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# The Efficacy of Custom and Prefabricated Orthotic Interventions for Common Running Related Injuries

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# The Efficacy of Custom and Prefabricated Orthotic Interventions for Common Running Related Injuries.

One of the most popular sports in the world is running. Nearly 17 million people in the United States alone crossed finish lines in road races in 2017.[1] Unfortunately, there is an extremely high rate of running related injuries (RRI) that prevent or hinder individuals from training and competing. A 2007 systematic review revealed that the incidence of lower extremity running related injuries ranges from 19.4% to 79.3%.[2] Orthotics are frequently prescribed as a conservative treatment option for various injuries such as plantar fasciitis (PF), patellofemoral pain syndrome (PFPS), medial tibial stress syndrome (MTSS), and stress fractures. Although commonly prescribed, the research on the mechanisms of orthotics and their effectiveness is convoluted and conflicting. The following paper aims to examine the following question: Does the current literature on orthotics and running kinematics/kinetics support the prescription/recommendation of custom or off-the-shelf orthotics for common running related injuries such as MTSS, PF, and PFPS?

Orthotics are shoe inserts designed to alter the function of foot during walking and running. There are two overlying categories for orthotics: custom and prefabricated. Custom orthotics are designed, fitted and molded for a specific individual. Prefabricated orthotics can be bought over the counter at most sporting goods stores or specialty running shops. For example, Dr. Scholls and Superfeet are prefabricated orthotics that come in different sizes and models, but are not specifically made for one individual. Orthotics can be categorized further by their purpose. Hard, or rigid, orthotics are generally meant to control the motion of the ankle complex.

Soft and flexible orthotics are more compressible and aim to absorb shock and increase comfort.[3] There are also semi-rigid orthotics which fall somewhere in the middle. There is one other way orthotics can be categorized: accommodative and functional.[4] Accommodative orthotics are softer and are designed to redistribute forces throughout the plantar surface of the foot. Functional orthotics are more rigid and aim to alter the movement pattern of the foot. Not only are there different ways to categorize orthotics, but there are many ways they can be customized. Posting is a common modification which involves adding material to one portion of the insert. Orthotics are usually posted medially, but can have lateral posting. The posting can also be shifted either anteriorly towards the arch or posteriorly by the heel. Another, more aggressive, type of modification places the foot in an in an inverted position.[5] On top of the various types of modifications, there are numerous materials that have been used for orthotics such as thermoplastics, acrylic, composite carbon fibers and polyethylene foam.[6]

Since there is various terminology and various modifications and material choices it is difficult to draw definitive conclusions from the literature on orthotics and RRIs. However, there is still a large amount of information on orthotics that might be useful for clinicians. There are multiple ways to observe how orthotics influencing either running gait or pain. It is common to observe how orthotics influence kinematics and kinetics.[7] Kinematic variables refer to the motion and timing of body segments. Some kinematic variables often looked at are maximum rearfoot eversion, eversion velocity, time to maximum eversion, tibial internal rotation, initial inversion angle and total rearfoot motion. Kinetic data involves the forces produced by or act upon our muscles and joints. Commonly assessed kinetics that concern orthotics are impact peaks, loading rate, ankle inversion moments and knee moments. These can be assessed in healthy participants or in participants with a specific injury history. There are studies that assess patients before and after orthotics interventions in either the short or long term. These can observe changes in kinematic and kinetic variables, or they can just track pain improvements. One more uncommon type of retrospective research looks at the musculature or soft tissue of cadavers.[7]

Pronation is a term many runners are familiar with. Pronation consists of subtalar eversion, ankle dorsiflexion, and forefoot abduction. Typically, at initial contact the foot is in an inverted position and then rolls inward (eversion) to absorb shock. It is a common theory that prolonged pronation alters lower extremity mechanics which may result in injury.[8] Lundberg et al. suggests that eversion is coupled with tibial internal rotation.[9] Eversion and tibial internal rotation typically occur between initial contact and mid-stance (foot in full contact with the ground). At mid-stance these movements should reverse as the foot prepares to push of the ground. If the subtalar joint remains pronated or continues to pronate, the tibia is unable to externally rotate. This may put unwanted stress on the lower extremity all the way up to the knee.[10] One of the main theories behind prescribing orthotics is that they will prevent proximal unwanted movements by changing distal kinematics. Before exploring how these mechanics relate to injuries, it is important to know if orthotics influence these variables.

