RHEUMATOLOGY

TITLE PAGE

Title: Clinical and biomechanical factors associated with falls and rheumatoid arthritis: baseline cohort with longitudinal nested case-control study.

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ABSTRACT

Objective: To identify the clinical and biomechanical characteristics associated with falls in people with RA.

Methods: 436 people aged 60 years or older with RA completed a one-year prospective survey of falls in the UK. At baseline, questionnaires recorded data including: personal and medical history, pain and fatigue scores, health related quality of life (HRQoL), physical activity and medication history. Occurrence of falls was monitored prospectively over 12 months by monthly self-reporting. A nested sample of 30 fallers (defined as the report of one or more falls in 12 months) and 30 non-fallers, were evaluated to assess joint range of motion (ROM), muscle strength and gait parameters. Multivariate regression analyses were undertaken to determine variables associated with falling.

Results: Compared with non-fallers (n=236), fallers (n=200) were older (p=0.05), less likely to be married (p=0.03), had higher pain scores (p<0.01), experienced more frequent dizziness (p<0.01), were frequently taking psychotropic medications (p=0.02) and reported lower HRQoL (p=0.02*).* Among those who underwent gait laboratory assessments, compared with non-fallers, fallers showed a greater anteroposterior (AP (p=0.03) and medial-lateral (ML) sway range (p=0.02), and reduced isokinetic peak torque and isometric strength at 60° knee flexion (p=0.03). Fallers also showed shorter stride length (p=0.04); shorter double support time (p=0.04); reduced percentage time in swing phase (p=0.02); and in knee ROM through the gait cycle (p<0.01).

Conclusion: People with RA have distinct clinical and biomechanical characteristics that place them at increased risk of falling. Assessment for these factors may be important to offer more targeted rehabilitation interventions.

Keywords: RA; falls; gait analysis; muscle strength; postural control

Key Messages

- Clinical and biomechanical factors are useful to identify people with RA at risk of falls.
- Age, disease severity and psychotropic medications are key factors associated with falls risk.
- People with RA who fall have reduced postural stability, reduced muscle strength and gait abnormalities.
- Exercise programmes targeting gait and strength deficits rather than overall physical activity may be indicated.

INTRODUCTION

Falls are a major health and social care challenge worldwide [1]. The aetiology is multifactorial, with an interaction between intrinsic, behavioral and environmental factors [2]. In addition to the associated injury risk, loss of confidence and independence, falls and subsequent fractures are a significant cause of illness and death in older people [1-3].

Rheumatoid arthritis (RA) affects approximately 1% of the UK adult population [4]. It results in significant morbidity and increased healthcare costs [5,6]. The prevalence of falls for people with RA has been reported to range from 10% to 43% [2], with Stanmore et al[7] reporting an incidence rate of 1,313 per 1,000 person-years. Older people with RA may be at particular risk of falls and fracture due to disease-related factors such as pain, joint deformity, decreased muscle strength and osteoporosis associated with long-term steroid use [8].

A number of clinical factors have been associated with falls in older people. These include: increased body mass index [9], increasing number of comorbidities and polypharmacy [10], falls history, pain and fatigue [11,12]. However, there remains uncertainty as to which specific clinical factors are associated with falls in people with RA. Furthermore, it remains unclear if specific biomechanical differences exist between individuals with RA who fall compared to those who do not experience falls. Previous biomechanical assessments of people with RA have focused on foot and ankle function[13-16] and gait comparisons to healthy controls [17]. However no studies have evaluated more global, kinematic features, which may be associated with falls such as gait speed [18]. Given that such kinematic measures differ in people with RA compared to non-RA cohorts [19], it is important to see if these could be associated to falls risk in this population. If shown to be associated, interventions to target specific deficits may be warranted.

Given this uncertainty in the RA population, this study aimed to characterise the clinical and biomechanical characteristics associated with falls among people with RA.

METHODS

Design: Prospective study with nested case-control biomechanical analysis.

