both of these techniques. However, when combined molding was the more successful of the two techniques. In other words, both techniques produced changes in kinematics, but when the two were combined, the effects of molding were the dominant results with just minor effects from posting being manifested (28). Their study was important because it was not well understood how these two techniques actually worked. This study was prompted because it has been suggested that certain faulty biomechanics can predispose runners to injury. They found that posting reduced foot eversion and foot eversion velocity, and tibial rotation, and ankle inversion. Also, there was an increase in external rotation of the knee and abduction occurred much later during stance. Impact peak and loading rate were also increased. Molding had the exact opposite effect that posting did. When posting and molding were combined, they had similar effects to that of molding but ankle inversion, impact peak and loading rate were further reduced and knee abduction occurred much later than molding alone (28).

There have been many that have suggested that one of the things that can cause faulty biomechanics during running is hyperpronation of the foot that occurs with a condition known as pes planus. Pes planus can be defined as a condition in which the arch of the foot collapses and comes in contact with the ground (45). It has been further suggested that people with flat feet should only receive orthotic prescription if the problem actually causes pain (45). This theory is further supported by a study done by Michelson, et al. They did a study of 196 collegiate athletes and concluded that there was no scientific basis to support the prescription of orthotics to asymptomatic athletes with asymptomatic pes planus (27). They came to this conclusion because in their study they could not find a correlation between pes planus as measured by medial midfoot contact area and the incidence of lower extremity injury of any sort (27). Another study was done by Hogan, et al that tried to see if there was a correlation between arch height and lower limb disability. They concluded that flexible flat feet in adults was not a source of disability and that orthotics should not be prescribed in children to prevent future adult disabilities (17). This paper referred to the fact that some believe that children should be treated before arch height develops in order to prevent any future problems (39). Gialdi et al did a study of army recruits and found that soldiers with higher arches were not less prone to injury. In fact, of all of the subjects that were studied, the soldiers with the lowest arched feet had the lowest incidence of stress fractures and the soldiers with the highest arches had the highest incidence of stress fractures (10). Also, Nigg showed that no one could conclude that impact forces due to pronation can cause the development of acute or chronic running-related injuries (30). Despite all of the studies that have shown that arch height is not a risk factor for injury, there is a study that showed that the intervention of orthotics significantly reduced oxygen consumption during walking in people with flat feet who had been complaining of fatigue (35). There have been other studies on oxygen consumption in patients with an ambulatory disability. Hussein et al did not use an orthotic as defined in the introduction of this paper, but they did show that a shoe-lift could improve oxygen consumption in people with an immobilized knee (19). To be more specific, shoe lifts that were placed on the side contralateral of the immobilized knee consumed 20% less oxygen during walking compared to without the use of a contralateral shoe lift (19).

Nigg et al performed a study to determine the effectiveness of orthotics on kinematics, center of pressure, and leg joint moments in runners (29). With respect to kinematics, they concluded that the use of orthotic devices were not sufficient to align the healthy individual. In regards to this alignment, it means that orthotics are able to minimize extreme joint amplitudes. It does not mean to say that healthy individuals are "misaligned" in their lower extremity, but means simply that the body will undergo more extreme stresses during running. Their study also showed that the center of pressure was altered with the use of orthotics. The interesting thing about this study was that there was little predictability in movement of the center of pressure when the insert was positioned underneath a certain part of the foot. With regards to joint moments, they concluded that the orthotics did not predictably improve the moments responsible for locomotion but it did improve dynamic stability. Williams et al also studied the effect of orthotics on the lower extremity mechanics of runners (43). Their study however, compared different types of orthotics rather than orthotics versus no orthotics. Their study concluded that the use of inverted orthotics reduced inversion at the rearfoot and subsequently reducing the risk of foot and ankle injury. However, there was a cost for this change because it put a greater strain on the lateral portions of the knee and possibly putting that joint at a greater risk for injury.

