Persistent pain is associated with poorer balance and gait performance for people with Chronic Obstructive Pulmonary Disease

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Abstract

Background
People with COPD fall due to balance and gait impairments, and frequently report pain. The influence of pain on balance and gait in people with COPD is unknown. We aimed to compare balance and gait in people with COPD with and without persistent pain and explore factors associated with poor balance and gait.

Methods
43 participants' characteristics and pulmonary rehabilitation outcomes were recorded. Participants were assigned to two groups, those with persistent pain (pain lasting ≥3months) (n=25) and those without (n=18) for analysis. Between-group differences were calculated for pain (BPI-SF), balance (BESTest, BBS), gait (GAITrite), isokinetic hip, knee and ankle strength (MVC), lower limb muscle endurance (30 sec STS), physical activity (PASE) and Maximal Inspiratory Pressure (Pimax). Associations between neuromuscular factors and balance/gait outcomes were investigated.

Results
BESTest and BBS scores were 14.0% (95% CI: 7.4-20.6) and 3.0 (95% CI: 0.7-5.3) lower, for the persistent pain group. Mean gait speed was slower for the pain group (0.99m/s vs 1.18m/s, 95%CI for difference: 0.03-0.35 m/s, group main effect: p=0.02). The mean reduction in dual-task vs single-task gait speed was greater in the pain group (0.12m/s vs 0.05m/s, interaction effect: p=0.045). Lower BESTest scores were associated with poorer muscle endurance (r=0.650), pain severity (r=-0.584), and weaker hip abductors (r=0.370) and ankle plantar-flexors (r=0.438). No associations were apparent for gait speed.

Conclusion
People with COPD plus pain have worse balance and slower gait speed, especially under dual-task conditions. Pain severity, muscle endurance and hip and ankle strength are associated with balance performance.

Key words: Chronic Obstructive Pulmonary Disease, Pain, Balance, Gait

Introduction:

Chronic Obstructive Pulmonary Disease (COPD) is characterised by progressive airflow limitation and shortness of breath on exertion, leading to reduced physical function and worse health-related quality of life [1]. The presence of two or more long-term conditions is common in people with COPD and approximately one-third are classified as being frail, increasing the risk of mortality [2, 3]. Poor balance and slower gait speed are important aspects of frailty and are major risk factors for falls. It is therefore unsurprising that people with COPD have worse balance and poorer gait than healthy peers and fall more frequently (1.17 vs. 0.7 falls per person per year) [4-8]. Pulmonary rehabilitation (PR) is a gold standard exercise-based intervention for people with COPD but assessment and management of falls, balance and pain are not routinely recommended despite these factors acting as potential barriers to exercise and attrition in PR [9-12].

It is unclear why people with COPD have worse balance, gait and fall more but lower limb weakness is likely to contribute [7]. Pain is also a significant problem in people with COPD with a 66% pooled prevalence of pain that persists over time [13, 14]. Musculoskeletal pain in the thoracic region is more commonly reported by people with COPD than healthy older adults [13]. People with COPD experience 2.6 times greater pain intensity and 3.7 times greater pain interference with daily activities than age and gender matched healthy peers [15, 16]. Pain intensity and interference are associated with worse health-related quality of life, breathlessness, anxiety, morbidity and mortality in people with COPD [17, 18]. In older adults, pain has been associated with a higher risk of falls [19] and a recent large secondary data analysis found that those with COPD and severe pain have almost a 40% predicted probability of falling in a two-year period [20]. However, the influence of persistent pain on risk factors for falls, namely balance and gait, has not yet been investigated prospectively in people with COPD. Therefore, the aims of this study were 1) to compare balance and gait in people with COPD who have persistent pain (pain more often than not for greater than three months duration) to those who have no pain or non-persistent pain, and 2) to explore factors, including pain, that may be associated with balance and gait impairment in people with COPD.

Methods:

The study was registered with clinical trials.gov (NCT04202991).

Participants:

Individuals with COPD were recruited from two NHS outpatient Pulmonary Rehabilitation (PR) services in the North-East of England between May and December 2019. Eligible participants had to have a confirmed diagnosis of COPD as per GOLD guidelines, be > 18 years, be exacerbation free for 6-weeks and have no uncorrected visual or somatosensory disturbance.

Individuals were excluded if they had other conditions known to impact on balance or gait (e.g., severe neurological or vestibular conditions) or were unable to speak English. All participants provided written informed consent.

