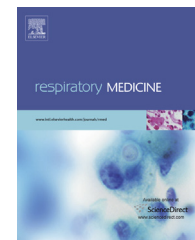Available online at www.sciencedirect.com

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# Pain and physical performance in people with COPD

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**Summary**

*Introduction:* Patients with Chronic Obstructive Pulmonary Disease (COPD) have been shown to experience significant pain that interferes with their daily activities and quality of life. The purpose of this study was to examine if pain is associated with functional exercise capacity (assessed with the six-minute walk test, 6MWT), physical activity (assessed by accelerometry), and muscle performance (maximal knee extensor torque) in people with COPD.

*Methods:* Twenty-six people with moderate to severe COPD completed the McGill Pain Questionnaire (MPQ), the Brief Pain Inventory (BPI), the Short Form-36 (SF-36), and a form to list medications and comorbidities. After spirometric testing, participants performed the 6MWT. Physical activity was monitored for two days using a tri-axial accelerometer (DynaPort MiniMod). At least 3 days after the 6MWT, maximal and fatiguing concentric contractions of knee extensors were assessed.

*Results:* Pain severity was negatively correlated with the 6MWT ($p < 0.05$), and quality of life ($p < 0.05$), whereas it was positively correlated with body mass index (BMI) ($p < 0.001$), and the number of comorbidities ($p < 0.001$). Subjects with severe pain showed lower standing and activity times ($p < 0.01$), lower 6MWT ($p < 0.05$), higher BMI ($p < 0.001$), a higher number of comorbidities ($p < 0.001$) and lower quality of life ($p < 0.01$) compared to subjects with minimal or no pain.

*Conclusion:* Pain in patients with COPD is associated with low functional exercise capacity, reduced physical activity, and high BMI. Pain can adversely affect physical activity and quality of life in

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## Introduction

People with stable COPD experience significant pain compared to age- and gender-matched healthy people and pain interferes with their daily activities [1−3]. COPD patients demonstrated 2.6 times more pain and 3.7 times more pain interference with daily activities compared to an age- and a gender-matched healthy cohort [1]. This greater prevalence of pain in COPD patients is similar to two other recent studies. Bensten et al. demonstrated that a significantly higher percentage of patients with COPD (45%) reported pain than the control group (34%; $p = 0.02$) [2]. Borge et al. stated that 72% of the patients with COPD reported pain as assessed by a body diagram [3]. These investigations unequivocally indicate that pain in COPD patients is more common and more severe compared to healthy people. Further investigation is required to better understand the impact of pain on physical activities.

Fatigue, dyspnea [4,5], and muscle weakness [6,7] are commonly reported to adversely affect functional mobility and physical capacity in COPD patients. Pain is another factor that may contribute to limitations of physical activity in this chronic respiratory disease similar to how pain affects people with other disorders. Physical activity is limited in those with osteoarthritis [8], and it is associated with reduced health related quality of life (HRQoL) in patients with nonmalignant pain [9]. In spite of the apparent frequent occurrence of this symptom, the effects of pain on muscle performance in people with COPD has not been described. A better understanding of how pain in COPD affects physical performance would facilitate the design of more effective prescription of exercise, physical activities, and help maintain independent mobility.

In order to provide further insight into the experience of pain in COPD and whether pain can be considered as an additional activity-limiting factor in COPD (besides fatigue and dyspnea), we determined the relationships between pain and three physical performance measures: 1) muscle performance (concentric torque of knee extensors), 2) physical activity levels (as measured by triaxial accelerometry), and 3) six minute walk test (6MWT).

## Methods and materials

### Subjects

A convenience sample of 26 people with moderate to severe COPD (forced expiratory volume in one second [$FEV_1$] of $30\% \leq FEV_1 < 80\%$ predicted, $FEV_1/FVC <0.7$) [10] were recruited from rehabilitation programs at local hospitals and from the local respirologists. People with COPD were included if they: 1) had moderate to severe disease [10]; and 2) were over 50 years of age. Participants were excluded if they: 1) had experienced an acute exacerbation of COPD during the last 3 months; 2) had unstable cardiovascular, neurological, musculoskeletal or other condition(s) that interfere with independent ambulation or safe performance of the testing; 3) had taken oral corticosteroids within the last three months; 4) had cognitive impairment; and 5) were not fluent in English. The clinical ethics board at the University of British Columbia approved the study and all subjects gave informed written consent before participation in the study.

