Title: Foot-related pain and disability and spatiotemporal parameters of gait during self-selected and fast walking speeds in people with gout: A two-arm cross sectional study

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HIGHLIGHTS

- Spatiotemporal gait parameters were assessed in people with gout while adjusting for BMI and pain
- People with gout exhibit different gait parameters compared to matched controls
- Higher levels of functional disability are associated with gait parameters in gout

TITLE

Foot-related pain and disability and spatiotemporal parameters of gait during self-selected and fast walking speeds in people with gout: a two-arm cross sectional study

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ABSTRACT

Objectives To examine gait parameters in people with gout during different walking speeds while adjusting for body mass index (BMI) and foot-pain, and to determine the relationship between gait parameters and foot-pain and disability.

Method Gait parameters were measured using the GAITRite™ walkway in 20 gout participants and 20 age- and sex-matched controls during self-selected and fast walking speeds. Foot-pain and disability was measured using the Manchester Foot Pain and Disability Index (MFPDI) which contains four domains relating to function, physical appearance, pain and work/leisure.

Results At the self-selected speed, gout participants demonstrated increased step time (p=0.017), and stance time (p=0.012), and reduced velocity (p=0.031) and cadence (p=0.013). At the fast speed, gout participants demonstrated increased step time (p=0.007), swing time (p=0.005) and stance time (p=0.019) and reduced velocity (p=0.036) and cadence (p=0.009). For participants with gout, step length was correlated with total MFPDI (r=-0.62, p=0.008), function (r=-0.65, p=0.005) and physical appearance (r=-0.50, p=0.041); stride length was correlated with total MFPDI (r=-0.62, p=0.008), function (r=-0.65, p=0.005) and physical appearance (r=-0.50, p=0.041); and velocity was correlated with total MFPDI (r=-0.60, p=0.011), function (r=-0.63, p=0.007) and work/leisure (r=-0.53, p=0.030).

Conclusion Gait patterns exhibited by people with gout are different from controls during both self-selected and fast walking speeds, even after adjusting for BMI and foot-pain. Additionally, gait parameters were strongly correlated with patient-reported functional limitation, physical appearance and work/leisure difficulties, while pain did not significantly influence gait in people with gout.

KEYWORDS: gout, spatiotemporal gait, foot pain, disability, activities of daily living

INTRODUCTION

Gout is a chronic disease of monosodium urate (MSU) crystal deposition, with a predilection for peripheral sites in the lower limbs [1, 2]. The presence of MSU crystals initiate local inflammation resulting in self-limiting flares of acute gouty arthritis. In the presence of persistent hyperuricaemia, chronic synovitis, tophi and tissue damage may develop [3-5]. People with gout report high levels of foot pain and disability [6-8] and experience difficulty in carrying out recreational and daily living activities requiring normal lower limb function [6, 9]. Furthermore, people with gout rate walking difficulty as a discriminatory feature of the disease [10]. This is supported by previous laboratory-based lower limb research in which people with gout walk slower with shorter step and stride lengths compared to people without gout whilst walking at a comfortable self-selected speed in their own footwear, even in the absence of current acute arthritis [8]. However, it is currently unclear if patient-reported foot pain and disability is associated with the decreased functional abilities observed in people with gout.

Aside from pain, several other factors may also contribute to walking strategies adopted by people with gout. Gout is a complex disease associated with several comorbidities, including obesity [11], which has been shown to influence walking patterns in individuals without gout [12, 13]. However, it is currently unclear whether excess body mass contributes to the altered gait patterns observed in individuals with gout as control participants in previous research have also had elevated body mass [8].

Maintaining a pain-free and adequate ability to walk at a variety of speeds is fundamental for safely and independently performing activities of daily living. Furthermore, assessment of walking ability is important in developing an understanding of the onset and progression of physical disability in chronic disease populations, including gout [8], rheumatoid arthritis [14, 15], psoriatic arthritis [16] and ankylosing spondylitis [17]. The aim of this study was to examine spatiotemporal parameters of gait during different walking speeds in people with gout while adjusting for BMI and foot pain, and to determine the relationship between spatiotemporal parameters of gait and foot-related pain and disability.