Data collection:

Patient demographics, including sex, age, BMI, and clinical characteristics, including medical history (comorbidities, medication, pack years and exacerbation history), FEV^1 and FEV^1/FVC (l), 12-moth falls history, MRC Dyspnoea Score, health status (COPD Assessment Test (CAT)), anxiety and depression (PHQ-9, GAD-7 or HADs) and exercise capacity (six-minute walk distance (6MWD) or incremental shuttle walk distance (ISWT)) were obtained from clinical records. These data were collected from PR assessments that occurred no more than 8 weeks before study assessments. Twelve-month retrospective falls history was reported verbally from participant recall. Comorbidities were calculated based on the Charlson comorbidity index, a subjective medical history was recorded and cross-referenced with medical records. Psychological symptoms and exercise capacity were assessed in accordance with the outcome measures used within the pulmonary rehabilitation programmes which differed between the two sites. If lung function results were not available from clinical records, spirometry testing was performed using a handheld device (Micro1 Handheld Spirometer, CareFusion, USA) in line with the ATS/ERS technical standards.

Additional clinical outcomes were assessed during a single appointment, of a maximum two hours, at Teesside University laboratories. The assessment took place before, or during the first half of a PR program. The tests were completed in a consistent order with five-minute rests between to avoid fatigue. Pain was assessed last to maintain blinding of the outcome assessor to pain status.

Pain was assessed using *The Brief Pain Inventory – Short Form (BPI-SF*) which is a short nine item questionnaire evaluating the severity and impact of pain. It has high internal consistency and validity in people with COPD [21-23]. Participants were also asked the question "have you experienced pain more often than not in the last three months?" (in line with International Association for the Study of Pain (IASP) for The World Health Organisation International Classification of Disease 10 (ICD-10)) to determine the presence of persistent pain, or no persistent pain for group allocation [24].

Balance was assessed using the Balance Evaluations Systems Test (BESTest) and the Berg Balance Scale (BBS). The BESTest evaluates six subsystems of balance; biomechanics, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation and stability in gait. It includes 27 functional tasks, each scored on a 0-3 scale to give an overall percentage of the maximum 108 points. The BBS assesses 14 performance-based tasks, each scored on a 56-point ordinal scale, with higher scores indicating better balance. Both tests have high validity and reliability in individuals with COPD and are able to identify falls status [25].

Temporospatial gait aspects were tested using the GAITrite platinum 4.27m walkway (CIR Systems, NJ, USA). A three-metre walk in and out was applied under single and dual task (the Stroop test) conditions [26]. GAITrite metrics representing gait speed (gait velocity (cm/s)), security (% time in single support), smoothness (step time standard deviation), symmetry (step time differential) and stability (step width (cm)) were collected.

Isokinetic concentric muscle strength of the hip abductors and adductors, knee extensors and flexors and ankle dorsi and plantar flexors were tested giving peak torque normalised to body weight (TQ/BW) (Biodex System 3, Biodex Medical Systems, Shirley, NY, USA). Hip abductors and adductors were assessed in standing, all other isokinetic strength testing was seated. Participants completed 10 repetitions of the dominant limb movements, at test speeds of 60°/s [27]. Biodex software calculated averages of repetitions in each test and highest test score was used for analysis.

The 30 second sit to stand test (30s STS) was used to assess lower limb muscle endurance. The 30s STS is validated and reliable in chronic respiratory disease populations [28].

Physical activity was measured using the Physical Activity Scale for the Elderly (PASE), which includes 12 questions on leisure, household, and work-related activity over the past 7-day period. Scores range from 0 to 400, calculated by multiplying pre-set activity weights by activity frequencies, and higher scores indicate greater physical activity. PASE is reliable and valid for use with older adult populations [29].

Maximum Inspiratory Pressure (MIP) was measured using a MicroRPM 01 (MicroMedical, Rhymney, UK) handheld electronic PiMax manovacuometer [30]. The best of three attempts at rest was recorded.

Data analysis:

A sample size calculation was performed using minimal detectable change data from published literature on the BESTest used to measure balance in people with COPD, powered to 80% with 5% type 1 error [31]. A sample size of 21 in each group (COPD with persistent pain vs. COPD with no persistent pain) had 80% power to detect a difference in means of 10 units, assuming that the common standard deviation is 11 units using a two-group t-test with a 0.05 two-sided significance level.