### Protocol

Participants were asked to refrain from physical exercise, caffeine and alcohol on test days. Participants made two visits to the laboratory. During the first laboratory visit, spirometry was performed to determine disease severity and patients were asked to fill out questionnaires including: a form to list medications and co-morbidities, the Medical Outcomes Study Short Form-36 (SF-36), the short form of McGill Pain Questionnaire (MPQ), the short form of the Brief Pain Inventory (BPI), and a form for screening the risks of exercise based on American College of Sports Medicine (ACSM) guidelines. Height and weight were measured, and each subject performed the 6MWT. Subjects were familiarized with the accelerometer, and received instructions on how to wear and use the device supplemented with a manual containing written instructions and figures. Subjects were asked to wear the device for two full days. During the second laboratory visit (at least 3 days after the first visit), subjects were tested for maximal voluntary concentric torque of the knee extensors, followed by repetitive fatiguing maximal concentric contractions using an isokinetic Biodex dynamometer. Medication history and information about comorbidities were confirmed by chart review.

### Outcomes and measurements

Spirometry was performed to determine COPD severity from $FEV_1$ and FVC values and percent-predicted values were calculated using prediction equations derived from the third National Health and Nutrition Examination Survey (NHANES III) [11].

Pain severity was assessed using the MPQ and BPI. The MPQ consists of: 1) fifteen items to assess sensory components; 2) four items to assess affective aspects of pain over one week; 3) a visual analogue scale to provide the intensity score of the pain over one week; and 4) a Present Pain Intensity (PPI) scale. This form is reported to be reliable [12], valid [13], and has been found to be appropriate for use with geriatric patients who experience pain [14].

The BPI was used to identify pain locations on a body diagram and to assess two dimensions of pain: severity and

interference with daily life over the last week. The BPI measures the interference of pain in the seven aspects of a patient's life including: general activity, mood, walking, sleep, normal work, enjoyment of life, and relationship with others. The BPI has been shown to have predictive validity in a number of patient populations with chronic conditions [15,16]. Because of differing attributes, both the BPI and MPQ were used to provide a more comprehensive description of the pain experienced by individuals [17]. The MPQ has been shown to be an excellent tool to evaluate the quality of pain while the BPI is preferred in the assessment of physical function and functional impact of pain [18]. MPQ and BPI scores were calculated as the percentage of the maximum score that could be obtained on each component of the questionnaire: severity for MPQ and BPI, and interference for BPI.

Assessment of functional exercise capacity was performed using the 6MWT [19]. Briefly, participants were instructed to walk as far as they could in 6 min in a 30-m loop located in a hallway, and the total distance walked was recorded in meters. Percent predicted values for 6MWT were calculated based on the method described by Enright & Sherrill [20]. Assessment of HRQoL was performed using SF-36 [21].

Assessment of physical activity level in daily life (activity monitoring) was performed with a DynaPort MiniMod Move-Monitor (McRoberts, The Hague, The Netherlands). The device has been validated and used in people with COPD. It measures step counts, and the time spent in different postures, such as standing, sitting or lying, walking and locomotion. Data were processed through online software to estimate physical activity for 2 days [22,23]. Subjects were asked to wear the accelerometer for 2 full days between the two laboratory visits. The data were assessed from 9 am to 9 pm on each day for the purpose of the analysis [23]. Participants were asked to perform their usual daily activities and not to change their routine while wearing the device [22]. For the purpose of data analysis, total number of step counts over 2 days, and the activity durations (in minutes) for different types of activity (lying, sitting, walking, and standing) were recorded.