It has been suggested that orthotics should not only be used as a preventative device but only as a means of treating injury. One of the more common injuries in runners is patellofemoral pain syndrome which is a knee injury that can be caused by over pronation of the feet which causes a compensatory rotation of the leg and disrupts the normal movement of the patellofemoral complex (44). Eng et al evaluated twenty adolescent females with patellofemoral pain syndrome while being treated with exercise programs and orthotic intervention (8). In this literature review all studies have been with adults as subjects. There was an exception made with this resource because not only is patellofemoral pain syndrome a common injury to runners (14), it is also the leading cause of chronic knee pain in adolescents (3) Their study consisted of a group that was treated with rehabilitation only and a group that was treated with rehabilitation and orthotic intervention. The results of their study showed that while both groups demonstrated a decrease in painful symptoms, the group that was treated with orthotics showed a much greater decrease in symptoms. The group that was treated with rehabilitation only also had a decrease in symptoms, but the decrease was significantly less that those that were treated with both rehabilitation and orthotics (8). Patellofemoral pain syndrome is just one of many lower extremity injuries that have been treated with orthotics. Gross et al performed a study of 500 subjects with various different lower extremity injuries (12). The group that they evaluated complained of, or was diagnosed with pes planus, leg length inequality, patellofemoral syndrome, plantar fascitis, Achilles tendonitis, and shin splints. They showed that of the 500 patients interviewed over 75% of the patients reported complete resolution or significant decrease in their symptoms. Also, 90% of the participants were so satisfied with the orthotic devices that they continued to wear the devices even after their symptoms had resolved (12).

The role of orthotics in the treatment of patellofemoral pain syndrome with regards to excessive pronation of the feet. Hertel et al studied the effects orthotics has on neuromuscular control with regards to the biomechanics of the patellofemoral joint (16). They wanted to measure the electromyographic activity of the gluteus medius and quadriceps muscles during selected exercises and see how they were affected by the use of orthotic shoe inserts. The subjects that were used in these exercises were of three different foot types: pes planus, pes cavus, and pes rectus. Their results showed that during slower and more controlled exercises, subjects had enhanced gluteus medius and quadriceps activity when the subjects were wearing orthotics. However, more explosive exercises did not show any significant improvement while wearing orthotics. Of all of the results that were posted, foot type had no influence at all on the results of the tests. This study was important because of the role that the previously mentioned muscles play in the development of patellofemoral pain syndrome. An imbalance between the vastus medialis and the vastus lateralis can cause an abnormal movement of the patella in the medial and lateral direction. If the gluteus medius is inhibited, control of the pelvis is lost, which can cause excessive internal rotation of the femur causing the patella to track laterally. This series of events will further cause internal rotation of the tibia and subsequent pronation of the foot. An interesting study was done by Olmsted and Hertel that measured the effects of orthotics on postural control in people with pes planus, pes cavus, and pes rectus (34). Their results were interesting. They showed that postural stability was improved with orthotics in patients with cavus feet but not in patients with rectus or planus feet. In this study postural control had two different meanings. Static postural stability is simply a measure of sensorimotor function and is assessed by one leg standing tests (34). Dynamic postural stability was assessed with a series of lower extremity reaching tests that would detect postural instability in subjects with chronic ankle instability (34). Their reasoning behind this result was that the patients with cavus feet had less contact between the plantar surface of the foot and the ground and therefore had less postural stability. When these patients wore orthotics they had less distance to pronate and thus provided a more solid base for them to stand on both statically and dynamically (34). Rome and Brown also participated in a study that showed the effects of orthotics on postural stability (36). Their study was different from the previously mentioned in that their subjects only had excessively pronated feet and static posture was measured but not dynamic posture. It is interesting to note that in the previous study only the cavus feet showed improvement while in this study only people with planus feet were measured but they still showed improvement. This is probably due to the difference in methodology of the two projects. Stude and Brink performed a study that measured the effects of orthotics on balance and proprioception in experienced golfers (41). The golfers were analyzed while simulating nine holes of golf without the use of orthotics. They were then given the orthotics and asked to wear them daily for six weeks at which point they were retested once again by simulation of nine holes of golf. Once again the results showed that after being retested after orthotic intervention both balance and proprioception were improved in all participants (41). Another interesting side note to this study is the fact that the fatigue that comes with playing nine holes of golf may have also been reduced after the intervention of orthotics. This would agree with the previous study that concluded that people wearing orthotics consumed less oxygen while walking and thereby reducing fatigue (35).