Numerous recent studies have examined how orthotics alter lower body kinematics.[11–14] Mündermann et al. examined the kinematics of twenty-one healthy runners. Participants ran over ground in a controlled condition as well as in medially posted orthotics. They found a 2.3° reduction in maximum rearfoot eversion. Additionally, maximum tibial internal rotation was also reduced.[11] Dixon and McNally found similar changes (2.2°) in eversion when twenty-two runners with a history of various RRIs wore custom semi-rigid orthotics with medial posting.[12] MacLean et al. examined the biomechanics of twelve female runners with a history of knee injuries. Semi-rigid, custom foot orthotics reduced maximum eversion and eversion velocity.[13] The results were replicated in another study done by MacLean et al. with what appeared to be the same subjects. In addition to rearfoot eversion, he found significant decreases in tibial internal rotation in the orthotic condition.[14] In each of these studies there was a small, but significant change in running mechanics. Although the changes are small, but given the number of steps a runner will take in a week of training, these small changes might make a big difference. For example, a runner who runs twenty miles a week at a pace of 9:00 minutes per mile will take over 30,000 steps per week if their cadence is 170 steps/min.

There are also some recent studies that do not corroborate the findings of the previously mentioned research.[15–18] Ferber et al. examined eleven runners with a history of RRIs in both standard orthotics and inverted orthotics. Rather than just observing rearfoot eversion, he examined the coupling between eversion and tibial internal rotation. They found no significant differences in joint coupling between the controls and treatments.[15] Donoghue et al. observed kinematics in twelve runners with past achilles injuries in a custom orthotic with medial support. Interestingly, they found a significant increase in maximum rearfoot eversion.[16] No changes in eversion were found when eight military recruits wore semi-rigid orthotics.[17] The previously mentioned studies examined kinematics using external markers, but a small study done by Stacoff et al. used different methods. Five subjects underwent surgery to place bone pins into the calcaneus and tibial condyle. Standard kinematics were compared to kinematics with prefabricated orthotics and two modified versions of the prefabricated orthotic. They found insignificant decreases in rearfoot eversion in the orthotic conditions and the three treatment conditions had no significant differences between each other. While they did not find a difference in eversion, they did examine reduced tibial internal rotation.[18] While these studies contradict the support for orthotics reducing kinematic variables, it should be noted that subjective measures of pain were reduced in two of the aforementioned studies.[15,16]

There is also literature that suggests orthotics alter kinetic variables such as loading rate and impact peak during gait as well.[13,14,17,19–21] Following initial contact, foot pronation contributes to a loading response. This is where our bodies absorb shock and dissipate ground reaction forces. Loading rate accounts for the ground reaction force (GRF) applied over an amount of time during loading response. Loading rate is similar to impulse. The more time spent in loading response, the lower the forces on the body will be. Therefore, a lower loading rate may decrease the likelihood of injury. Loading rate leads up to an impact peak. This is the largest ground reaction force during running besides the force generated during propulsion. Recent literature seems to be consistent in suggesting orthotics reduce these two variables. For example, Dixon et al. (semi rigid, no medial posting)[17] and MacLean et al. (custom, semi-rigid, medially posted)[13,14] both found significant reductions in vertical impact peak and loading rate. However, Butler et al. found no difference in kinetic variables in a group of healthy runners who wore soft, medially posted orthotics. A previously mentioned study done by Mündermann et al. found reduced loading rate due to orthotics that were molded, but found increased loading rate in the posted orthotic group.[11]

Another interesting kinetic variable is ankle inversion moment. During pronation, the ankle invertors (tibialis posterior) resist and eccentrically control eversion. MacLean et al. suggest that a smaller ankle inversion moment represents the work done by this musculature.[13] Therefore, we can infer that the smaller this moment is, the less strain on lower extremity musculature which may decrease the likelihood of injury. Two studies done by MacLean et al.

found decreased inversion moments with the use of orthotics.[13,14] Additionally, Nigg et al. also reported smaller inversion moments when fifteen healthy runners wore a full medial insert.[22]

Clearly, orthotics can alter running kinematics and kinetics, however, it is slightly variable. A limitation to only examining kinetics and kinematics is that mechanisms for injury are not always clear. There is evidence and theories that suggest mechanics such as excessive pronation can be linked to PF, stress fractures, MTSS, and PFPS, [10,23–27] however these variables do not always predict injuries correctly.[28–30] Therefore, it is important to consider studies in which orthotic interventions were used on individuals with specific injuries.

PF is the inflammation of the plantar fascia, a thick band of tissue that originates from the calcaneal tuberosity and inserts on the proximal phalanges.[31,32] Excessive pronation may place strain on the plantar fascia.[33] A meta-analysis done by Taunton et al. did found that roughly 55% of individuals with PF exhibited overpronation.[32] Kibler et al. found strength deficits in the posterior calf and foot musculature of PF athletes compared with asymptomatic athletes.[34] Posterior calf muscles such as the tibialis posterior and gastrocnemius are play a role in eccentrically controlling pronation. This suggests that there is a relationship between these muscles, excessive pronation, and PF, but it is unclear which of the three is the root of the issue. On the contrary, Warren and Jones were unable to predict PF in runners based on running tests.[28] Additionally, Pohl et al. observed female runners with and without PF and found no differences in rearfoot kinematics. Although, they did find that the runners with PF exhibited significantly larger loading rates.[29] Despite the conflicting mechanisms for PF, Taunton et al. found that orthotics were prescribed to around 50% of individuals with PF. Given that orthotics consistently decreased loading rate, it is possible that orthotics might play a role in decreasing forces through the foot in individuals with PF. One study that provides support for prescribing orthotics examined the influence of custom and prefabricated orthotics on PF symptoms and pain. 236 patients were assigned to one of a five groups. A stretching group, stretching and prefabricated (three different models), and stretching with custom orthotics. They found that the best improvements were found when using prefabricated orthotics in combination with stretching.[35]