Maximal voluntary concentric torque of the knee extensors was assessed on the dominant leg (the leg that a person uses to kick a ball) using an isokinetic dynamometer (Biodex System 4; Biodex, Shirley, NY). The shin pad was placed at 75% of the distance from the head of the fibula to the distal edge of the lateral malleolus. The knee was aligned with the rotating lever. Subjects were familiarized with producing maximal concentric contractions of the knee extensors. Concentric torque of the knee extensor muscles was tested by having the subject performing 3 to 5 sub-maximal warm-up contractions followed by 5 maximal voluntary contractions (MVC) through a range of motion from 80° to 10° of knee flexion at an angular velocity of 90° per second [24]. Participants received vigorous verbal encouragement. MVCs were performed until the maximum force recorded during two contractions differed by 5% or less [25]. The highest MVC peak torque was used to represent the subject's maximal concentric contraction [25].

For the fatigue protocol, subjects performed repetitive maximal concentric contractions of the knee extensors while the counter movements were performed passively by the device. The contracting and passive return time ratio

was 2:1 with a 1 s rest during the counter movement. Subjects were asked to perform as many contractions as they could up to a maximum of 100 contractions [24]. Visual and verbal feedback was provided during each contraction to ensure that the maximum amount of force was produced. The first 34 contractions were chosen for measuring fatigue index (FI) because it was the maximum number of contractions that all patients were able to perform. The FI was calculated by the following formula to yield a percentage decrease in peak isokinetic torque: FI = 100 − [(Peak MVC of 34th contraction ÷ Peak MVC of 1st contraction) × 100] [26].

## Statistical analysis

Statistical analyses were performed using the SPSS software package (version 16.0, Chicago, IL). Frequencies were determined for the total number of pain locations, comorbidities and medications. Descriptive statistics were performed to describe subject characteristics and frequency distributions of the outcomes. The distribution of data was tested for normality using the Kolmogorov−Smirnov and Shapiro−Wilk tests. Levene's test was used to test for the homogeneity of the variances. Pain severity, as measured by MPQ and BPI, was tested for correlations with the physical activity data (step counts, activity duration), peak torque, fatigue index (FI), and HRQoL (SF-36). The Pearson product moment correlation coefficient (PCC) was used for normally distributed data and the Spearman's correlation coefficient was used for non-normally distributed data. Correlations ($r$) were categorized as low ($0 < r < 0.25$), moderate ($0.25 < r < 0.50$), strong ($0.50 < r < 0.75$), and very strong ($0.75 < r$) [27].

The subjects were divided into two groups: those with severe pain and those with mild to moderate or no pain, and two-tailed $t$-tests were performed to investigate between group differences in functional exercise capacity, physical activity, muscle performance, and HRQoL. The cut points of 30, 40, and 40% were selected for MPQ intensity, BPI severity and BPI interference scores, respectively, based on visual inspection of the distribution plots. The ratio of the number of patients with mild to moderate pain for MPQ, BPI severity, and BPI interference scores were (21/5), (20/6), and (21/5), respectively. The significance level of $p < 0.05$ was selected.

## Results

Twenty-six patients with moderate to severe COPD completed the study. Subjects had a mean age of 70.4 ± 9.3 years (14 males), and a mean BMI within the normal range (Table 1). Means and standard errors for pain levels, 6MWT, quality of life scores; physical activity and torque measures are reported in Table 2.

MPQ pain severity was negatively correlated with the 6MWT (Table 3, Fig. 1). Subjects with severe pain (based in the MPQ) walked a shorter total distance (−115 ± 57 m; $p < 0.01$) (Table 4). Females walked 350 ± 121 m (70% predicted) while males walked 402 ± 119 m (88% predicted). Those with more pain had 41% less active time ($p < 0.01$), had 49% less standing time ($p < 0.01$), and had 16% more sedentary time ($p < 0.05$) (Table 4). No significant

**Table 1** Subject characteristics (mean $\pm$ SD).

| Characteristics | Subjects | | |
| --- | --- | --- | --- |
| | Male (n = 14) | Female (n = 12) | All |
| Age (years) | 72.6 ± 10.6 | 67.8 ± 6.9 | 70.4 ± 9.3 |
| BMI (kg/m$^2$) | 26.5 ± 4.4 | 26.8 ± 6.3 | 26.4 ± 5.3 |
| FEV$_1$ (% predicted) | 48.4 ± 15.4 | 47.7 ± 17.0 | 48.9 ± 15.8 |
| FEV$_1$/FVC | 0.61 ± 0.16 | 0.59 ± 0.17 | 0.60 ± 0.16 |

BMI: body mass index; FEV1: Forced expiratory volume in one second; FVC: forced vital capacity.

correlations were found between knee extensor MVC and pain severity or pain interference.

