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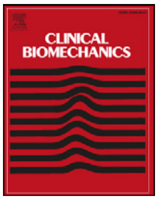

CLINICAL BIOMECHANICS

The effect of neutral-cushioned running shoes on the intra-articular force in the haemophilic ankle

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ABSTRACT

Background: The ankle continues to be one of the most affected joints in the haemophilia patient, and as cartilage damage progresses, the joint can feel unstable, painful and stiff. Anecdotally, patients often report that sports trainers can improve their pain and daily function, however the actual mechanism for this remains unclear.
Methods: Nine patients with ankle haemarthropathy and three controls were examined using 'CODAmotion' analysis and a force plate. Kinematic and kinetic variables of the hip, knee and ankle were recorded. Data was imported from CODA to Excel, where a programme using 2D modelling of the ankle joint forces was employed. This calculated intra-articular force from heel strike to toe-off.
Findings: The haemophilia group at midstance showed an increase in intra-articular force in the ankle when wearing the trainer compared to the shoe ($P = < 0.05$). Overall the haemophilia cohort had an increased joint force in both the trainers and shoes, compared to controls.
Interpretation: The type of footwear worn by individuals with ankle arthropathy has a significant effect on the amount of force acting at the joint surface. Sports shoes, in providing better comfort and foot support, may facilitate an increased muscular activity around the ankle and therefore improved dynamic joint stability, accounting for why some patients with ankle arthropathy report less pain. Further research is needed to establish levels of acceptable force and the combined effects of orthotics and footwear.

1. Introduction

Haemophilia is an inherited bleeding disorder characterised by a deficiency or complete absence of clotting factors VIII (Haemophilia A) or IX (Haemophilia B). They are X-linked disorders, thus affecting only males and the worldwide prevalence is estimated to be one in 5000 males for Haemophilia A and one in 25,000 males for Haemophilia B (Bolton-Maggs and Pasi, 2003). The baseline factor VIII or IX determines the severity of the disorder, and the classification in most common use is the one recommended by the International Society on Thrombosis and Haemostasis (ISTH). Those with procoagulant factor levels below 1% are severe, 1–5% moderate and mild being >5% (White et al., ISTH communication, 2000). Patients with severe Haemophilia A or B are characterised by spontaneous bleeding into joints, muscles and other internal organs, and the latter can be fatal. Modern management is regular infusion of the deficient factor, with either recombinant or plasma-derived factor VIII or IX two to three times a week to prevent spontaneous bleeding (termed prophylaxis.) Recurrent joint bleeds cause synovial hypertrophy and subsequent destruction of articular cartilage resulting in haemophilic arthropathy (Jansen et al., 2007). Bleeding into the knees, elbows and ankles account for almost 80% of episodes (Rodriguez-Merchan, 1996) with the ankle now accepted as being the most affected joint (Stephensen et al., 2009).

Ankle cartilage is relatively uniform in thickness ranging from 1 to 1.7 mm whilst the knee having variations anywhere from 1 to 6 mm thick (Shepherd and Seedhom, 1999). The thinness of the ankle articular cartilage and the high peak contact stresses to which it is submitted may make it less adaptable to incongruity, decreased stability, or increased stresses that may follow a traumatic event (Daniels and Thomas, 2008).

It still remains unclear what effect poor articular geometry may have on ankle intra-articular forces and indeed the actual transmission of the force across the talar surface. Tochigi et al. (2008) reported that ankle instability events involved distinctly abrupt increases or decreases in local articular contact stresses, and that the degree of abruptness had an almost linear correlation with the abnormality in the kinematics, concluding that ankle instability resulted primarily from loss of contact between the anterior distal tibial surface and the talar dome.

The above is of clinical value as many patients in the authors treatment centre empirically report symptoms of ankle instability and pain secondary to established joint arthropathy. However, a recurring theme with some patients is the positive effect footwear, in particular

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trainers and softer soled shoes have on such symptoms, although the mechanism remains unclear.

Relatively little has been done previously in gait assessment in Haemophilia. Studies done on young boys with haemophilia reported statistically significant increases in swing, stance, single and double support time in the asymptomatic individuals, suggesting a possible contribution of these gait changes to lower limb dysfunction (Bladen et al., 2007; Stephensen et al., 2009). Another study analysing the effect on gait with and without silicon heel cups highlighted that even with no clinical evidence of motion restriction in the ankle joint with a low degree of haemarthropathy, a distinct difference in comparison with normal gait could be detected (Seuser et al., 1997). More recently it has been highlighted that 3-dimensionl gait analysis is useful for assessing the abnormal gait patterns secondary to arthropathy in people with haemophilia (Lobet et al., 2010) and the same authors have described how the metabolic energy cost in gait is higher in such individuals because of a decrease in muscle efficiency (Lobet et al., 2012). Interestingly, a further study looking at gait changes with custom made foot orthoses with the haemophilic ankle reported that rocker bottom shoes improved ankle propulsion, postulating that this may be secondary to improved comfort and decreasing ankle pain (Lobet et al., 2012).

Multiple studies have investigated the effects of footwear on ground reaction force and shock attenuation, and the vast majority of these have been related to sport and running. Light et al. (1980) compared the effect of walking barefoot, with conventional and shock absorbing footwear and concluded that the shock absorbing shoe moderated deceleration of the leg and produced a longer and lower shock wave in the tibia, with similar outcomes reported by LaFortune and Hennig (1992).