Subjects: Six hundred men and women with RA attending a rheumatology clinic at the Norfolk and Norwich University Hospital (NNUH) were invited to take part by letter of invitation during July 2012 to January 2014. Participants were eligibile if they were: aged 60 years or older with a diagnosis of RA; under the care of a rheumatologist; and provided written informed consent. Participants were excluded if they presented with severe and enduring mental health problems or other co-morbidities which in the clinician's judgement made them unable to adhere with the protocol.

Baseline Assessment: Participants were asked to complete a questionnaire recording: age, gender, relationship status (married/single), employment status (employed/retired/other), visual analogue scale (VAS) pain score, VAS fatigue score, self-reported dizziness experienced, EQ-5D[20] and previous 12-month history of falls. The Phone-FITT[21] was used to assess physical activity (frequency, intensity, time and type). In addition, participants were asked to give details of their medication use and whether they had been diagnosed with Parkinson's disease or stroke.

Ascertainment of Falls: Participants returned a postcard monthly for 12 months to report the timing, circumstances and severity of fall(s). In ascertaining falls, participants were asked to report any slip or trip in which they lost balance and landed on the floor, ground, or lower level. This definition of falls follows the recommendations of the Prevention of Falls Network Europe (PROFANE) and the Outcomes Consensus Group documented in Lamb et al [1]. The recommendations include that a fall should be defined as "an unexpected event in which the participants come to rest on the ground, floor, or lower level" This was included in our questionnaire wording.

Nested sample: A group of 30; 'fallers' (n=30) who reported having had one or more falls in the 12-month interval and 30 who reported that they had not fallen were invited to attend a biomechanical assessment. The fallers were selected at random from the base cohort; each faller was matched one to one to a non-faller, stratifying on age and gender.

Biomechanical Assessment: Participants in the nested study were assessed with the following biomechanical measures:

a) Balance

Force plate data were collected at 1000Hz using Vicon Nexus software (Vicon, Oxford, UK). Data were filtered in Vicon Nexus software using a 4^{th} order Zero-lag Butterworth filter with 5Hz cut-off. The data were processed using a custom written Matlab script to extract values for statistical analysis. Data were split into X/Y components with the mean subtracted to account for position on the force plate. The mean of the three trials, each for 30 seconds with participants eyes open and then eyes closed, was calculated. The mean and standard deviation for the lateral and forward-backward directions of postural sway was calculated, the root mean square (RMS) for the deviations from the mean position served as the extent of postural sway (COP-RMS). The parameters extracted were: (1) Anterior/Posterior (AP) postural sway (COP-RMS), (2) Medio/Lateral (ML) postural sway (COP-RMS), (3) AP Sway range, (4) ML sway range, (5) resultant velocity; and (6) resultant path length.

b) Muscle Strength

Participants' knee flexor and extensor muscle strength was assessed using isokinetic and isometric dynamometry (Cybex NORM 770, Cybex International, Inc., New York, USA). During isometric testing the lower limb was placed and secured with straps so that the tested knee was maintained in a fixed position during testing. Knee flexion at 90°, 60° and then 30° were tested for both knees. During isokinetic testing angular velocities were set at three speeds: 120°/s, 90°/s, and 60°/s through the available voluntary range of movement (ROM) for individual participants. Three maximal contractions for each condition were performed with a 15 second rest between each contraction. The participant was asked to push or pull as hard as they could. During the contraction the researcher provided verbal encouragement and the participant was able to see their progress as displayed on screen. A practice contraction for each movement was completed prior to the test contraction. The highest peak torque for each of the six conditions was used for analysis. The parameters extracted were: (1) peak torque, (2) limb asymmetry: defined as the difference in peak torque between limbs as a percentage of the most powerful limb, and (3) knee flexion/extension muscle imbalance: calculated as a ratio between the ipsilateral hamstring and the ipsilateral quadriceps concentric peak torque (H:Q ratio). Asymmetry was defined as the difference in peak torque between limbs as a percentage of the most powerful leg ((peak torque of weak limb – peak torque of strong limb) / peak torque strong limb) x 100. Using this analysis, the value 0% represents equal strength between the lower limbs.

