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Foot function is well preserved in children and adolescents with juvenile idiopathic arthritis who are optimally managed

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ABSTRACT

Purpose: The objective of this study was to compare disease activity, impairments, disability, foot function and gait characteristics between a well described cohort of juvenile idiopathic arthritis (JIA) patients and normal healthy controls using a 7-segment foot model and three-dimensional gait analysis.
Methods: Fourteen patients with JIA (mean (standard deviation) age of 12.4 years (3.2)) and a history of foot disease and 10 healthy children (mean (standard deviation) age of 12.5 years (3.4)) underwent three-dimensional gait analysis and plantar pressure analysis to measure biomechanical foot function. Localised disease impact and foot-specific disease activity were determined using the juvenile arthritis foot disability index, rear- and forefoot deformity scores, and clinical and musculoskeletal ultrasound examinations respectively. Mean differences between groups with associated 95% confidence intervals were calculated using the *t* distribution.
Results: Mild-to-moderate foot impairments and disability but low levels of disease activity were detected in the JIA group. In comparison with healthy subjects, minor trends towards increased midfoot dorsiflexion and reduced lateral forefoot abduction within a 3–5° range were observed in patients with JIA. The magnitude and timing of remaining kinematic, kinetic and plantar pressure distribution variables during the stance phase were similar for both groups.
Conclusion: In children and adolescents with JIA, foot function as determined by a multi-segment foot model did not differ from that of normal age- and gender-matched subjects despite moderate foot impairments and disability scores. These findings may indicate that tight control of active foot disease may prevent joint destruction and associated structural and functional impairments.

1. Introduction

Juvenile idiopathic arthritis (JIA) is a chronic and progressive inflammatory arthritis of childhood which often results in persistent and disabling foot impairments [1–3]. The primary disease process – synovitis, has a predilection for the lower limb joints and results in well-recognised clinical features including joint pain, swelling, limited joint range-of-motion and development of deformity [3–5]. Inflammatory pathology is not limited to joints and studies employing musculoskeletal ultrasonography have also detected tenosynovitis, enthesitis, and bursitis in the periarticular ankle region [6]. Unsurprisingly disruption to global gait patterns has been frequently reported as an early and common consequence of JIA [7,8].

The impact of JIA on global function has been studied extensively with the use of patient reported outcome measures (PROMs) such as the childhood health assessment questionnaire (CHAQ), a widely used 30 item measure of childhood disability [9,10]. Studies employing PROMs have demonstrated strong associations between clinical symptoms such as pain or radiographically detected joint destruction, with poor long-term functional outcomes [11]. At a local level, the impact of active disease and related impairments remain unclear. The development of juvenile arthritis foot disability index questionnaire (JAFI) [12], a 27 item measure organised by three dimensions related to impairment, activity limitation, and participation restriction, has allowed researchers to quantify levels of disease-related foot impairments and disability [1,2]. However questions remain regarding its sensitivity and specificity particularly during early stages of disease [2].

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Recent studies of foot function have improved our understanding of foot impairments in adults with rheumatoid arthritis (RA) [13,14]. In particular, studies employing three-dimensional (3D) multi-segmented foot models have demonstrated an ability to quantify subtle but functionally important changes to foot segment kinematics and kinetics at an early disease stage [15]. In contrast, little is known about the functional consequences of active foot disease and/or residual impairments such as foot deformity in patients with JIA.

Patients with JIA who have lower limb involvement tend to walk slower, as a result of a reduced step length, reduced cadence and an increased period of double limb support [2,16]. Reduced peak pressures have been recorded in those with forefoot pain, metatarso-phalangeal (MTP) joint and lesser toe deformity [17]. While elevated focal pressures in the forefoot have previously been associated with pes cavus foot types [8]. Abnormal ankle-joint-complex motion has been described where the foot has been modelled as a single segment [7,16]. However this approach provides limited information concerning other foot joint function compared to the multi-segment approach [18]. Accordingly, the aim of this study was to compare disease activity, impairments, disability, foot function and gait characteristics between a well described cohort of JIA patients and normal healthy controls using a 7-segment foot model and 3D gait analysis.

2. Methods

2.1. Patient selection

Fourteen patients with a definitive diagnosis of JIA, based on the International League of Associations for Rheumatology (ILAR) criteria [19] were consecutively recruited from a phase II randomised controlled trial of a multi-disciplinary foot-care programme [20]. Participants had a documented history of active inflammatory foot disease affecting the joints and/or soft tissues. Ten community dwelling healthy children and adolescents matched as closely as possible by age and gender, with no history of trauma, neuromuscular or musculoskeletal diseases were recruited for comparison. This study was approved by the Glasgow West Local Research Ethics Committee on the 18th March 2008 (reference number 08/S0709/36). All participants and parents/guardians provided their informed consent to participate in this study.

