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Characterising the clinical and biomechanical features of severely deformed feet in rheumatoid arthritis

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Abstract

Purpose: Foot deformity is a well-recognised impairment in patients with rheumatoid arthritis (RA) which results in functional disability. Deformity can occur at the rearfoot, midfoot, forefoot or in combination and the impact that site-specific foot deformities has on functional disability is largely unknown. The aim of this study was to describe the clinical and biomechanical characteristics of patients with severe rearfoot, forefoot or combined deformities and determine localised disease impact.

Methods: Twenty-eight RA patients with severe forefoot (FF group $n = 12$), rearfoot (RF group $n = 10$) or combined deformities (COMB group $n = 6$) were recruited. Each patient underwent 3D gait analysis and plantar pressure measurements. Localised disease impact and foot-specific disease activity were determined using the Leeds Foot Impact Scale and clinical examination respectively. Comparison was made against a normative control group ($n = 53$).

Results: Patients in the COMB group walked slowest and the double-support time was longer in the RF and COMB groups compared to those in the FF group. Patients in the RF and COMB group had higher levels of foot-related disability and demonstrated excessive rearfoot eversion and midfoot collapse compared to those in the FF group. Forefoot deformity was associated with reduced toe contact, high forefoot pressures and delayed heel lift.

Conclusions: Abnormal gait patterns were identified and were distinguishable among those patients with predominantly forefoot, rearfoot or combined foot deformity.

Keywords: Rheumatoid arthritis; Foot; Gait analysis; Foot pressure; Disability; Impairments

1. Introduction

Foot deformities such as hallux valgus, claw toe and pes planovalgus are some of the most striking features in patients with rheumatoid arthritis (RA) [1] Radiographic studies have shown that the development of foot deformity increases with longer disease duration and is accelerated in the presence of more severe disease [2,3]. This finding is true both for deformity localised to the forefoot and in the rear and midfoot [3,4].

Factors associated with deformity such as pain, functional loss and disability have been studied extensively but the mechanisms of how these may be related are still unclear [2–5]. Deformity, especially in its severest form, may be troublesome for patients, in terms of obtaining comfortable footwear but is not always painful. After adjusting for disease duration and severity, foot deformity in a heterogenous population of RA patients was found to have no predictive value for foot-related impairment or disability [6]. Indeed, only in RA cohorts who are well defined by disease duration or severity, or by localisation of impairments to the rear- or forefoot can this association be found [2,5,7].

Foot pain probably has the strongest influence on functional ability regardless of disease duration [5–7]. Foot joints which are stiff and deformed may also play an important role but this is less clear. Semi-quantitative functional indices correlate poorly with foot deformity whereas objective measurements such as gait analysis indicate a relationship albeit weaker than pain [4,5,7]. The recent pursuit of objective gait data has yielded a better

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understanding of foot impairments in RA. Thus RA patients with foot deformity will shorten their stride length and walk slower, particularly if the rearfoot is involved [5]. Deformity alters the shape of the foot and changes the distribution of pressure on the plantar surface. Elevated focal pressures in the forefoot increase with disease duration and are associated with pain during walking and gait adaptations [8–10]. These parameters, as well as any accompanying gait compensations can now be successfully quantified using increasingly sophisticated three-dimensional (3D) gait models of the foot and ankle [11–15].

Investigating well-defined RA subpopulations is helpful in understanding the pathway leading from underlying disease processes to localised impairment and to enable the development of disease-staged targeted treatment. We have previously undertaken this approach in early RA detecting clinically important functional changes in the foot within 2 years from disease onset [16]. At the opposite end of the disease spectrum this present study investigates RA patients with the most severe forms of foot deformity since these represent an important clinical challenge for both conservative and surgical management. More precisely, the aim of this study was to characterise the clinical and biomechanical features of well-established severe foot deformity in patients with RA grouped by location of deformity in comparison with normative data.