MPQ pain severity, BPI pain severity, and BPI interference scores were negatively correlated with the Physical Component Score (PCS) of SF-36 ($p < 0.05$) (Table 3). Between group comparisons showed that those subjects with more pain severity ($p < 0.01$) and interference ($p < 0.001$) scored lower on PCS of the SF-36 (Table 4). Significant negative correlations were found between Mental Component Score (MCS), and pain severity ($p < 0.05$) and pain interference ($p < 0.001$) of the BPI (Table 3). Between group comparisons also showed that those with more severe pain (BPI) and greater pain interference (on the BPI) had lower MCS of the SF-36 ($p < 0.05$).

MPQ severity ($p < 0.001$, Fig. 1) and BPI interference scores ($p < 0.05$) were positively correlated with BMI (Table 3). Compared to those with minimal or no pain, subjects with severe pain reported more pain interference with daily

**Table 2** Pain, functional exercise capacity, physical activity, health-related quality of life and muscle performance measures (mean $\pm$ SE).

| Category | Variable | Mean ± SE |
| --- | --- | --- |
| Pain severity | MPQ | 16.8 ± 3.1 |
| | BPI-S | 27.3 ± 5.0 |
| Interference | BPI-I | 25.0 ± 4.9 |
| Functional exercise capacity | 6MWT % predicted | 82.7 ± 4.8 |
| HRQoL | SF-36 PCS | 35.7 ± 1.9 |
| | SF-36 MCS | 48.3 ± 3.0 |
| Physical activity | Step count | 4588 ± 548 |
| | Standing time (min) | 146.4 ± 12.9 |
| | Sedentary time (min) | 486.7 ± 15.9 |
| | Active time (min) | 219.9 ± 16.8 |
| Muscle performance | Fatigue index | 52.1 ± 2.7 |
| | CON $T_{max}$ (N m) | 90.5 ± 7.0 |

MPQ: McGill Pain Questionnaire; BPI-S: BPI severity score; BPI-I: BPI interference score; 6MWT: Six minute walk test; HRQoL: health related quality of life; PCS: SF-36 Physical Component Score; MCS: SF-36 Mental Component Score; CON $T_{max}$: Peak concentric torque.

**Table 3** Significant correlations between pain measures and 6MWT, quality of life measures, number of comorbidities, and BMI ($p < 0.05$).

| Variable | MPQ | BPI-S | BPI-I |
| --- | --- | --- | --- |
| 6MWT % predicted | −0.41 | | |
| SF-36 PCS | −0.43 | −0.39 | −0.40 |
| SF-36 MCS | | −0.40 | −0.59* |
| Number of comorbidities | 0.70* | 0.42 | 0.47 |
| BMI | 0.47* | | 0.50* |

The table shows the *r* value for Spearman or Pearson correlations; all comparisons are significant at $p < 0.05$ except for the values with asterisks that are significant at $p < 0.001$.
Abbreviations: MPQ: McGill Pain Questionnaire; BPI-S: BPI severity score; BPI-I: BPI interference score; 6MWT: Six minute walk distance test; PCC: SF-36 Physical Component Score; MCS: SF-36 Mental Component Score; BMI: body mass index.

activities as measured on the BPI ($p < 0.05$), and had on average 2−3 more comorbidities (Table 4). The number of comorbidities was positively correlated with MPQ severity ($p < 0.001$) (Table 3, Fig. 1), BPI severity, and interference scores ($p < 0.05$) (Table 3). The most common comorbid condition was cardiovascular (54%), followed by endocrine that included osteoporosis (50%), and musculoskeletal disease (46%). Of the 26 patients, eight had diagnosed osteoporosis, 11 had diagnosed osteoarthritis, and 9 reported calf pain during the 6MWT.

