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Short communication

Region-specific foot pain and plantar pressure in people with rheumatoid arthritis: A cross-sectional study

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ABSTRACT

Background: It is unclear whether region-specific foot pain may influence plantar pressure in people with established rheumatoid arthritis. The aim was to determine the association between region-specific foot pain and region-specific plantar pressure.

Methods: Twenty-one people with rheumatoid arthritis and 19 age- and sex-matched controls participated in this study. Self-reported foot pain in the toes, forefoot, midfoot and rearfoot was assessed using foot diagrams. Peak pressure and pressure time integrals for the toes, forefoot, midfoot and rearfoot were calculated using a pressure mat system. Differences in foot pain and pressure between the groups were calculated using appropriate regression models. To determine associations between region-specific pain and pressure, linear regression models were used while adjusting for body mass and participant group.

Findings.

Participants with rheumatoid arthritis were primarily elderly female with long disease duration. Compared to controls, participants with rheumatoid arthritis had higher odds of foot pain at the toes (Odds Ratio (OR) = 10.4, $P = 0.001$), forefoot ($OR = 6.3$, $P = 0.006$) and rearfoot ($OR = 10.1$, $P = 0.011$). Participants with RA had higher peak pressure at the rearfoot ($P = 0.003$) and higher pressure time integrals at the forefoot ($P = 0.005$), midfoot ($P = 0.016$) and rearfoot ($P < 0.001$). After adjusting for body mass and participant group, peak pressure was significantly higher at the toes in those with midfoot pain and rearfoot pain.

Interpretation: People with rheumatoid arthritis experience region-wide foot pain and demonstrate differences in pressure distribution compared to people without rheumatoid arthritis. Foot pain at the midfoot and rearfoot is also associated with increases in plantar pressure at the toes.

1. Introduction

Over 90% of patients with rheumatoid arthritis (RA) report foot problems (Michelson et al., 1994), with foot pain being a common complaint (Otter et al., 2010). Although foot pain in early RA is regarded as the first indicator of synovitis (Turner et al., 2006; van der Leeden et al., 2008), it is also associated with mechanical causes including foot deformity, altered gait and increased plantar pressures (Turner et al., 2003; Turner et al., 2008; Turner and Woodburn, 2008). The forefoot, being the most common site of deformity in RA, has been the focus of considerable biomechanical research in this area (Goksel Karatepe et al., 2010; Grondal et al., 2008; Rome et al., 2009). Several studies have described an increase in forefoot plantar pressure (Hodge et al., 1999; Minns and Craxford, 1984; Otter et al., 2004) which has been related not only to foot deformities (van der Leeden et al., 2006; Woodburn and Helliwell, 1996), but also foot pain. There is currently no universally accepted standard for the measurement of foot pain and self-reported pain intensity is the most frequently used research tool to measure pain (Hawke and Burns, 2009). Instruments include visual analogue scales (VAS), numeric rating scales and verbal category/Likert scales. Previous studies have reported on the association between plantar pressure and region-specific foot pain in older adults (Riskowski et al., 2015). However, a region-specific analysis of foot pain and plantar pressure has not been undertaken in people with established RA. An understanding of the relationship between plantar pressure and foot pain will not only provide insights into the mechanism of pain, but may also direct management strategies which attempt to off-load high-stress areas in the aim of reducing pain in people with rheumatoid

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arthritis. The primary aim of the current study was to determine differences in foot pain and plantar pressure at the toes, forefoot, midfoot and rearfoot regions between people with RA and controls, and secondly, to determine whether region-specific foot pain was associated with region-specific plantar pressure.

2. Methods

2.1. Participants

Participants with RA were recruited from the Auckland University of Technology (AUT) Podiatric Rheumatology Clinic, Auckland, New Zealand. Participants with RA were classified according to the 2010 ACR/EULAR classification criteria (Aletaha et al., 2010). Age- and sex-matched controls were recruited from public advertising at AUT. Participants were excluded if they could not understand the English language, were under 20 years of age, could not walk 5 m unaided, had recent surgery or injury to the lower limb, or other inflammatory arthropathies or neuromuscular disorders. All participants provided informed consent prior to data collection. The study was approved by the AUT Ethics Committee (AUTEC 16/362).

2.2. Data collection

All data was collected during a single clinical visit at the AUT Podiatry Clinic by researchers (MK and LB). Participant demographic and medical characteristics were recorded. Body pain, foot pain and overall wellbeing were assessed using a 100 mm visual analog scale (VAS). Activity limitation was assessed using the Health Assessment Questionnaire (HAQ-II) (Wolfe et al., 2004). Participants were asked to indicate any foot pain on the Chatterton et al. (2013) foot pain diagram which was used to identify the presence of region-specific pain at the toes, forefoot, midfoot and rearfoot. Peak plantar pressure was recorded for both feet, over three trials, using a TekScan MatScan (TekScan Inc., South Boston, USA) pressure mat in accordance with a two-step gait initiation protocol (Bryant et al., 1999). The average of the three trials was used for analysis. Each foot was masked into four regions (toes, forefoot, midfoot, rearfoot) (VanZant et al., 2001) and peak pressure (kPa) and pressure time integrals (kPa $*$ s) were calculated for each region.