c) Gait

An eight-camera 3D-gait motion analysis system (Vicon, Oxford, UK) was used to assess gait. Fourteen reflective markers (25mm) were bilaterally attached onto the participant's skin using the Plug-In-Gait model (Vicon) based on the Newington Model[22]. All participants were asked to walk at a self-selected speed, wearing flat shoes along a seven-meter walkway. To ensure that three left and three right foot contacts were recorded, it was necessary to ask participants to undertake repeated walks. Two floor embedded forces plates (Bertic 4060) were used to collect ground reaction forces. Joint moments were normalised to body weight. Discrete gait kinematic and kinetic parameters were obtained from a mean of three trials for each side. These were: ROM, peak extension and flexion at the hip and knee; peak abduction at initial swing at the hip and peak varus in mid stance at the knee; the ROM, peak plantarflexion in pre-swing/early swing and dorsiflexion at late single support at the ankle.

Statistical Analysis

Cohort characteristics and biomechanical data were assessed using descriptive statistics. To assess the association between falls and clinical characteristics, a multivariate logistic regression analysis was undertaken to determine which variables influenced the occurrence of one or more falls in the previous 12-months prior to the baseline questionnaire. Physical activity was analysed as two composite variables (physical activity home and physical activity recreation). This was achieved by summing the frequency, duration and intensity for each 'type' of activity and then summing all the activities to make the two composite variables (physical activity home and physical activity recreation). Stepwise regression (using backwards elimination) was used to remove the non-significant variables from the initial model.

Biomechanical Study: For each balance measurement, and the dynamometry data, an unpaired Student T-test was performed to assess mean differences between the two groups. Gait data were analysed using a two-way repeated measures analysis of variance (ANOVA) with side (left and right limb) as the within-group factor, and group (fallers/non-fallers) as the between-group factor. Inter-group differences with 95% confidence intervals (CI) were estimated from the ANOVA model. Differences were considered statistically significant for $p<0.05$. All statistical analyses were calculated using Stata 14.2/SE (Stata Corp, Texas, USA).

Sample Size: A target sample size of 600 was chosen so as to detect an odds ratio (OR) with 95% CI associated with a 10% exposure of 1.7, assuming a baseline annual falls rate of 35%, and assuming a 50% non-particaption rate. In the nested case-control study, the sample size of 30 fallers and 30 non-fallers was determined *a priori* to detect a possible 0.5 standard deviation (SD) difference in kinematic measures (i.e. stride length, swing:stance ratio; knee ROM) between cases and controls, with a power of 80% and a significance of $p<0.05$.

RESULTS

Participants

Of the 600 people who were invited, 436 people agreed to take part (response rate: 73%). The demographic characteristics of the cohort are presented in **Table 1**. In total, 200 (46%) reported at least one fall in the 12-month period prior to the questionnaire. The mean age of those who reported a fall was 73.2 years (SD: 7.9) and for those who did not report a fall, 71.4 years (SD: 6.8). Seventy-three percent of the falls group were female, compared to 65% for the non-falls group. Those in the falls group reported higher pain scores (VAS: 48.4 vs. 34.7), fatigue (VAS: 52.4 vs. 41.5) and a greater proportion experienced dizziness (76% vs 49%). There was no difference between groups in physical activity levels at home (Phone-FITT: 26.9 vs. 29.9) and engagement in recreational activities (Phone-FITT: 12.5 vs. 13.9).

Clinical Factors Associated with Falls

In the multivariate model, five variables were retained to indicate a difference between the groups in the final model after stepwise elimination (**Table 2**). Compared to those who did not fall, those who reported one or more falls in the past year were older, (OR: 1.04, 95% CI: 1.01 to 1.07, p=0.05), not married (OR: 1.73, 95% CI: 1.06 to 2.86, p=0.03), had higher pain scores (OR: 1.02, 95% CI: 1.01 to 1.03, p<0.01), experienced dizziness (OR: 2.46, 95% CI: 1.56 to 3.91, p<0.01) and were taking psychotropic medications (OR: 1.82, 95% CI: 1.09 to 3.05, p=0.02). There was no significant relationship between falling and gender, employment status, home-based physical activity, recreational physical activity, VAS fatigue, a diagnosis of Parkinson's disease or a previous stroke, or taking four or more medications (p>0.05).