Differences between group demographics were tested using either an independent student’s t-test or Mann Whitney as appropriate. Group mean differences between the “persistent pain” group and the “no persistent pain” group were quantified using multivariable-adjusted (age, sex, BMI) general linear models (GLM) for single condition outcomes, and a repeated measures GLM was used for gait temporospatial outcomes to compare the effects of both group and condition, using SPSS statistics software (version 26.0.0). A Pearson’s Correlation was conducted with the 10 outcomes (BESTest, single and dual task gait speed, pain severity, PASE scores, inspiratory muscle strength, 30s STS, hip abductor and ankle plantar flexors included in the correlation matrix on all study participants (i.e., those in both the persistent pain and the no persistent pain groups)) based on a logical theory prioritisation basis (supplement 1). Confidence intervals (95%) for r values were calculated, based on the Fisher r-to-z transformation. To assess for the impact of missing data, a regression technique was used to impute missing values across the matrix and compared with Pearson Correlation to assess the sensitivity of missing data.

Results:

A total of 233 people were screened. Of these n= 121 met the inclusion criteria and n= 76 agreed to speak to a researcher. N= 7 declined further involvement and n= 16 did not meet the inclusion criteria. N= 53 met the criteria and agreed to take part but n=10 did not attend the assessment (figure 1).

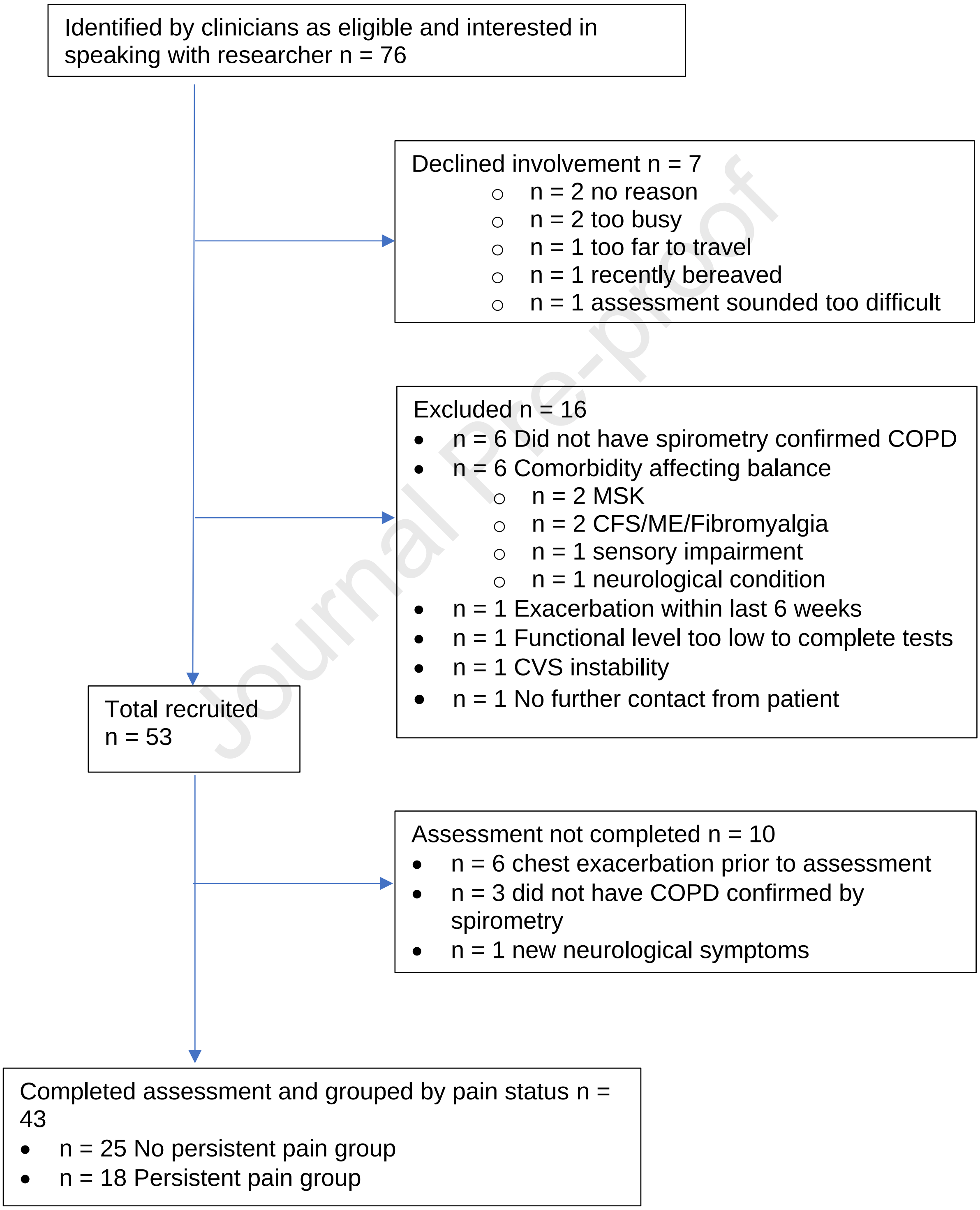

Figure 1. Flow diagram of study recruitment from referral to researcher group division by pain status.