Wegener et al. (2008) compared in-shoe plantar pressure loading and comfort in running in three shoe types and found sports training shoes significantly decreased peak pressures and force at the forefoot. They suggested also that comfort was an important issue and was multifactorial. The notion of comfort has been proposed to be primarily associated with the cushioning aspect of running shoes, as well as fit, anatomical characteristics of the foot inside the shoe and foot sensitivity; it may affect pressure distribution and above all is a subjective experience (Nigg and Segesser, 1992; Reinschmidt and Nigg, 2000).

Conversely, Kersting and Bruggemann (2006) found no consistent relationship between in-shoe force and impact when examining subjects running with similar findings reported by McNair and Marshall (1994) and Hardin et al. (2004). These studies imply that footwear simply acts as a buffer to peak forces at heel strike and that the motor programme responsible for the pattern of the lower limb was unaffected by footwear. They postulate that this was due to highly individual adaptation strategies employed by each subject and that individuals use these strategies of mechanical and neuromuscular adaptation to make the most of the characteristics of the footwear.

There is paucity in work to look at the intra-articular forces at the ankle joint, and researchers have relied on the application of mathematical models, usually based on cadaveric studies. Scott and Winter (1990) examined the internal forces at chronic running injury sites using a two-dimensional mathematical model. They reported a peak ankle compressive force of 5700 N (11.2 times Body weight [BW]) and noted that 82% of the peak compressive force is created by the muscles crossing the joint, whilst the reaction force accounts for only 18%. However in this model, it was acknowledged that no account was taken of the dampening effect of soft tissue or footwear, therefore values could be overestimated.

Burdett (1982) utilised a 3D mathematical model to predict forces that occur in the stance phase of running. They reported that the compressive forces on the foot reached values of between 8 and 13 BW for all three subjects, with the largest tendon forces occurring in the plantar flexion group. Procter and Paul (1982) attempted to quantify muscle and joint loads in the ankle using a 3D modelling system, based on cadaveric studies of five specimens. They found a talocrural compressive joint force peak of approximately 4 BW, with a muscle force peak of the calf group of around 2.5 BW. Stauffer et al. (1977) proposed a very simple 2D hinge model of the ankle to calculate forces within the ankle joint as well as the calf and anterior shin muscles. In comparing the compressive joint forces in normal and diseased ankles in stance phase, they found a maximum peak force of 4.5–5.5 BW in normals, but in the diseased ankles this force rose only to 3 BW.

From the literature it remains unclear what effect footwear has on shock absorbency and forces acting at the ankle. Specifically, it is not clear what the effect is of poor joint congruency from degenerative disease on these forces. In an attempt to ascertain force without the additional cofounding factor of foot posture alteration, this study aims to examine the effect of a neutral sports trainer on the forces acting on the talocrural joint of adult haemophiliacs with haemarthropathy as compared to conventional footwear.

2. Methods

This study used kinematic and kinetic data supplied by a CODA motion analysis system applied to a two-dimensional model in the sagittal plane of ankle motion. The model assumes that from the point of initial contact, the main moment force is that of plantarflexion (from the Gastrocnemius complex) and that the forces from ligaments and capsule restraints are negligible in the sagittal plane of movement of the ankle. This method of modelling is similar to the studies mentioned previously. Also Burdett (1982) on comparing a 2D model with a 3D model, found both to be similar in predicting compressive forces in the ankle joint.

20 patients were identified from attendance at a Haemophilia review clinic according to inclusion/exclusion criteria (Table 1) and subsequent physiotherapy assessment and joint scoring (Manco-Johnson et al., 2000) as appropriate for participation in this study. Nine agreed to take part (Table 2). A control group ($n = 3$) of normal male population was recruited locally from within the hospital.

A same-subject experimental design was used to compare measurements between using a shoe and a trainer, as appropriate for this study (Hicks, 1995). Ethical approval was obtained from Moorfields and Whittington NHS Research Ethics Committee (Reference number: 08/H0721/30). Permission was also gained from the Research and Development Departments at the Royal Free Hospital Hampstead and The Royal National Orthopaedic Hospital (RNOH), Stanmore, UK.

The anthropometric data of each participant was recorded (height, weight, thigh and shank length, knee and ankle joint width, foot length and ASIS width). Length measures were ascertained with an anthropometric counter recording instrument ('Harpenden' Anthropometer, Holtain Ltd, Pembrokeshire, UK). As per lab protocol, the markers were attached to the following anatomical landmarks (bilaterally) using double sided tape: lateral knee joint line, lateral tip of the lateral malleolus, over the point of the postero-inferior calcaneus and 5th metatarsal whilst the footwear (shoe or trainer) was *in situ*. Wands with anterior and posterior markers were attached to the pelvis, thigh and shank. Markers and battery packs were attached to the wands

Table 1
Participant inclusion/exclusion criteria.

Inclusion criteria	Exclusion criteria
• Male • Aged 18–60 • Haemophilia A or B • Only ankle joint affected with arthropathy on physical assessment (unilateral or bilateral)	• Multiple joint damage • Chronic synovitis • Any other acute illness • Lower limb bleed in previous four weeks • Active joint or muscle bleed • Significant/gross joint abnormality