Biomechanical analysis of the role of shoe inserts for over pronated foot during running

by

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Introduction

1.1 Pronation
Subtalar joint pronation is a motion which combines dorsiflexion, abduction, and eversion of the foot which respect to the leg, providing the primary mechanism by which transverse rotations occur between the leg and foot [1]. Excessive and an increased velocity of pronation during stance, have been related with overuse injuries in running, although the mechanisms behind this relationship are still unclear [2] [3] [4].

![Figura 1.1 Pronated foot Vs Normal foot](adapted from Philadelphia Runner website: http://www.philadelphiarunner.com)

1.2 Overuse Injuries
Overuse injuries are those injuries that result from repetitive subtraumatic forces that overuse and stress the musculoskeletal tissues [5]. Willems et al. 2006 have identified the central heel strike, the excessive eversion and the increased lateral roll off of the ankle as risk factors for exercise related lower leg pain. Exercise related leg pain includes, shin splints, shin pain, medial tibial stress pain, periostitis, compartment syndrome and stress fractures [2]. On a second study, Willems found that the risk factors running with shoes are the increased pronation excursion and accelerated reinversion[3]. These studies were carried on by comparing an injury group of subjects that developed exercise related lower leg pain with a group of subjects who had never
1.3 Inserts, Orthoses, Shoes

had an injury history in the lower limb. The results from these studies showed that the gait pattern of subjects who developed this type of injury is different from a normal population who hadn’t had injuries in the lower limb. The general approach to find the causes that lead to overuse injuries from an over-pronated foot is by comparing different gait variables between the healthy population and the foot pronated population with different type of inserts that artificially change the pronation [1] [4]. The most common types of gait parameter evaluation used in literature are: kinematic, kinetics or plantar pressure and electromyography [6][7].

1.3 Inserts, Orthoses, Shoes

Inserts, orthoses and special shoes are the common ways of changing the gait pattern for rehabilitation or to correct the foot posture in individuals. Murley et al. 2009[7], carried out a systematic review to find the effects of foot posture, foot orthoses and footwear on the lower limb muscle activity during walking and running. The papers taken into consideration were included in the study if they satisfied the inclusion criteria which were: main outcome measure for muscle were EMG or MRI, independent variables include variation in posture, footwear or orthoses used, statistical analysis must have been carried out, and more than one subject with no neurological disease were tested. Finally 38 papers were chosen: 6 on foot posture, 12 on foot orthoses and 20 on footwear. A quality assessment was then made based on the way the EMG measurement methodology was reported on in each paper. The foot orthoses studies compared different types of orthoses of different materials; customized foot orthoses[8][9] or fixed medial wedging[9][10], semirigid polypropylene shells [8][11] or ethylene vinyl acetate(EVA) made midsoles, with standard control shoes (walking) or sandals(running). A general result independent from the type of orthoses was that peroneus longus, tibialis anterior EMG amplitude and tibialis anterior duration, were greater when wearing foot orthoses. The majority of the papers examined were about footwear and showed different styles of footwear. Shoes with varying heel height were reported to make changes in both lower back and lower limb EMG muscles activity with increased heel height. Destabilizing footwear designed to enhance the ankle musculature were used also to treatment injury groups and for prevention[12] [13] [14]. Similar results as the orthoses studies were found for the footwear studies but a clear conclusion on the effect on muscle function couldn’t be found due to different methods and results.
1.4 Problem Statement