Forty-three people with COPD were recruited and completed the study. Twenty-five people were assigned to the persistent pain group and eighteen to the non-persistent pain group based on answers to the pain question. A power comparison was performed indicating that with 21 participants in each group as per the recruitment aim power would be 81.2%, and with the actual split was 81.1%. There were no significant differences between groups for age, BMI, pack-years, FEV_1 or % predicted FEV_1, MRC dyspnoea score, 6MWD (n=31), 12-month falls history, HADs-A and HADs-D. The persistent pain group had worse health status indicated by lower CAT scores, shorter ISWT distance (n=11), a greater number of comorbidities, and worse anxiety and depression indicated by higher scores on the PHQ-9 and GAD-7 (n=29) (Table 1).

Table 1. Table of demographics

	Persistent pain n = 25 (58%)		No persistent pain n = 18 (42%)		Group mean difference	Confidence intervals		P-value
	Mean (or median if stated)	SD (or IQR if stated)	Mean (or median if stated)	SD (or IQR if stated)		lower	upper	
Age	70	7	68	7	2.1	-3	6.7	0.36
BMI	29	6	27	6	2.2	-1.7	6.1	0.27
Pack years	51	62	44	23	7.6	12.8	-18.6	0.56
% female	40		61			-0.2	0.2	0.18
FEV_1	1.5	0.4	1.4	0.6	0.1	-0.2	0.5	0.49
FEV_1% predict	60.1	16.3	55	19.5	5.1	-6.7	16.9	0.38
6MWT n = 31	196.8	142.8	258.2	63.8	-61.3	-148.24	25.6	0.16
ISWT n = 11	142.9	45.1	357.5	117.9	-214.6	-349.5	-34.8	0.03*
MRC**	median 3.0	IQR 1.0	median 3.0	IQR 1.3				0.160
CAT	23.6	7.8	17	5.8	6.6	2.2	11.0	0.004*
12-m falls**	median 0.0	IQR 1.0	median 0.0	IQR 1.0				0.963
No of comorbidities**	median 3.0	IQR 2.0	median 1.0	IQR 3.0				0.006*
PHQ-9 n = 29	12.4	7.2	5.5	4.0	6.93	2.1	11.8	0.007*
GADs n = 29	8.1	6.6	3.1	2.9	5.02	0.3	8.7	0.01*
HADs-A n = 15	6.5	5.5	4.9	4.3	1.64	-4.0	7.2	0.54
HADs-D n = 15	4.1	3.3	4.4	2.7	-0.30	-3.7	3.1	0.85

**statistically significant difference between groups. ** analysed with Mann-Whitney test. SD = standard deviation, IQR = inter quartile range, BMI = body mass index; FEV1 = forced expiratory volume in one second; 6MWT = 6 minute walk test; ISWT = incremental shuttle walk test; MRC = MRC dyspnoea scale; CAT = COPD assessment test; PHQ-9 = patient health questionnaire; GAD-7 = generalised anxiety disorder; HADs-A = hospital anxiety and depression scale; HADs-D = hospital anxiety and depression scale, n = describes the sample size of each group and has been added after outcome name where data are not available for the whole study sample.*

Pain characteristics were worse for the persistent pain group. Pain severity, interference and number of pain locations were greater in the persistent pain group than the no persistent pain group (Table 2). Some differences were apparent for the locations of pain reported and for pain causing comorbidity. For persistent pain and non-persistent pain lumbar spine pain (48% and 39%) and knee pain (48% and 22%) were common, however the persistent pain group tended to more frequently report pain in the cervical (36% vs 22%) and thoracic spine (24% vs 0%), chest (16% vs 11%) and shoulders (36% vs 6%) than the no persistent pain group. Almost half of people in the persistent pain group had osteoarthritis (OA), and 32% had spinal pain, compared to the no persistent pain group in which only 22% and 11% presented with OA and spinal pain respectively.

Table 2. Table of pain outcomes in the persistent pain and no persistent pain group.