METHODS

A two-arm cross-sectional study was undertaken at AUT University, New Zealand. A sample size of 20 participants with gout and 20 age- and sex-matched controls was calculated based on data derived from our previous research in which the mean (SD) gait velocity was 0.90 (0.3) m/s for participants with gout and 1.03 (0.3) m/s for controls [8]. Power was set to 80% with a significance level of 5%. Gout participants were recruited from the Rheumatology Department at Auckland District Health Board, New Zealand. All gout participants met the 1977 preliminary American Rheumatism Association classification criteria for gout [18]. The age- and sex-matched controls were recruited by public advertising. Participants were excluded if they were experiencing an acute flare at the time of assessment, had a history of lower limb amputation, recent surgery or injury to the foot or ankle, or other rheumatic conditions. Age, gender, ethnicity, body mass index (BMI), current medications and co-morbidities were recorded for all participants. In addition, gout disease duration and clinical characteristics of gout, including flare frequency in the preceding three months and the presence and number of subcutaneous tophi, were recorded for the gout participants. Ethical approval for the study was obtained from the AUT Ethics Committee (13/100) and locality assessment was obtained from Auckland District Health Board (A+5891). All participants provided written informed consent prior to data collection.

The GAITRite™ system (CIR Systems Inc, New York, USA), which consists of a 700cm x 90cm electronic walkway with an active sensor area of 610cm long and 60cm wide, was used to measure spatiotemporal parameters of gait. The active area contains 23,040 embedded pressure-activated sensors with a spatial resolution of 1.27cm and a sampling rate of 120Hz. The GAITRite™ was positioned in a large room to allow the participant to begin walking 1m before the walkway and continue walking 1m past its end to ensure a constant walking velocity. Following an initial test-walk to familiarise the participant with the walkway, each participant was instructed to walk barefoot along the walkway at two different speeds specified with the following instructions: (1) ‘‘Walk at your normal, preferred speed''; and (2) ''Walk as fast as you can safely walk, but do not run'' [19]. These walking speeds reflect conditions that individuals are likely to face during community ambulation. Three repetitions for each walking speed were recorded with a 5-minute rest period between trials to minimise fatigue. The first and last footsteps recorded on the electronic runway were removed from the analysis. For the remaining steps the following parameters were calculated: step time (s), step length (cm), stride length (cm), swing time (s), stance time (s), velocity (cm/s) and cadence (steps/min).

Patient-reported foot pain and disability was assessed using the Manchester Foot Pain and Disability Index (MFPDI) [20]. This 19-item index measures foot-related items in four domains associated with functional limitation (10 items), physical appearance (2 items), pain (5 items), and work/leisure (2 items). Statements relating to each item were answered 'none of the time' (scored as 0), 'on some days' (scored as 1) and 'on most/every day(s)' (scored as 2) in the past month. The total MFPDI score, as well as the total scores for each of the four domains were calculated for each participant with higher scores corresponding to more severe foot pain and disability. The MFPDI is a reliable [20] and valid tool [21] and has been used previously in gout research [6, 22].

Descriptive statistics relating to participant demographics and clinical characteristics were presented as mean (SD) for continuous data and frequency (%) for categorical data. All spatiotemporal data was reviewed for normality using random effects from a linear model through both visual and formal tests with the participant group (gout or control) as the independent variable. To determine the differences between gout and controls for each gait parameter, mixed linear models were used. A scaled identify covariance structure was used which assumes equal variance between each of the three walking trials performed at each speed. A participant-specific random effect was included to account for the repeated measures on right and left feet and participant-nested random effects for foot-side were added to the model. The final model was adjusted for BMI and MFPDI pain. Additionally adjustments for age and ethnicity as covariates were considered for each gait parameter only if they achieved at least 10% on an F-test. Associations between the MFPDI scores and gait parameters were assessed with Pearson correlation coefficients, denoted r. For the purpose of this analysis, gait variables measured for right and left limbs were collapsed into a single measure by taking the mean of the two observations. An r value of 0.1 was considered a small effect size, 0.3 a medium effect size, and 0.5 a large effect size [23]. All data was analysed using SPSS v.20 (IBM Corporation) at a 5% level of significance unless otherwise noted.

RESULTS

Table 1 presents the demographic information for the gout and control participants. Participants with gout were predominantly middle-aged European men with higher BMI than controls ($p = 0.006$). The total mean MFPDI score was higher in participants with gout compared to controls ($p < 0.001$). In the gout group, mean disease duration was 16 years, and 60% of participants had clinically apparent subcutaneous tophi.