Biomechanical Factors Associated with Falls

The characteristics of the 30 fallers and 30 non-fallers who took part in the nested case control gait laboratory study are presented in **Table 3.** The median number of falls was 2.00 (inter-quartile range: 1.00, 3.75). There was no difference in BMI, employment status and relationship status between groups. There was no difference in knee flexion and extension peak torque at 120°, 90° and 60° knee ranges. Differences in biomechanical parameters assessed among those with and without a fall in the previous year are outlined below.

a) Balance

The fallers had a significantly higher postural sway (COP-RMS) and sway range in both the AP (5.2mm vs. 4.1mm, p=0.03; 28.3mm vs. 21.3mm, p=0.02) and ML (3.3mm vs. 2.3mm, p=0.01; 19.7mm vs. 12.7mm, p=0.02) directions compared to non-fallers during standing with eyes open (**Table 4**). Both groups had increased sway with eyes closed, but there was no significant difference between the groups for this measure.

b) Muscle strength

Twenty-three fallers and 28 non-fallers completed the isokinetic tests and 25 fallers and 30 non-fallers completed the isometric tests. Tests were not completed either due to pain in their knee or physical inability. Fallers had a lower isokinetic peak torque at each speed during flexion compared to non-fallers (**Table 5**). At 60° this is significantly lower (48.23Nm vs. 57.95Nm, p=0.03). Fallers had a higher isokinetic peak torque at each speed during extension than the non-faller although level of significance was not reached. Fallers had a lower isometric peak torque than the non-fallers during extension and flexion at each position tested but this was not statistically significant (**Table 5**).

The fallers had a significantly greater asymmetry during isometric extension at 90° (22% vs. 13%, p=0.05) and 60° (23% vs. 13%, p=0.02) compared to the non-fallers (**Table 5**). No significant differences between the fallers and non-fallers H:Q ratio was seen during isokinetic contractions (**Table 5**).

c) Gait

The fallers had a significantly shorter stride length (1.05m vs. 1.18m, p=0.04), longer double support time (0.39s vs. 0.32s, p=0.04) and reduced percentage time in swing (34.2% vs. 36.8%, p=0.02) than the non-fallers (**Table 6**). Fallers had significantly smaller knee ROM through the gait cycle compared to the non-fallers (50.3° vs. 58.3°, p<0.01). This smaller knee ROM at the knee in the fallers was accompanied by smaller knee flexion than the non-fallers (51.6° vs. 56.0°, p<0.01). In all other parameters no significant differences between fallers and non-fallers were seen (**Table 6**).

DISCUSSION

Our analysis has shown that people with RA who are older and unmarried, and who have higher pain scores, dizziness and who take psychotropic medications are at greater risk of falls. While physical activity performance was not associated with falls risk, those who fell appeared to have a characteristic biomechanical signature with increased postural sway, reduced peak torque and strength, and gait differences showing a shorter stride length, reduced swing-phase, and knee ROM through the gait cycle.

The findings in our cohort of people with RA are supported by a number of other cross-sectional[2,23] and longitudinal studies in similarly aged cohorts [24]. Being single was also reported as a significant factor for the occurrence of falls. This too has been previously reported in the English population [25]. However, due to the data collected processes, we were unable to explore whether this finding reflects previous marital histories (such as long-term first marriages, never married, widowed, divorced, long-term partners) which have been reported as important distinctions within health and mortality outcomes in older people [26].

While previous studies of the biomechanics of falling in RA have been limited in their scope of assessment, taken together, their findings are in broad agreement with our own. Hayashibara et al [27], reported that postural sway was larger for people with RA who had fallen compared to non-fallers. Rome et al[28] reported that people with RA have poorer dynamic and static postural control than aged matched non-RA[28]. Our RA fallers and non-fallers showed similar results to Rome's study, although we report slightly poorer results for AP and ML sway range during eyes open. This may be due to differences in methodology. Rome et al[28] presented the participants with a target to focus on during eyes open. This was not part of the protocol in our study. Our findings indicate that non-fallers have a better use of their visual systems.