Subjects with more pain had a higher number of pain locations and medications (Table 4). Consistent with the fact that all subjects had a diagnosis of COPD and the most prevalent comorbidity was cardiovascular disease ($n = 14$), respiratory and cardiac medications were the most common ($n = 70$).

## Discussion

Our study demonstrated that pain severity (assessed by the MPQ) was inversely related to 6MWT. People with more severe pain walked 25.6% less than those with moderate to no pain on the 6MWT. Those with severe pain also had significantly lower standing and activity times, and a higher sedentary time as compared to those with less pain. BMI and the number of comorbidities were positively associated with pain severity and those with severe pain had 2 to 3 more comorbidities compared to those with lower levels of pain.

During the 6MWT, those with more pain walked 114 m less than those with less or no pain. Based on the normative values described by Bohannon [28], our male participants walked 53 m, and females walked149 m less than their age and gender predicted distances. These differences are considerably higher than the minimal important difference of 25 m for the 6MWT in people with COPD [29]. Limitations of the 6MWT have been attributed to COPD-related symptoms and comorbidities [30]. Painful osteoarthritis (OA) of the hips or knees might be another underlying cause of limited walk distance in addition to symptoms of fatigue and dyspnea; 42% (11 of 26) of our COPD participants had
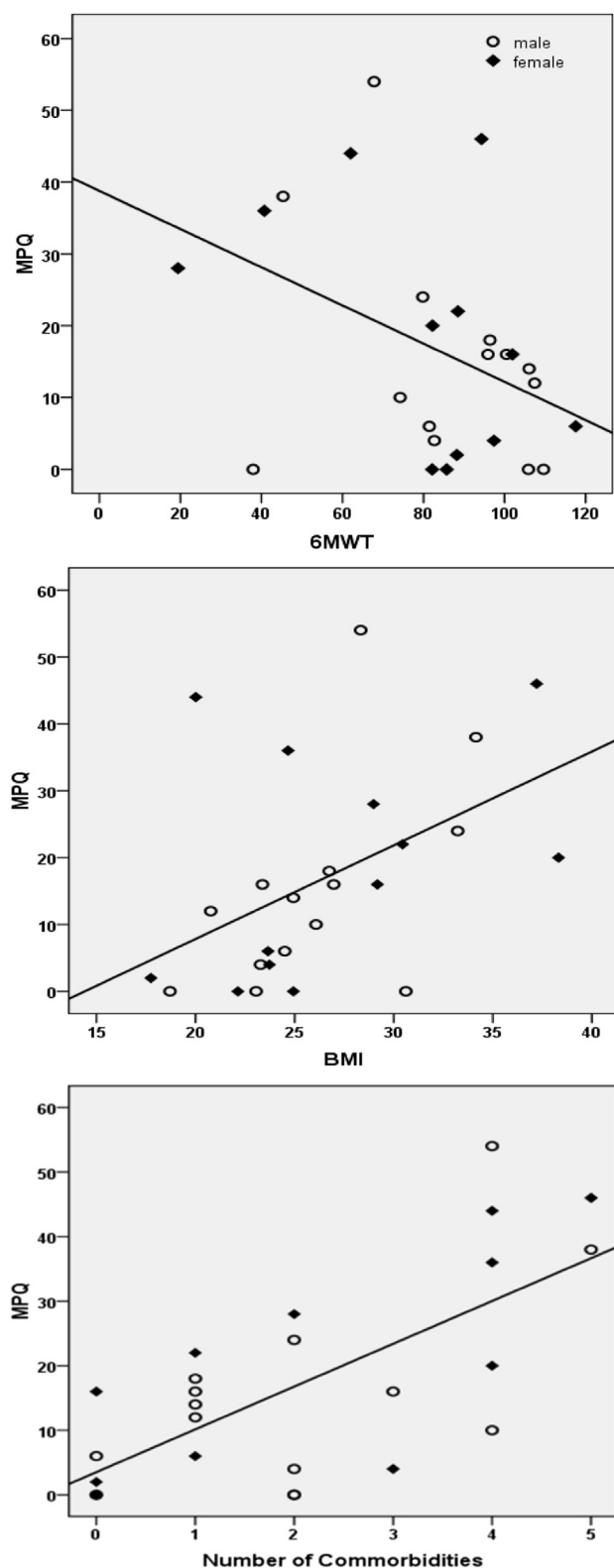
**Figure 1** Significant correlations between pain severity measured on the McGill Pain Questionnaire (MPQ) vs the 6 minute walk test (6MWT) ($r = -0.41$, $p < 0.005$), body mass index (BMI) ($r = 0.70$, $p < 0.001$), and number of comorbidities ($r = 0.47$, $p < 0.001$).