2. Methods

2.1. Patients

Patients with confirmed diagnosis of RA, based on the American College of Rheumatology criteria [17] and symptomatic foot deformity based on an impairment/footwear subscale of the Leeds Foot Impact Scale ($LFIS_{IF}$) $\geq$4 were recruited [18]. One foot was randomly selected for assessment. Fore- and rearfoot deformities were quantified using the Structural Index (SI) score, which considers hallux valgus, metatarsal phalangeal (MTP) subluxation, 5th MTP exostosis, and claw/hammer toe deformities for the forefoot (range 0–12) and calcaneus valgus/varus angle, ankle range of motion and pes planus/cavus deformities for the rearfoot (range 0–7) [5]. Patients were sub-classified by the localised severity of foot deformity. Those with a forefoot SI score of $\geq$10 were assigned to the forefoot (FF group), those with a rearfoot SI score $\geq$4 to the rearfoot (RF group) and those with scores exceeding both minimum criterion for fore- and rearfoot to the combined foot deformity group (COMB group) [5]. Community dwelling adults with no history of inflammatory arthritis or musculoskeletal disease involving the lower limb and foot were recruited for comparison. Local Research Ethics Committee approval was obtained for this study. In total 28 patients were recruited into the study, 12, 10 and 6 were assigned to the FF, RF and COMB groups respectively. All gait and clinical data were collected on the same day.

2.2. Demography, disease and clinical data

Age, gender, body mass index, disease duration and disease activity (using the 28 joint count) were recorded for each patient. The impact of the disease localised to the feet was measured using the LFIS, which has two subscales to measure impairment/footwear ($LFIF_{IF}$) and activity limitation/participation restriction ($LFIS_{AP}$) [18]. A single clinician recorded swollen (SJC) and tender (TJC) 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). The number of patient reported painful (PJC) joint sites was also recorded (range 0–14).

2.3. Gait analysis

An instrumented walkway (GAITrite, CIR systems, Clifton, NJ, USA) was used to capture spatial and temporal gait parameters. Plantar foot pressures were measured using the EMED-ST platform (Novel GmbH, Munich, Germany). A six-camera 60 Hz video-based motion analysis system (Falcon System, Motion Analysis Corporation, Santa Rosa, CA, USA) was used to track the motion of 22 spherical reflective targets placed on the shank and foot [6,13]. Visual3D software (C-motion, Inc., Rockville, MD, USA) was used to build segmented foot models which comprised of the shank, rearfoot, forefoot, and hallux. Marker placement and segment models were based on those described by Carson et al. [19]. Spatial and temporal parameters were collected from two passes along the walkway. Kinematic and plantar pressure variables were collected simultaneously from five barefoot walking trials (except in five cases where foot pain limited two patients to four trials and three patients to three trials).

A pre-determined core set of foot biomechanical variables was extracted from an average of the walking trials. These included walking speed and double-support as objective measures of global function [6,12,13]. Intersegment kinematics and plantar pressures represented intrinsic foot function. Rearfoot motion was expressed in the shank coordinate reference system as dorsiflexion (+)/plantarflexion (−), inversion (+)/eversion (−) and internal (+)/external (−) in the sagittal, frontal and transverse planes respectively. Forefoot motion was expressed in the coordinate reference system for the rearfoot as dorsiflexion (+)/plantarflexion (−), inversion (+)/eversion (−), and adduction (+)/abduction (+). The motion of the hallux was measured in the sagittal plane only, expressed in the coordinate reference system for the forefoot as dorsiflexion (+)/plantarflexion (−). The rise and fall of the medial longitudinal arch during stance was measured vertical (z) coordinate of a single motion tracking marker placed over the navicular.

Peak pressures in the forefoot and contact area for the toes (defined using automated software) were used as metrics to capture functional changes associated with MTP deformity. Off-loading the forefoot (a characteristic gait compensation strategy) was measured by recording the time (as a % of stance) when the centre-of-pressure (COP) reached 50% of foot length [10]. Contact area in the midfoot was used to assess collapse of the medial longitudinal arch [6,12].

2.4. Statistical analysis

The mean motion pattern of intersegment kinematics normalised in the time domain (0–100% stance), was displayed graphically for each group. On these graphs, a colour-coded reference scale was used to show RA subgroup variation from normal in S.D. multiples (−3 to +3) during each % of the stance phase [20]. Phases