Both groups show a strength imbalance across quadriceps and hamstring. Both fallers and non-fallers had a significantly higher H:Q ratio in their weaker leg compared to their stronger leg during isokinetic contractions. The increase in the H:Q ratio in the fallers and non-fallers in their weaker leg was due to a lower peak torque in the quadriceps. Given these issues around imbalance, general lower limb strength training intervention through physical activity programmes may not necessarily be the most appropriate exercise intervention for this population. Targeting such imbalance through specific muscle-based exercise programmes has a plausible physiological rationale.

This study is the first to investigate the risk of falls and physical activity participation in people with RA. The PHONE-FITT tool was used due to its reported reliability and validity[21]. This self-reported tool provides valuable data on both home-based physical activity and recreational physical activity performance. This is important for this population based on their potentially wide-ranging levels of physical activity pursuits[29]. The data indicated that neither home-based nor recreational physical activity were significantly associated with falls risk. Whilst previous studies have suggested that strength and balance are associated with a reduced risk of falls in people with osteoarthritis[30], it appears that this may not relate directly to physical participation, which assesses multiple components of physical function. Given the identified biomechanical factors which are associated with falls, targeting biomechanical deficits rather than simply promoting more global physical activity engagement, would be indicated from these findings.

A notable strength of this study is the recruitment of a representative RA cohort as the basis for the nested study. Previous studies of biomechanical factors involved in falls have been based on small selective samples, with falls history based on recall. Our sample was selected from a large group of clinic attenders with RA in whom falls were identified prospectively. Limitations of the study include the fact that not all participants completed the dynamometry tests due to having a painful knee or unable to create any level of torque due to weakness. Participants were recruited from a regional rheumatology service; accordingly, they may have presented with more severe disease activity compared with those from the community. The relatively small number of cases in the biomechanical evaluation cohort precluded any analysis of the relationship between specific clinical or biomechanical features and the frequency of falling because of insufficient power. We were also unable to assess disease activity using the DAS [31] at baseline or during follow up in the cohort study, given the self-completed nature of the questionnaire. We note that pain was associated with falls risk in the survey study, providing an indication that disease severity may be related to falls. However, given the small sample, this finding should be considered exploratory.

CONCLUSIONS

Characteristic clinical and biomechanical factors have been identified as associated with falls in people with RA. Our findings suggest that physical activity performance alone may be insufficient to reduce falls, and that targeting interventions to address specific biomechanical deficits for those individuals with RA at increased falls risk, would be appropriate.

DECLARATIONS

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Ethical approval: The study was approved by the East of England (Cambridge) NHS Research Ethics Committee (REC Ref 11/EE/0335).

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Conflict of interest: The authors declare no conflicts of interest in relation to this study.

FIGURE AND TABLE LEGENDS

Table 1: Baseline characteristics from those who had experienced one or more falls and those who had not experienced a fall in the previous 12-months prior to administration of the questionnaire.

Table 2: Results for the initial and final regression models to assess risk factors for falling in people with rheumatoid arthritis from the baseline cohort study data.

Table 3: Characteristics of the longitudinal cohort of subjects who completed biomechanical tests.

Table 4: COP balance measures in fallers and non-fallers in the longitudinal cohort during quiet standing with eyes closed and eyes open.

Table 5: Mean peak isokinetic and isometric torque (Nm) for the fallers and non-fallers for three speeds; 120°/sec, 90°/sec and 60°/sec and three positions; 90° 60° and 30° for extension at the knee (quadriceps) and flexion at the knee (hamstring).

Table 6: Kinematic and temporal-spatial parameters for fallers and non-fallers (mean and SD data).

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Table 1: Baseline characteristics from those who had experienced one or more falls and those who had not experienced a fall in the previous 12-months prior to administration of the questionnaire.