	Persistent pain n = 25 (58%)		No persistent pain n = 18 (42%)		Group mean difference	Confidence intervals		P-value
	Mean	SD	Mean	SD		lower	upper	
Mean pain severity score (1–6)	5.1	2.0	1.5	1.5	3.7	2.6	4.8	<0.0001*
Mean pain interference	4.8	2.0	1.1	1.8	3.7	2.4	4.9	<0.0001*
No. of pain locations	4.4	2.2	1.6	1.9	2.8	1.5	4.2	0.0001*

**statistically significant difference between groups, n = describes the sample size of each group*

Balance

People with COPD and persistent pain had worse balance than those with no persistent pain (BESTest and BBS, table 3). A greater proportion of those with persistent pain were classified as being at risk of falls (64%), according to pre-determined cut off scores for the BESTest, compared with the no persistent pain group (22%).

Muscle strength and endurance

Those with persistent pain also had worse lower limb muscle endurance (30s STS, table 3). Group mean differences for isokinetic concentric muscle strength of the hip abductors and adductors, knee extensors and flexors and ankle dorsi and plantar flexors were all lower for the persistent pain group but these differences did not reach significance (TQ/BW, table 3). People with persistent pain were often unable to complete the muscle strength testing; 20% and 24% of people with persistent pain were unable to tolerate testing for TQ/BW knee and ankle muscles respectively, vs 0% and 5% for the no persistent pain group. This was due to mobility limiting correct positioning on the biodex dynamometer, or highly irritable or severe pain (table 3).

Table 3. Table of primary and secondary outcomes in the persistent pain and no persistent pain group.

	Persistent pain n = 25 (58%)		No persistent pain n = 18 (42%)		Group mean difference	95% Confidence Interval of the Difference		P-value
	Mean	SD	Mean	SD		Lower	Upper	
BESTest	76.2	12.7	89.6	7.3	-13.4	-20.1	-6.7	0.0001*
BBS	51.0	4.9	54.1	2.7	-3.0	-5.6	-0.4	0.02*
PASE	52.5	50.0	60.7	51.9	-8.3	-40.3	23.7	0.60
30s STS	9.4	3.3	12.3	3.3	-2.9	-5.0	-0.7	0.01*
PiMax	63.4	4.2	58.9	5.7	4.5	6.9	-9.6	0.52
TQ/BW Hip ab	55.9 (n = 20)	17.8	64.5	30.5	-8.7	-25.1	7.7	0.29
TQ/BW Hip ad	35.9 (n = 20)	30.2	51.1	43.6	-15.2	-40.0	9.5	0.22
TQ/BW Knee ext	76.9	33.5	88.0	37.5	-11.0	-34.8	12.7	0.35
TQ/BW Knee flex	34.3	22.7	35.4	18.7	-1.1	-15.0	12.8	0.88
TQ/BW Ankle df	21.7 (n = 19)	9.4	28.6 (n = 17)	27.0	-6.9	-21.3	7.6	0.33
TQ/BW Ankle pf	15.9 (n = 19)	7.6	23.8 (n = 17)	4.0	-7.9	-16.8	1.1	0.08

**statistically significant difference between groups. BESTest = Balance Evaluations Systems Test; BBS= Berg Balance Scale; PASE= Physical Activity Scale for the Elderly; 30-s STS = 30-second sit to stand; PiMax= inspiratory muscle strength; TQ/BW = peak torque to body weight; hip ab= hip abductors; hip ad = hip adductors; knee ext = knee extensors; knee flex = knee flexors; ankle df = ankle dorsi flexors; ankle pf = ankle plantar flexors. n = sample size of each group, where added to a row, this indicates the sample included in that measurement, where some data are missing.*

Temporospatial gait outcomes

Gait speed (cm/s)

People with COPD and persistent pain walked slower over 4.27 m than people with no persistent pain across all walking trials combined (99 cm/s vs118 cm/s respectively, 95% CI for difference: 3 to 35 cm/s, group mean difference, 19cm/s group main effect: p = 0.02). People with persistent pain reduced their gait speed under dual-task conditions compared to single-task conditions to a greater extent than those without persistent pain (12cm/s vs 5cm/s respectively, interaction effect: p=0.045) (table 4 and figure 2). Other temporospatial gait outcomes were not available for analyses for the full data set due to a software corruption issue that could not be resolved. Analyses for these data (% single support, step time standard deviation, step time differential and step width) include n= 20 people with persistent pain and n= 15 people without persistent pain (table 4).

Table 4. Gait outcomes under single and dual task conditions in those with COPD and persistent pain vs. COPD and no persistent pain.