1.3.1 Randomized Controlled Trials (RCTs)
The previously discussed studies on orthoses, were based on laboratory research and aimed at finding the biomechanical effect of footwear and orthoses. An approach to establish the effect of footwear to prevent overuse injuries, is the randomized controlled trials method (RCTs). The RCTs is a statistical method that compares a treatment group with a control group under a defined protocol which follow a generally accepted guideline[15]. The aim of this method is to reduce the risk of bias, i.e. when there is an error in choosing the population sample and the assumptions on the subjects are not true so that no reliable interpretation of the results could be done. A systematic review of RCTs studies was conducted to analyze the effect of orthoses or shoes to prevent overuse injuries[16]. The quality assessment of the papers reviewed was based on their methodology and assessed the following features: randomization, concealed allocation, baseline similarity of the study group, blinding of participants, blinding of care providers, blinding of assessors, co-interventions, compliance, drop out rate, timing of outcome measures, and intention-to-treatment analysis. Many of these studies were done on military recruits due to the homogeneity of the population (age, physical characteristics, race, gender) and the possibility of controlling the trials in the military academy. A subdivision of the papers was done based on the type of study: orthoses or inserts, external joint supports, and training programs. The orthoses and insoles studies selected were aimed at reducing the shock absorption. The analysis confirmed that the use of insoles [17][18][19], could be effective in preventing injuries, but still these results are in contradiction with other studies[20] and a real comparison was difficult because of the clinical and methodological differences of these studies.

1.4 Problem Statement

1.4.1 Background
Solutions to prevent injuries due to over pronation are provided by special shoes[21], inserts [22] or orthotics [9]. Murley et al. 2009 [7] reviews several papers that have found evidences of the feasibility of preventing some lower limb injuries (specially femoral stress fractures and shin splints) with foot orthoses. Since the clear mechanism that lead to injuries is not identified, the main goal of these solutions is to directly reduce the pronation (providing a support to the medial foot) and the shock absorption during stance phase to reset the normal condition. Changes have been found in muscle activity. According to Mundermann et al. 2006 [9], the tibialis anterior, the vastus medialis, the vastus lateralis and rectus femoris revealed significant changes in global EMG intensity during pre-heel-strike with orthoses compared to control insert. The
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tibialis anterioris, the peroneus longus, the gastrocnemius medialis, the biceps femoris showed significant changes in global EMG intensity during post-heel-strike with orthoses compared to control insert. Nawoczenski et al. 1999 [8] compared customized foot orthoses with running sandals and obtained significant greater RMS EMG amplitude values with orthoses in the tibialis anterior, and significantly lower RMS EMG amplitude for the biceps femoris. O’Connor et al. 2006[23] found a similar result for the tibialis anterior comparing a neutral running shoe with a running shoe with medial wedge. Some studies suggest that pronation is associated with greater EMG amplitude of invertor muscles such as tibialis anterior and flexor hallus [24,25] and lower EMG amplitudes for evertor muscles such as peroneus longus. Nigg et al. 2001[26] suggested a new paradigm that defines the forces acting on the foot during the stance phase, as an input signal. According to this new concept, a muscle adaptation followed by these inputs aims at maintaining the preferred joint movement path for a given movement task (e.g. running). Any intervention that supports the preferred movement path, reduces the muscle activity, if it counteracts the preferred movement path, muscle activity must be increased. This concept implies that the “movement control” during stance phase is not important to align the skeleton but attempts to control the movement change muscle activity during the stance phase which result for the person in an improved comfort. In the studies cited orthoses and shoe inserts were able to influence muscle activity. Shoe inserts, basically provide a support to the foot arch and limit its collapsing during foot pronation in the stance phase of gait. This solution may alter the ankle joint and the knee joint muscles activity. Foot orthoses and shoe inserts aim is also to adsorb the shock transmission to the lower limb during heel strike of the foot.

Several studies on shoe inserts that have given different results were discussed. Some confirm the hypothesis that inserts change the gait pattern[9] and others didn’t find any differences in the gait pattern compared to normal insoles[4][27]. The gait pattern can be analyzed by studying the dynamic of different parameters during gait. In this project we focused on the parameters that in the literature were widely confirmed to change due to shoe inserts when positive results were obtained [8][9][10][28]. According to these papers shoe inserts, change the muscle activity that stabilize the ankle and knee joint kinematic. It’s not clear if the change must be an increased or decreased muscle activity; literature showed differences on it, probably because each person has its own favorite gait pattern that maximizes comfort[26], therefore there is a subject-specific change in the gait pattern of the muscle activity. Several studies were conducted to study the shock absorption. Some studies used RCT methods[16][17][18][19] to find out if the reduced impact force caused a reduced risk of overuse injuries and other studies were carried out in laboratory experiments that use pressure insoles[29] or force platforms[30] to compare treatmented shoes with control shoes and found out the evidence of