	Fall Group	**Non-Falls Group**
N	200	236
Age [Mean (SD)]	73.2 (7.9)	71.4 (6.8)
Gender – Females (%)	73	65
Employment Status		
Employed (%)	5	11
Retired (%)	89	86
Other including Carer (%)	7	3
Relationship Status		
Single (%)	34	21
Married (%)	66	79
Physical Activity (Phone-FITT data)[21]		
Home [Mean (SD)]	26.9 (12.0)	29.9 (12.2)
Recreation [Mean (SD)]	12.5 (11.6)	13.9 (19.2)
Medical Status		
Pain (VAS) [Mean (SD)]	48.4 (25.9)	34.7 (25.2)
Fatigue (VAS) [Mean (SD)]	52.4 (24.6)	41.5 (24.6)
Dizziness (%)	76	49
Four or more medicines each day (%)	77	60
Medicine for anxiety / depression (%)	34	16
Stroke or Parkinson’s disease (%)	6	2

SD – standard deviation; VAS – visual analogue scale

Table 2: Results for the initial and final regression models to assess risk factors for falling in people with rheumatoid arthritis from the baseline cohort study data.

	Initial Regression Model (n=388 (89%))		Final Regression Model (n=410 (94%))	
	Odds Ratio (95% CI)	**P-value**	**Odds Ratio (95% CI)**	**P-value**
Age	1.03 (0.99, 1.06)	0.119	1.03 (1.00, 1.06)	0.051
Gender (male)	reference			
Gender (female)	1.20 (0.73, 1.97)	0.483		
Relationship (married)	reference			
Relationship (single)	1.75 (1.03, 2.98)	0.040	1.73 (1.06, 2.86)	0.030
Employment (employed)	reference			
Employment (retired)	0.99 (0.40, 2.63)	0.987		
Employment (other)	2.25 (0.60, 9.10)	0.240		
Physical Activity (home)	0.99 (0.97, 1.01)	0.415		
Physical Activity (recreation)	1.00 (0.99, 1.02)	0.605		
Pain (VAS)	1.02 (1.01, 1.03)	0.004	1.02 (1.01, 1.03)	<0.001
Fatigue (VAS)	1.00 (0.98, 1.01)	0.441		
Dizziness (yes)	2.32 (1.43, 3.80)	<0.001	2.46 (1.56, 3.91)	<0.001
Four or more medicines each day (yes)	1.21 (0.71, 2.05)	0.491		
Medicine for Anxiety / Depression (yes)	1.67 (0.95, 2.94)	0.074	1.82 (1.09, 3.05)	0.023
Stroke or Parkinson (yes)	1.68 (0.52, 6.12)	0.402		

CI – confidence interval; VAS – visual analogue scale

Table 3: Characteristics of the longitudinal cohort of subjects who completed biomechanical tests.

	Fall Group	**Non-Fall Group**
N	30	30
Age [Mean (SD)]	72.4 (7.3)	72.5 (7.0)
BMI [Mean (SD)]	28.1 (5.4)	26.2 (4.5)
Body weight kg [Mean (SD)]	75 (16)	72 (14)
Height cm [Mean (SD)]	163 (10)	166 (10)
Gender - Females (%)	50	47
Employment		
Employed (%)	0	7
Retired (%)	73	73
Other (%)	27	20
Relationship		
Single (%)	3	13
Married (%)	90	87
Divorced/Separated/Widowed (%)	7	0
Disease Activity Score[22]		
Swollen joint count, (median IQR)	2.5 (1-4)	1 (0-1)
Tender joint count, (median IQR)	2 (0-8)	1 (0-5)
Patient global health (mean (SD))	56.5 (24.9)	72.1 (19.8)
EQ-5D[20]		
EQ-5D, utility, mean (SD)	0.65 (0.27)	0.78 (0.20)
EQ-5D, VAS, mean (SD)	70 (19.25)	76.7 (17.59)
Peak Torque		
Max flexion 120° [Mean (SD)]	40.6 (13.7)	41.4 (15.7)
Max flexion 90° [Mean (SD)]	53.2 (15.0)	52.8 (18.2)

Max flexion 60° [Mean (SD)]	64.0 (19.1)	62.9 (22.2)
Max extension 120° [Mean (SD)]	109.5 (31.0)	103.8 (34.4)
Max extension 90° [Mean (SD)]	97.8 (28.7)	95.9 (31.6)
Max extension 60° [Mean (SD)]	74.8 (25.3)	77.1 (29.7)

BMI – Body Mass Index; cm – centimetre; IQR – inter-quartile range; kg – kilograms; SD – standard deviation; VAS – visual analogue scale

Table 4: COP balance measures in fallers and non-fallers in the longitudinal cohort during quiet standing with eyes closed and eyes open.