Outcome	Group	Single task condition Mean (SE); 95% CI	Dual task condition Mean (SE); 95% CI
Gait Speed (cm/s)	Persistent pain n = 25	104.7 (5.2) 95% CI: 94.2–115.2	93.0 (5.7) 95% CI: 81.4–104.3
	No persistent pain n = 18	121.3 (6.1) 95% CI: 108.9–133.7	115.8 (6.7) 95% CI: 103.2–129.4
Gait security (% single support)	Persistent Pain (n = 20)	34.8 (0.5) 95% CI: 33.9 -35.8	34.4 (0.6) 95% CI: 33.2-35.6
	No Persistent Pain (n = 15)	37.1 (0.6) 95% CI: 36.0-38.2	37.0 (0.7) 95% CI: 35.6-38.4
Gait smoothness (step time SD [s])	Persistent Pain (n = 20)	0.027 (0.004) 95% CI: 0.020-0.035	0.037 (0.005) 95% CI: 0.027-0.047
	No Persistent Pain (n = 15)	0.015 (0.004) 95% CI: 0.007-0.024	0.013 (0.006) 95% CI: 0.001-0.025
Gait symmetry (step time difference [s])	Persistent Pain (n = 20)	0.018 (0.002) 95% CI: 0.013-0.022	0.026 (0.005) 95% CI: 0.015-0.037
	No Persistent Pain (n = 15)	0.017 (0.002) 95% CI: 0.012-0.023	0.025 (0.006) 95% CI: 0.012-0.038
Gait Stability (step width [cm])	Persistent Pain (n = 20)	59.9(2.0) 95% CI: 56.1-63.7	57.6 (2.0) 95% CI: 53.4-61.7
	No Persistent Pain (n = 15)	68.5 (2.19) 95% CI: 64.-72.9	65.8 (2.4) 95% CI: 61.0-70.7

SE = standard error, CI = Confidence Interval, SD = Standard Deviation, cm = centimetres, s = second, n = describes the sample size of each group and has been added after outcome name where data are not available for the whole study sample.

Gait security (% time in single support)

People with COPD and persistent pain had lower gait security (% single support) than people with no persistent pain (34.6% vs 37.0% respectively, 95% CI for difference: -0.8% to -4.0%, group mean difference, -2.4% group main effect: p = 0.005). There was no difference in gait security (% single support) between DT and ST conditions (35.7% vs 35.9% respectively, 95% CI for difference: -0.3% to 0.8%, group mean difference = 0.2%, group main effect: p = 0.359). There was no significant interaction effect for people with pain reducing % single support more during DT vs ST than people with no pain task (-0.4% vs -0.1% respectively, interaction effect: p=0.588).

Gait smoothness (step time standard deviation, s)

People with COPD and persistent pain had more variability in gait (step time SD) than people with no persistent pain (0.032 s vs 0.014 s respectively, 95% CI for difference: 0.004 s to 0.031 s, group mean difference, 0.018 s, group main effect: p = 0.011). There was no difference in step time variability between DT and ST conditions (0.025 s vs 0.021 s respectively, 95% CI for difference: -0.001 s to 0.009 s, group mean difference = 0.04 s, group main effect: p = 0.106). People with persistent pain increased the variability of their gait (lack of smoothness) under dual task conditions compared to single task conditions to a greater extent than those without persistent pain (0.010 s vs -0.002 s respectively, interaction effect: p=0.032).

Gait symmetry (step time differential, s)

There was no difference in left-right symmetry (step time differential) between people with COPD and persistent pain and people with no persistent pain (0.022 s vs 0.021 s respectively, 95% CI for difference: -0.01 s cm to 0.01 s, group mean difference, 0.00 s group main effect: p = 0.929). However, step time asymmetry did increase during DT versus ST condition (0.025 s vs 0.018 s respectively, 95% CI for difference: 0.00 s to 0.016 s, group mean difference, 0.008 s group main effect: p =0.045). There was no significant interaction effect for people with pain increasing asymmetry more during DT vs ST than people with no pain task (0.008 s vs 0.008 s respectively, interaction effect: p=0.941).

Gait stability (step width, cm)

People with COPD and persistent pain had lower step width than people with no persistent pain (58.7 cm vs 67.1 cm respectively, 95% CI for difference: 2.2 cm to 14.7 cm, group mean difference, 8.4 cm group main effect: p = 0.01). Step width was lower during DT than ST (61.7 cm vs 64.2 cm respectively, 95% CI for difference: 1.3 cm to 3.6 cm, group mean difference 2.5 cm, group main effect: p < 0.001). There was no significant interaction effect for people with pain reducing step width further during DT vs ST than people with no pain task (-2.3 cm vs -2.6 cm respectively, interaction effect: p=0.809).