All spatiotemporal and MFPDI data conformed to a normal distribution. Neither age nor ethnicity reached significance for any parameters ($p > 0.10$) so were not included in the final model. The mean estimates and inferential statistics adjusted for BMI and MFPDI pain for the self-selected and fast walking speeds are shown in Table 2. At the self-selected walking speed participants with gout demonstrated increased step time ($p = 0.017$), increased stance time ($p = 0.012$), reduced velocity ($p = 0.031$) and reduced cadence ($p = 0.013$) compared to controls. At the fast speed participants with gout demonstrated increased step time ($p = 0.007$), increased swing time ($p = 0.005$), increased stance time ($p = 0.019$), reduced velocity ($p = 0.036$) and reduced cadence ($p = 0.009$) compared to controls.

Table 3 presents the correlations between the MFPDI scores and the spatiotemporal parameters for the gout participants. Step length was negatively correlated with total MFPDI ($r = -0.62$, $p = 0.008$), function ($r = -0.65$, $p = 0.005$) and physical appearance ($r = -0.50$, $p = 0.041$); stride length was negatively correlated with total MFPDI ($r = -0.62$, $p = 0.008$), function ($r = -0.65$, $p = 0.005$) and physical appearance ($r = -0.50$, $p = 0.041$); and velocity was negatively correlated with total MFPDI ($r = -0.60$, $p = 0.011$), function ($r = -0.63$, $p = 0.007$) and work/leisure ($r = -0.53$, $p = 0.030$). Table 4 presents the correlations between MFPDI scores and the spatiotemporal parameters for the control participants in which no significant correlations were observed ($p > 0.05$)

DISCUSSION

The findings from this study demonstrate that people with gout exhibit altered spatiotemporal gait parameters during both self-selected and fast walking speeds when compared to age- and sex-matched controls. Additionally, the results showed that shorter step and stride lengths and reduced walking velocity were strongly correlated with the total MFPDI score and sub-domains, including functional limitations.

Previous research has shown that people with gout walk slower with reduced cadence, step length and stride length compared to controls whilst walking at a self-selected speed in their own footwear [8]. Our findings for both walking speeds mirrored these results with respect to velocity and cadence. However, we observed no difference in step or stride length, but rather, increased step and stance times, with the addition of increased swing time at the fast walking speed. This suggests that gait impairments exhibited by people with gout, particularly in terms of spatial and time parameters may differ between shod and barefoot conditions.

Importantly, even after adjusting for BMI and foot pain, patients with gout in the current study still demonstrated altered gait characteristics when compared to healthy controls. This suggests that other factors may contribute to gait changes in this population. This is emphasised by the absence of an observed correlation between foot pain and parameters of gait. Although the increased step and stance times may be reflective of the reduced walking velocity, they may also reflect an inability to efficiently transfer body weight forward during walking [24, 25]. Several existing biomechanical studies have proposed that people with gout may adopt apropulsive gait strategies as a result of reduced ankle and first metatarsophalangeal joint (1MTPJ) plantarflexion strength [6, 26], decreased plantar pressure beneath the hallux [8] and restricted 1MTPJ dorsiflexion motion [6]. However, further research is warranted to determine the relationship between these foot and ankle characteristics and gait patterns in this population.

The ability to walk at not only usual speeds, but also faster speeds is a central component to daily mobility [27]. Faster walking speeds are fundamental in safely and independently carrying out many day-to-day activities including crossing the road, doing housework/gardening, and participating in sporting activities and active occupations. This study has shown that people with gout have difficulty reaching faster walking speeds compared to age- and sex-matched controls which is consistent with previously reported difficulties in the gout population including limited home and work productivity, increased dependency on others and social isolation [28-30].

The results from this study also showed that the patient-reported measures of foot pain and disability were strongly associated with parameters of gait in people with gout. Functional limitation appeared to be the leading influence of gait, and was significantly correlated with step and stride lengths and velocity. The association between foot pain and decreased functional abilities has been demonstrated in other long term chronic disease conditions [31-36]. Interestingly, foot pain was not associated with gait characteristics. However, it should be acknowledged that the participants with gout were not experiencing current symptoms of acute arthritis at the time of the study. It may be that pain/fear-avoidance mechanisms may be persistent or learned strategies adopted by patients in an attempt to prevent triggering an episode of acute arthritis. This behaviour has been illustrated in qualitative research in which people with gout report an inability to participate in physical activities with family and friends for fear of triggering a flare [28, 37].