	Non-faller (N=29)	Faller (N=29)	P-value
Eyes Open			
AP Sway (COP-RMS) (mm)	4.1 (1.9)	5.2 (2.6)	0.03
AP Sway Range (mm)	21.3 (9.1)	28.3 (14.2)	0.02
ML Sway (RMS) (mm)	2.3 (1.3)	3.3 (2.0)	0.01
ML Sway Range (mm)	12.7 (7.6)	19.7 (14.8)	0.02
Resultant Velocity (mm/s)	5.7 (4.0)	6.1 (68.0)	0.32
Resultant Path Length (mm)	170.7 (119.1)	183.3 (82.4)	0.32
Eyes Closed			
AP Sway (COP-RMS) (mm)	6.5 (8.6)	6.3 (5.0	0.46
AP Sway Range (mm)	27.0 (15.5)	31.2 (11.8)	0.12
ML Sway (RMS) (mm)	4.6 (9.9)	4.0 (5.4)	0.39
ML Sway Range (mm)	15.5 (12.4)	19.0 (10.4)	0.13
Resultant Velocity (mm/s)	8.2 (6.1)	9.0 (4.7)	0.28
Resultant Path Length (mm)	244.7 (183.5)	269.9 (140.8)	0.28

AP – anteroposterior; COP-RMS – postural sway root mean square; mm – millimeters; mm/s – millimeters per second

Table 5: Mean peak isokinetic and isometric torque (Nm) for the fallers and non-fallers for three speeds; 120°/sec, 90°/sec and 60°/sec and three positions; 90° 60° and 30° for extension at the knee (quadriceps) and flexion at the knee (hamstring).

			Mean peak torque (Nm)					**Asymmetry %**			**H:Q Ratio**		
			Faller		**Non-Faller**		**P-value**	**Faller**	**Non-Faller**	**P-value**	**Faller**	**Non-Faller**	**P-value**
			Mean	**SD**	**Mean**	**SD**		**%**	**%**				
Isokinetic	120°/sec	Flexion	32.2	20.0	38.0	24.9	0.05	31.0	36.0	0.57	0.97	1.31	0.24
		Extension	44.3	24.3	39.0	24.6	0.16	43.1	38.8	0.64			
	90°/sec	Flexion	40.4	22.6	48.7	25.8	0.41	31.2	33.8	0.72	0.82	1.07	0.07
		Extension	55.3	24.7	51.9	25.1	0.12	25.5	29.1	0.64			
	60°/sec	Flexion	48.2	22.9	58.0	28.5	0.03	21.7	31.2	0.15	0.82	1.01	0.09
		Extension	65.6	28.0	64.2	29.3	0.26	29.2	26.3	0.71			
Isometric	90°	Flexion	34.5	14.1	36.8	14.9	0.57	19.3	15.5	0.31			
		Extension	85.8	37.2	95.5	31.1	0.31	21.9	13.1	0.05			
	60°	Flexion	47.4	15.9	48.5	17.7	0.80	16.0	13.9	0.55			
		Extension	77.7	32.3	89.0	30.2	0.19	24.1	13.3	0.02			
	30°	Flexion	57.8	18.7	58.3	20.9	0.93	14.4	12.5	0.51			
		Extension	60.5	28.1	70.2	26.9	0.20	17.7	13.2	0.27			

Sec – seconds; SD – standard deviation; Nm – Newton meters

Table 6: Kinematic and temporal-spatial parameters for fallers and non-fallers (mean and SD data).