Another common injury associated with running is PFPS. As mentioned previously, excessive pronation may delay tibial external rotation which creates a biomechanical dilemma at the knee.[8–10] As in PF, there is variability in the research when relating biomechanics to injury. For example, Boldt et al. examined 20 runners with and without PFPS. They found no kinematic differences between the two groups when running in a medially supported orthotic.[36] While there is inconsistencies in the literature regarding kinematics, a few studies found that orthotics was a positive treatment for individuals with PFPS.[30,37,38] Eng et al. compared an exercise treatment to exercise paired with a soft custom orthotic with medial posting. Both groups reported pain decreased significantly, but the orthotic group decreased significantly compared to the exercise only group.[30] Collins et al. supported this in a larger study with 179 participants. One group received only physiotherapy while other treatment groups received a prefabricated orthotic or both orthotics and physiotherapy. All groups improved, but the orthotic alone was just as effective as physiotherapy.[37] Lastly, Barton et al. found reductions in pain while performing single leg squats, sit to stand, and reported usual and worst pain when assigned a prefabricated orthotic with medial arch support.[38] An interesting similarity between these three studies is that the interventions all included medial posting. It is possible that medial posting decreased either maximum eversion or time to eversion and did not delay external rotation of the tibia. This would potentially decrease the strain on the patella during running.

MTSS and stress fractures are commonly associated RRIs. MTSS is a periostitis of the medial portion of the tibia. This is when muscle fibers rip away from the bone and cause inflammation.[39] It has been reported that excessive pronation is one cause of the periostitis by putting strain on the muscles that attach to the tibia, mainly the tibialis posterior and soleus.[25,26,39] This microdamage may result in a stress fracture if high loads are continually applied to the extremity. Military recruits often experience high loads as they are frequently training at high intensities.[40] Given that orthotics have shown to reduce loads during running, the relationship between stress fractures and orthotics has been examined in the military.[41,42] Simkin et al. examined arch type, orthotics and stress fractures in 295 male military recruits. 143 recruits wore prefabricated semi-rigid orthotics. They found that orthotics significantly reduced femoral stress fractures and metatarsal stress fractures in recruits with high and low arches respectively.[41] Finestone et al. examined rates of stress fractures in 404 infantry recruits who used either soft or semi-rigid orthotics, or a normal shoe insert. The incidence of stress fractures in those groups were 10%, 15%, and 27% respectively.[42] These studies support the notion that orthotics can absorb shock effectively enough to reduce the incidence of stress fractures.

Despite some conflicting research, various types of orthotics can be successful at modify gait kinematics and kinetics as well as reducing pain and reducing the likelihood of injury. However, due to variability and some inconsistent findings, the exact mechanism by which orthotics are effective is unknown. Additionally, there is not a clear link between certain kinematics or kinetics and RRIs. There are many limitations to summarizing the research on orthotics. There are many differences between studies and it is difficult to compare them all. Some studies use just males or just females. Some studies observe healthy individuals in orthotics while others use orthotics for injured individuals. Stacoff et al. suggests that markers placed on the body might not be accurate due to skin and soft tissue movement.[18] However, the use of bone markers is invasive and impractical for studies with large numbers of subjects. Aside from research methodology, there are also inconsistencies in the types of orthotics used. There are many different categories of orthotics and many variations in molding and material. The variability in literature and the endless amounts of orthotics is a vicious circle. No single type of orthotic is supported by research so businesses and scientists are designing many different types of orthotics. Because there are so many types of orthotics out there, it is researchers must choose a few types to study and it would be impossible to design a controlled study that tests all the options for orthotics.

It would be unrealistic to make a blanket statement on the efficacy of prescribing orthotics. There are numerous factors to consider when dealing with RRIs. For example, it has been estimated that up to 60% of running injuries can be explain by training errors.[43] Therefore, orthotics should not be blindly prescribed without considering training related factors. For example, the mileage of the athlete, how competitive they are, the surfaces they run on, and how fast they run should all be taken into consideration. If a runner's history is considered, it is difficult to ignore the evidence that supports the use of orthotics for RRIs. Despite the limitations mentioned above, orthotics potentially alters deleterious running mechanics and have even been found to reduce pain even when mechanics remain unchanged.  In conclusion, the literature does not support nor refute the use of orthotics for RRIs, but on a case by case basis orthotics do seem to be a viable option for treating and preventing RRIs such as PF, PFPS, and MTSS/stress fractures.

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