This study should be considered in light of some limitations. Firstly, participants were recruited from secondary care rheumatology clinics, and had long disease duration with high frequency of tophaceous disease. These results may not be generalizable to less severe gout treated in primary care. Furthermore, our gout cohort was relatively small and may not be representative of secondary care patients. We also did not directly assess the extent of joint damage or tophus deposition through imaging in our gout participants, and it is likely that our clinical observations underestimate the degree of joint involvement. Next, the causal link between gait characteristics and foot pain cannot be determined from the cross-sectional design. It must also be acknowledged that the patient-reported outcome measure used in this study represented a reflection of pain and disability in the past month and not during the measurement of gait data. Furthermore, the MFPDI focused on foot-related pain and disability and did not recognise pain or other musculoskeletal disorders at other joints involved in gait. Future studies may investigate the relationship between gait strategies in people with gout and other lower limb biomechanical characteristics including lower joint function and muscle strength. Future longitudinal research may investigate the effect of pharmacological interventions, particularly urate lowering therapy on foot function. The contribution of gout-specific features to walking strategies, including tophus formation in lower limb joints, would also provide important insight into the mechanisms behind the functional impairment observed in the gout population.

CONCLUSION

The findings from this study demonstrate that gait patterns exhibited by people with gout are significantly different from age- and sex-matched controls during both self-selected and fast walking speeds, even after adjusting for BMI and foot pain. Additionally, higher levels of self-reported functional limitations, physical appearance and work/leisure difficulties were strongly correlated with parameters of gait, including reduced step and stride lengths and slower walking velocity.

CONFLICT OF INTEREST STATEMENT

The following may be potential conflicts of interest: ND has received personal fees or grants from Takeda, Teijin, Menarini, Pfizer, AstraZeneca, Ardea, and Fonterra. The other authors declare no competing interests.

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Table 1: Demographics & clinical characteristics

Variable	Control	Gout	*p*
N	20	20	
Gender, male, n (%)	19 (95%)	19 (95%)	1.00
Age, years, mean (SD)	53 (12)	60 (7)	0.06
Ethnicity, n (%)	European 20 (100%)	European 12 (60%)	0.004
	Maori 0 (0%)	Maori 1 (5%)	
	Pacific 0 (0%)	Pacific 3 (15%)	
	Asian 0 (0%)	Asian 4 (20%)	
Height, m, mean (SD)	1.75 (0.07)	1.75 (0.07)	0.904
BMI, kg/m^2, mean (SD)	26.7 (4.3)	31.5 (5.9)	0.006
Diuretic use, n (%)	1 (5%)	3 (15%)	0.640
NSAID use, n (%)	0 (0%)	12 (60%)	0.998
Prednisone use, n (%)	0 (0%)	2 (10%)	0.998
Hypertension, n (%)	6 (30%)	12 (60%)	0.061
Cardiovascular disease, n (%)	1 (5%)	5 (25%)	0.110
Diabetes, n (%)	1 (5%)	4 (20%)	0.180
Microscopically proven gout	-	4 (20%)	-
Disease duration, years, mean (SD)	-	16 (11)	-
Serum urate, mmol/l, mean (SD)	-	0.37 (0.15)	-
Flares in preceding 3 months, mean (SD)	-	1.1 (1.6)	-
Any subcutaneous tophi, n (%)	-	12 (60%)	-
Subcutaneous tophus count, mean (SD)	-	3.9 (6.1)	-
Tophus site, n (%)	-	Elbow, 7 (35%)	-
		Hand, 9 (45%)	
		Knee, 1 (5%)	
		Ankle, 3 (15%)	
		1MTP, 4 (20%)	
		Toes, 4 (20%)	