	Non-Faller (n=29)	Faller (n=24)	Mean difference (95% CI)	P-Value
Hip Kinematic				
Flexion – extension ROM	38.3 (5.5)	36.1 (7.8)	2.9 (-0.75,6.53)	n.s.
Hip extension	-11.9 (7.6)	-8.5 (10.5)	-3.3 (-8.23,1.61)	n.s.
Hip Flexion	26.3 (6.8)	27.6 (7.0)	-0.42 (-4.14,3.3)	n.s.
Peak Abduction at initial swing	6.0 (3.9)	5.3 (4.7)	0.08 (-2.23,2.39)	n.s.
Extension in the loading response	0.52 (0.17)	0.52 (0.16)	-0.03 (-0.13,0.08)	n.s.
Flexion in late stance	-0.81 (0.37)	-0.75 (0.26)	-0.1 (-0.3,0.1)	n.s.
Abduction in mid-stance	0.89 (0.20)	0.93 (0.21)	-0.09 (-0.22,0.03)	n.s.
Adduction at terminal stance	-0.08 (0.07)	-0.07 (0.05)	-0.01 (-0.05,0.02)	0.24
Knee Kinematic				
Flexion – extension ROM	58.3 (5.5)	50.3 (12.7)	9.44 (4.27,14.61)	<0.001
Knee extension	-2.3 (5.0)	1.3 (7.3)	-2.89 (-6.21,0.43)	n.s.
Knee flexion	56.0 (5.6)	51.6 (10.6)	6.55 (2.12,10.95)	0.004
Peak valgus/varus in mid swing	9.5 (7.4)	9.7 (10.6)	-2.64 (-7.44,2.16)	n.s.
Peak valgus/varus in stance	2.4 (4.1)	2.6 (7.6)	-0.7 (-3.9,2.49)	n.s.
Extensor in the loading response	0.48 (0.22)	0.52 (0.21)	-0.01 (-0.14,0.12)	n.s.
Flexor in terminal stance	-0.33 (0.1)	-0.31 (0.12)	- 0 (-0.06,0.07)	n.s.
Valgus in mid-stance	0.40 (0.16)	0.44 (0.27)	-0.08 (-0.2,0.04)	n.s.
Var in terminal stance/initial swing	-0.07 (0.03)	-0.06 (0.03)	0 (-0.02,0.02)	n.s.
Ankle Kinematic				
Dorsiflexion - plantarflexion ROM	22.8 (5.0)	23.9 (5.7)	-0.95 (-3.81,1.92)	n.s.
Plantarflexion in pre swing/early swing	12.7 (5.0)	13.5 (7.0)	-0.6 (-3.87,2.67)	n.s.
Dorsiflexion late single support	-10.2 (7.3)	-10.4 (9.2)	0.35 (-4.07,4.77)	n.s.
Plantarflexion at pre-swing	1.24 (0.21)	1.19 (0.25)	0.02 (-0.11,0.16)	0.330
Dorsiflexion in the loading response	-0.18 (0.1)	-0.18 (0.1)	-0.01 (-0.07,0.05)	n.s.
Temporal-Spatial Parameters				
Speed (m/s)	1.0 (0.2)	0.9 (0.3)	-0.13 (0.26,0.00)	0.054
Stride length (m)	1.2 (0.2)	1.1 (0.3)	-0.13 (-0.25,-0.01)	0.039
Step length (m)	0.6 (0.1)	0.5 (0.1)	-0.06 (-0.12,0.00)	0.057
Cadence (steps/min)	10.3 (11.5)	10.0 (9.5)	10.30 (-5.60,6.20)	0.266
Single support (s)	0.4 (0.1)	0.4 (0.1)	0.00 (-0.06,0.06)	0.205
Double support (s)	0.3 (0.1)	0.4 (0.1)	0.10 (0.05, 0.16)	0.041
Swing (%GC)	36.8 (1.9)	34.2 (3.9)	2.61 (0.93, 4.25)	0.019

CI – confidence intervals; GC – gait cycle; m – meters; m/s - meters per second; min – minutes; n.s. – not significant; s – seconds; SD – standard deviation