There are other ways to objectively measure the effectiveness of orthotics. The efficacy of orthotics has been measured by plain film radiograph. Kuhn et al measured the alignment of the foot by radiograph pre and post orthotic intervention (21). Their study measured people with flexible pes planus. Their study as predicted showed improvement in pedal alignment after orthotic intervention. They concluded that orthotics should be used for the following reasons: preventing pronation and supporting supination, because an asymmetric pedal foundation is a contributing factor in pelvic unleveling, flexible scoliosis, and low back pain (6,11,23,37); improve heel shock absorption because excessive pronation or supination make people more susceptible to stress fractures (2,25); prevent biomechanical stress that leads to ankle sprains, lower leg compartment syndromes, patellofemoral dysfunction, medial knee degenerative joint disease, stress fractures, iliotibial band inflammation, pelvic unleveling, and low back pain(7,11,15); and enhance neuromuscular re-education which is altered in subjects with pes planus and can disturb balance, gait, reciprocal inhibition, innervation of muscles, and posture(4,13,22)(21).

Faulty biomechanics of the lower extremity or more specifically the knee, can be measured by the quadriceps femoris angle. This angle is formed by lining up the anterior superior iliac spine with the center of the patella and the center of the patella with the tibial tuberosity. An excessively pronated foot can alter this angle. Kuhn et al also performed a study on how the insertion of an orthotic device can alter the quadriceps femoris angle (20). All subjects in this study exhibited excessive pronation bilaterally. The results of this study showed an immediate reduction of the quadriceps femoris angle in most of the participants. There was also a reduction in asymmetry from knee to knee in participants. The subjects in this study were all asymptomatic and it was recommended that a functional evaluation be performed in the future.

There have also been a number of studies trying to discover a way to screen patients to see if they would be legitimate candidates for orthotic intervention. Smith et al published a case report on how they used taping as a way to judge if a patient was a good candidate for orthotics (38). The subject used in their study was a 32-year-old soccer player with a history of Achilles tendonopathy. Their hypothesis was to tape the patients' feet in such a way to prevent pronation. If this procedure were effective in eliminating or reducing symptoms then this patient would qualify for orthotic intervention. As predicted the patient received a marked decrease in painful symptoms after anti-pronation taping. This patient therefore was given orthotic inserts and received similar results to that of the anti-pronation taping.

Discussion/Conclusion

There are two different mechanisms that have been proposed to be the reason behind the effectiveness of orthotic inserts. First of all, orthotics can limit excessive pronation of the foot thereby preventing excessive rotation at the ankle, knee, and hip (28). All of this excessive rotation can lead to an increased risk of injuring the previously listed joints and has even been known to be a contributing factor in the cause of low back pain (6, 11, 23, 37). Secondly, orthotics has been shown to be effective in improving neuromuscular re-education (34). More specifically patients who have been prescribed orthotics have shown an improvement in postural stability both statically and dynamically (34).

The topic of how effective orthotics could actually be is one that can be taken in many different directions. First of all, clinicians need to more closely examine why they are prescribing the orthotics. Are they preventing injury or are they treating injury? Are they enhancing neuromuscular re-education or are they simply trying to make walking and running more comfortable? All of these questions need to be addressed. Also, if a patient is a probable candidate for orthotic intervention what type of orthotic should be employed and how should it be placed in the shoe? (28)

Research has shown that orthotic devices have great potential to be of therapeutic benefit to people in the realm of lower extremity injury and biomechanics (18,24,26,28,40). In almost every study that was reviewed in this paper there was some type of change or improvement in subjects, who were fitted with orthotic devices, and in many cases the changes were expected and in some cases there were a few surprises. In order for the success of orthotic devices to be realized all of the previous situations must be taken into account and researched meticulously until a satisfactory understanding of orthotic devices can be reached. From the research cited in this review, custom molding of foot orthotics seems to be a good start for measuring further clinical successes (2,21,28). It is the opinion of this author that further research should be done on this topic beginning with the studies like the ones listed above that have some type of clinical efficacy. If this occurs it could be of great benefit for many health care fields that may include chiropractic, podiatry, physical therapy, and athletic training. It is also suggested that more study should be done on what the intervention of orthotic devices can do for the treatment of low back pain and possibly other spinal conditions.

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