Colchicine use, n (%)	-	9 (45%)	-
Urate lowering therapy, n (%)	-	18 (95%)	-
Allopurinol use, n (%)	-	16 (80%)	-
Febuxostat use, n (%)		2 (10%)	
Probenecid use, n (%)	-	2 (10%)	-
MFPDI, total score, mean (SD)	2.1 (4.3)	12.4 (8.6)	<0.001
Function, mean (SD)	0.9 (2.0)	6.5 (4.6)	<0.001
Physical appearance, mean (SD)	0.0 (0.0)	1.1 (1.2)	<0.001
Pain, mean (SD)	1.0 (2.2)	3.4 (2.5)	0.005
Work/Leisure, mean (SD)	0.2 (0.4)	1.2 (1.3)	0.001

Table 2: Mean estimates and inferential statistics

	Control	Gout	Difference (95%CI)	*p*
Step time (s)				
Self-selected	0.54	0.59	0.05 (0.01 – 0.09)	0.017
Fast	0.43	0.49	0.06 (0.02 –0.10)	0.007
Step length (cm)				
Self-selected	68.1	70.4	-2.2 (-8.4 – 3.9)	0.459
Fast	85.3	82.1	-3.2 (-11.4 – 5.0)	0.433
Stride length (cm)				
Self-selected	141.1	136.5	-4.6 (-17.1 – 7.9)	0.456
Fast	170.9	164.5	-6.5 (-22.9– 10.0)	0.393
Swing Time (s)				
Self-selected	0.42	0.45	0.03 (-0.01 – 0.07)	0.164
Fast	0.36	0.40	0.06 (0.02 – 0.08)	0.005
Stance Time (s)				
Self-selected	0.65	0.72	0.07 (0.02 – 0.12)	0.012
Fast	0.50	0.57	0.07 (0.01 – 0.13)	0.019
Velocity (cm/s)				
Self-selected	132.7	117.4	-15.3 (-29.2 – -1.5)	0.031
Fast	201.9	171.4	-30.4 (-58.7– -2.1)	0.036
Cadence (steps/min)				
Self-selected	113.0	103.3	-9.7 (-17.2 – -2.2)	0.013
Fast	141.2	124.5	-16.7 (-28.8 – 4.6)	0.009

Table 3: Correlations between gait parameters and MFPDI scores for the gout group

	Spatiotemporal gait parameters, Pearson's r (*p*)						
	Step Time	Step Length	Stride Length	Swing Time	Stance Time	Velocity	Cadence
Total	-0.16 (0.531)	-0.62 (0.008)	-0.62 (0.008)	0.16 (0.530)	0.30 (0.243)	-0.60 (0.011)	-0.14 (0.592)
Function	-0.14 (0.600)	-0.65 (0.005)	-0.65 (0.005)	0.17 (0.508)	0.30 (0.251)	-0.63 (0.007)	-0.14 (0.592)
Physical Appearance	-0.37 (0.149)	-0.50 (0.041)	-0.50 (0.040)	-0.10 (0.692)	0.05 (0.855)	-0.38 (0.137)	0.13 (0.633)
Pain	-0.09 (0.735)	-0.42 (0.094)	-0.42 (0.093)	0.17 (0.513)	0.28 (0.283)	-0.43 (0.082)	-0.18 (0.494)
Work/ Leisure	0.06 (0.811)	-0.46 (0.064)	-0.46 (0.064)	0.31 (0.220)	0.38 (0.131)	-0.53 (0.030)	-0.27 (0.301)

Table 4: Correlations between gait parameters and MFPDI scores for the control group

	Spatiotemporal gait parameters, Pearson's r (*p*)						
	Step Time	Step Length	Stride Length	Swing Time	Stance Time	Velocity	Cadence
Total	0.22 (0.360)	0.06 (0.821)	0.04 (0.859)	0.08 (0.742)	0.28 (0.240)	-0.13 (0.591)	-0.25 (0.303)
Function	0.17 (0.478)	0.23 (0.352)	0.21 (0.395)	0.10 (0.670)	0.18 (0.453)	0.01 (0.982)	-0.18 (0.452)
Physical Appearance[a]	- -	- -	- -	- -	- -	- -	- -
Pain	0.28 (0.253)	-0.15 (0.555)	-0.15 (0.548)	0.07 (0.776)	0.38 (0.110)	-0.29 (0.231)	-0.32 (0.189)
Work/ Leisure	0.19 (0.430)	-0.07 (0.772)	-0.08 (0.755)	0.04 (0.887)	0.28 (0.246)	-0.18 (0.473)	-0.22 (0.361)

[a]Variable redundant