(OA). The prevalence of OA has been shown to increase with aging from 14% at the age of 50 to 58% at the age of 86 years [31]. OA most commonly affects the hips, knees and hands [32] and might contribute to pain and limited walk distance in people with COPD. Another potential cause of pain during walking might be the intermittent claudication of the calf muscles associated with the high prevalence of cardiovascular diseases in COPD. Thirty-five percent (9 of 26) of our sample reported calf pain during the 6MWT.

Lower levels of physical activity were demonstrated in COPD patients who experience pain, as shown by shorter standing and active time, and sedentary time being approximately twice the active time. Similar mean differences in sitting, standing and active times have been reported when COPD patients were compared to healthy age- and gender-matched controls [24]. Lower physical activity levels could be, in part, due to osteoporosis and OA that were reported by the significant proportion of our patients (31% and 42%, respectively). Osteoporosis [33–35] and associated spinal compression fractures are more common in people with COPD (31% of patients vs 18% of controls) [36]. Pain due to osteoporosis-related vertebral fractures is significant as shown by ratings of 6–7 out of 10 cm on a visual analogue scale [37,38]. The contribution of osteoporosis-related compression fractures to pain and physical inactivity in people with COPD requires further study. Another reason might be the pain associated with OA. Similar to COPD, physical inactivity is very common in people with OA [39,40] and has been shown to be associated with severe pain in people with OA [41]. Thus, it is likely that OA of lower extremities and back may have contributed to decreased standing and active time in COPD patients with severe pain.

Other pain-inducing activity limiting factors in COPD patients might be related to the specific medications and symptoms of deconditioning i.e. calf pain that was reported in 35% of our patients. It has been documented that some COPD specific medications, such as beta-2 agonists cause cramps in the calf muscles [42] that might interfere with walking ability and activity duration in COPD patients. Furthermore, decreased physical activity and its related deconditioning effects in COPD [43] might contribute to the increased pain in COPD over time. According to the Vlaeyen's fear-avoidance model [44], the vicious cycle of deconditioning begins with an attempt to avoid pain by reducing daily physical activities. While avoiding activity may result in less pain over the short term, the reduction in activity may lead to more deconditioning, which then can lead to increased pain in some disorders. The increase in pain then leads to more avoidance of activity.

We found a significant positive correlation between BMI and MPQ pain severity and BPI interference in COPD patients. This is consistent with data from a recent study that found a higher BMI in people with COPD who experienced more pain as compared to those with no pain [3]. Chronic pain is reported to be strongly associated with obesity in the elderly [45]. Obesity (as measured by BMI) is known to be an important health issue in patients with COPD with a reported prevalence that ranges from 28% [46] to 54% [47]. Obesity is postulated to increase the prevalence of pain by increasing proinflammatory cytokines, and increasing the risk

**Table 4** Significant between group differences for 6MWT, physical activity measures, BMI, number of comorbidities, pain locations and medications, and quality of life measures.