2.2. Demographic, disease and clinical examination

Age, gender, body mass index, disease subtype, disease duration, and current pharmacological therapy were recorded for each patient. Functional health status was recorded using the CHAQ [10]. Local disease impact was measured using the JAFI [12]. Localised disease activity was estimated by a podiatrist [GH] who recorded tender and swollen joint scores in the foot for the ankle, subtalar, calcaneocuboid, talonavicular, MTP, interphalangeal joint of the hallux and proximal interphalangeal joints of the lesser toes (range 0–14). Tender and swollen soft tissue sites in the foot were also recorded for the tibialis posterior, flexor digitorum longus, flexor hallucis longus, peroneus longus and peroneus brevis tendons, the retro-calcaneal bursa (RCB), and the calcaneal tendo-achilles (TA) and calcaneal plantar fascia entheses (PF) (range 0–8). Fore- and rearfoot deformities were measured using the structural index (SI) [21]. The SI summates hallux valgus, 5th MTP exostosis, lesser toe deformities and MTP subluxation for the forefoot (range 0–12) and calcaneal valgus/varus, ankle range of motion and pes planus/cavus deformities of the rearfoot (range 0–7). The weight-bearing varus/valgus alignment of the heel was measured using a standard hand-held goniometer [15]. A fully trained paediatric musculoskeletal ultra-sonographer [DET] independently assessed localised disease activity in the foot. Those joints from the clinical examination were assessed for effusion, synovial hypertrophy (SH), and power Doppler signal (PDS). Tendons were assessed for grey-scale features of fluid within the tendon sheath and PDS; the TA and PF for abnormal thickening, and RCB for bursal effusion (bursitis). Standardised definitions for ultrasound (US) -derived pathology (defined by the outcome measures in rheumatology 7 consensus statement) [22] were employed throughout. US imaging was conducted using an Esaote Mylab 25 Gold (Genova, Italy) with LA435 (10–18 MHz) probe (footprint size 40 mm × 10 mm). US features were recorded as present/absent.

2.3. Biomechanical foot function

An 8 camera 120 Hz motion analysis system (Qualysis Oqus, Gothenburg, Sweden) was used to track the motion of 25 surface-mounted, spherical, and retro-reflective markers (5 mm and 10 mm diameter) placed on the shank and foot which were positioned in order to represent the underlying skeletal structure. This model was adapted from the original model proposed by Hyslop et al. [23] previously to measure foot function in adults with psoriatic arthritis (*See supplementary online material for full model description*), and was selected for use on the basis that JIA is an inflammatory arthropathy with similar disease features. Visual3D software (C-motion, Inc., Rockville, MD, USA) was used to build segmented foot models which comprised the shank, a single foot segment, rearfoot, midfoot, lateral forefoot, 1st metatarsal and hallux, based on the surface marker coordinates. Ground reaction forces (120 Hz) and plantar pressure distributions were measured separately using force (Kistler, Winterthur, Switzerland) and pressure (Emed-X, Novel GmbH, Munich, Germany) platforms. An instrumented walkway (GaitRite, CIR systems, Clifton, NJ, USA) was used to measure spatial and temporal gait parameters.

A pre-determined core set of foot biomechanical variables were selected a priori for analysis based on previous survey and gait analysis data in RA, psoriatic arthritis and JIA [2,13–15,23]. These included walking velocity, cadence, step length, double support time and cycle time as objective measures of global function. Intersegment kinematics, kinetics and plantar pressure distribution parameters were selected to best capture the functional changes associated with joint and soft-tissue damage in JIA. Initial foot contact angle, rearfoot terminal stance range-of-motion in the sagittal plane, peak vertical ground reaction forces, ankle joint moment and ankle joint power were selected to describe the three rocker functions of the foot [13,24]. Peak rearfoot eversion, peak lateral forefoot abduction, peak 1st metatarsal dorsiflexion, peak hallux dorsiflexion, minimum navicular height, midfoot and lesser toe contact areas, and peak pressures in the rear- and forefoot were selected to describe localised functional impairments, compensations and deformities [13,14]. The average velocity and duration of the centre-of-pressure (CoP) throughout the foot, heel, midfoot, forefoot and toe regions was recorded to quantify compensatory foot-loading strategies associated with degraded and adapted (antalgic) gait [25]. Peak midfoot dorsiflexion was selected for exploratory analysis as both high- and low-arched midfoot posture is a frequent clinical finding in JIA.

A relaxed standing (static) trial was collected for the foot from each participant in order to define 0° (neutral) for the kinematic data [26]. Kinematic and kinetic and parameters were collected from 5 barefoot walking trials in each patient. Spatial and temporal parameters were recorded from 5 barefoot self-selected walking speed trials over the walkway. Plantar pressure distribution parameters were collected separately from 5 barefoot trials using