2.3. Data analysis

A sample size calculation was undertaken based on existing data (Turner and Woodburn, 2008) which showed a mean (SD) difference in combined rearfoot and forefoot peak pressure between RA and controls of 452 (156) kPa. The calculated sample size was 28 participants in each group to provide 80% power to detect between group differences at a significant level of 5%. To determine the difference in frequency of region-specific foot pain between RA participants and controls, binary logistic regression models were used. To determine differences in mean peak pressure and pressure time integrals at each region between RA participants and controls, mixed-models linear regression was used with body mass included as a covariate. Analyses accounted for repeated measures taken from right and left feet through a participant-specific and participant-nested random effect for foot-side. To determine the association between pressure data and the presence of pain at each location, mixed-linear regression models were used as above, in which participants were stratified into two groups based on the presence or absence of pain, with the addition of participant group as a covariate. Significance levels were reported adjusted for multiplicity at an alpha of $P < 0.0125$. All data were analysed using SPSS v20.0 (IBM Corp., Armonk, NY).

Table 1
Demographic and clinical characteristics of participants.

n	Control	RA	*P*
	19	21	–
Gender, female, n (%)	18 (95%)	17 (81%)	0.35
Age	71.1 (7.0)	68.7 (7.9)	0.32
Ethnicity, n (%)	European 19 (100%)	European 19 (90%) Asian 2 (10%)	0.49
Body mass index	28.0 (4.6)	29.4 (6.0)	0.41
Disease duration, years	–	19.1 (13.2)	–
DMARD use, n (%)	–	11 (52%)	–
Biologic agent use, n (%)	–	1 (5%)	–
Prednisone use, n (%)	–	8 (38%)	–
NSAID use, n (%)	0 (0%)	2 (10%)	0.49
Anti-hypertensive use, n (%)	0 (0%)	7 (33%)	**0.009**
Diuretic use, n (%)	0 (0%)	2 (10%)	0.49
Hypertension, n (%)	2 (11%)	7 (33%)	0.13
Cardiovascular disease, n (%)	0 (0%)	2 (10%)	0.49
Pain VAS	11.1 (20.2)	34.2 (29.1)	**0.006**
Foot pain VAS	9.4 (17.9)	33.8 (30.9)	**0.004**
Wellbeing VAS	9.8 (16.5)	36.1 (28.7)	**0.001**
HAQ-II	0.18 (0.31)	0.90 (0.55)	< **0.001**

Values are displayed as mean (SD), unless otherwise indicated. *DMARD* Disease Modifying Anti-Rheumatic Drug; *NSAID* Non-Steroidal Anti-Inflammatory Drug; *VAS* Visual Analogue Scale; HAQ-II Health Assessment Questionnaire - II. Bolded *P* values indicate significance differences between control and RA groups ($P < 0.05$).

3. Results

Twenty-one participants with RA and 19 control participants were included in the study. Demographic and clinical data are presented in Table 1. Participants were predominantly elderly female of European ethnicity. Participants with RA scored significantly higher on the pain VAS, foot pain VAS, wellbeing VAS and HAQ-DI scores compared to controls.

Twenty-three (55%) feet from participants with RA had pain in two or more foot regions, while 16 (38%) had pain in three or more foot regions. Compared to controls, participants with RA had a higher odds of foot pain at the toes (*OR* 10.4, $P = 0.001$), forefoot (*OR* 6.3, $P = 0.006$) and rearfoot (*OR* 10.1, $P = 0.011$) (Table 2).

Participants with RA had higher peak pressure at the rearfoot ($P = 0.003$) (Fig. 1A) and higher pressure time integrals at the forefoot ($P = 0.005$) and rearfoot ($P < 0.001$) (Fig. 1B) (Table 3). After adjusting for body mass index and participant group, peak pressure was significantly higher at the toes in those with midfoot pain and rearfoot pain (Table 4).

Table 2
Differences in frequency of foot pain at each region between controls and RA participants.

	Control[a]	RA[a]	Odds ratio	95% CI for OR		*P*
				Lower	Upper	
Toes	6 (16%)	26 (62%)	10.4	2.5	42.4	**0.001**
Forefoot	5 (13%)	20 (48%)	6.3	1.7	23.4	**0.006**
Midfoot	1 (3%)	13 (31%)	16.2	1.7	157.8	0.02
Rearfoot	2 (5%)	15 (36%)	10.1	1.7	59.6	**0.011**

[a] Frequency values are displayed as n (%) for feet (control = 38 ft; RA = 42 ft). *MTP* metatarsophalangeal joint; *CI* confidence interval; *OR* odds ratio. Bolded *P* values indicate significance differences between control and RA groups at a Bonferroni-adjusted significance level of $P < 0.0125$.