| Outcomes | MPQ | BPI severity | BPI interference |
|---|---|---|---|
| 6MWT (% predicted) | $-25.6 \pm 11.3$** | $-10.9 \pm 11.4$ | $-19.1 \pm 11.8$ |
| Sedentary time (min) | $56.4 \pm 40.9$* | $89.9 \pm 36.7$* | $39.3 \pm 41.2$ |
| Standing time (min) | $-4.4 \pm 33.5$ | $-78.3 \pm 19.2$** | $-7.9 \pm 33.5$ |
| Active time (min) | $-4.8 \pm 40.5$ | $-99.1 \pm 35.3$** | $-19.3 \pm 43.3$ |
| BMI (kg/m$^2$) | $3.1 \pm 2.6$ | $4.3 \pm 2.4$ | $5.7 \pm 2.4$* |
| Number of comorbidities | $3.0 \pm 0.6^{\dagger}$ | $2.0 \pm 1.5$** | $2.2 \pm 0.7^{\dagger}$ |
| Number of pain locations | $6.0 \pm 1.3^{\dagger}$ | $3.6 \pm 1.5$** | $3.5 \pm 1.6$* |
| Number of medications | $3.3 \pm 1.9$* | $2.1 \pm 1.8$ | $4.1 \pm 1.8$* |
| SF-36 PCS | $-11.9 \pm 4.3$** | $-4.7 \pm 4.6$ | $-13.2 \pm 4.2^{\dagger}$ |
| SF-36 MCS | $-6.8 \pm 7.7$ | $-14.7 \pm 6.6$* | $-20.4 \pm 6.6^{\dagger}$ |

Groups were defined as those with severe pain vs those with minimal to moderate pain based on the maximum scores achieved on MPQ and BPI severity, and BPI interference measures. Data are mean $\pm$ SE. * significance level of $p < 0.05$, ** significance level of $p < 0.01$, $^{\dagger}$ significance level of $p < 0.001$.
Abbreviations: MPQ: McGill Pain Questionnaire; BPI: Brief Pain Inventory; BMI: body mass index; 6MWT: Six minute walk distance test; PCC: SF-36 Physical Component Score; MCS: SF-36 Mental Component Score.

of osteoarthritis and low back pain [48]. In a vicious cycle, pain might also increase the risk of obesity by reductions in physical activity or hormonal changes [45].

There was evidence of knee extensor muscle weakness and fatigability in our subjects with an average peak torque of 90.5 N m for the whole group compared to previously reported values of 203 and 179 N m for healthy males and women, respectively [24]. Furthermore, the average torque reduction was 50% with only 34 repetitions which is consistent with another report of COPD patients [24]. Despite this clear deterioration in muscle performance, we did not find significant correlations between maximal concentric torque and pain severity in patients with COPD. This is similar to the findings of Steultjens et al. who found no clear relationship between pain and muscle strength in 123 patients with hip and knee OA and that muscle strength only accounted for about 5% of the variance in pain levels [49]. Given that muscle weakness has been well documented in COPD, one explanation for the lack of association with pain could be that other factors such as the systemic effects of the disease account for the major loss of muscle strength in COPD. These systemic effects include the prolonged inflammation, and changes in muscle metabolism and structure (fiber atrophy, fiber loss). Another reason might be related to the small sample size and variability amongst subjects in muscle strength, and fatiguability may have resulted in type II error. Furthermore, we found that the fatigue index was not related to pain severity. This finding suggests that the distance traveled in the 6MWT might be influenced more by pain, pulmonary and cardiovascular factors than muscle fatigue of the knee extensors.

## Limitations

The major limitation of this study was the relatively small sample size, especially when the group was divided in two groups. We used convenience sampling such that our sample was recruited from a small geographical location, which

might limit the generalizability of our findings. However, it is unlikely that our subjects were different in any systematic way from the usual COPD patients attending these clinics. The study did not consider the social and psychological aspects of pain as a multidimensional experience that might affect how each patient responds to various items in the questionnaires that queried pain. Finally, muscle testing was limited to the knee extensors.

## Conclusion

Our study demonstrated that pain in people with COPD is associated with decreased exercise capacity and physical activity, and higher BMI. The implications of these findings are that the evaluation of pain should be considered in the comprehensive management of people with COPD.

## Conflict of interest

None.

## Acknowledgment

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