Factors associated with pain, balance and gait speed

Balance impairment (BESTest total score) in all participants was significantly correlated with poorer lower limb muscle endurance (30s STS) (r=0.65, 95% CI 0.42 to 0.80), pain severity (BPI severity scores) (r=-0.59, 95%CI -0.76 to -0.34), weaker hip abductor muscle strength (TQ/BW) (r=0.37, 95%CI 0.06 to 0.62) and weaker ankle plantar flexor strength (TQ/BW) (r=0.44, 95%CI 0.13 to 0.67). Single and dual task gait speed were not correlated with any other outcomes (see supplement 2, table 1 for all correlations).

Discussion:

This is the first study to investigate the influence of pain on balance and gait in people with COPD. Findings suggest that balance and gait, particularly under dual-task conditions, are more impaired in people with COPD and persistent pain when compared with people with COPD and no persistent pain. Those with persistent pain also reported more pain in the chest and thoracic region, alongside lower limb pain, more sites of pain across the body and greater pain interference in daily functioning than those without persistent pain.

The difference in balance performance between those with and without persistent pain is unsurprising given that pain has been highlighted as a risk factor for falls in older adults and that people with COPD have both a higher prevalence of pain and a higher risk of falls than healthy peers [19]. These findings highlight that persistent pain in people with COPD may add to the risk factors for falls and may be due to multi-site pain and pain in the trunk [13, 32]. Trunk muscles including the diaphragm have a dual role in respiration and postural control that may be impaired by both respiratory disease and pain in people with COPD when both functions cannot be coordinated [33, 34]. Evidence suggests that people with COPD are unable to rely on trunk mechanisms that older adults usually increase reliance on with increasing age to maintain balance. A stiffening effect of the trunk muscles in people with COPD may encourage over use of ankle strategies that have become slower and less effective for maintaining balance in older adults [35, 36]. Ankle muscles involved in ankle strategies are also weaker and lower limb stepping reactions are slower in people with COPD [4, 37]. It seems likely that pain may enhance these effects [38].

Pain has also been associated with poor muscle endurance and in this study people with persistent pain also had poorer muscle endurance [39, 40]. Muscle endurance and pain severity were both correlated with balance performance. This may explain a previously noted increase in falls risk with an observed interaction of COPD and severe pain in a previous study; both COPD and persistent pain feature poor muscle endurance [20, 40].

Gait speed was slower and gait security, smoothness and stability were worse in people with COPD and persistent pain. These are important findings because many falls happen during walking [41]. Studies have demonstrated that people with COPD have altered gait patterns that make gait less efficient [42]. Slower gait speed also predicts falls, loss of functional independence and frailty in older adults [43]. Although the link between gait speed and falls has not yet been investigated in people with COPD, slower gait speed can predict readmission and mortality after exacerbation in people with COPD [44, 45]. It has also been reported that fallers with COPD had worse gait rhythm (slower steps) than those with COPD who had not fallen [46].

Participants in this study with persistent pain had greater reductions in gait speed and smoothness under dual task conditions. The attention of people with COPD is not only divided by their thoughts and surroundings but also by a potential combination of pain, breathlessness and anxiety and this may represent a higher cumulative cognitive demand than for those without either pain or COPD. Gait speed was not however correlated with balance impairment in this population. It may be that gait speed is primarily limited by reductions in exercise capacity rather than balance impairment, but the inability to perform dual task gait effectively may be a mechanism underlying falls that is independent of balance impairment by limiting safe mobility in environments that divide attention [47]. The reduction of dual task gait speed and smoothness, particularly in the persistent pain group, highlights the role of cognitive function and whilst executive control of gait may be impaired in some people with COPD, pain may further impair dual task ability [48, 49].

Limitations of this study should be noted. The definition of pain often varies across the literature. The definition used for this study, based on the IASP resulted in some people in the no persistent pain group still reporting pain on their BPI questionnaire and the use of a different definition may have impacted findings. However, 56% of the study population were classified as having persistent pain which is consistent with the literature [13]. The impact of pain on study procedures was also apparent. The safety and well-being of participants was a priority and if any procedure was felt to be uncomfortable or have the potential to irritate areas of pain it was omitted. This meant that data for muscle strength were not missing at random, but whilst this may have impacted group mean differences, sensitivity analyses of correlations indicated little difference in findings. In contrast to previous literature no between-group differences for falls and physical activity were noted. Falls were recorded retrospectively, and this method of recording is subject to recall bias alongside the stigma associated with falling which may explain this. The PASE scores rely on retrospective recall of physical activity performed in the past 7 days. As all participants were recruited from PR programs, most had started their classes at the time of the assessment which may have artificially homogenised PASE scores. While between-group differences were detected for the PHQ-9 and GAD-7, this was not apparent for the HADS. The HADS is responsive to pulmonary rehabilitation so this is likely due to the smaller sample size for the HADS compared to the PHQ-9/GAD-7 (n=29 v n=15) [50]. Fluctuations in outcome data collected from medical records (psychological symptoms and exercise capacity) may have occurred between PR assessment and study assessment however, more than 80% were collected within 4 weeks.

Future research is required to investigate the impact of pain further, specifically factoring in pain in balance interventions for people with COPD. This could include specific strength and endurance training for the hip and ankle muscles and training gait under dual-task conditions. Findings from this study suggest that pain is a risk-factor for falls and should therefore be given greater consideration during the initial assessment for PR, particularly in those who report balance issues.

Conclusion:

People with COPD and persistent pain have worse balance and gait, particularly during dual-task conditions, compared to those without pain. Pain is an important factor to consider when assessing the balance, gait and falls risk of people with COPD. Targeting pain, dual-tasking, alongside balance training will likely be important to reduce falls risk in people with COPD.

Contributors:
KL, SLH, DM and JD conceived and initiated the study. SLH, DM and JD provided research supervision for KL. KL, SLH, DM and DT designed and initiated the study. KL, CFJ, RS conducted screening and recruitment of participants with support from SLH. KL, CHJ and RS conducted data collection. KL drafted and edited the manuscript. KL, SLH, GT and DT carried out data management and data analysis. All authors have read and approved the final version of the manuscript.

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None declared.

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Data sharing:
Data are available on reasonable request.

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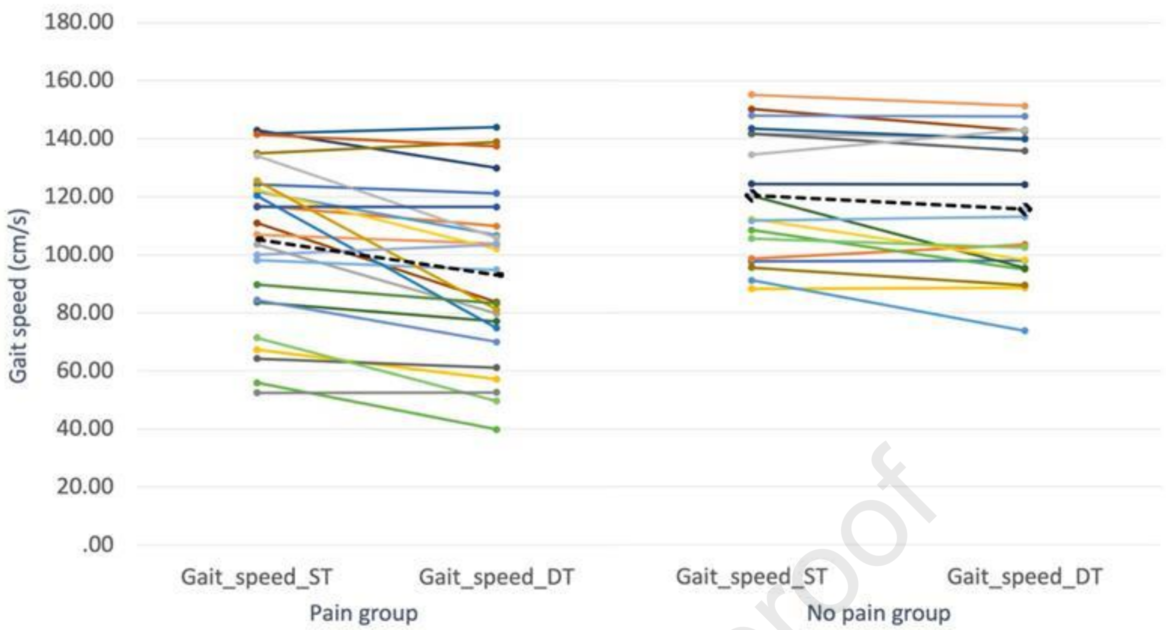

Figure 2. Individual differences between ST and DT task condition gait speed in the persistent pain and no persistent pain groups. Mean values shown by black dashed line.

Highlights (3 to 5 bullet points)

- People with COPD and pain have worse balance and slower walking speed than those without pain
- Additional cognitive demands reduce walking speed more in those with pain
- Worse balance was associated with higher pain severity and weaker leg strength
- Assessment and management of pain in those with COPD who have fallen is important
- Consider pain when delivering interventions to prevent falls in people with COPD

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: